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Electricity - Full Circle?

By Walt Patterson

In November last year I was invited to contribute an article to the launch issue of a new glossy trade magazine called *Cogeneration and On-Site Power Production*. I wrote a short paper, read it through and found myself wondering 'Do I really mean this?' Then I read the paper again, and thought 'Yes - I do'. I called the paper 'Full Circle'. The more I thought about it, the more I thought it might be important; so when I sent the paper to the magazine I kept the copyright. It first appeared in the magazine in February this year; since then it has been republished in an industry yearbook called *WorldPower* and in the online conference of the World Energy Council, called EnergyResource 2000. It's also on the web site of the Royal Institute of International Affairs, and I've emailed copies to many of my friends and colleagues.

The paper has elicited a gratifying number of comments and critiques; I'm still thinking about them. But I've been frankly delighted to find how many people in companies and governments seem to share my outlook on what appears to be happening. Today I'd like to outline some key features of this analysis.

As the title indicates, the central premise of my short paper is that after more than 120 years, electricity may be starting to come full circle, back to where it began. Until the time of Thomas Edison, at the beginning of the 1880s, anyone wanting electric light had the entire system on the same site - generator, cables, switches and lamps. The arrangement was dauntingly expensive. Edison's great idea was to scale up the whole process, to reduce its unit costs. That in turn meant finding customers willing to pay for electric light on many different premises, all connected by cables to Edison's central generating station on Pearl Street in lower Manhattan. At the outset Edison charged his customers according to how many lamps they used; he was selling electric light, not electricity. In order to keep costs as low as possible, he had to optimize the entire system, to deliver what customers wanted - electric light - at a price they could afford.

Then - and this is the point I'd like you to think hard about - it all began to go wrong. Shortly after the Pearl Street system started up, along came the electricity meter. From that time on, Edison, and his many contemporaries in the US, Europe and elsewhere, were no longer in the business of selling electric light. They were in the business of selling electricity, by the unit. Think about what that implies. If you are selling electric light, you want to make the whole system as efficient as possible, to deliver what the customer wants - the light - as cheaply as possible. If, however, you are in the business of selling electricity by the unit, you the seller actually benefit by having your customer use less efficient lamps. To get the same level of illumination, your customer has to purchase, and pay you for, more units of electricity. Inefficiency on the customer's premises is good for your business. This perverse incentive has underpinned the electricity business for more than a century - because the electricity business has been based on selling users electricity by the unit.

And what's wrong with that?, you may ask. Electricity, you may say, is just 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. Throughout the past decade, 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 the end-use equipment connected at any given moment. The whole system has to be in place and in stable operation, all the time. You can't stockpile electricity for contingencies. On the other hand, electricity can be generated anywhere, at a price. Just ask the person with the hissing headphones sitting next to you on the bus.

The key word here is 'price'. The whole remarkable infrastructure of electricity systems we've put in place in the past century is there for one reason only: to keep down the price of using electricity. For natural gas and other fuels, a delivery system of some kind is essential; the fuel itself has to be transported from its source to where it is to be used. Electricity is different. An oil well, a gas well or a coal mine has to be sited where the oil, gas or coal is. In principle, however, an electricity generator can be sited anywhere; some of you are probably wearing one on your wrist right now. The choice of site is influenced by the combined cost of building and operating the generator, and delivering the electricity in suitable form to where it is to be used. The choice of site and other details are also of course influenced by what is on the system already - other generators, network and loads, the system already in place. Historically, throughout the past century, with the technologies and fuels available, the combination of large-scale generators, remotely sited, and a large-scale network to deliver the electricity to users has appeared to be the cheapest arrangement. Traditional electricity systems around the world are all based on this common technical model, the central-station synchronized alternating current electricity system.

Note that I say that this has 'appeared to be' the cheapest arrangement. That qualification is necessary. Historically, the financial structure of the traditional electricity system has been based on a franchised monopoly, in which captive customers pay whatever the system is allowed to charge them. The captive customers bear all the risk. Long-term guaranteed flows of revenue make the cost of capital very low. Moreover, the tax and other fiscal framework for electricity systems has usually been generous, especially for such a capital-intensive activity. Under the combined influence of government finance ministries and government-appointed regulators, the price the customer pays for a unit of electricity from a traditional system is basically whatever the government wants it to be. Keep that in mind as we consider what is now starting to happen.

The remarkable success of the traditional configuration of system in modern industrial countries 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, in operation and earning revenue 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 steadily gathering momentum, as I describe in my book *Transforming Electricity*. 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 remember the arbitrariness of traditional system finances; conventional price comparisons based on traditional criteria are almost always heavily biased against technologies that don't fit those criteria.

Moreover, 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 high-voltage 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. The effect will intensify as other small-scale options prove themselves.

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. Small-scale generation will have to overcome the inertia of traditional networks, and the obstacles they will raise; but I remain confident that the advantages of small-scale local generation will eventually prevail.

What this will do to the rest of the electricity system over time is still an open question. It depends on how the networks themselves evolve; but even at best the consequences may still 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 what on a liberalized system, if the lights start going off, the government will be in the front line.

A much more positive positive possibility also, however, arises. After nearly 120 years, the re-emergence of local 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. Accordingly, enlightened companies are already seeking different ways to win customers and retain their loyalty.

I am increasing convinced that before long, while the big players may participate in markets and trade electricity among themselves, final customers will no longer be buying electricity by the unit. Instead companies will contract to deliver the services customers actually want - comfort, illumination, refrigeration, motive power, information handling and so on - at fixed prices over time, in continuous business relationships between company and customer. Some companies have already begun to offer some customers this kind of business relationship; I think the trend will accelerate. 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. If you are generating and using your own electricity, in your own economic interest you and your energy service company will want to ensure that your buildings, lighting, motors, and electronics use this 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 all 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.

The most difficult part, however, will be getting there from here, with our cumbersome legacy of traditional technologies, institutions and mind-sets. On 22 June, at the Planetarium in London, I gave the Melchett Medal Lecture for Britain's Institute of Energy. The lecture was entitled 'Energy 21 - Making The World Work'. I argued that we are now starting to see an accelerating evolution, gradual but inexorable, of the entire energy infrastructure of human society. One of the key determinants of this evolution will be electricity - how we produce, deliver and use it. Getting electricity right will be a crucial key to making the world work better, for everyone, everywhere.