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Technological Revolution

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Since the time of Matthew Boulton and James Watt, the energy industries have always been centred on and shaped by technology. They have used a steadily evolving and expanding catalogue of techologies to locate, extract, and process energy resources, and to deliver energy carriers like petroleum products, natural gas, coal and electricity. The technologies available have, in turn, strongly influenced the activities of the energy industries. The first steam engines, for instance, burned coal; but the first major role for such steam engines was to drive the pumps that kept deep coal mines dry. Steam engines needed coal, and coal needed steam engines. The history of technology in energy industries is like a parish record of such mutually supportive marriages - not always quite so directly reciprocal, but mutually supportive nevertheless, the role of each boosted by the other. Think, for instance, of the incandescent lightbulb and the steam turbine generator; the internal combustion engine and the oil refinery; and so on. In all such technological partnerships, neither partner could have established such a rapid and major presence in modem society without the other. The evolution of the energy industries has been driven in large part by the evolution of the techologies that supply and use the energy carriers. In the past two decades that evolution has been steadily accelerating. I'm not sure whether it quite constitutes a 'revolution', as the title suggested to me for this presentation proclaims, but its effects promise to be fully as fundamental as a revolution, for the future shape and role - that is, the future structure - of energy industries.

In the time available, of course, I cannot hope to cover all the energy industries, nor can I reasonably generalize from one to another, since each has its distinctive family of technologies for supply and use. I propose, therefore, to concentrate on electricity, for several reasons. It is the industry with which I am most familiar; it is linked to all the fuel supply industries; and it is the industry in which some of the most striking technological change is happening. Moreover electricity is the most versatile energy carrier, and is widely claimed to be the one energy carrier whose use will continue to increase worldwide, no matter what happens to the others.

Historically, the electricity supply industry, like the other energy supply industries, strove to increase its sales and its market by lowering the price of a unit of electricity and by widening the number of ways you could use electricity. Lowering the price meant improving the performance of supply technologies, especially their technical efficiencies, and striving for economies of scale in generating plant. Throughout most of this century the electricity supply industry succeeded impressively in meeting these technical and economic objectives. However, by the early 1970s the classical thermal power station, using the Rankine cycle and steam turbine generators, was closing in on its technical limit of efficiency, and economies of scale were proving illusory. In pursuit of such economies, electricity suppliers were ordering individual power station units with nameplate outputs approaching or even exceeding 1000 megawatts of electricity. Unfortunately units so large proved to require more than six years - sometimes considerably more - to construct and commission, before generating a single saleable unit of electricity, while initial capital outlays in thousands of millions of dollars or equivalent had to be serviced. The on-site fabrication necessary compounded the problems; some units overran schedules not merely months but years. When they finally came on stream, power stations so large often proved less reliable, partly because of their sheer complexity, with more parts to malfunction. Forecasting of electricity six years or more ahead proved to be impossible, leaving many suppliers with punishingly expensive surplus capacity. The OPEC oil price rise of 1973-4 added to the turmoil, by making both fuel prices and future use patterns even more uncertain. Recession took its toll; customers faced with sharply higher prices became aware of the possible advantages of more efficient use of energy; and electricity use fell well below the growth rates expected. Meanwhile, environmental concerns were becoming pressing. New plants on this scale became ever more difficult to site; and power stations had to incorporate cleanup technology that added to capital cost and reduced efficiency.

What showed electricity suppliers a way to escape from this blind alley was a combination of technical innovation and institutional imagination. Historically, an electricity supply organization was almost always a 'utility': a monopoly supplier of electricity throughout a designated region, given a franchise by government and regulated by government. The breakthrough came with the Public Utilities Regulatory Policy Act (PURPA) in the US in 1978. PURPA recognized that whereas electricity transmission and distribution might be 'natural monopolies', electricity generation was not; and PURPA stimulated a new breed of independent power producer or IPP. It spurred such producers to introduce innovative technologies, especially those considered comparatively environmentally benign, like renewables and cogeneration. The generating technologies that benefited from this encouragement included advanced coal technologies like fluidized-bed combustion and gasification, renewable technologies like wind power, and - above all - the gas turbine.

Until the 1980s the gas turbine was looked upon more or less as a grounded jet engine, that required costly premium fuel, had a distressingly low efficiency and could be used, therefore, only for specialized generating applications like peak-lopping and emergency standby power. But the gas turbine was about to become a partner in another of those technological marriages that appear to be made in heaven. In the early days of natural gas, when it was regarded almost as more of a nuisance than a resource, it had been used, casually, as a boiler fuel for steam turbine-generators, especially in the US; to anyone sensitive to thermodynamics, however, this bordered on technological perversion. By the late 1970s the distinctive virtues of natural gas had been recognized, and large-scale transmission and distribution grids were spreading; but it appeared to be in short supply, at least from gasfields close to users; its price was expected to escalate, and its use for generating electricity was even subjected to official bans. Only a decade later, however, the situation had been transformed. The industrial gas turbine, benefitting from research and development for aero-engines, had improved its operating efficiency by at least ten percentage points, with further improvement anticipated; and natural gas had become not scarce but superabundant, from more and more gasfields in more and more places, linked by ever larger transmission systems. The child of the marriage was the natural-gas fired combined-cycle power station, the epitome of the new philosophy of electricity generation. In the past five years combined-cycle stations, using gas and steam turbines together, have begun to spring up like mushrooms, even in places like the UK with an existing surplus of generating plant, and yet more so in the burgeoning and electricity-hungry economies of the Asian rim.

The advent of the gas turbine has brought with it a whole new technical perspective for electricity supply. The unit capital cost of a gas turbine is much less sensitive than that of a steam turbine to economies of scale; a gas turbine can be at once small, cheap and efficient. Gas turbine generators can be built in factories instead of on site. They can be built rapidly, and replicated rapidly as necessary, so that a power station can consist of a series of essentially identical modules, ordered, constructed and commissioned just in time to deliver electricity when users want it. The investment profile and cashflow associated with such small, modular stations is much smoother and more predictable than that of the traditional gigawatt units. Small, modular stations are easier to site, for both technical and political reasons. Land and water requirements are smaller, the installation is less instrusive, and gas turbines lend themselves well to the new, cleaner and more environmentally acceptable combustion systems. Natural gas itself contains essentially no sulphur or particulates; but if natural gas is not available or too expensive, other technologies now emerging will be able to use coal or biomass in combined-cycle or other gas turbine configurations to generate electricity in environmentally more acceptable ways. As renewable energy technologies like wind and perhaps photovoltaics become commercially established they, too, will expand the supply options available.

Nor does the technological evolution stop there. If electricity is generated in smaller stations, sited closer to customers, long-distance high-capacity transmission systems, with their high cost and environmental problems, become less necessary. The electricity system can gradually evolve into a 'distributed utility' in which not only electricity use but also electricity supply is connected to the system at many different points. Management and maintenance of the stability of such a system, in tum, is made easier by the availability of new monitoring, control and communications technologies. These technologies will also ensure that all those connected to the system are billed or paid, as appropriate, for the electricity they take from or supply to the system. The 'intelligent' electricity metre could become a key interface, as on-site local generation, perhaps cogeneration, wind or photovoltaics, supplies the grid as well as taking from it.

As traditional electricity supply organizations evolve into such 'distributed utilities' their corporate roles and responsibilities will evolve accordingly. On a technical level they will have to manage, maintain and guarantee the stability of the system, as loads and supplies are connected and disconnected throughout the day and throughout the year. They will own and operate part of the system, and have contractual commitments for the rest; and undoubtedly some sort of government regulator will be present as arbitrator and referee, not least to protect the interest of the smaller players on the system, like domestic householders. But a further ramification is also in train. Historically, an electricity supplier's interest in the system stopped at the metre; anything beyond it - including all the equipment using the electricity supplied - was none of the supplier's business. Now, however, the disciplines of integrated resource planning and demand-side management have carried electricity companies onto the customer's side of the metre. Electricity supply companies are evolving into electricity service companies; they can often earn a better return by installing more efficient end-use technology, to deliver electricity services that are cheaper and more reliable, with less environmental impact, than they can earn by installing additional generation. In a distributed utility, with independent generators and independent users alike linked physically and contractually, this is entirely consistent, although suitable ground-rules will need to be both clear and explicit.

Although I have focused on electricity, let me conclude by saying that the scope for technical innovation and new structures affecting also the other traditional energy industries may be equally substantial - not least because both the gas and coal industries now regard electricity as a major market. Major gas suppliers are already building power stations; the coal industry, too, might benefit from doing likewise, to bring the new 'clean coal' technologies more rapidly on stream and - not incidentally - to earn more added value by selling not coal but electricity. In due course, if all these trends continue, we could see the boundaries between traditional energy industries disappear - and we might even see the traditional boundaries between energy suppliers and energy users disappear. On reflection, I guess you could well call that a technological revolution.