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The commercialization of new technologies

Is energy policy led by the market or driven by government? The question is intriguing; but my problem starts earlier. What do we mean, 'energy policy'? All too often the 'energy policy' in question is really just old-fashioned 'fuel and power policy' by a snappier name, and the only 'energy' of interest is in the form of fuels and electricity - that is, energy carriers. This 'energy policy', so-called, does not encompass the energy services that we actually want - comfort, illumination, cooked food, mobility and so on. Nor does it encompass the energy hardware that converts fuel and electric energy to provide the energy services - the buildings, lights, appliances, industrial plant, vehicles and so on. Nevertheless, the 'new technologies' that are already competing for 'commercialization' include not only fuel and electricity supply technologies but also end-use technologies, a vast and expanding range of them. These end-use technologies are much more important than any supply technology, and I intend to proceed accordingly.

I understand 'commercialization' of a technology to mean the process whereby the technology comes to play a useful role in society, such that its manufacturers gain a return from selling it at a price that persuades people to buy it. 'Commercialization' is thus a quintessential 'market' concept; if the price is too high, people won't buy the technology; if the price is too low, the manufacturers will gain no benefit from selling it, and will stop. So far so good; but this bald formulation conceals a lot more than it reveals. One key point arises immediately; there is nothing inevitable about commercializing a technology. It may be entirely successful technically, work fine, and do everything asked of it, but be hopelessly uncommercial, for a variety of reasons. For instance, it may simply cost too much to make; or it may be for such a specialized purpose that it can never find enough purchasers to warrant tooling up for production, even though this would reduce its unit cost; or it may face competition from another technology that does the same thing either better, or cheaper, or both. Some technologies fit tidily into the existing technical, social and political context; others change the context itself - and the traditional power structure of society opposes their introduction.

Moreover, in the context of new energy technologies, some technologies make others unnecessary. As a hand-waving and imprecise but crucial example: one 20W compact fluorescent lamp gives the same energy service - illumination - as one 100W incandescent bulb. Ten million 100W incandescent bulbs require 1000MW of power station to light them. Ten million 20MW compact fluorescent lights require only 200MW of power station. The choice before society is obvious; but the process of choosing, and the people who choose, distort the choice. No 'market' exists here. The same discrepancy arises repeatedly across the spectrum of energy alternatives. Do we expand the supply of fuels and electricity, or do we instead apply similar funds, resources, skills and time to improve the end-use hardware that delivers the services we actually want, with compact fluorescent lamps, variable-speed motor drives, high-efficiency freezers, refrigerators and air-conditioners, and so on? Up to a point, market criteria can apply; but the point at which they fail is far too early in the process of choosing. A litany of imperfections distorts any credible 'market'-based choice between fuel and electricity supply on the one hand and end-use efficiency on the other. End-users are demonstrably ill-informed about opportunities for improving efficiency. Suppliers apply more lenient discount rates for investment in supply than end-users apply for investment in improved efficiency. Suppliers have much more ready access to capital than end-users, at significantly better terms. Fuel or electricity supply is the main interest of suppliers; end-use energy may be only a comparatively minor consideration for industry, commerce or households, and therefore not worth much attention or effort. And so on; the list could be much longer. The cumulative impact of all these factors means that 'commercialization' of new end-use technologies is on a very different footing from commercialization of new supply technologies.

Even for choosing between supply technologies, however, the classical 'market' has serious limitations. Take electricity supply. It is sometimes assumed that the progress of a technology can be traced smoothly through three stages: research and development, demonstration, and finally commercialization. The historical record shows, however, that this is far from the whole story. As concerns electricity generating technology, some technologies are a lot more equal than others. I'm thinking of course of nuclear power, which might serve as a textbook example of how not to commercialize a new technology. You start by exaggerating the promise of the technology, and by overselling its technical and economic potential. With the backing of indulgent governments you spend an enormous budget of taxpayers' money on research and development into every conceivable permutation of the concept, but somehow overlook major problem areas like waste disposal and decommissioning of dead reactors. You scale up far too fast, making design changes on the fly, so that the experience you do gain emerges too late to feed into subsequent development. You do all this under a blanket of secrecy, fudging the figures you do publish to make them look better than they really are, especially when your actual achievements fall desperately short of your original overstatements. You also, and not incidentally, do your best to nobble other innovative technologies that might pose a competitive threat to your own. Inevitably, when all these shenanigans finally emerge to public view, you have fashioned for your technology a millstone of distrust, on the part of politicians, financiers and the public, that will cripple any subsequent effort, however open and forthright, to achieve genuine and valid commercialization.

Nuclear fission power is by no means the only offender under these headings. The recent media spasm of enthusiasm for nuclear fusion indicates that fusion's promoters are intending to follow the same dubious route that fission did, extracting vast sums from the public purse by hyperbolic exaggeration of potential. I have a personal touchstone to measure the commercial potential of a technology: the commercial potential varies inversely as the willingness of the technology's promoters to enter into multinational collaboration. The very fact that so many different countries have pooled their efforts in pursuit of fusion tells me that nobody involved actually expects to make any money out of it.

In direct contrast, however, consider the innovative technology called circulating fluidized-bed combustion, or CFBC. The first CFBC pilot plant started up only in 1979. In the ensuing 12 years it has carved a niche for itself as one of the fastest-growing energy supply technologies. In some countries it reached this status with no government support at all; and elsewhere the support terminated after less than five years. CFBC's commercial potential is such that many of the world's major heavy engineering companies now offer their own designs, in fierce competition one with another for every new order. CFBC is a text-book example of how to commercialize a new energy technology. It offers just what today's market demands: fuel flexibility, including the ability to burn cheap low-grade fuels interchangeably; convenient size ranges for rapid construction and commissioning; competitive capital cost; ease of siting; demonstrated reliability in service; automated operation; enhanced environmental performance, complying with stringent controls on emissions of sulphur and nitrogen oxides; and the possibility of increased efficiency through cogeneration of electricity and heat, for industrial processes and district heating. CFBC was scaled up gradually, using very conservative designs and operating conditions; as experience accumulated the margins could be reduced, the unit capital cost lowered and the operating conditions made more demanding. Every aspect of the technology was investigated, from fuel handling to waste disposal. As a result CFBC is now accepted as a fully commercial alternative to traditional boilers, with well over one hundred sizeable units in service around the world and new orders being placed by the month.

Timing is crucial for a new energy technology. CFBC arrived just as its time was ripe. Gas turbines, by contrast, arrived far ahead of their time, and spent decades waiting in the wings, while electricity suppliers pursued their conviction that a bigger power plant was always a better power plant. The corporate ethos of utilities has a profound influence; in the UK, the old Central Electricity Generating Board would never have ordered a combined-cycle plant, and did its best to suppress cogeneration. However, all over the industrial world electricity suppliers were badly burned by overruns on costs and completion dates for gigawatt units, and egregiously inaccurate demand forecasts over the necessary timescales. As a result, the traditional corporate ethos is changing, away from monoliths toward diverse, decentralized and flexible systems better able to cope with today's uncertainties. Electricity suppliers have at last recognized the advantage of being able to order a new plant and bring it into service within three years, to match demand. For this and other reasons gas turbines are now the flavour of the month. They are easier to site than gigawatt units; they can be used in combined cycles to improve fuel efficiency; and if they burn natural gas their emissions are lower than those from coal- or oil-fired plant. Two major questions, however, remain. Will natural gas supplies continue to be cheap and reliable enough to fuel all the new combined cycle plants springing up around the world? And is it really sensible to use this premium fuel to generate electricity, and waste half its energy content, if the electricity is then going to be used to deliver *heat* to end-users? As a physicist I have a profound respect for the second law of thermodynamics; using high-quality electricity for space-heating and water heating offends my sensibilities, and doubly so if the electricity has been generated by burning natural gas. Amory Lovins calls it 'cutting butter with a chainsaw'.

In any case, many more new supply technologies are now striving for commercialization, especially for generating electricity. I'm thinking in particular of those that are grouped under a label I personally find grotesque - the so-called 'renewable energy' technologies. These technologies intervene in natural ambient energy flows like sunlight, wind, waves, tides and geothermal fluxes, and convert the energy into forms we can use. I'd prefer to call them 'ambient energy technologies'; but I'm hopelessly outnumbered, and I know when I'm licked. The 'renewables' share one crucial attribute: unlike technologies based on fossil fuels, the renewables do not discharge fossil carbon into the atmosphere. They have other environmental advantages and disadvantages; but in the context of concern about the greenhouse effect the absence of fossil carbon is of overriding importance. In this respect the renewables form an attractive partnership with efficient end-use hardware; but they both suffer from an intractable problem that is still only dimly perceived. I am a physicist, not an economist; but it appears to me that this problem will require fundamental redefinition of resource economics.

Market competition is intended to lower the prices of fuels and electricity. If their prices are lower, more will be used, and more CO2 emitted. However, energy policy is no longer driven by the scarcity of fuel and electricity resources. For the foreseeable future, energy policy will be driven by environmental concern. Five hundred years after Christopher Columbus, we still have not come to terms with the fact that the world is round. Our approach to resource economics focuses entirely on the sources of our resources. But it assigns no value to the sinks: the parts of our finite earth - the earth, the oceans and the atmosphere - into which we discharge the leftovers. On a finite earth, resource economics is incomplete unless we include the whole sequence of events and processes in our calculations and quantifications. That must, for instance, include the disposal of fossil carbon, at a rate the planetary sinks - the atmosphere, the biosphere and the oceans - can accommodate. At the moment it does not; and the effect is clear. Renewable energy supply technologies and efficient enduse technologies are asked to meet criteria for commercialization that are established by comparison with fossil fuels. Suppose, for the sake of argument, that governments everywhere took the greenhouse effect seriously, and implemented vigorously all the measures regularly cited to foster efficiency and renewables. The demand for fossil fuels would fall; and so would their prices.

Commercializing efficiency and renewables would be trying to hit a moving target: the more successful the efficiency and renewables, the lower the price of fossil fuels. On the basis of traditional resource economics, compared to fossil fuels, efficiency and renewables might never be truly commercial - even though fossil fuels are overloading the atmospheric sink, and efficiency and renewables lighten the burden on it.

Innovative resource economists are now trying to devise ways to assign value to the sinks, at least indirectly, by tradeable emission targets, carbon taxes and the like. But their efforts come up against a massive and obvious obstacle. Not only major corporations but whole countries currently depend for economic success on selling fossil fuels; and valuing the atmospheric carbon sink may seriously upset their economic status. Any attempt to assign values to sinks will thus meet stubborn and potentially implacable opposition.

The problem of commercializing new energy technologies is thus inherently political. It will confront governments everywhere, until we have a global energy market which can deal equitably in both supply and end-use of energy, and which values not only sources but also sinks. Politicians have to establish the ground rules for this market. Real energy policy includes not just fuels and electricity, but also the energy hardware that delivers the services we actually want. For the foreseeable future, politicians who want to leave energy policy - real 'energy' policy - to the marketplace are simply ducking their responsibilities, not only to today's voters but also to their descendants.