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## **Full Circle**

By Walt Patterson

After more than 120 years, electricity may be starting to come full circle.

In the 1870s, the first systems for electric light - the generator with its motive power, the cables, the switches and the lamps - were all together on the same premises. The owner, say, of a stately home desiring the striking new status symbol of electric light had to buy, operate and control the entire system. The light, from arc-lamps, was noisy, smelly and inconvenient; but it was spectacular. It was also, of course, reassuringly expensive; the cost alone made it a status symbol, not available to the common herd. The owner-operator was buying, and paying for, electric light - not electricity.

Thomas Edison's great idea was simply to scale up the whole process, to reduce its unit costs. The motive power - steam engine or water wheel - and the generator attached to it both exhibited substantial economies of scale. A steam engine or water wheel ten, twenty or fifty times the size would light ten, twenty or fifty times as many lamps, without costing ten, twenty or fifty times as much. Indeed the larger the generator, the lower the cost per lamp, even allowing for the extra cost of more and longer cables. A system so large would light more lamps than the most extravagant single individual could possibly desire. To demonstrate the effectiveness of this arrangement, Edison therefore had to recruit a roster of different property-owners on whose separate premises he could install lamps, all connected to the same central generator.

His first such system, with a single large steam engine and generator in a building on Pearl Street in lower Manhattan, went into operation in 1882, lighting offices on Wall Street and at the *New York Times*; Edison always knew how to attract attention. Edison billed his customers for the light they used, according to the number of lamps on each premises. In order to keep the cost from being even more prohibitive, Edison had to minimize waste, and optimize the entire system - engine, generator, cables and lamps - to make it as efficient as possible

Then, in the mid-1880s, it all began to go wrong. No one realized this at the time. Even today the profound importance of the crucial misstep is still lost on almost all participants. But a bald statement of the facts leaves no room for doubt. The single most effective deterrent to improving the efficiency of electricity systems is the electricity meter. From the moment it was introduced, only a year or two after the start-up of the Pearl Street system, the electricity meter changed the ground-rules. Its pernicious effects have been felt ever since. If what you are selling is electric light, you want the whole system to be as efficient as possible. If, on the other hand, you are selling units of electricity as measured by an electricity meter, someone using less efficient lamps has to buy more electricity from you to get the same level of illumination. From the point of view of you, the seller, inefficiency on the customer's

premises is good for your business. This perverse incentive has underpinned the electricity business for more than a century.

The received wisdom, of course, sees the matter very differently. It considers electricity to be a commodity like natural gas or water, delivered to a customer's premises for the customer to use as desired. The meter just measures the flow of the commodity; the customer is billed accordingly. Throughout the twentieth century the economies of scale of ever-larger steam-turbine and water-turbine generators have steadily reduced the cost of a unit of electricity, so much so that electricity is now ubiquitous in modern industrial society, indeed taken completely for granted. In the 1990s, liberalization and the introduction of competition have underlined the view that electricity is a commodity. The whole market apparatus now being laboriously erected across Europe, North America and elsewhere is based on this presumption.

Unfortunately, however, electricity is not a commodity. A commodity can be stored and held back from the market until the seller gets the price desired. Electricity cannot be stored. Nor, despite frequent usage to the contrary, is electricity a fuel. A fuel such as coal, oil or natural gas is a physical substance. It comes out of a hole in the ground at a particular place. If you want to use it anywhere else you must physically transport it there. Electricity, by contrast, is a physical phenomenon happening instantaneously throughout the entire interconnected system, including all end-use equipment. Moreover, electricity can be generated anywhere, at a price. Just ask the person with the hissing headphones sitting next to you on the bus.

The traditional configuration of electricity system is based on large-scale remote central stations generating electricity as synchronized alternating current, and delivering it to users over a network of cables usually including substantial lengths of high-voltage transmission lines. This configuration, the common technical model replicated all over the world in the past half-century, arose for one main reason: scaling up the generating technology powered by steam or water turbines reduced the cost of a unit of electricity. Other technologies for generating electricity have long been available, everything from diesel generators to wristwatch batteries. But the electricity they produce costs more per unit, often a great deal more; imagine powering even a single 60-watt lamp with wristwatch batteries.

In modern industrial countries the remarkable success of the traditional electricity system through the 1980s confirmed and reinforced the underlying tacit view of electricity as a commodity. This in turned enabled free-market theorists to launch the process of liberalization of electricity, beginning in Chile and the UK in the late 1980s and spreading through the 1990s at an accelerating rate over much of the world. By a remarkable coincidence, liberalization got under way just as a new fuel, natural gas, was emerging as a serious option for electricity generation in many parts of the world. Moreover, this new fuel could be used in generating technologies whose economies of scale were very different from those of traditional steam-turbine and water-turbine generators.

The first breakthrough technology was the gas turbine. A gas-turbine generator can be efficient and economic at a much smaller size. It can be ordered, installed and in

operation in under two years. Firing natural gas it requires no fuel storage; it produces no solid waste, and its emissions can be very low. It can therefore be sited much more easily, close to users and indeed on the site where the electricity is to be used. It also lends itself well to cogeneration, producing both electricity and usable heat, with overall fuel efficiency above 80 per cent.

In the early 1990s, in the first rush of enthusiasm for liberalization, new gas turbine stations tended to be aggregations of generators on a single remote site, essentially equivalent to traditional steam-turbine and water-turbine stations in the traditional system configuration. Gradually, however, understanding dawned that gas-turbine technology makes smaller stations closer to users not only feasible but frequently desirable, reducing the need for long transmission lines and the accompanying losses, especially when generators can be located actually on site. The trend toward more and smaller generators closer to users is a sharp break with the traditional trend toward ever-larger stations ever farther away.

The new trend toward decentralization of electricity systems has been gathering momentum since the mid-1990s; see *Transforming Electricity*, by Walt Patterson (RIIA/Earthscan 1999) for details and possible implications. Other innovative generating technologies now emerging, among them microturbines, fuel cells and modular renewable energy technologies, will reinforce this new trend. As yet these small-scale technologies remain more costly than traditional options considered in the traditional context. But liberalization is also changing the financial ground-rules. In a traditional monopoly franchise, captive customers guaranteed a revenue stream to support large-scale long-term projects like gigawatt-scale power stations and long HV transmission lines. In a liberal context such projects become acutely risky, not for captive customers but for company shareholders and bankers. The new financial ground-rules are already affecting the choice of electricity technologies; and the effect will intensify as other small-scale options prove themselves.

The consequences may nevertheless prove uncomfortable. Traditional monopoly systems tend to include substantial redundancy - extra generating and network capacity, available for use in case of faults and failures, not to mention staff to cope, all paid for by captive customers. In a liberal context both redundancy and staffing levels drop, sometimes dramatically. At the same time, major electricity users with significant heat loads find the option of on-site cogeneration increasingly attractive, since they no longer have to face punitive charges from a monopoly for backup connection to the network. Major users, however, tend to represent the large stable loads easiest for the large inflexible generators of a traditional system to supply. As these loads migrate to cogeneration and leave the system, the remaining load profile on the system grows peakier, more difficult and expensive to supply. System reliability and power quality may deteriorate. If they do, more and more users may resort to on-site power generation, whose reliability and power quality the user controls. Even if on-site generation is more expensive, the extra cost may be justified as a form of insurance against the failure or poor quality of supply from the network.

Reliability and control may prove to be potent drivers of the move toward on-site generation. As micro-turbines, fuel cells and other small-scale generating technologies

mature, more and more places with ever smaller loads will become candidates for on-site generation - not only industrial sites but office buildings, shopping malls, airports, railway stations, hotels, hospitals, schools, blocks of flats and perhaps even individual residences. What this will do to the rest of the electricity system over time is still an open question; but it may be progressively disruptive. In due course it may even put those without access to on-site generation at a severe disadvantage, a corollary as yet inadequately considered. With an abundance of options to choose from, major players will be able to take care of themselves. But who will ensure that poor neighbourhoods and rural areas still have access to electricity services? Will industrial countries, like too many developing countries, divide into electricity 'haves' and 'have-nots'? No matter who owns a liberalized system, if the lights start going off, the government will be in the front line.

A much more positive possibility, however, also arises. After nearly 120 years, the re-emergence of on-site generation brings with it the promise of overcoming at last the pernicious effect of the electricity meter. If you generate your own electricity on site, no one benefits by having you use inefficient buildings and equipment. Instead, like Edison on Pearl Street but with technical options that would astonish him, you can seek to optimize the whole local system. Nor must you do it yourself. In a liberal context, electricity companies are already learning that competing to sell anonymous units of electricity at a customer's meter is a precarious business. They can compete only on price; their margins become vanishingly small. If, at the same time, customers can switch suppliers more or less at will, this form of business is a good way to go bankrupt. Enlightened companies are already seeking different ways to win customers and retain their loyalty. After years of frustration the age of the genuine 'energy service company' may be dawning at last. Local electricity systems with on-site generation may prove a potent manifestation of the new business now emerging. In your own economic interest you and your energy service company will want to ensure that your buildings, lighting, motors, and electronics use your own electricity as efficiently as possible. Optimizing the whole local system makes economic sense; and economics and environment point in the same direction.

How this will work out in practice no one yet knows; and it won't happen over night. But after 120 years electricity may eventually come full circle, back to where it belongs: on site.

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