*Networks for Sustainable Power Systems - The Need for Change*
*Energy Networks Strategy Group Seminar, Institution of Electrical Engineers,*
*London, 2 February 2006*

# Sustainable Electricity: Cultural Barriers

Presentation by Walt Patterson

Let me make you a proposition. Suppose I am an electrical engineering student. I have been assigned a project to design an electricity system. When I submit my design to my professors it proves to have the following specifications. It is based on large central-station generators, most of which operate either intermittently or at only partial load most of the time. The central-station generators that use fuel waste two-thirds of the fuel energy before it even leaves the power plant. The system necessitates long lines of network, in which line losses cost another significant fraction of the energy flowing. The configuration is inherently vulnerable to disruption, by mishap or malfeasance, over a wide area and almost instantaneously. It assumes that every load is essentially equivalent, requiring the same high quality of electricity. The system produces and delivers high-quality electricity as required by sensitive loads, much of which is then used for undemanding services such as heating and cooling. The generators are almost all at least two, and more often four or five orders of magnitude larger than most of the loads on the system. Most of the loads are inherently intermittent or variable; but the system's large fuel-based generators are inherently inflexible.

Do you think my professors would give me a pass mark for my project?

Of course they would, if they were traditional professors of traditional electrical engineering. My project design looks exactly like the systems to which they have devoted their careers. Indeed it also looks like the systems to which three previous generations of electrical engineers have devoted their careers. That, needless to say, is our problem in 2006. Our expectations are so low - not only those of electrical engineers but those of politicians, regulators, financiers, manufacturers and the general public. We put up with electricity system design and performance that would be embarrassing if we actually looked at it dispassionately, instead of taking it for granted. That, to my mind, is the overriding 'cultural barrier' we have to confront and overcome. We need to look again at what we want from electricity, and how best to get it, given what we now know about technology, fuels, finance, business, regulation and environment. I can guarantee one thing. If we were starting from scratch to design the best possible electricity system with what we now know and what we now have available, my student project would bear little resemblance to the one I just described. Much of what we have already heard today reinforces that conviction.

By 'best possible' I would stress three criteria. The system would have to deliver what we want from electricity - call them 'electricity services' - reliably, universally and sustainably. It would keep the lights on; it would keep everyone's lights on, everywhere; and it would do so indefinitely, without unacceptable side-effects of any kind, local or global. As yet we don't know in detail what 'sustainable electricity' might look like. But we can be pretty sure we know what 'unsustainable electricity' looks like. It looks like almost all the electricity we're now using, here and around the world. That is doubly frustrating, because we know we can do better - much, much better.
That, to be sure, raises another question. We are not starting from scratch - far from it, at least in OECD countries and most urban areas of the world. The cultural barrier - the low and misleading expectations and all that goes with this - is accompanied by a major physical barrier: the existing system assets of generation, networks and loads, in their traditional configuration and their traditional role. In the US they're called 'legacy assets', a legacy that begins to look more like a

liability. They bring in train a 'legacy mindset' that may be even more difficult to change. To tackle the cultural barrier we must also work out a sequence of feasible changes, physical as well as financial and administrative, that will keep the lights on even as the system evolves to become more reliable, more universal and more sustainable. Unless we can imagine, in detail, how to get there from here, the cultural barrier will remain insuperable.

First we need a vision - a vision of what a sustainable electricity system might look like. Only if we have such a vision can we judge whether we are moving in the right direction, whether any given decision advances or retards our progress. In the time available I can't go into detail about my version of this vision; but I've described it repeatedly in my writing, and I'll happily supply references to anyone interested.

Then we need a different way to think about what we are doing with electricity. Liberalizing electricity, at least as we have done it in the UK, is based on a fundamental misconception. The electricity liberalizers tried to import all the concepts, financial arrangements and business relationships of the oil industry. They tried to establish a 'market' treating electricity as though it were a fuel, a commodity. The result has been less than satisfactory, for a lot of reasons; but the underlying reason is basic. Electricity is not a fuel. It's not a commodity. It's a process, occurring simultaneously and instantaneously throughout an entire interconnected circuit. A process cannot be stored. A fuel such as coal, oil or gas comes out of a hole in the ground at a particular place. If you want to use it anywhere else you must carry it there. But you can start the electricity process anywhere, in an extraordinary range of ways, from vast to minute. Electricity exists only in the infrastructure of assets that generate, deliver and use it, and through which it flows. Electricity is a function of infrastructure. Understanding this is the key to the necessary changes. You can produce and use electricity without fuel, but not without infrastructure.

Treating electricity as a commodity is therefore asking for trouble; and it is arriving. The flow of electricity through the infrastructure is easy to measure; but the price of a unit of electricity is ultimately arbitrary. The so-called 'electricity market' is illusory. The price of a unit depends not only on the price of any fuel involved, but on asset accounting, taxation, regulation, risk, subsidies, network and system effects and other factors usually unmentioned. The arbitrary and volatile price of an ephemeral kilowatt-hour is not an adequate basis for the requisite investment, finances, transactions and business relations.

Put simply, the main cultural barrier we have to overcome is to recognize, belatedly, that we have to stop treating electricity as a commodity issue. Electricity is an infrastructure issue. What matters most of all is the physical infrastructure within which we use electricity. We should think of it accordingly. Governments should make policies and companies make plans accordingly. That applies to generation, to loads, and - above all - to the network that links them. The infrastructure is the system - the whole infrastructure, including not only the explicit loads such as lights, motors and electronics, but also what we might call the 'implicit loads', especially the buildings. Once you start thinking this way, you rapidly find yourself in fascinating new territory.

Suppose, for example, you are planning a new office building. You bring together your enlightened architect, building services engineer, construction manager and energy service company at the outset. You start by getting the building fabric and layout right, with ample thermal inertia, convective air circulation and daylighting. The extra expense on the fabric you save by having smaller active heating and ventilation. You install high-performance lighting, motors and electronics. The electronics all require low-voltage DC, and the lighting works better with it. So you install your own DC generation, with a photovoltaic facade and a fuel cell in the basement. You install three sets of cabling: one for telecoms, one for synchronized AC from the network, and one for low-voltage DC. Since you're supplying low-voltage DC directly, all your computers and other electronics can eliminate the heavy 'power packs' that convert AC to DC, also eliminating the

accompanying wasteful heat and the noise of fans. Your electronics are also protected from the junk transients and harmonics now so prevalent on network AC. As long as your lights stay on and your computers work, you may not even bother measuring how much DC is flowing through your building. You'll measure and pay for the fuel coming into the fuel cell; but the overall DC supply network, including your own on-site generation, is just part of the building infrastructure. It's an investment, not a running expense. You don't pay for it by the unit. You use it as and when you want to. All you need to know about the flowing DC is that it's enough.

That brings with it an intriguing corollary that I love pointing out. Every official forecast you see, from the World Energy Council or the International Energy Agency or similar august bodies, always says that no matter what happens to world use of oil, gas or coal in this coming century, world use of electricity is going to vanish out the top right-hand corner of the graph. But think about this: the word 'statistics' means 'information of interest to the state'. Look it up. If you don't measure the DC flowing through your building, the government certainly isn't going to measure it. Long before the end of this century we'll no longer have electricity data to draw those graphs out the top right-hand corner.

If we get this right, if we overcome the cultural barrier of low expectations and a legacy mindset, our grandchildren may discover that sustainable electricity is invisible. The infrastructure keeps the lights on.