CHATHAM HOUSE
Chatham House, 10 St James's Square, London SW1Y 4LE
T: +44 (0)20 7957 5700 E: contact@chathamhouse.org.uk
F: +44 (0)20 7957 5710 www.chathamhouse.org.uk
Charity Registration Number: 208223

Energy, Environment and Resource Governance Working Paper

Managing Energy: Rethinking the Fundamentals

Managing Energy Data

Working Paper Two

By Walt Patterson

May 2009

University of Sussex
SPRU – Science & Technology Policy Research

INTRODUCTION: SEEING ENERGY

How you manage energy data depends on how you see energy. To most of us, energy suggests vigour, vitality, an ability to get things done. Scientists and engineers make that impression more precise. To them energy is not just a metaphor; it is a quantity they can describe with numbers. A scientist or engineer can watch something happen and measure the energy involved. The measured energy describes not just a vague ability to get things done, but how much gets done and how fast it happens. Scientists and engineers call such measurements energy data. 'Data' is the Latin plural of 'datum', meaning 'given'. By using measured energy data as the starting point, scientists and engineers can draw important inferences about natural systems and human technologies. When scientists or engineers gather and analyze energy data they always have a purpose in mind. The purpose determines what data to gather and how, how to analyze them and what inferences to draw. Scientists and engineers manage the data accordingly. Energy data help them understand how the world works.

Most people, however, see energy differently. Most of us take for granted the vast flows of energy around us, in sunlight, wind and moving water, in plants and animals, the energy of natural systems. What we notice is the additional energy we use, under human control, to fine-tune natural flows - to keep us comfortable whatever the ambient temperature, to provide light when the sun is not shining, to multiply the force available from our muscles, and so on. In particular we notice the energy contained in fuel - energy we can store, to use when and where we want it. For scientists and engineers, the data of interest about fuel will include attributes such as ignition temperature, flame temperature, combustion rate and other characteristics affecting its usefulness. For the rest of us, however, when we think about fuel, one number is of overriding importance: its cost. What matters to most people is the cost of a load of wood, a tonne of coal or a tank of petrol. For fuel, the data we notice are not scientific but commercial, the costs and quantities involved when we sell or buy it.

For centuries such transactions were of interest only to the seller and the buyer, perhaps of firewood, charcoal, coal or whale oil, small batch transactions at a price agreed between buyer and seller. The seller might keep a record of quantities and prices, for business purposes; but these recorded data would be of minimal interest to anyone except, possibly, a tax-gatherer. They would not be public, but commercially confidential, to avoid helping competing fuel-sellers. Town gas, produced from coal in central-station retorts and piped to burners in other locations, especially for lighting, was delivered not in batches but continuously, bought and paid for as it was used. The emergence of petroleum and its refined products, initially in Romania and the US in the 1860s, dramatically widened the range of fuels being sold, not just for heating, lighting and steam-raising, but also for the internal combustion engine. Before the end of the nineteenth century the scope and variety of transactions in the oil business - production, transport, refining and marketing, wholesale and retail, with fortunes made and lost - multiplied many-fold the amount of relevant commercial data of interest to those in the business, and those affected by it. Data on quantities and prices of lamp oil, heating oil, petrol, lubricants and other petroleum products helped managers to determine when, where and how much to invest in producing and processing petroleum. But the data mainly stayed within the business, except for instance when the enforced break-up of Rockefeller's Standard Oil monolith in the US in 1911 became a media sensation.

In the late nineteenth century the coal business likewise expanded rapidly in many countries, not only for traditional uses such as fireplaces, ovens, furnaces, boilers in factories, steamships and railway locomotives, and for manufacturing 'town gas' for lighting, but also for the new technology of electricity generation. Here again those involved gathered two distinct but closely related categories of data. Electricity pioneers such as Thomas Edison and Joseph Swan needed to measure the performance of steam engines, generators, cables, switches and lamps. They were seeking to find ways to make the technology work better, not just for intellectual satisfaction but to bring down the cost of delivering electric light to their customers. Data on technology and data on costs were thus intimately interlinked. Indeed, for fuel, once you moved beyond the bonfire, the commercial value of the fuel was determined by the performance of technology to use it. On its own, a tonne of coal or a barrel of oil was almost useless. Technology made fuel useful, and gave it value.

FUELS, TECHNOLOGIES AND COMMERCE

One important cost of electric light was the cost of coal, the commonest fuel for steam engine generators. Another was the cost of the hardware. In the early years all the hardware, from the generators through the cables to the lamps, was purchased or manufactured by and belonged to the system operator, perhaps an Edison company or one of its competitors. The company charged its customers according to the number of lamps in use. The customer was buying illumination - electric light, the actual service desired. Then, in the mid-1880s, came a practical electric meter, to measure the amount of electricity a customer used. From that time on, electricity companies sold not illumination but electricity, by the measured unit. The data they collected described how much electricity each customer used, but not what it was used for. The customer bought, paid for and owned the lamps and motors. The company no longer cared how well a lamp or motor worked. On the contrary, if lamps were inefficient the customer might have to buy more electricity to get the desired illumination. Poor performance from a customer's technology meant more revenue for the electricity company. This perverse incentive has persisted ever since.

In the decades that followed, the data of interest to electricity companies about user-technology focused primarily on 'load-building', on encouraging customers to buy a lengthening catalogue of technology - heaters, cookers, refrigerators, irons, washing machines, radios - for which the customer would then have to buy electricity. Data on the actual performance of this technology, however, only covered how much electricity it might use and when, as it affected operation of the electricity system. As far as companies were concerned, the more electricity the customer-technology used, the better. Customers in general paid no attention to the electrical efficiency of their technology. As long as it worked as advertised they were content. Appliance manufacturers likewise saw no reason to concern themselves with energy performance. What mattered was cost. If lower cost meant poorer performance, so be it. No one gathered, analyzed or publicized comparative data on the energy performance of user-technology such as lamps, motors or refrigerators.

Armed forces were becoming major users of technologies - tanks, ships, aircraft, armaments - needing fuels, and manufacture of these technologies also required rapidly increasing amounts of electricity. Governments, growing concerned with possible threats to fuel supplies, began to gather data, for their own use, on sources, quantities and prices of oil products and various grades of coal, particularly before, during and after World War II. During the war years such data were effectively secret; but thereafter, as Europe and other parts of the world emerged from devastation, official commentaries such as *Fuel And The Future* (His Majesty's Stationery Office, 1948) in the UK presented both data and analyses on prospects for supplies and prices of coal, oil products and electricity, all in the same report, as public information. For Europe one fuel - coal - had a major influence on the future. The European Coal and Steel Community, established to bring together the industries of wartime enemies, was to become, in due course, the European Union. Another EU precursor, the European Atomic Energy Agency, Euratom, nominally created to coordinate civil nuclear activities, was likewise focused on fuel supply, albeit less effectively.

By mid-century the world oil business, although expanding rapidly, was nervous that too rapid build-up in production would undercut prices. Moreover, keeping crude output, refinery capacity and tanker availability in step was becoming tricky. US antitrust legislation after the Standard Oil break-up meant that the 'Seven Sisters', the seven major international oil companies, wanted to avoid any appearance of collusion. Under the aegis of British Petroleum they agreed to pool their data to produce an open document, first published in 1952 as the *BP Statistical Review of the World Oil Industry.* It became an annual publication which is still going strong more than half a century later, a global bible of industry data. But its title and contents were to undergo a significant change.

After World War II electricity, too, expanded rapidly in many parts of the world, almost entirely within national borders. Expanding electricity systems entailed major investment in generation and networks, predicated on corresponding expansion of electricity use. That in turn entailed gathering and analyzing data on the use of electricity on the system, how much and when, to forecast how electricity use might increase. By this time electricity systems essentially everywhere were organized as monopolies, regulated or actually managed by government at national, regional or local level. Investment usually required some form of approval, that might or might not involve public discussion of forecasts and data on present and projected electricity use and costs. From the mid-1950s onwards, in the US, the UK and subsequently a growing number of other countries, proposed construction of nuclear power stations often led to public debate. Until the late 1960s, however, in the absence of practical experience, proponents' data on nuclear performance and costs were mainly hypothetical. They often proved optimistic.

In the late 1960s another fuel began to attract serious attention - natural gas. The oil industry had historically regarded natural gas as a nuisance and a hazard, to be separated at wellheads and burned off in a flare, simply to get rid of it. From the 1950s onwards, if the local electricity system permitted, some companies burned their natural gas as boiler fuel in power stations, still mainly to get rid of it. Then, gradually, the potential to collect natural gas and pipe it to paying customers began to catch on, initially in the Netherlands, Romania, the US and the UK, then more and more widely. After the discovery of natural gas in the North Sea, for instance, from 1966 through the following decade the UK converted its entire gas-supply network, and every single piece of user-technology attached to it, from town gas to natural gas. In one neighbourhood after another, gas technicians went door to door, replacing every burner in every cooker, heater and boiler, removing and replacing any appliance that could not be converted. It was a dramatic demonstration of the intimate interdependence of a fuel and the technology using it. It also upgraded an entire country's user-technology, while gathering detailed data on its attributes and performance. In 1967 the UK government published an official report on *Fuel Policy,* presenting and analyzing data on all the fuels - coal, oil and oil products, and natural gas - as well as electricity and nuclear power, with detailed projections and forecasts of future developments of each category of supply.

ENVIRONMENT AND CRISIS

Into the 1960s governments and publics took for granted that increasing use of fuels and electricity was a sign of increasing prosperity. But the book *Silent Spring* (1962), by Rachel Carson, presented alarming evidence that human activities were inflicting serious damage on natural systems. By the late 1960s the environment had become a political issue, particularly in North America and Europe. The wreck of the supertanker *Torrey Canyon* off Cornwall in 1967 and the oil spill from an offshore rig near Santa Barbara in 1969 demonstrated dramatically the negative side of producing and transporting petroleum. Generating electricity polluted air with particulates and sulphur oxides from coal-fired stations. Dams flooded vast areas and destroyed settlements and natural habitats. Nuclear stations created radioactive waste and raised issues of safety. Within a few years many non-specialist members of the public in many parts of the world had begun to pay close and critical attention to both scientific and commercial data about producing and using fuels and electricity.

In 1971 the Ford Foundation in the US launched what it called the Energy Policy Project. For the first time in public, as far as can be ascertained, the expression 'energy policy' took the place of what had hitherto been 'fuel policy' or 'fuel and power policy'. Over more than four years the Project team carried out intensive analyses of energy information and data covering many aspects of energy in society. Published reports from the Project covered fuel and electricity supplies and technologies; user-technologies; fuel and electricity prices since 1960; fuel and electricity conservation; research and development; taxes, subsidies and finances; oil pollution; nuclear power; electricity; energy and industry; energy and US foreign policy; and a number of other specialist commentaries - twenty volumes in all, including a book-length summary with conclusions and recommendations entitled *A Time To Choose* (Ballinger 1974). It was an extraordinary exercise, unlike any that had gone before. Its findings and recommendations were intensely controversial, challenging many traditional precepts of policy and antagonizing powerful corporate interests. Nevertheless the Project set the stage for a whole new approach to energy, energy policy and energy data. It also proved prescient. Before it had run its course, energy policy had become front page news, in the US and all over the world.

In April 1973 US president Richard Nixon removed the oil-import quota that had protected Texas oil from foreign competition. Overnight the US became a major oil importer. At the time the world price of crude was less than $3 per barrel. The Organization of Petroleum Exporting Countries, OPEC, wanted a larger share of the much higher price paid for refined products. In October 1973, when war broke out between Israel and its Arab neighbours, OPEC seized the opportunity. US import dependency, coupled with a Middle Eastern conflict providing political cover, saw the world price of crude quadruple within weeks. Moreover, this so-called 'oil shock' coincided with renewed labour unrest in UK coal mines, problems with natural gas supply in the US, and trouble on a number of electricity systems. In the weeks that followed, through the winter of 1973-74, politicians and the media began to refer collectively to all fuels and electricity as 'energy'. The world was in the grip of an 'energy crisis'. Heating oil ran low. US drivers fought gun-battles at petrol pumps. In the UK, as coal-miners 'worked to rule', then went on strike, the government ordered industry to work only a three-day week. Governments exhorted the public to 'switch off something now' and 'save it'. 'Energy conservation' became the watchword. It was taken to mean cutting back on use of fuels and electricity by cutting back on services, doing without, rhetorically 'freezing in the dark'. It paid no attention to user-technology except to use it less.

Suddenly almost everyone was caught up in energy policy, at least in the form of popular slogans. It was not, however, the energy policy of the Ford Foundation project, extending into every aspect of energy in society. The energy policy that emerged into political and popular parlance in 1973-74 was essentially the old familiar fuel and power policy of the preceding decades, merely using the single word 'energy' as a convenient headline shorthand to mean 'all fuels plus electricity'. It was, however, a seriously misleading usage. Smearing together oil, coal, natural gas and electricity with a single label made them sound interchangeable, as though one could take the place of another. The practical reality however was, and is, that in modern industrial society almost any user-technology requires a fuel or form of electricity meeting precise specifications. Moreover, once user-technology and matching supply technology are in place, any changeover will take significant time, years if not decades.

As the previous working paper in this series, 'Managing Energy Wrong', noted:

One of the first responses to the energy crisis was for governments, politicians and commentators to demand a 'substitute for oil'. An immediate beneficiary of this sudden enthusiasm was nuclear power, notably in France and Japan. Few politicians seemed to realize the obvious inconsistency of this proposal. The most important and distinctive role of petroleum and its products was and still is in fuelling transport, particularly motor vehicles. Nuclear power produces baseload electricity. It was and still is essentially irrelevant for motor vehicles. Even for less specialized applications such as heating, the substitution entails not just replacing fuel oil with electricity but replacing the entire system of technology through which it flows, especially the end-use technology. You cannot run an oil heater on electricity, or an electric heater on oil.

The search for a 'substitute for oil' in the mid-1970s nevertheless set the pattern for future discussions of what was thenceforth called energy and energy policy. Using the word 'energy' as shorthand for all fuels plus electricity allowed non-specialists, particularly politicians, to presume that they were all more or less the same commodity and interchangeable, that one could substitute for another, with no reference to the timescales or technologies involved. In the intervening decades, government statistics, energy forecasting and scenarios, and other analytic and planning tools of energy policy have focused on measured commodity quantities and flows of fuels and electricity, described as aggregates and averages. This approach takes technology and physical assets for granted - not only the technology to produce and deliver the fuel or electricity, but also the technology to use it, to deliver the service the user actually wants. It tells us about commodities, but nothing about the multifarious physical infrastructures through which they flow, or the investment the infrastructures entail. The aggregates and *averages of commodity quantities smear together many different applications and services, with vastly different attributes, ranging from vital and acutely sensitive to incidental and undemanding. If all you want to know is how much oil, coal or natural gas is sold, such information will tell you. For purposes of managing energy, however, we collect the wrong data, and we analyze it wrong.*

Two early examples of headlong misuse of energy data were notably ambitious. In the US, President Nixon's short-lived 'Project Independence', proposing drastically unrealistic expansion of domestic supply, ran into the sand by 1975. Not to be outdone, the European Commission rushed out a series of policy papers under the reference number R/3333, calling for a 14-fold increase in nuclear power generation in member states by 1985.

Responding to the 'energy crisis', the Organization for Economic Cooperation and Development created what it called the International Energy Agency. From its inception its name was a misnomer. In all but name it was an international petroleum agency, an organization of petroleum importing countries, an OPIC conceived as a counterweight to OPEC. It main purpose was to gather, collate and analyze data on world petroleum and petroleum products on behalf of its member governments, to coordinate stock-holdings and to provide emergency supplies to any member facing shortages, especially shortages arising from international oil politics. These were and still are eminently sensible and valuable measures, but about oil, not about energy - much narrower in scope than was implied by the name of the organization. That was to change, but only gradually.

AGGREGATING ENERGIES

One striking consequence of the energy crisis was its curious effect on energy data. Commercial fuel data arise ultimately from individual transactions - buying and selling West Texas Intermediate crude by the barrel, washed graded bituminous steam coal by the carload, JP8 jet-fuel by the tanker-load, 97-octane petrol by the litre and so on, batch transactions in measured quantities of fuels of tight specification at an agreed unit price. The specification ensures that the performance of the particular fuel corresponds to the requirement of the technology in which it is to be used. That is obviously important for retail fuels to use, say, in a particular car engine; but it also applies, for instance, to the crude fed into a particular refinery, or the coal to fire the boiler in a particular power station.

Historically, a company buying, processing or selling fuel would aggregate all the separate transactions of a particular kind, to produce a single figure for, say, the total amount of 97-octane petrol sold in a year - essential information not only for the company accounts but also for planning its future investments. The company might then aggregate sales figures for 97-octane petrol with those for 95-octane, for diesel and other fuels, for its own accounting purposes, to develop an overall picture of company business and finances. But the company would take for granted that such aggregation applied only to the financial aspect of fuel business, not to the technical.

After the oil shock, a rapidly expanding array of data on fuels and electricity, much of which originated with companies, came into the public domain. From 1973 onward, commercial energy data that had been gathered internally, for companies to use for their supply businesses, were taken up not only by governments but also by international organizations, academics and consultants, whose involvement in the supply business was at best indirect and often non-existent. Their interest in energy data therefore had nothing directly to do with investment or other commercial activity that would require emphasis on the specifics of individual proposals. Commercial data was taken up by non-commercial analysts seeking more broad-brush pictures of what they thought of as energy activities in economy and society. Accordingly, they aggregated and averaged the data across companies, regions and countries, in ways that often buried specifics in sweeping generalizations. By implication, and sometimes explicitly, these aggregates and averages were interpreted not merely as financial but also as physical and technical.

One corollary of this approach was the rise of what came to be called 'primary energy' as a quantity of apparent interest. One definition says 'Primary energy is energy that has not been subjected to any conversion or transformation process. Primary energy is energy contained in raw fuels and any other forms of energy received by a system as input to the system. The concept is used especially in energy statistics in the course of compilation of energy balances', a form of physical thermodynamic flow chart. Another definition, from the present author's *Discussing Energy: A Style Guide,* says primary energy is 'a synthetic term, used for statistical purposes to aggregate forms of energy whose only common attribute is that they are measured, usually in a commercial context. Suggests substitutability that may not exist. In common use, but best regarded warily.' From the first viewpoint, 'Secondary energy is energy which has been transformed from one form to another. Electricity is the most common example being transformed from coal, oil, natural gas, wind, etc.' The *Style Guide*, however, reiterates that secondary energy is 'used for statistical purposes to aggregate forms of energy whose only common attribute is that they are measured, usually in a commercial context. Suggests substitutability that may not exist. Best regarded warily.'

The emergence of primary and secondary energy as inferred aspects of energy data reinforced the impression that what was significant in an energy system was the flows of energy through it, and in particular the commercially measured forms of energy. What the energy was actually flowing through - the technology and especially the user-technology - was taken for granted. Although energy data is always gathered and analyzed for a purpose, the purpose for defining and tracking primary and secondary energy was not and is not obvious.

FORECASTS AND SCENARIOS

The purpose behind most energy data, however, was quite clear. Well before fuel data and electricity data coalesced into energy data, those in the various supply businesses had developed two broadly different ways to gather, analyze and use data for decision-making. One approach was to identify, extrapolate and, if necessary, qualify trends in past and current use of a particular fuel or electricity, to anticipate future growth of the market and guide appropriate investment in supply facilities. Trend extrapolation also incorporated estimates of anticipated economic growth, especially gross domestic product, on the then-accepted basis that growth in use of fuels and electricity evolved in step with the economy - that, say, 2 per cent economic growth would mean 2 per cent growth in use of some aggregated quantity of commercial energy. Until the early 1970s such trend extrapolation was routinely called 'forecasting', until the divergence between such forecasts and eventual reality became too gaping to ignore. By the mid-1970s energy analysts prefaced most such pronouncements with the proviso that 'forecasts are always wrong, including this one'. Thereafter the term 'forecast' fell into disuse, even for data-analyses that continued along similar lines.

By that time, however, a different approach, originally developed by Shell in the 1960s, was gaining adherents. Instead of deriving quantitative forecasts for the amounts of fuel or electricity to be used at some future time, this approach laid out so-called 'scenarios' to describe possible futures, in the form of narrative accounts of circumstances that would affect the uses of fuels and electricity. Such scenarios were more qualitative than quantitative, and accordingly drew quite different inferences from past and present energy data. Instead of a single forecast, analysts would offer two or more scenarios, from two or more sets of differing assumptions. In this, as in many other aspects of data management in public, the Ford Foundation Energy Policy Project was a pioneer. Its analysis presented three scenarios, labelled 'Historical Growth', 'Technical Fix' and 'Zero Energy Growth', implying very different possible futures, all apparently achievable but requiring very different policies, as the labels indicated. From the mid-1970s onwards, narrative energy scenarios of some kind took the place of most energy forecasts, at least in public.

Scenarios in turn were often paralleled by so-called mathematical models, in which quantitative data laid out as spread-sheets were linked by mathematical formulae to describe their inter-relationships. By adjusting initial conditions and interlinking formulae, modelers could track the consequent effects on interconnected economic phenomena such as fuel use and economic growth. After the mid-1970s, the advent of affordable and available computing power made such models progressively easier to design and use. But the very ease and fluency of computer modelling created a pitfall for unwary non-specialists such as politicians and journalists, often dazzled by the surface elegance of the analysis. Computer people gave the pitfall the acronym GIGO, standing for 'garbage in, garbage out'. The inferences you could draw from a computer model were only as good as the data and assumed interconnections you fed into it. In due course at least one major global energy modelling exercise publicized worldwide fell into the GIGO trap.

VISIONS OF ENERGY

Nor were scenarios and models to manipulate energy data limited to those working in the various businesses. The rise of environmental awareness from the late 1960s, followed by the 1973-4 oil shock and energy crisis, turned what had been a narrow specialist preoccupation into a major political issue, even in the popular press. It triggered an outpouring of analysis and commentary throughout the following decade, much of it directed not to specialists but to governments, politicians and the public. Most commentary was based on the available commercial data about sources, supplies and costs of fuels and electricity. But the pictures presented varied widely from one commentary to another. Earlier analyses of energy data were undertaken for quite specific business purposes, to guide investment and commercial activities intended to augment fuel and electricity supply to meet anticipated demand. The purposes behind the various public and popular analyses and commentaries on energy published from the early 1970s onward were not so readily obvious. Nevertheless, from then on, anyone interested could survey a widening range of representations, indeed visions, of energy in human society, with different emphases, different priorities and different foci. They all quoted and interpreted energy data; but the pictures derived from the data were inconsistent and incompatible, and the underlying purposes required close examination.

Some were straightforward continuations of previous surveys of fuels and electricity. The BP *Statistical Review of the World Oil Industry* added natural gas, coal and electricity and became the *Statistical Review of World Energy*, still focused on sources and quantities supplied. The International Energy Agency launched *World Energy Outlook*, initially likewise focused on supplies of fuels, to which it then added electricity. Conversely, the World Power Conference of electricity companies became the World Energy Conference (WEC), adding fuels. Soon thereafter it became the World Energy Council. By 1977 it was able to publish *Energy Resources: availability and rational use*, based on its triennial conference, addressing not only what it called 'conventional energy resources' and 'unconventional energy sources' but also conservation, energy system options and a future energy scenario. Prepared by the International Institute for Applied Systems Analysis (IIASA) near Vienna, this scenario considered a dramatic increase in the contribution from nuclear power, including plutonium-fuelled fast breeder reactors. A year later the Conservation Commission of WEC published *World Energy: Looking Ahead to 2020.* Its 252 pages of text included a 14-page chapter on 'Energy conservation', defined thus: 'The goal of energy conservation is to achieve acceptable economic growth with a minimum increase in total energy consumption'.

The role of nuclear power in energy systems was a key theme in several major commentaries prepared by ad hoc study groups convened for the purpose. In 1976 a follow-up to the Ford Foundation Energy Policy Project reported on *Nuclear Power Issues and Choices.* The Massachusetts Institute of Technology convened an international 'Workshop On Alternative Energy Strategies' (WAES) with participants drawn from many countries, which reported in 1977 on *Energy: Global Prospects 1985-2000.* The US National Academy of Sciences set up a Committee on Nuclear and Alternative Energy Systems (CONAES), whose report on *Energy In Transition 1985-2010* appeared in 1979. The most ambitious undertaking, however, was that of IIASA, which in 1981 published a massive tome entitled *Energy In A Finite World,* about which more will follow below.

All these various analyses concentrated on data and projections about sources and quantities of energy carriers flowing through energy systems and economies. They paid little or no attention to the technologies actually using the energy carriers, except as broad-brush aggregates such as 'industry' and 'transport'. But another strand of commentary based on existing and projected energy data was also unfolding, taking quite a different approach. In this strand a common theme was to dispute the hitherto accepted connection between economic growth and growth in use of fuels and electricity, so-called energy growth. Another common theme was scepticism about or active opposition to expansion of nuclear power generation.

An early example was the 1971 title *Energy,* published by the Sierra Club in the US. Its author, John Holdren, was later to become president of the American Association for the Advancement of Science, and - in 2009 - science advisor to incoming US president Barack Obama. Another example, also written before the oil shock, was *World Energy Strategies*, by Amory Lovins. Initially published in the UK in November 1973, it subsequently appeared in successive versions and in translation into many other languages. Lovins followed up with a paper in *Foreign Affairs* (1976) entitled 'Energy strategy: the road not taken?', in which he introduced the concept of two alternative routes into the world energy future, what he called the 'hard path' and the 'soft path'. Amid reverberating controversy both inside and outside the US, Lovins expanded the analysis and commentary into a book-length version entitled *Soft Energy Paths* (1977), eventually translated and published all over the world. Lovins went on to found the Rocky Mountain Institute in Colorado, whose work remains at the cutting edge of policy on energy and environment.

From the late 1960s an intriguing aspect of energy data management was so-called 'energy analysis', tracking energy flows through complete cycles of processes and products. Analysts and commentators in a number of countries pursued these ideas; the International Federation of Institutes of Advanced Study convened a major conference on the topic in 1974. In the UK, in the mid-1970s, the Open University, teaching tens of thousands of far-flung students by television, radio and correspondence, established an Energy Research Group (ERG) whose focus differed significantly from that of engineering departments in more traditional universities. Rather than carrying out and analyzing measurements on laboratory equipment, the OU ERG undertook energy analysis as a major theme of research. It carried out studies on energy flows and energy performance of technologies already in use in industry and in electricity generation, as well as on the organization and management of such energy activities - a novel interplay between scientific and commercial approaches to energy data. The OU ERG work explored the energy 'content' of materials - that is, the amount of measured fuel use or other energy conversion required to produce, say, a tonne of steel, glass or aluminium. One corollary of this analysis became for a time hotly controversial - the so-called 'net energy' payback associated with fuel or electricity technologies themselves. In the case of a nuclear power station, for instance, how long would the station have to operate to generate as much commercial energy as had been required to build and fuel it, given the heavy electricity requirements for enriching uranium fuel? Disputes raged, then subsided, with no clear answers, because so much depended on the time frame, the scope of the analysis and other initial assumptions in any given case.

A yet more quirky slant on energy in society came from ERG staff member Peter Chapman. In his book *Fuel's Paradise* Chapman advanced the concept of using energy as a form of currency in transactions - in effect synthesizing both the scientific and the commercial dimensions of energy data. Not entirely tongue-in-cheek, his commentary was a thought-provoking challenge to the more orthodox presumptions of energy policy.

Interpretations of energy data thus developed into two distinct categories. Companies, especially those involved in supply fuel or electricity, continued to carry out their own internal analyses, to guide their own business and investments. From the mid-1970s onwards, however, governments, academics, consultants and environmental organizations carried out and presented analyses on much broader panoramas, usually arguing, at least implicitly and sometimes explicitly, a preference for some possible vision of an energy future over other possible visions. Many commentators in many countries, often spurred by controversy over nuclear power, offered politicians and the public a wide assortment of views of energy in society, of the appropriate aspects to note, to measure and to analyze, and of the consequent scope and range of energy policy. In Sweden, for example, where nuclear power was intensely controversial, Måns Lönnroth, Peter Steen and Thomas B Johansson carried out a series of studies for the Swedish government Secretariat for Future Studies. They compared *Solar vs Nuclear,* described *Solar Sweden* and reported on *Energy In Transition*, with analysis and commentary of such scope and penetration that all the studies were subsequently translated and published in English.

BACK TO SPECIFICS

As well as the usual data-processing for fuel and electricity supply businesses, and the broad-brush panoramic visions of energy futures, one other distinctive approach to energy data also emerged from the mid-1970s. It differed from both other approaches, in that it focused explicitly and in specific detail on the performance of user-technology. In the UK, for instance, the government Department of Industry in 1976 launched what it called the Industrial Energy Thrift Scheme, eventually publishing more than two dozen booklets about as many different industrial processes, the technologies involved, the fuels and electricity used and the opportunities for improvement. In the US the Alliance to Save Energy (ASE), established in 1977, and the American Council for an Energy-Efficient Economy, established in 1980, developed similarly detailed analyses. In Denmark, from the late 1970s, Niels Meyer and colleagues studied households and energy.

In the UK, as noted in the previous Working Paper,

in January 1979, a team led by Gerald Leach at the International Institute for Environment and Development (IIED) in London published a landmark report entitled A Low Energy Strategy for the United Kingdom*. Three decades later it makes unnerving reading. If its policy proposals had been adopted and implemented, the UK would have led the world in showing how to avoid fuel supply problems and minimize climate disruption. Instead, the Leach team report was rejected out of hand by the UK's energy establishment. Yet it was by no means radical, much less heroic. As its opening page explains, 'This book presents a different view of the future. It does so for the United Kingdom, but its approach and findings should hold broadly for other industrial countries. It demonstrates, systematically and in detail, how the United Kingdom could have 50 years of prosperous material growth and yet use less primary energy than it does today ... We show that Britain - and by implication other countries - can move into a prosperous low-energy future with no more than moderate change. All that is necessary is to apply with a commitment little more vigorous than is being shown today by government, industry and other agencies some of the technical advances in energy use which have been made, and are still being made, in response to the oil price increases of 1973-74.'*

The key feature of the approach the Leach team adopted was to move on from commodity aggregates and averages, to separate out the many distinct strands of energy use in UK society and analyze them one by one. To do this they had to identify and characterize not only the individual fuels and the electricity used, but also - and explicitly - the end-use technologies involved, starting with buildings. They analyzed the energy services desired and delivered, the technologies and infrastructure and their performance, separated out into precise details, and only then the fuel or electricity required *for any particular service. They called this a 'bottom-up' analysis, by contrast with the 'top-down' analysis of fuel and electricity aggregates and averages then otherwise typical of 'energy forecasting'.*

A key message of the Leach team report, emerging from page after page of meticulous dissection, was that managing energy means managing technology, physical assets and infrastructure, not just commodities; indeed that commodity fuels and electricity should enter the picture only after the appropriate management of the energy service infrastructure; and that investment decisions are not and should not be determined only by prices of fuels and electricity, actual or anticipated.

Similar arguments also appeared, for instance, in the US. In 1979 the Energy Project at the Harvard Business School, not noted as a hotbed of radicalism, published a report entitled *Energy Future* (Random House 1979), which, as the chapter title put it, called 'Conservation: the Key Energy Source'. The chapter was written by Dan Yergin, later to win the Pulitzer Prize with his history of world oil *The Prize.* His commentary on the varieties of user-technology, their potential for improvement and the impediments hindering such improvement, echoed themes from the Leach study. *Our Energy: Regaining Control,* by Marc Ross and Robert Williams (McGraw-Hill 1981) was yet more focused on use rather than supply, with a chapter entitled 'Saved Energy As The Major Energy Resource', and detailed commentaries on homes, cars, industrial activities and local energy systems.

Throughout these and similar studies in other countries the most striking feature was the shift of emphasis away from flows of commodity fuels and electricity toward user-technology as the focus not only of data but of the policy it indicated. That implied in turn a major shift in the scope and content of what could be described as energy policy, as pursued particularly by governments. But no such shift was to be forthcoming - not for many years.

GLOBAL REACH

In the late 1970s the International Institute for Applied Systems Analysis, near Vienna, undertook what was at that time much the most ambitious analysis of energy data ever attempted. Its final report, published in 1981, was entitled *Energy In A Finite World.* The concise volume 1 was subtitled *Paths To A Sustainable Future* - one of the earliest appearances of the adjective 'sustainable' in the context of energy. Volume 2, *A Global Energy Systems Analysis,* ran to over 850 pages. On many levels it was and remains a stunningly impressive achievement, a meticulous compilation of detailed data and projection of energy flows over the entire planet for the ensuing half-century until 2030. That, however, was one of its weaknesses. The energy flows identified and tracked were those of so-called primary, secondary, final and useful energy - that is, forms of energy measured, bought and sold commercially. But it said little of substance about what the energy was flowing through. Although the study gathered and examined extensive data on the materials requirements for fuel and electricity supply technologies, it paid little attention to any aspect of user-technology of any kind, except as the locus of 'conservation'. The section headed 'How much energy will be needed?' was less than three pages long. The environmental impacts were evaluated according to the acronym WELMM, standing for water, energy, land, materials and manpower. But the energy systems analyzed were systems of fuel and electricity supply, not the complete systems that deliver the energy services society actually wants.

A more crippling shortcoming, moreover, gravely undermined the entire enterprise. The clue is in the title of the study. The 'finite' aspect of the world that concerned the IIASA team was the anticipated finiteness of the earth's fuel resources. With this as an initial premise, the study identified two long-term options to supply the world's energy requirements - nuclear power and solar power. As the report itself stresses, 'The models of the kind that we use here provide only a way of examining the consequences of the assumptions that are made'. Using the existing data available, the study's assumptions about the practical feasibility of various solar supply options were at least optimistic; three decades later they have yet to be seriously attempted on a global scale. But the assumptions about the practical feasibility of the nuclear option were tested effectively to destruction in the ensuing decade. The study acknowledged the limits on availability of adequately concentrated uranium ore to fuel the postulated global array of reactors. It therefore assumed the rapid expansion of nuclear generation by plutonium-fuelled fast breeder reactors, 'for which the required demonstration units are already operating', accompanied by the requisite panoply of reprocessing and plutonium fuel cycle facilities. The fast breeder demonstration units that did operate, in the US, the UK, France, Germany, the Soviet Union, Japan and India demonstrated, however, that fast breeder power stations were painfully unreliable and prohibitively expensive, and might also be seriously hazardous. All were definitively shut down, with no plans for any successor anywhere. With the single exception of Japan, the only reprocessing plants still in operation in 2009 are in nuclear-weapons states. Extrapolation from the limited and ambiguous existing nuclear data to a self-sustaining global programme of nuclear generation by 2030 was optimistic going on foolhardy.

Furious international controversy greeted the IIASA study, then faded away. Its impact on policy, though difficult to assess in hindsight, appears to have been modest. It nevertheless deserves to be remembered as much for its ambition as for its ultimately unrealistic conclusions. It set the stage for later attempts to use energy data of every kind to develop plausible global visions of future energy systems, on what is - as we now understand ever more deeply - not only a finite world but the only one we have.

ENTER END-USE

By the early 1980s energy was no longer front-page news. The spate of popular books on energy subsided. Energy became again a specialist preoccupation. Behind the scenes and away from public view, however, the ferment of discussion and debate about the future of energy in society continued, in academic circles at least, all over the world. International friendships initiated during high-profile energy gatherings in the 1970s led to international collaboration in the 1980s.

One especially fruitful connection brought together physicists from four continents, two industrial countries and two developing countries - Jose Goldemberg from Brazil, Thomas Johansson from Sweden, Amulya Reddy from India and Robert Williams from the US. In the 1970s Johansson had been co-author of *Energy In Transition* and other Swedish work, and Williams of *Our Energy: Regaining Control*, both mentioned earlier. Working together with the newly-available tools of rapid intercontinental communication, the four drafted a paper published in the *Annual Review of Energy* for 1985, entitled 'An end-use oriented global energy strategy'. As the title indicated, its approach was diametrically opposed to that of the IIASA study. Two years later the group expanded their collaboration into an astonishing 500-page book entitled *Energy for a Sustainable World*. It represented a stunning break with what had long been the conventional approach to energy data, analyses and projections. More than two decades later *Energy for a Sustainable World* remains a landmark, both for its panoramic sweep and for its meticulous attention to detail. It is also lucidly readable, almost irresistibly quotable. No brief summary can do it justice.

Our main finding is that it is possible to formulate energy strategies which are not only compatible with, but even contribute to, the solution of the other major global problems - including North-South disparities, the poverty of the majorities in the developing countries and of minorities in the industrialized countries, food scarcities and undernutrition, environmental degradation in *both the industrialized and developing countries, the threat of global climatic change, the pressure from population growth, and global insecurity and risks of nuclear weapons proliferation and thus the threat of nuclear war. Thus it appears that the energy problem can be turned into a powerful and positive force for improving the human condition on this globe. Instead of being the destabilizing force that it is today, energy can become an instrument for contributing to the achievement of a sustainable world.*

The formulation of such energy strategies is made possible by shifting the focus of energy analysis from the traditional preoccupation with energy supplies to the end-use of energy. In this end-use approach, much closer attention is paid to present and future human needs served by energy, the technical and economic details of how energy is being used, and alternative technical options for providing the energy services that are needed...

What links our interest in solving the energy problem to ... other global problems ... is a commitment to certain basic social goals - equity, economic efficiency, environmental soundness, long-term viability and peace.

These challenging criteria became the touchstone of the study. Like the Leach study in the UK a decade earlier, but this time on a global scale, with its daunting diversity and complexity, *Energy for a Sustainable World* asked what we use energy for, and in what technologies - what the authors called an 'end-use methodology'. From the outset it targeted what the authors called 'basic human needs' - food consumption, shelter, health, education and employment. Needless to say, the data deployed and the analyses undertaken bore little resemblance to traditional analysis and extrapolation of data on the use of fuels and electricity, as manifest in earlier studies by IIASA and the World Energy Council. The data used in *Energy for a Sustainable World* were drawn from a vast canvas of primary sources, not only on essentially every variety of fossil, nuclear and renewable supply but also on an extraordinary catalogue of specific user-technologies - buildings of every kind, fittings, appliances, industrial process plant, vehicles - even down to particular makes and models of passenger car.

Nor did *Energy for a Sustainable World* focus only on the elaborate panoply of commercial energy uses in industrial countries. Fully 100 pages of the report were devoted to energy strategies for developing countries, recognizing from the outset that the convenient and misleading label 'developing' covered a wide disparity from place to place, both between and within countries. Even to gather and collate the data used was an undertaking that still boggles the mind; the report included, literally, tens of thousands of cited references. The analysis and commentary considered not only the traditional straightforward quantification of aggregated amounts and flows of energy through unspecified technologies, but also performance data on user-technologies and activities, at a level of differentiated detail never hitherto presented in such a broad panorama. The 500 pages of *Energy for a Sustainable World* were an unprecedented, encyclopaedic guide to the world's energy systems.

But the authors intended more than just to compile an encyclopaedia. The closing chapters of the report presented, in detail similar to that of preceding analyses, what they called 'Policies for implementing energy strategies for a sustainable world' and 'The political economy of end-use energy strategies'. Rereading their commentary prompts one over-riding, baffling question: why not? Why did this unique global analysis, commentary and - in effect - manifesto have so little impact on the day-to-day practice of energy policy and decision-making around the world? As a demonstration of managing energy data it had no equal at the time, and remains a landmark, at least for those who still remember it. But why do so few of today's energy decision-makers even remember it? Possible reasons go to the heart of why, two decades later, we are still managing energy wrong.

MANAGING THE DEMAND SIDE

In traditional electricity, when electricity suppliers have a monopoly franchise, regulators are charged with protecting the interests of electricity users who are otherwise captive customers of the monopoly. Historically, the traditional role of the regulator has been to oversee the company's proposed investment; only investment deemed prudent may be recovered from customers. In the US, in 1978, this proviso underwent a significant change. The Public Utilities Regulatory Policies Act of the Carter administration stipulated that electricity regulators had to consider all available options to ensure that the lights stayed on. In the 1980s, accordingly, rather than simply projecting anticipated future demand and authorizing electricity companies to invest in matching supply, regulators began to ask whether a given company might do better by investing in reducing customers' waste of electricity. The corresponding procedure came to be called 'demand-side management' or DSM.

On one level DSM was an overdue acknowledgement that using electricity required a complete circuit of assets, not just generators and network but also user-technologies, interconnected and operating together in real time - that what mattered was the entire system, not just the 'supply'. Since the time of

Edison, electricity suppliers had been concerned only with how much electricity might be used and when - not how it might be used, or what for. DSM entailed gathering data of a kind unfamiliar to most electricity suppliers, on the actual performance of their customers' technologies, - buildings, fittings, appliances and so on. Only with such data could companies and regulators ascertain the potential for improvement, the financial implications for the system of undertaking the improvement, and the consequent implications for customers' bills and company revenue. Technologies that performed poorly, using electricity extravagantly, hitherto welcome to companies precisely for that reason, were suddenly suspect.

For a few years from the mid-1980s DSM made measurable headway in a number of jurisdictions, almost entirely in the US. But it was controversial from its inception, for a variety of reasons. The single biggest reason was the direct culture-clash it created. For almost exactly one hundred years electricity companies had been doing their utmost to sell more and more electricity. Selling electricity was how they made money. For companies and their employees to be told that they were now to help their customers buy less electricity was simply alien to their thinking. All the talk of returns on investment in, say, insulation or high-efficiency lamps on customers' premises could not reconcile traditional electricity people to DSM. It just felt wrong.

In time, perhaps, that discomfort might have abated. But DSM, involving a form of investment and consequent longer-term relationship between a company and its customers, ran directly counter to the surging wave of enthusiasm for 'free markets' and competition that roared into power with Ronald Reagan in the US and Margaret Thatcher in the UK, among others. In 1988 the UK government announced plans to sell its government-owned electricity system to private investors, to break up the previously integrated monopoly system and introduce competition in an 'electricity market'. By 1990 it had done so. UK electricity evangelists carried the message of electricity liberalization and competition far and wide, even to the US. DSM, as practiced to that point, had been imposed by a mandate from a regulator overseeing a monopoly franchise. The end of the monopoly franchise shattered the traditional ground-rules for electricity and its regulation. The consequences are still working their way through liberalized electricity systems all around the world. One almost immediate consequence was the disappearance of demand-side management as a way to upgrade overall system performance. A corollary was the corresponding corporate loss of interest in the performance of user-technology. Data on the demand side was no longer in demand, not at least by those with money to invest.

CLIMATE AND COMMODITIES

In the mid-1960s the United Nations Educational, Scientific and Cultural Organization UNESCO, in a programme called Man and the Biosphere, convened a major international scientific study entitled 'Man's Impact on Climate'. Drawing on the best available scientific data from around the world, it was the first global assessment of what might be happening as a result of human activity. Its book-length summary report, published in 1968, bore the unnerving title *Inadvertent Climate Modification.* Outside the scientific community it attracted little attention at the time; but scientists became increasingly concerned. At length, two decades later in 1988, at a large-scale conference on 'The Changing Atmosphere: Implications for Global Security' in Toronto, climate exploded onto the political agenda. Leading politicians including UK prime minister Margaret Thatcher declared themselves alarmed. Suddenly the data of interest were not just scientific but economic, and intensely controversial.

The controversy arose because scientific data indicated that a key factor perturbing the climate was carbon dioxide released into the atmosphere by burning fossil fuels - the coal, oil and natural gas that powered the industrialization of human society. Economic data in turn underlined just how important was the burning of fossil fuels to the functioning of the global economy, and the social organization it by now supported. The clash was head-on, one set of data against another set of data, both as accurate as could be achieved, whose interpretations and policy implications appeared to be flatly incompatible, indeed irreconcilable.

Battle was joined in earnest at the UN conference in Rio in 1992, known as the 'Earth Summit'. It created a 'Framework Convention on Climate Change' (FCCC) and an Inter-Governmental Panel on Climate Change (IPCC), convening many hundreds of leading climate scientists from around the world to collate and analyze all available data on climate, and weigh the implications. Observers noted, however, that by no means all Rio participants supported the process. Representatives from oil exporters, oil companies, coal producers and car manufacturers were among those understandably unenthusiastic about attempts to reduce emissions of fossil carbon dioxide. From its inception as a concept, climate policy was inextricably intertwined with climate politics; and every viewpoint, every faction cited data to support its case.

Among the vast outpouring of analysis, commentary and polemic that has since ensued, however, one detail has hitherto attracted little notice. For more than two decades the issue has been portrayed as pitting climate security versus energy security. The core data invoked have been the amounts of fossil carbon dioxide emitted into the atmosphere, and the amounts of fossil fuel burned to produce this carbon dioxide. From the viewpoint of climate security, so goes the argument, the urgent need is to reduce the amount of fossil fuels burned. From the viewpoint of energy security, goes the counter-argument, reducing the amount of fossil fuels burned may let the lights go out. Both viewpoints focus on tracking the data on batch transactions in commodities, carbon dioxide on the one hand, oil or coal or natural gas on the other. This approach to data and their application to policy, centred on short-term commodity flows, has dominated every aspect of the climate/energy issue since it burst onto the political agenda.

In the negotiations that led to the Kyoto Protocol to the FCCC, agreed by more than 100 countries in 1997, the key undertaking debated and eventually ratified was the amount by which participating countries would reduce carbon dioxide emissions by the target date of 2012. Various policies and measures to achieve this reduction were identified. A government might impose levies or taxes on measured amounts of carbon dioxide emitted from various economic activities within its borders. It might impose an overall cap on emissions, allocate permits accordingly, and allow users of fossil fuels to trade their permitted allocations; those who reduced fuel use below the allocated level could sell their unused allocation to those who would otherwise exceed their allocation. Levies, taxes and emissions-trading all depended on measured data describing flows of commodity carbon dioxide in the economy. Carbon dioxide itself was seldom measured directly. Recorded data were and are based instead on inferred releases from measured uses of the various fossil fuels. On an international level, Kyoto Protocol activities under 'Joint Implementation' and the 'Clean Development Mechanism' likewise depend on inferred reduction of emissions as a corollary of measured reduction in the use of fossil fuel.

As well as endeavouring to reduce the use of fossil fuel, policymakers have been seeking ways to make up the consequent presumed deficit, by expanding sources of energy supply involving little or no emission of carbon dioxide. Support arrangements for renewable electricity generation include 'feed-in tariffs', guaranteeing a premium price per unit generated, in Germany and a number of other European countries; in the UK 'renewable obligation certificates' or ROCs, paid for a defined number of units of renewable electricity delivered to the network; and in the US 'production tax credits', allowing generators a premium off their tax obligations according to how much electricity they generate. The EU has adopted targets calling for 20 per cent improvement in 'efficiency', 20 per cent contribution from renewable supply, and 20 per cent reduction of emissions by 2020 - tidily memorable numbers, all linked to commodities. China is likewise calling for a 20 per cent improvement in 'efficiency', and the Obama administration in the US is proposing similar measures.

In each of these instances, policy is intended to stimulate investment in new technology; but the policy measure itself is applied not directly to investment, technology or infrastructure but to some measured commodity-flow associated with its operation. Potential investors in costly new nuclear power and so-called 'clean coal' with carbon capture and storage have thus far been reluctant to commit, if the only support available is through short-term, unpredictable commodity-based benefits such as emission credits.

FROM COMMODITIES TO INFRASTRUCTURE

Data on flows, quantities and prices of measured commercial commodities - fuels, electricity and now carbon dioxide - have long dominated thinking about energy policy, energy security and climate security. Such commercial commodity data obviously serve the purpose for those who gather and analyze them, to support their businesses of buying and selling these commodities. To call them 'energy data', however, gives a seriously incomplete and misleading picture of human energy activities, their current status worldwide and their potential for improvement. Missing from this picture is what the energy is flowing through: the technologies and infrastructure that actually deliver the services we want.

The missing data exist, in abundance. They have been gathered and analyzed at least since the mid-1970s, as indicated earlier. Some notable commentators and commentaries are listed in Annex 1. What was a trickle in the 1970s is now a torrent, far too copious to list. For more than three decades we have had access to a rapidly expanding array of published data on the energy performance of buildings; lighting; motors and controls; heating, ventilation and refrigeration; electronics; process plant; and vehicles of every kind. We already know an astonishing amount of information about the performance of essentially every kind of user-technology and user-infrastructure through which energy flows.

What we still do not know, however, is why this crucial aspect of our energy systems fades almost out of the picture when most politicians, journalists and other commentators discuss energy policy. Many analysts have carefully explored the question. An outstanding book-length example, for instance, is *Energy Efficiency and Human Activity*, by Lee Schipper and Stephen Meyers

(Cambridge, 1992), detailed, thoughtful and illuminating, still dismayingly relevant many years later even though the data have since altered beyond recognition. Those in the field can readily tick all the usual boxes, the reasons why so-called 'energy conservation' and 'energy efficiency' remain a knee-jerk afterthought in energy policy. They include:

- Lack of information and lack of understanding;
- Lack of incentives, as when fuel bills are a small proportion of overall costs;
- Lack of access to capital;
- Divided interests, as for instance between landlord and tenant;
- The so-called 'rebound effect' - if improved performance makes fuel or electricity bills lower, more may be used;
- And the familiar 'hassle factor', making improvement just too much trouble to bother with.

But these various factors are not really causes. They are symptoms of a deeper problem. We don't care enough about how we use energy, simply because we see energy wrong. The expressions 'energy conservation' and 'energy efficiency' betray the central confusion. Both concepts, when they can be measured, tell us how well technology and infrastructure use fuel or electricity, not how well they deliver services. 'Energy conservation' and 'energy efficiency' belong to the suite of commodity concepts that dominate the picture we get from our energy data.

We have to change this picture, change how we see energy, and change the focus of energy data accordingly. The essential change is simple and obvious. It is to accept, as a practical reality and determinant of policy, that fuel and technology compete directly with each other - that energy users' *assets* and *infrastructure* compete directly with energy commodities. Better user-technology requires less fuel to deliver the same or better services. We need to recognize that key competitors for ExxonMobil are not Shell nor BP but Toyota and Honda; competitors for Gazprom are Europe's manufacturers and installers of thermal insulation; competitors for EdF and E.On are the manufacturers of compact fluorescent and LED lamps; and so on, across the entire range of user-technology and infrastructure around the world. When we view energy data as we should - all the data, for entire systems - that is the picture we should see.

Energy is not a commodity to be consumed. Across the vast and disparate panorama of human energy use, one unifying principle prevails. All energy use is a process - a process in technology and infrastructure. We need to manage energy data accordingly. We have abundant scientific and engineering data about the energy performance of user-technology and user-infrastructure. We need to make this data commercial, to transform it into the basis of practice. Subsequent Working Papers will discuss the implications for business activities and relationships, finance, planning, institutions, systems and policy.

User-technology and user-infrastructure, competing directly with fuel, should become not merely an incidental afterthought but the central focus of energy policy and energy business. To protect climate security and enhance energy security, the central objective of energy policy ought to be equally simple: to *minimize* requirements for fuel. Energy companies - true *energy* companies - will profit and prosper by providing what society wants: not commodities but infrastructure and its services.

To see energy as we should, we need vision. The time has come to see energy for what it really is: an unparalleled global opportunity.

ABOUT THE AUTHOR

Walt Patterson is associate fellow in the Energy, Environment and Development Programme at Chatham House, London, and visiting fellow in the Sussex Energy Group, University of Sussex. His latest book is ***Keeping The Lights On: Towards Sustainable Electricity*** (Chatham House/Earthscan 2007). This is the second Working Paper in his current project, ***Managing Energy: Rethinking the Fundamentals***. His website archive Walt Patterson On Energy, <www.waltpatterson.org>, offers free downloads of 39 years of his work, including five complete books.

ANNEX 1: USER-TECHNOLOGY AND USER-INFRASTRUCTURE

(This is a brief but representative selection of data sources and commentaries in English since the 1970s, including some mentioned in the main text: individuals and organizations, and their books, reports and other documents. The sources listed here in turn include many additional references.)

Amory B Lovins

(now Rocky Mountain Institute: <http://www.rmi.org/>)

World Energy Strategies (1973, many editions in many languages)

Soft Energy Paths (1977, many editions in many languages)

(many subsequent books, papers and reports; see RMI)

Måns Lönnroth, Peter Steen & Thomas B Johansson

Energy In Transition (English edition University of California Press, 1980)

(numerous other titles from each author)

Niels Meyer

(particularly household energy use - many papers, authored and co-authored, since 1970s)

Gerald Leach

(lead author, A Low-Energy Strategy for the United Kingdom, International Institute for Environment and Development, 1979; many other papers and reports on energy analysis)

Lee Schipper

Explaining Energy (Lawrence Berkeley Laboratory 1974); Energy Efficiency and Human Activity (with Stephen Meyer; Cambridge University Press 1992); many other papers and reports

Art Rosenfeld

(Lawrence Berkeley Laboratory; many papers, authored and co-authored, since 1970s)

Robert Stobaugh & Daniel Yergin

Energy Future (Harvard Business School; Random House 1979)

Marc Ross & Robert Williams

Our Energy: Regaining Control (McGraw-Hill 1981)

Jose Goldemberg, Thomas B Johansson, Amulya K N Reddy & Robert Williams

'An end-use oriented oriented global energy strategy' (Annual Review of Energy, 1985)

Energy for a Sustainable World (John Wiley, 1988)

Brenda Boardman et al.

40 % House (Environmental Change Institute, University of Oxford, 2005)

Stephen Fawkes

Outsourcing Energy Management (Gower, 2007)

Alliance to Save Energy (US): <http://ase.org/>

American Council for an Energy-Efficient Economy (US): <http://www.aceee.org/>

Association for the Conservation of Energy (UK): <http://www.ukace.org/>

EuroACE (EU): <http://www.euroace.org/>

International Energy Agency: <http://www.iea.org>: (reports on user-technology - see for instance Light's Labour's Lost, 2006)

European Commission:
<http://ec.europa.eu/energy/efficiency/index_en.htm>: see for instance Energy Performance of Buildings Directive, Eco-design Directive

United Nations Statistics Division: Oslo Group:
<http://unstats.un.org/unsd/energy/oslogroup.htm> (reviewing energy statistics, including performance of user-technology and infrastructure)

United Kingdom Market Transformation Programme:
<http://www.mtprog.com/> (gathering information on user-technology, to guide policy)

United States Energy Information Administration:
<http://www.eia.doe.gov/emeu/consumption/index.html> (energy performance of households, buildings, industry and vehicles)

California Energy Commission: <http://www.energy.ca.gov/efficiency/> (a leading regional programme on user-technology and infrastructure)