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HOW SCIENTISTS ARE HELPING THE PUBLIC TO UNDERSTAND THE C WORD

Changing public attitudes towards climate change owe a lot to the partnership between populism and serious science, argues **DR MARK EVERARD,** Vice-Chair of the Institution of Environmental Sciences

Wherever you turn in the media today, you can't avoid the 'C' word. Carbon (what else?) is high on the agenda of everyone from politicians to insurance companies, broadcasters to financial service providers, and even Formula One teams and airlines. It is even being mentioned cheek-by-jowl with farm gate prices and skittles scores in my local pub.

The C word is, of course, a major contributor to the also increasing popular 'CC' words. The concept of climate change is also now much more widely discussed through public awareness about thinning ice sheets and stranded polar bears, retreating glaciers and rising sea level, flooded cities and spoiled crops. We're also beginning to see a retreat from the cuddly-sounding, implication-masking term 'global warming'.

Full marks then to the populists, Al Gore and his shiny new Nobel Prize prime amongst them, who have helped society realise that climate change is not a remote and theoretical issue but one that might quite literally come flooding through our doors at any minute.

Without the underpinning environmental science, the potential threat, mechanisms and implications of the issue could never have been discovered nor become increasingly well understood. However, without the media and its numerous talking heads, the 'close to home' implications may never have been brought to bear to shift societal perception and concern.

Detailed science and popular interpretation can often form an uneasy partnership, but recent progress with social attitudes towards climate change demonstrates the potential value of this partnership for driving advances in the many other pressing environmental issues.

The 'environmental sciences' in their broadest sense embrace not only the 'warp' of a variety of inter-related disciplines but also the 'weft' running from primary research through to practical applications, education and broader understanding, and interpretation for the media, policy-makers and commercial users. All are necessary for the environmental sciences to inform society's collective and ultimately practical progress towards sustainability.

This special edition of *Environmental Scientist* is not solely about 'C' or even 'CC', but addresses the timely topic of the source of our energy supply.

Energy, in its broadest sense, is a widely 'cross-cutting' issue for society, spanning everything from transport to domestic and industrial power supply, a primary input to agriculture, a key issue for international development and globalised trading, healthcare and domestic security. And the consequences of our historic reliance upon non-

renewable energy are every day pressing themselves upon our consciousness. So what are the 'right answers' for development of renewable energy supply to feed our future?

Contemporary concerns drive a great deal of the current impetus for renewable generation. This is a strength and a weakness. Where there is momentum for change, as for example with 'C' and 'CC', then why not use it? But, if we hitch our aspirations for renewable energy solely to the political wagon of climate change and carbon reduction, we risk arriving at solutions that are at best partial.

For example, the much-trumpeted role of biomass to harness solar energy (and also grow fibre, chemical feedstock, dyes, pharmaceuticals and so forth) appears attractive when viewed solely through the dimension of carbon reduction. However, bring into play the breadth of other environmental sciences – the 'take' of biofuels from food-producing lands, conversion of increasingly scarce natural habitat, loss of biodiversity and critical ecosystem functions, water demands and water-borne pollution, energy and agrochemical inputs for crop production, soil compaction through use of machinery – and the case is far less compelling.

Cast a scientifically critical eye upon all of the inputs to biofuel production, importantly including the full life balance of energy required to nourish, irrigate, produce, transport and process the farmed (or pharmed) products, and even the apparently bullet-proof carbon-based case itself appears somewhat more shaky.

It is for this reason that this special edition of *Environmental Scientist* is dedicated to the issue of energy in the round, spreading the net wide and ducking no controversy. From energy crops to tidal generation, established solar energy technologies to emerging methods such as CSP (concentrated solar power), and even seemingly 'supping with the devil' of nuclear generation.

It is prudent at this time to remind ourselves that the views expressed by contributors are not necessarily those held by the Institution of Environmental Sciences itself. It is also prudent to acknowledge that, as environmental scientists, we have to retain open minds, trusting to the science itself to guide us towards sustainable outcomes. If we do not, we run the risk of 'solutions' as blinkered as our framing of the problem, and hence a perpetuation of the industrial age habit of solving yesterday's problems with tomorrow's.

> 'We have to retain open minds… If we do not, we run the risk of 'solutions' as blinkered as our framing of the problem'

Finally, let's remind ourselves that a waste of energy, renewably-generated or not, is one of the major contributors to society's energy 'footprint'. So the apparently trivial steps of turning off unused lights, not leaving the television or computer on standby all night and a million other small contributions are as significant for the cultural shift to the truly renewable society – from energy to material resource use and even the harnessing of personal creativity – towards which our scientific awareness and personal instincts compel us to aspire.

◆ The views expressed in this article are those of the author, and do not necessarily represent those of the Institution of Environmental Sciences

CATCHING SOME RAYS

'Solar energy' is generally perceived as novel technology. Yet in reality it is the oldest energy source enjoyed by society. **DR MARK EVERARD** discusses how it is all a matter of timescale, and of the 'collateral damage' involved in exploiting it

Spinning round the sun

This small blue planet is sustainable by virtue of the cycling and slow sedimentation of chemicals within its thin upper layer of soil, and in its water and air. Proportionately thinner than the shell of a hen's egg, the biosphere of planet Earth comprises diverse and profuse ecosystems that collectively interact to circulate water, nutrients, carbon, oxygen and other chemicals, which also build atmospheric shields against harmful radiation from space, store energy and sustain meteorological patterns. These self-regulating, life-sustaining systems are powered in perpetual cycles by the net capture of radiation from the small (in stellar terms) star some 93,000,000 miles distant, around which we spin.

Over billions of years, physical and biological processes have sequestered away excessive heavy metals including their long-lived radioisotopes, carbon, nutrients and other substances into inert forms in the Earth's crust. This progressive 'cleansing' of our atmosphere is such that, compared to most of our evolutionary history, we now enjoy purified air, water and soils.

Powering the Industrial Revolution

In large measure, the Industrial Revolution was enabled by a reversal of these purifying processes as we learnt to dig things up from the ground as sources of energy and materials.

Our early industrial and trading progress was powered significantly by energy that was essentially solar. This included, and still includes, watermills and windmills (and their novel electricity-generating variants), vessels powered by sail, horses or humans, the burning of wood, straw and other biomass, and a host of other potentially renewable sources. Each of these was solar-powered through harnessing the energy captured by natural cycles in meteorological patterns, water flows and biological productivity. Tidal power was vital too, albeit that this harvests energy largely produced by gravitational effects. However, the hallmark of renewability here is one of timescale, drawing upon energy transformed into flows within the biosphere in natural scales from hours to years.

By contrast, a great deal of subsequent and continuing industrial progress was enabled by the discovery of carbon-rich fossil reserves, initially coal but latterly oil and gas, which liberate energy in a concentrated form when oxidised. From powered ships to railways, steam hammers to beam engines, generators to tractors, water pumps to jet engines, 'black gold' drives the model of progress that now pervades the habits of developed society. So deep is our addiction and dependency that society would collapse were fossil energy removed suddenly. Alarmingly, the spectre of 'peak oil' promises exactly that, over a surprisingly short timescale for which society seems almost wholly unprepared. This, however, is a tale for another dark day.

Though at the time appearing novel, the energy carried by fossil carbon fuels is of course also ultimately solar in origin. Differentiation from 'renewables' is only in terms of timescale between capture and liberation, and in the relative pace of each. Fossil fuel reserves are the residue of biological activity over geological timescales, most notably during the Carboniferous era (345-280 million years ago). In the absence of knowledge about longer-term implications, it is unsurprising that fossil fuels overtook shorter-cycle energy carriers, presenting revolutionary technological and economic opportunities. Fossil fuel usage has proliferated owing to three principal factors. Firstly, they are cheap due to externalisation of environmental and social costs entailed in their production and use. Secondly, they have a relatively high bulk density, making for easy transport and storage. Thirdly, they are also a highly concentrated form of energy: coal, oil and gas have energy values of 35, 43-47 and 36MJ/m^3 respectively, compared to 18-19MJ/kg (dry weight) or 15-16 MJ/kg (assuming a 20% moisture content) for energy crops.

Since the start of the Industrial Revolution, we have learned to harness at an ever greater rate the abundant, cheap and portable energy locked up in these fossil fuel reserves in the Earth's crust. This has resulted in many benefits, including on-demand heat and light, pumping of water and sewage, high-yield agriculture, rapid transport, generation of electricity, and wealth creation activities of all types. However, we did not understand the substantial down-sides of fossil fuel use – including their implications for climate change, urban air pollution and ultimate depletion of reserves that must once have appeared inexhaustible – with which we are now having to grapple.

Renewable energy and renewable society

We are now waking up slowly to the need for a more ardent pursuit of 'renewable energy', albeit that the term is often poorly defined. One of the conclusions of the UN's Millennium Ecosystem Assessment was that energy use across the world not only accounted for the major degradation of global ecosystems but also remains the fastest-growing pressure. We need therefore to use and source energy on a fully renewable basis, not to continually 'mine' historic reserves which will not only run out but which release pollutants sequestered from the biosphere over vast geological timescales and that now pose serious threats to our future. A transition is essential if we want a renewable – i.e. sustainable – society that enjoys a resilient supply of energy.

There is some confusion about what exactly comprises a renewable energy source. For example, in considering energy sources for exemption from the Climate Change Levy during 2001, the UK's DTI (Department of Trade and Industry) included energy generation from the combustion of domestic, industrial, agricultural and forestry wastes, exploitation of landfill gas, and CHP (combined heat and power). All contribute to lowering total carbon emissions relative to today's profligate baseline, but most are far from inherently sustainable. Truly renewable energy is that obtained from the continuous, repetitive currents of energy occurring in the natural environment, used at or below the rate at which they are replenished. We may make short-term total emission-reduction choices, such as landfill gas and waste combustion, though we have to achieve this without fostering a dependence upon perpetuating waste streams. However, for our longer-term future, we have to understand and respect the finite limits of energy flows within ecosystems. Although the 'natural limits' concept is not wildly popular in industry or with many economists, and is often perceived as a barrier, it can in fact spur advances. A new generation of technologies defined by respect for the first and second laws of thermodynamics as they pertain to ecosystem impacts should represent fertile and certainly profitable grounds for innovation.

Efficiency of energy use across society is a major factor to be addressed, though not the subject of this article. But we also have to learn to tap renewable energy sources more effectively, efficiently and equitably. In so doing, we have to be mindful that no energy source – 'renewable' or not – is entirely benign; all have potential implications arising from perturbing water flows, fish and bird migration, use of rare and exotic chemicals and disturbance to society. Even biomass – energy crops, forestry waste and other 'short-cycle carbon' technologies – while having oft-quoted benefits, also carry significant implications for biodiversity, water use, chemical and energy inputs and other problems besides that need to be balanced and refined in decision-making.

One of the key challenges for energy generation is about 'moving upstream', away from energy carrier systems like fossil fuels which have accrued energetic content over hundreds of millions of years along with associated contaminants. Instead we must tap into shorter-cycle energy flows such as, in decreasing order of timescale, geothermal rocks, biomass, water, wave, tide and wind currents and, right at the 'upstream' end, direct capture of solar energy as it falls to Earth.

Direct solar capture technologies

Solar energy is at the heart of most energy systems. It is liberated from fossil fuels wherein it has been captive for hundreds of thousands of years, from trees and crops where it may have been captive from years to centuries, and in wind and water movement where it may be far more recent. However, sunlight falling to Earth is the primary, infinitely (at least from our parochially terrestrial perspective) renewable resource of what are now more generally thought to comprise 'solar energy' technologies. Sunlight is diurnal, and then may be intermittent with levels of incoming ground-level radiation influenced by seasonal and climatic conditions. Today's solar energy capture technologies are diverse, but can be classified into three main groups: photovoltaics, passive solar capture, and embedded design.

Photovoltaic (PV) systems are familiar from sci-fi movies and space documentaries as the 'solar collectors' seen on spacecraft, though they are in reality a diverse group of technologies. They are also surprisingly old. The photovoltaic effect was first discovered in a wet cell by Edmond Becqueral in 1839. Adams and Day observed it in selenium in 1877, with Fritts proceeding to produce the first selenium solar cell in 1883. During the 1950s, the effects of light on semiconductors were observed and understood, and the first silicon solar cell was developed. Modern PV systems produce low-voltage direct current, often with a service lifetime of at least 25 years. They are usually solid-state semiconductors which generate an electrical potential when exposed to light, and are clustered in arrays to bulk up output. The main semiconductor material now used in PV arrays is silicon, in mono-crystalline, poly-crystalline or amorphous forms, although cadmium telluride (CdTe) and copper indium diselenide (CIS) are also used. Though relatively expensive to produce, the energy generated is carbon-neutral during product life, with lifetime carbon and other pollution 'footprints' determined by longevity and efficiency of use.

Passive solar systems, by contrast, are nothing new. In essence, 'passive solar' systems catch the heat of the sun in the same way that a greenhouse, car or house heats up as sunshine falls on it during a clear day. However, the term 'passive solar' in the context of energy systems is most often reserved for technologies like solar water heating collectors. The technologies are mature, though still evolving, with many market options available for domestic and commercial properties. Typically, these take the form of roof-mounted solar capture panels through which water is passed, though free-standing units are also regularly seen, particularly in hotter climates. These systems may be free-standing, and indeed are often so in rural Africa and India, but are most usually connected to a traditional hot water system in developed regions and in cities.

Solar water heating systems can provide over half of a typical British household's hot water requirements over the year, and all of it during the summer. There are two principal types of solar water heating collector: flat plate and evacuated tubes. Flat plate collectors are the simplest form of solar panel, generally made from a sheet of black-painted metal embedded in an insulated box and covered with glass or clear plastic. Water is fed through pipes – most often copper pipes for better conduction – attached to the metal sheet to exchange heat and feed it into a hot water system, swimming pool or other application. Evacuated tube systems comprise series of glass heat tubes, highly insulated within an evacuated frame, that capture solar energy to heat water at higher efficiency.

'Embedded design' is simply design of buildings in ways that exploit 'solar gain' through the passive solar effect. Even as far north as Scotland, the average home receives around 15% of its space heating from solar energy permeating through walls and windows. Passive solar design aims to optimise the amount of energy derived directly from the sun, by careful choice of site, orientation, design, roofing, windows and louvres, construction materials including 'thermal mass', and external landscaping, thereby reducing the need for external energy inputs from other sources for heating, cooling and lighting. Although not a generation technology, embedded design with solar capture in mind can make a major contribution to the energy efficiency of buildings, using incoming solar energy at point of need and cutting dependency upon external energy sources. Passive solar design is most effectively implemented in new-build, but can be applied to existing buildings to complement most traditional energy conservation measures. By planning for solar gain in advance, features are designed as alternatives rather than additions, so costs may be far from excessive and can even be lower. Indeed, they invariably should be so when lifetime energy costs are factored into building design.

Obstacles and incentives for solar generation

There are a number of oft-cited obstacles to uptake of solar energy. These primarily include cost and connectivity to power networks.

Some solar technology is expensive, but others not dramatically so, particularly when compared to expenditure on traditional systems. As stated, embedded design uses alternative rather than additional methods, so need not be costly and may even be cheaper. The cost of a solar water heating collector system depends on its size and the modification required to the existing hot water systems. Typically, a domestic installation may cost anything from £1,500 for a DIY system up to £9,000 for a larger specialist-installed system. Payback can be anything from three to nine years, based on replacement or reduction of demand for external fuels. But isn't cost a killer for more expensive technologies such as PV systems? Again, not necessarily so. Already, building-integrated solar panels can replace roofing and cladding materials, competing favourably with premium facings on price while then offering a lifetime payback of embedded power supply, with minimal transmission loss, and the capacity for profit from both reducing building energy consumption and the export of excess electricity into the grid. In a period of rising fossil fuel prices which seems set only to continue, the cash savings from all solar systems will increase and payback periods will decline along with total greenhouse gas emissions. Furthermore, as large-scale manufacturing is achieved, economies of scale can be expected to bring initial costs down substantially.

However, one of the biggest conceptual barriers to the uptake of solar and other renewable energy forms is not the technology but ingrained ways of thinking about energy systems. We have grown up with the idea of centralised generation systems: gigantic power stations, burning fossil fuels or reacting nuclear material, sprouting high-voltage lines and networks to deliver power over long distances and across wide territories. That grid is not only a physical reality, at least in the developed world, but also a conceptual cage. Often, one hears of the difficulty of connection of small-scale dispersed and intermittent sources, necessitating boosting, inverting and two-way metering to feed into the distribution network, as if the grid were a given fixture that all should serve. And yet our daily reality is quite different to that. As energy users, most of us are – like the small-scale energy conversion systems themselves – small, intermittent, dispersed, and based on (usually transformed from the high-voltage AC grid) low, direct current voltages.

Where solar and other renewable technologies excel is in providing a standalone power supply. This is not a distant aspiration but now a daily reality – as commonly used in telecommunications, navigational lights, road signals, bus shelter and ground lighting, clocks, calculators, radios, rechargeable torches and batteries, laptop PC power sources in remote locations, and a growing range of other applications. Even for those of us living in 'ordinary' houses, PV arrays can provide for some of our needs, topped up from the grid during periods of higher demand. Meanwhile, the technological feasibility of two-way metering and sale back to the grid is becoming more tenable and affordable, with numerous installations already in operation across the country.

Rewiring society

The rewiring is required not so much in our energy supply circuitry, but in our minds. In today's early stages of our quest for a carbon-neutral future, conflicts with established perceptions and vested interests are all too common. For example, just look at the vociferous opposition to some wind farms or the petty objections to domestic-scale wind turbines in conservation areas for purportedly 'environmental' reasons. The underlying logic is that environmental quality can degrade so long as it looks pretty! Consents for installation of solar panels have often suffered the same fate at the hands of our planning visionaries.

A more distributed, truly renewable energy generation system will require more enlightened, local and inclusive decision-making in developing local solutions to meet energy needs. However, purely localised decision-making cannot work in isolation from a degree of centralised planning to take account of distribution infrastructure, pricing, energy security, and the meeting of government targets. Long-term planning is undoubtedly required, with appropriate economic incentives and legal compulsions and easements, to facilitate a transition from centralised generation and distribution systems towards hybrid systems that are more carbon-efficient. Decentralised generation, close to point of use, offers greater efficiency due to many factors including energy access to remote communities, low- or no-carbon energy, and reduced loss on transmission and transformation. However, with prudent phasing, notwithstanding the currently capital-intensive conversion infrastructure for renewable energy, there is not necessarily any reason to believe that a transition to renewable energy, with solar systems playing their part, would have a negative impact on the economy. Indeed, transition to a brave new renewable energy future will undoubtedly be net beneficial when we internalise the costs and dividends of investment in new technologies, improved energy security, and pollution impacts on ecosystems and health.

And let us not forget that this is just thinking about the minority of the world already enjoying relatively cheap and reliable access to energy. What about the billions for whom energy deficiency conspires with inadequate water supply, sanitation and other resources to reinforce poverty and denial of life opportunity? The G8 nations and wider international community have made a promise to these silent billions. What better way to help local people in sunnier countries meet their energy needs than the transfer of technology for decentralised, small-scale solar generation and storage?

For many of us involved in environmental issues, the future can seem challenging in the extreme. However, with solar technologies, we at least have rays of sunshine to light our way.

FUTURE DIRECTIONS FOR RENEWABLES – WIND POWER

PETER HULSON surveys the success of Government targets for 10% of electricity to be met from renewable sources by 2010, and the potential barriers. He focuses on onshore wind as the key mechanism through which renewables may be deployed in the UK

While the UK now joins a limited group of seven other countries which have achieved 2GW plus from wind energy, delivery of onshore consents is still subject to delay within the planning determination process, and determinations appear to be less favourable for wind farm development when compared with other major developments. The article concludes with an examination of the future 20% EU target for renewables and the extent to which political and economic incentives will have a pivotal role in ensuring its success.

Fair winds?

Following the commissioning of the 72MW Airtricity Braes of Doune wind farm near Stirling, the UK has reached a landmark of 2GW plus (80% onshore and 20% offshore) installed electrical capacity from wind farm schemes. In combination with the 136 other consented wind farm schemes, this equates to approximately 1.5% of total UK electricity supply. The then Secretary of State for Trade and Industry Alistair Darling provided a strong endorsement of the role of onshore wind on passing the 2GW wind capacity threshold:

'We want 20 per cent of our electricity to come from these green sources and we are working hard on removing any barriers to achieving that aim. Wave and tidal and offshore wind can make a significant contribution… but onshore wind energy is delivering capacity here and now.'

Beyond the hyperbole, have there been substantial steps forward to securing the Government's target of 10% of electricity from renewable sources by 2010? Has delivery improved since 2004, when the House of Lords Science and Technology Committee asserted that 'a dramatic change in the rate of introduction of renewable generating capacity will be required if the Government are to come anywhere near their target for 2010[1]'? Critically, while the UK has enhanced its delivery rate from 14 years to achieve its first gigawatt to 20 months to reach the second, renewables still generate only 5% of supply – against an expected target at 2007 of 6.7%. If so much still needs to be done to satisfy the 10% renewables target, then what are the barriers for effective delivery of onshore wind which is seen by many as the key mechanism by which the renewables commitment may be delivered?

Facing the barriers

A key barrier to the delivery of the 10% target for electricity generation from renewables is available planning resource and consequential planning delay. Whilst the UK's attainment of 2GW installed capacity ensures that we are one of only eight countries to have achieved this landmark, we are languishing well behind our European neighbours Germany (with 20,622MW); Spain (11,615MW); and Denmark (3,316MW)[2]. Some sobering statistics revealed through a study by the British Wind Energy Association (BWEA)[3] indicate that 8GW future installed capacity from onshore wind is stalled in the planning process. The approval of only a quarter of this total by 2007 would deliver the consents required (in the time needed for construction and commissioning) for adherence to the commitments at 2010. However, average periods to planning determination are 15 months at the local planning level and on appeal 28 months. This time delay has significant consequences for the downstream construction programme and therefore the extent to which the 10% target for renewables may be delivered.

The spotlight thrown on the possible economic effects of climate change by the Stern Review in October 2006 has done little to accelerate the delivery of renewables projects (also identified by many as a key mechanism by which carbon offsetting can be achieved), with UK planning approval rates dropping to 33%. This compares unfavourably with other types of major development which have approval rates in the order of between 76 and 90%. Arguably, this reflects the complexities associated with this type of development, and in particular achieving an acceptable landscape and visual compositional 'fit', particularly for local stakeholders. The apparent paradox between central Government targets and local authority delivery has created a significant sense of frustration for those involved in the consents process for onshore wind farm schemes. There are high profile calls within the industry requesting enhanced support from central Government, the Welsh Assembly and Scottish Executive for planning decision makers. In particular, for large scale Section 36 Electricity Act wind farm schemes (50MW plus), there are significant delays visible within the former Department of Trade and Industry, sparking suggestions of poorly connected policy targets and available resources.

The Government provided an economic instrument for realisation of the 10% (and EU approved 20% by 2020) electricity generation from renewables. Introduced in April 2002, the Renewables Obligation calls on all licensed electricity suppliers in England and Wales to supply a specified and growing proportion of electricity sales from eligible renewable sources (including onshore wind). The (former) Department of Trade and Industry consultation paper 'Reform of the Renewables Obligation'[4] published alongside the 2007 Energy White Paper provided for, amongst other items, banding of Renewables Obligations to provide groups of technologies needing similar support in order to bring forward generation solutions. Within this paper, the Government has recognised that the incumbent delays for delivery of onshore wind projects suggest a step-change is required in alternative technologies to deliver viable renewable energy commitments beyond 2010.

While this may indeed provide a more balanced portfolio of technologies for moving into the future, the mechanisms for delivery of the 10% renewables commitment rest predominantly with onshore wind. This was echoed in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment report which highlighted the pressing need to consent and commission existing renewable energy technologies at a large scale in order to combat climate change. In addition, there is a strong argument which suggests the Renewables Obligation has had no small measure of success in providing incentives for developers to bring forward onshore wind farm sites in particular. This is reflected in the current number of planning applications lodged in the planning system. However, whether this incentive can be maintained where there is relatively poor delivery of sites is open to question. It is entirely possible that investor confidence in renewables projects may be adversely affected by relatively poor delivery of onshore consents.

The Renewables Obligation alone is unlikely to provide enough delivery of renewables projects to satisfy the 10%

1 *Renewable Energy: Practicalities* House of Lords Science and Technology Committee, 4th Report, 2003-04 Session (paragraph 2.24) www.parliament.the-stationery-office.co.uk/pa/ld200304/ldselect/ldsctech/126/126.pdf

2 Global Wind Energy Council: February 2007 (www.gwec.net)

3 BWEA: March 2007: *Planning Status Report – Onshore Wind*

4 Department of Trade and Industry: May 2007: *Reform of the Renewables Obligation*

(let alone the 20%!) commitments for electricity generated from renewable sources. There is no suggestion that 'inappropriate' sites be consented, nor that the planning system be fundamentally reformed beyond the changes brought about by the Planning and Compulsory Purchase Act 2004, the 2007 Planning White Paper and the 2007 Energy White Paper. These reforms alone have stretched existing planning resources to the point where further measures may be counter-productive to the delivery of renewables targets. Rather, a package of measures providing for a more strategic level of support, consistent with the government's stated aims, would appear to be the most apt and expedient course of action. In particular, if the government is committed to the 10% target as a short-term horizon, measures need to be introduced to address planning delay, both at the local authority and Secretary of State level, and to ensure that planning deliberations centre around issues of local importance – including a more cohesive approach to cumulative assessment. Further, there is a need to examine opportunities for decision makers to share expertise and knowledge through technical fora. While robust and thoroughly detailed environmental statements continue to provide an important information source to assist planning officers and councillors, the extent to which balanced, unbiased information is available from non-statutory agencies, and the manner in which this shapes planning determination, is open to conjecture.

Clearly then, breaking into a select band of countries achieving 2GW plus should be heralded as a major step forward for the UK's adherence to its 10% target. Yet for substantive advancement towards the EU 20% target, there must be greater collaboration between central government, the Welsh Assembly, Scottish Executive, local authorities and prospective wind farm developers. This step-change must be delivered against a challenging programme allowing for consent delivery and wind farm construction.

◆ Peter Hulson is an Associate at Arup.

POWER PLANTS

CLAIRE HOLMAN weighs up the costs and benefits of biofuels for our future transport needs

Road transport in the UK contributes just under a quarter of the country's carbon dioxide emissions; and more if all the emissions from well-to-wheel are included. It is widely accepted that there is a need to reduce CO_2 emissions dramatically, and many believe that the government's target of 60% by 2050 may not be sufficient. To achieve a large reduction in emissions, road transport will need to play a part.

With other emissions from vehicles, such as carbon monoxide and nitrogen oxides, there have been a number of technologies that have made a real difference. The best example is the use of three-way catalysts on petrol cars since the early 1990s when they were first mandated. Early catalysts reduced the raw engine emissions by around 90% (modern ones go even further), and despite the growth in total traffic, emissions have fallen by significantly more than 50%.

There are no comparable technologies to combat carbon emissions. While new methods have gradually made vehicles more fuel efficient, there has been no single solution that has made a large difference. The most important technological advance in recent years has perhaps been the refinement of small direct injection diesel engines which has resulted in the switch towards more fuel efficient diesel cars over the last decade or so. However, these and other improvements have been overwhelmed by vehicles becoming larger, more powerful, and having air conditioning, as well as the increase in traffic.

So the question is: will biofuels be the answer?

Biofuels

The main biofuels in use today are biodiesel and bioethanol made from plant material. The use of bioethanol, in particular, has a long history in Brazil and parts of the United States, and more recently in Sweden.

Biofuels can be blended with conventional diesel or petrol or used on their own. Vehicle manufacturers' warranties cover 5% biofuel blends, and no engine modifications are required. 100% biodiesel must meet the relevant EU standard, but can be used with no modifications. With engine modifications bioethanol can be used in higher proportions such as 85% bioethanol in petrol (known as E85).

Biodiesel can be blended at the refinery and distributed using the existing system. Bioethanol has to be blended at terminals because it cannot be distributed using the current pipeline system due to its affinity for water.

Biofuels are part of the EU's climate change and energy policy, and the European Council has agreed a binding target of 20% renewable energy in the EU by 2020. This applies to all energy sectors, i.e. electricity and heat as well as biofuels.

Economic costs

The biggest obstacle to biofuels is that they are not as cost-effective as conventional petrol and diesel; they cost about twice as much as fossil fuels. To encourage the biofuel market the UK government has cut the duty on biofuels by 20p/litre compared to petrol and diesel, and has guaranteed that this tax differential will remain until 2009-10. It is also to introduce the Renewable Transport Fuels Obligation (RTFO) that will require transport fuel suppliers to ensure 5% of total sales are from renewable sources by 2010-11. This equates to about 2.5 billion litres of fuel per annum, and most is expected to come from biofuels.

Carbon benefits

In theory these fuels are carbon neutral. However, biofuels tend to require higher energy inputs than fossil fuels: oil can be pumped out of the ground and processed more efficiently than biofuels can be grown and processed.

In reality, the benefits depend on the crops, where they are grown, agricultural process, how much pesticide and fertiliser is used, how the raw materials are processed and how they are transported. Some studies have shown the first-generation transport biofuels can be as bad, or even worse, than conventional fuels.

A European study on the greenhouse gas emissions of biofuels found that the life-cycle carbon emissions of biodiesel from seed crops (e.g. rapeseed) and bio-ethanol from starch crops, can have almost as high CO_2 emissions as fossil fuels. Other studies show that biofuels can save around half the carbon emissions of equivalent fossil fuels.

The energy balance is more favourable for biofuels made from crops grown in subtropical or tropical areas than those made from crops grown in temperate areas. This is largely due to the increased yield of biomass from crops in areas that receive more sunlight, but for UK use these fuels will need to be transported large distances, eating into the benefits.

Food or energy?

An important issue with biofuels is whether energy crops are being grown at the expense of food. As demand for energy crops increases farmers have an incentive to grow biofuels rather than food. There is already some evidence of this occurring. Tortilla prices in Mexico have risen, as corn is being diverted from food production to biofuels. Heineken is reported to have blamed its reduced profits on higher barley prices as farmers have swapped to growing corn for energy.

Historically, food surpluses have existed in some countries – including the UK, where the wheat surplus was around 2 million tonnes in 2005. This has been estimated to be sufficient to replace around 2.5% of the UK's petroleum consumption. However, since 2005 the surplus has disappeared and world wheat prices are increasing, and this is thought to be due to the demand for energy crops. Recent newspaper articles suggest that the rising grain prices will drive UK poultry farmers out of business, causing a shortage of eggs by Christmas.

Currently biofuels are made from sugar, starch, vegetable oil, or animal fats (i.e. food crops), using conventional technology. It is widely accepted that this is not sustainable and that a second generation of biofuels from non-food crops using advanced processing technologies is needed. These new energy crops include the stalks of wheat and corn, wood, special energy crops (e.g. miscanthus) and waste. Pilot processes exist, for example for the production of ethanol from wheat straw and of synthetic diesel from wood chippings. Another advantage of these new fuel crops is that they have a greater potential to reduce carbon emissions (by up to 80-90%) compared with conventional fuels.

Deforestation and biodiversity

In some parts of the world a combination of increasing demand for food and for biofuels is causing deforestation and threatens biodiversity. An example is the expansion of oil palm plantations in Malaysia and Indonesia, where rainforest is being destroyed to establish new plantations. Most is currently used as vegetable oil for food but if global demand for palm oil grows to meet the need for biofuels the pressure to deforest will increase. This conflict is recognised, and the Roundtable on Sustainable Biofuels is working to define standards for biofuels.

Similarly, the number and size of sugar cane plantations will increase to meet the demand for bioethanol. This will also increase pressure on ecosystems, including rainforest in South America. Deforestation itself has a huge negative impact on climate change; the production of a biofuel to ameliorate the problem actually contributes to it, as well as adversely impacting on biodiversity.

Conclusion

Given the disadvantages of energy crops, is converting them into transport biofuels the most sustainable approach? In the 1990s there was a large European collaborative programme between the oil and motor industries to identify the composition of both petrol and diesel that best matched the pollution abatement technology to be used. As a result, stringent environmental fuel quality standards were introduced from 2000 (known as the Fuel Quality Directive).

Fuels used in boilers have far less onerous requirements, and can be burnt without the need for energy intensive processing. Therefore would it be better to use locally grown energy crops in Combined Heat and Power (CHP) plants?

The EU and the UK government agree that increasing use of biofuels should not have unacceptable environmental, social or economic costs. The European Council's aim to increase the biofuel contribution to 10% is conditional on production being sustainable, second-generation biofuels becoming commercially available, and the Fuel Quality Directive being amended to allow for adequate levels of blending.

In the 2007 Energy White Paper the government states its intention to increase the RTFO beyond 5% after 2010-11, provided certain conditions are met. These include confidence that the biofuels will be produced sustainably; certainty that blends of biofuel higher than 5% will not lead to mechanical problems; and confidence that the costs to consumers will be acceptable, both in terms of fuel prices at the pump and in terms of wider economic impacts, such as those on food prices and other industries which make use of similar feedstocks.

If these checks are properly applied biofuels may have a significant future in the UK, but they are unlikely to have the large impact on transport carbon emissions needed. Other policies will be required, and it may well be better to leave the biomass for heat and power generation, where it can be used without intensive processing.

In the long term, carbon-based transport fuels from mineral and biological sources will need to be replaced with other propulsion systems, for example solar/electric, sustainable hydrogen or fuel cells.

◆ Claire Holman is Senior Associate and Leader of the Air Quality Team for Peter Brett Associates (PBA).

SECOND AND THIRD GENERATION BIOFUELS

Over the past few months the production of biofuels for motor transport has come in for considerable criticism in the media. **STUART SHALES** discusses the current production of biofuels and the criticism raised

In the UK in 2005 38.1 million tonnes of fuel was used for road transport (source: DTI) of which 18.7 million tonnes was petrol and 19.4 million tonnes was diesel. In fact this was the first year that diesel usage exceeded that of petrol. The demand for diesel is likely to continue to grow as more and more diesel fuelled cars appear on the market. Road freight is also a large consumer of diesel.

Fossil fuels are limited and we are reaching 'Peak Oil' where oil production will start falling. Some argue that Peak Oil has already been reached; what is very critical is that worldwide demand for petroleum fuels is growing at an alarming rate as the economies of China and India grow and cars become more affordable to the private citizens. Already the price of crude oil has reached record highs. At the time of writing Brent crude costs $79 per barrel as against $62 a year ago. It is quite possible that in the next decade we will see crude oil at $100-150 per barrel or maybe even more; much will depend on OPEC countries and their policy for releasing supplies of crude oil.

For the UK there is another driver for alternative fuels. Since the development of North Sea oil production the UK was a net exporter of crude oil. However, over the past few years the reserves of crude oil in the North Sea have dwindled so much that now the UK is a net importer. Strategically, and to offset negative balance of payments, an alternative, home produced source of fuel would be desirable.

Another significant driver for alternative fuels is EU legislation. The UK has to meet various EU targets for alternative fuels. We have the RTFO, but in the longer term there is an EU target of 10% substitution by 2020. A final driver in the UK is the stimulation of the rural economy if indigenous crops are used for biofuel production – although there are concerns that this may lead to higher food prices; this will be discussed later.

What is meant by the terms first-, second- and third-generation biofuels? First-generation biofuels are those where the technology currently exists and is being applied now. Second-generation biofuels are those where the technology is in an advanced state and may reach commercialisation in the next few years. Third-generation biofuels are a longer term option.

Considering the first-generation biofuels there are two principal products: bioethanol, a substitute for petrol, and biodiesel, a substitute for diesel. Bioethanol is produced by fermentation processes using sugar feedstocks (sugar cane, beet) or starch (grain). Since the early 1970s it has been widely used in Brazil as a motor fuel and is becoming more popular in the USA with several fermentation and distillation plants coming on stream recently. This has led to food-or-fuel issues. Another problem with producing alcohol, especially from grain starch, is that the energetics are not particularly favourable; distillation of the alcohol produced by fermentation requires a lot of energy.

Biodiesel is derived from vegetable oils. These oils are processed by transesterification which is a very simple chemical process using methanol and sodium hydroxide as a catalyst. The reason for undertaking transesterification is to reduce the viscosity of the oil to bring it closer to that of diesel fuel. Pure vegetable oil tends to be too viscous to use directly in a diesel engine; it also contains gums that may clog the injectors and other components in the engine. A variety of plant oils can be used in biodiesel production including sunflower, rape, jatropha and palm.

These first-generation fuels are in production. In Europe biodiesel is now produced on a relatively large scale. Germany accounts for about 50% of all biodiesel used in Europe because favourable duty regimes have been applied. In the UK biodiesel usage is very limited as biodiesel is still subject to duty, although it is 20p per litre less than that applied to normal diesel.

One of the criticisms raised about these first-generation fuels is the amount of land required to grow them. This problem stems from the fact that only the seed, a relatively small part of the plant, is used to produce the biofuel. In the UK, for a 5% fuel substitution (by volume) about 2.3% of the UK's agricultural land would be required to produce the appropriate amount of bioethanol from grain such as wheat and barley. For biodiesel production from oilseed rape about 5.2% of the UK's agricultural land would be required; thus a total of 7.5% of our agricultural land would be required. A 5% fuel substitution could be feasible using home-grown crops. However, if for example a 100% biofuel substitution was required then a total of 150% of the UK's agricultural land would be required!

This is of course impossible, and demonstrates clearly the conflict between land-use for food versus fuel production. In the UK we are already seeing increases in the price of grain and oilseed crops and this has been blamed on biofuel production. A similar pattern has occurred in worldwide markets. Biofuel production is not necessarily the sole cause; other factors include poor harvests and growing demand for food by countries such as India and China.

So, with the limited land in the UK how can the targets for biofuel use be met? One option is to import feedstock crops. For biodiesel production these include jatropha oil and palm oil. Palm oil production is causing considerable environmental concern at present. Oil palms produce five times more vegetable oil per hectare than oilseed rape and growing them is commercially lucrative. The problem is that tropical rainforests are being destroyed to make way for oil palm plantations. This releases huge quantities of carbon dioxide as the forest is burnt in the clearing process or as tropical peatlands are drained. A report issued last year by Wetlands International found that biofuels from these sources are thus capable of being up to ten times more carbon intensive than fossil fuels. These practices also reduce biodiversity. In Borneo the orang-utan and its special habitat are under threat. Similarly, in Brazil tropical rainforests are threatened as they are cleared to grow sugar cane.

Is there a solution to the food versus fuel conflict? The answer to this lies in second- and third-generation biofuels. The problem with the first-generation fuels is that only a small percentage of the crop biomass is used to produce the fuel, be it bioethanol or biodiesel. What are required are fuels produced from the complete biomass. Also, it would be desirable to use perennial crops such as miscanthus (Elephant grass) or short rotation coppiced willow as these have a greater yield per hectare than annual crops such as wheat and oilseed rape.

Bioethanol could be produced by the fermentation of sugars derived from the lignocellulose in plant biomass. Lignocellulose has to be converted to fermentable sugars by a process called saccharification. Saccharification can be undertaken in a variety of ways, one of which is to use cellulases and other enzymes to hyrdrolyse the lignocellulose. The Canadian company Iogen (in association with Shell) has developed a commercial process to undertake this from paper and pulp waste. The logical extension to their process would be to use a cocktail of enzymes capable of saccharifying wood biomass.

A different approach in second-generation biofuel production would be to convert wood biomass into 'synthetic diesel' and other synthetic hydrocarbons. This can be undertaken by gasifying the wood biomass to a synthesis gas which is a mixture of hydrogen and carbon monoxide. The synthesis gas is then cleaned and passed over a catalyst in the Fischer-Tropsch process to produce a range of synthetic hydrocarbons closely related to those found in crude oil derived fuels. In Germany, Choren Industries working in association with DaimlerChrysler have built a prototype plant to produce Sundiesel™ by this process. At the moment the synthetic diesel costs about three to four times more to produce than conventional diesel but larger scale plants should bring production costs down.

With second-generation fuels using complete wood biomass and high yielding perennial crops the biofuel yield per hectare could be five to ten times higher than that with the first-generation fuels. This would partly resolve the food versus fuel conflict. Yet the main hurdle at present is both technical and economic. There are technical improvements that can be made in the saccharification process – for example using more effective enzymes capable of rapidly breaking down lignocellulose. Gasification and Fischer-Tropsch synthesis also need optimising. However, the cost of these processes is a major impediment at present. One solution to this is political: to make the duty and tax regimes favourable for companies to invest in this technology. This would be very important to ensure that targets for fuel substitution by biofuels can be achieved in the timescales that have been set.

Third-generation biofuels offer even greater yields per unit area – fifty to one hundred times compared to the first-generation fuels. These could offer an opportunity to substitute 50% or more of current petroleum derived motor fuels, especially if this is linked up with developing more efficient road vehicles. In this regard, vehicle manufacturers are producing vehicles with considerable fuel savings. Some diesel cars now compete in fuel economy with hybrid drive cars.

One third-generation biofuel that is receiving growing attention is microalgal biodiesel. Microalgae such as Chlorella vulgaris produce large quantities of lipids that can be converted by simple processes of hydrogenation and transesterification into biodiesel. Microalgae have a higher photosynthetic efficiency than plants; therefore their yield per unit area is considerably higher. Furthermore, under specific nitrogen-limiting conditions the lipid production is enhanced. Research into microalgal biodiesel has been undertaken in several academic and research institutions including the National Renewable Energy Laboratory (NREL) in the USA and at the University of the West of England in the UK. The microalgae could be grown in ponds or tubular photobioreactors and do not necessarily compete with agricultural land for food production. Brownfield sites and other waste land could be used to culture them.

So what are the hurdles here? Again these can be subdivided into technical and economic. One of the technical hurdles which the NREL investigated at length is how to extract the lipids from the algal cells effectively and economically. A principal economic hurdle is that of culturing the algae. The large ponds or photobioreactors required will represent a significant capital cost.

Third-generation biofuels such as microalgal biodiesel may well be the answer to dwindling petroleum resources. However, considerable research and development is required before a commercial operation can be undertaken on an economic basis. This needs time and investment. Competing against this is the hydrogen economy and the development of hydrogen fuelled road transport.

Current first-generation biofuels can only realistically meet a relatively low substitution of our road transport fuel requirements without putting excessive demands on the environment and threatening food production. Second- and third-generation biofuels offer considerably higher yields on an area basis but are currently uneconomic. But as the price of crude oil escalates the economic viability of these processes will improve. It is essential that we invest in the research and development now so that the timescales for fuels substitution can really be met.

◆ Stuart W. Shales is Senior Lecturer in Environmental Biotechnology at the University of the West of England, Bristol.

AIR QUALITY AND CHP

Combined Heat and Power (CHP) is set to be one of the ways Britain will manage its future energy needs. NICKI TROUGHT looks at its implications for air quality

The introduction of combined heat and power (CHP) plants brings a new challenge to planners and air quality professionals. While CHP plants provide a more fuel-efficient form of power generation they often bring the polluting gases associated with burning fossil fuels closer to residential areas and therefore have the potential to worsen local air quality. However, based on a number of air quality studies carried out by PBA, it appears that the impacts of CHP plants on local air quality can be managed through good design and masterplanning, thereby making CHP a viable and sustainable option.

Why CHP?

CHP plants can significantly increase the fuel efficiency of electricity generation by using the heat that would otherwise be wasted. Typically CHP plants have a fuel efficiency of over 75% as compared to around 33% from conventional forms of power generation. This improved efficiency is achieved in two key ways; firstly the 'waste' heat is captured and used locally for domestic or industrial purposes, and secondly CHP plants typically provide electricity locally, therefore reducing losses through transmission and distribution.

Defra estimates that the gas and electricity used in our homes produces around 25% of the UK's emissions of carbon dioxide. With its increased fuel efficiency, the use of good CHP has the potential to cut carbon emissions and have an important role in helping the UK reach its challenging 60% reduction target by 2050. As such, the Government has introduced a package of measures to encourage the use of CHP, outlined in the government's Strategy for Combined Heat and Power published in 2004 and in the 2007 White Paper on Energy.

Trade-off: air quality and climate change

With the potential increase in fuel efficiency, good CHP can reduce the net emissions of greenhouse gases and other air pollutants across the UK. This is great in terms of GHGs where we are interested in the UK's total emissions. However, in terms of Local Air Quality Management (LAQM) and the national air quality objectives we are concerned with pollutant concentrations at relevant receptors, typically residential areas. The location of pollutant emissions relative to sensitive receptors is therefore important. By encouraging CHP plants within new developments, the pollutants produced by power generation are being brought closer to receptors, both existing and proposed. The introduction of these new local pollution sources can have potentially adverse impacts on air quality.

> 'Buildings can force air down to the ground and trap pollutants close to ground level where pollutant concentrations are likely to be greatest due to road traffic emissions. It is important these effects are taken into account when modelling the pollutant dispersion from a CHP stack'

Local authorities are therefore keen that the potential impacts of CHP plants are included in air quality assessments supporting planning applications, for example, the London Councils Air Quality and Planning Guidance (2007).

Points to consider when assessing the air quality impact

The key pollutants for most land development schemes are nitrogen dioxide (NO_2) and particulate matter (PM_{10}). These pollutants are emitted from both road traffic and CHP plants. The CHP plant emissions will largely depend on the fuel type – a biomass CHP plant would have significantly higher PM_{10} emissions than an equivalent sized CHP plant running on gas. However, biomass is a renewable energy source and the life-cycle CO_2 emissions can be dramatically lower. This trade-off between climate change and air quality needs to be carefully considered for each proposed CHP plant, taking account of local conditions.

Assessing the potential impact of a CHP plant fairly early in the masterplanning process can provide important input, for example, giving advice on the optimum locations and potential size of a CHP plant while minimising the impact on local air quality. When assessing the impact of a CHP plant it is likely that a number of assumptions will need to be made, especially at the outline planning stage. It is common that the plant specifications and even the CHP plant location will not be known. In these cases it is often necessary to use data from a comparably sized operational CHP plant. It is important to make conservative, yet realistic, assumptions. If the air quality impact is acceptable using conservative assumptions, the actual impact will probably be less, and hence even more acceptable.

Buildings can significantly impact on air flows and, in turn, on pollutant concentrations. For example, buildings can force air down to the ground and trap pollutants close to ground level where pollutant concentrations are likely to be greatest due to road traffic emissions. It is therefore important that these effects are taken into account when modelling the pollutant dispersion from a CHP stack. Also, we must not forget that if the proposed CHP plant site is in a Smoke Control area it will need to be an exempt fireplace (www.uksmokecontrolareas.co.uk/appliances.php).

Impacts and mitigation

The impacts of a CHP plant can be mitigated by careful consideration of the location of the stack. In areas of poor air quality the main problems faced by developers are often related to unsuitable air quality at lower level dwellings. Positioning the stack at high levels (e.g. on the roof) will typically reduce the effects on these dwellings. Obviously, high stacks may not be desirable with respect to the visual impact, so a compromise between this and local air quality may be required. Dispersion modelling can provide a useful tool for optimising the location of the stack to minimise high ground level concentrations.

Other considerations include using low NOx burners, and cleaner fuels (for example, using gas instead of biomass or oil), although the latter may be contrary to a local authority's policies on renewable energy.

Experience has shown that the impacts of CHP plants on local air quality can be managed through sensible masterplanning. Typically the impacts of CHP emissions on local air quality are small in comparison to road traffic emissions and the background air quality.

◆ Nicki Trought works for Peter Brett Associates as an Assistant Air Quality Specialist.

ENERGETIC POLICIES

ROBERT KYRIAKIDES is an author and managing director of the solar thermal company Genersys, the largest supplier of solar thermal technology in Britain. He has also been an outspoken critic of British government policies on energy and climate change

With your book *The Energy Age* you have re-classified our epoch in a way similar to Paul Crutzen's use of the term 'Anthropocene'. Do you really think where we get our energy from is the defining feature of the modern world?

■ I think that energy itself and our very intensive use of it is the defining feature of the age we live in. I think it follows that where we get our energy from and energy security dominates what we do. I think this will become an increasing problem in the near future. We have what was previously called the third world in their billions using more energy as they seek to emulate the way of life of the first world, which will of course put pressure on the availability of energy. You can compare the government's statement in the 2003 Energy Review to the effect that the markets will provide us in the UK with our energy, and that we can rely on them, with the 2006 position – we should make sure that the UK gets its fair share of energy. I was very interested in Alan Greenspan's comments that the Iraq war was largely about oil; I think he was saying not that America wanted the oil but it wanted the Iraqi oil on the market.

I have some ideas from your open correspondence with DTI etc [available on the Genersys website], but what do you think are the main faults with the government's Energy Review? Do you think the government is putting short-term policy gains before scientific facts?

■ It is very difficult for a government to say to people that any essential commodity has to become more expensive, so in the sense that the government is not raising taxes for renewables, or forcing people to spend money on renewables, they are putting short term popularity first, but that is probably the nature of democracy, which follows public opinion rather than leads it. I think the government feels that their device of an emissions trading scheme will be the only thing that works and they like to think that it will work because there is no direct unpopularity caused by rising prices involved. I also think that they are too immersed in small issues to see the big picture. They distrust small businesses to deliver carbon savings, and are giving the task of doing this (and the profits) to the fossil fuel energy companies, which is a bit like putting the fox in charge of the chicken hut. The thread that runs through all government initiatives is that they are to be delivered by large organisations. With renewable energy you have many committed small businesses whose talent, drive and dedication is being deliberately excluded in favour of large energy companies. If you go to a government climate change function you will find it sponsored by one of the fossil fuel energy companies and their 'director of renewables' given a long speaking platform. I was at one a few months ago when the head of renewables at E-on used his time in front of Members of Parliament to call for more regulation of the renewables industry, and this call has now been heeded. Amazing but true.

In light of all this, what do you think are the most crucial areas for change now? What would you prioritise?

■ You either have to make fossil fuel energy much more expensive (which is hard to do in a free market without taxation) or make renewables mandatory or do both. You will see that these are going to be really unpopular measures. The easy option is to increase tax on petrol and raise VAT on domestic fossil fuel energy to 17.5%. This will increase fuel poverty so some tax money has to be found for the less well off to cover the VAT increase. Next, it should be legislation to require some form of inbuilt renewable on every new building, developing the concept of the Merton Rule, and homeowners should be given some tax breaks if they install microgeneration at home. And there ought to be a law requiring minimum levels of insulation in buildings. These are easy things to do. Harder to do but probably almost inevitable will be the nationalisation of the fossil fuel energy companies, restricting by law the size of car engines, and having a much more rigorous energy efficiency requirement for appliances. Finally, so that you can encourage the rest of the world, there should be a trade embargo or a tax on goods imported that are made with highly polluting fossil fuel energy, or an encouragement for people to personally embargo such goods. I think that any party going to the country with these policies would be ridiculed, but that is what is needed – real measures.

Ultimately, do you think that the Stern Report has been a red herring for policy makers? Is it really, as you have said before, just 'gathering dust'?

■ I cannot think of any of its recommendations that have been followed. I don't see the civil service committed to it, but rather committed to finding ways around it. Britain leads the world in writing reports about energy and climate change.

How strong is the case for microgeneration in Britain? and what can we learn from European models like the one we see in Germany?

■ There is plenty of scope for microgeneration in the UK; take my company's product – why should anyone use fossil fuel to heat water for eight months of the year when they can use sunlight? We can build lots more off-shore wind farms and work with heat pumps and develop tidal energy. We have not even scratched the surface of what we can do. I think the German model has many imperfections, not least in the stop-start nature of its renewable subsidies and the occasional problems with feed-in tariffs on PV generated electricity, but it does offer real encouragement for renewables, unlike the UK. Plenty of other countries in the world are developing policies founded on real measures, but the UK isn't.

How serious is the abolition of the Merton Rule for the energy firmament in the UK?

■ Very serious; it's the only game in town! There is no other rule that requires on-site generation. The Merton Rule only applies to England; the rest of the UK are introducing or have introduced real measures. Also, who rules Britain – the government or the National Federation of Housebuilders?

Do you think the Conservative Party are offering viable/superior policy alternatives in the energy sector?

■ I can't see the Conservative Party offering policies like those in my answer to your question about priorities until they are sure that the whole country deems them necessary. Eventually, as the effects of climate change are more acutely felt, we'll probably have consensus that these kinds of policies are necessary and I hope by then it won't be too late. No party's policy on energy is adequate to protect the people of this country. Of the major parties the Liberal Democrats seem to come closest to what we need.

Finally, for a projective/hypothetical 2050 UK energy policy, what would you like to see? And what do you think that realistically we can expect?

■ I would like to see the kind of policies outlined in my answer to your question about priorities being implemented now, today, immediately. I would like to aim for 2050 targets by 2020.

◆ Robert Kyriakides gave his views to David Hawkins.

RENEWABLE ENERGY FROM FOOD WASTE

JAMES CHERRY, Environmental Manager of food company Greencore, shows that innovative techniques can be used to extract unexpected energy from the waste of other sectors. In a truly sustainable society, nothing is really thrown away…

The introduction of the Animal By-Products Regulations (2005) and the forthcoming pre-treatment requirements for waste under the Landfill Directive have presented significant challenges to the UK food industry.

As a leading UK food manufacturer with facilities producing a variety of products including sandwiches, ready meals, cakes, desserts, pickles, soups and sauces, Greencore has a range of food wastes to deal with, often comprising mixed food waste and packaging. While a strong emphasis is placed on waste minimisation and recycling at all our facilities, inevitably some waste will still require disposal. With some elements of the waste streams classed as ABP waste, and packaging waste contaminated with food residues unsuitable for recycling, an alternative solution was required that both met future legal obligations and was environmentally sustainable.

A number of solutions were explored for the range of wastes produced. Many of the more commonly available technologies such as anaerobic digestion, composting and rendering were severely limited in the scope of wastes that could be readily processed. In order to pursue these options a significant effort would be required to effectively segregate the packaging waste from the food waste. This presents a major obstacle for part or fully processed packaged products such as ready meals, soups and sauces, where some form of washing would be required in addition to segregation, making the process both costly and inefficient.

The option that emerged both as the most efficient and

The Inetec patented Thermomechanical Treatment system (left)

Thermal cracking in the GEM® gas converter (right)

sustainable came in the form of energy from waste technology, manufactured by Inetec. The Inetec technology converts organic material into a solid bio-fuel through a thermo-mechanical drying process. The biofuel can then be used to generate renewable energy, providing a sustainable solution to the problem of food waste disposal, particularly for ABP waste or food residue contaminated packaging materials that are not suitable for recycling. A major advantage with this option is the ability of the equipment to deal with mixed food and packaging waste, removing the necessity for the complex segregation steps that are a major drawback to many other solutions. The process can even process metal capped glass jars of pickles and sauces! After processing, the biofuel can be readily separated from the metal caps and broken glass fractions, both of which can then be recycled.

We have signed an agreement for the processing of all of the relevant waste streams from Greencore UK manufacturing facilities to produce renewable energy. This agreement has enabled the EnCycle project (led by Inetec) to commence, with the development of waste processing facilities in the UK specifically to deal with these types of waste. The first site near Immingham was granted planning permission in May 2007, and should be operational from the second half of 2008. The full process entails three main steps: fuel preparation (conversion of organic waste to solid biofuel), gas conversion (conversion of the solid biofuel to a gas) and CHP for the generation of renewable electricity and thermal energy in the form of steam and hot water.

The key stages in this process are outlined below.

Waste collection

The principal advantage of the Inetec process is the ability to process mixed organic waste and packaging. This removes the requirement for multiple waste containers and collections from sites, or inefficient processes to attempt segregation and/or cleaning of contaminated packaging materials. Segregation systems will however be maintained, where appropriate, in order to remove suitable materials from the waste stream to go for animal feed (such as waste bread) or for recycling (e.g. clean packaging materials), which both represent a step up the waste hierarchy from recovery for energy generation.

All remaining organic materials will be collected and transported to one of a number of biofuel preparation facilities to be developed to service different geographical regions of the UK.

The Inetec process

The Inetec patented Thermomechanical Treatment system is a proven biofuel conversion process, linked with advanced thermal technology and an energy recovery system for processing a wide range of packaged and unpackaged foods, and the processing of packaging contaminated with food residues.

The system involves an **abrasive drying process** designed to process various food wastes, with widely ranging moisture content. The food waste can be readily processed, almost irrespective of type, moisture content, paper, card or plastic packaging materials. What is produced is a highly classified and remarkably stable biofuel which invariably consists of a mixture of organic powder and fibre combined with the residue of the plastic packing mostly in the form of randomly sized shreds.

A proportion of the fuel can be used to heat the fuel conversion process. The remaining fuel is used to produce electricity (the majority of which is eligible for Renewable Obligation Certificates), steam and hot water which can be available to a local manufacturing facility.

The Inetec process sequence is detailed as follows:

Stage 1 – The input of packaged or un-packaged food waste into the Inetec biofuel conversion process.

Stage 2 – Water is removed by physical abrasion and heat during an 18-22 hour batch cycle (typically 50% of the original waste). Energy required to remove the water is around 1.5kWh to remove 1Kg of water from 2Kg of food waste.

Stage 3 – Biofuel (approximately 50% of the original waste volume) goes forward for gas conversion. The calorific value of bio-fuel is typically 5-8kWh per Kg (subject to input feed).

Benefits of the Inetec system include:

- Utilisation of a simple physical abrasive drying process which is able to handle all food waste.
- No segregation of food waste from packaging.
- Produces a stable biofuel with a high calorific value that can be stored.
- Complies with all existing and planned legislation including the Animal By-Products Regulations and incoming Landfill Directive.
- Diversion of waste away from landfill.
- Potential to reduce fossil fuel demand lending considerable weight to improved environmental performance and 'corporate green image'.
- The process is available in modular units ranging from 2-10 tonnes per day throughput and multiplies thereafter to meet waste arisings.

The GEM process

The process for the conversion of organic material to gas is generally known as thermal cracking. Thermal cracking is the chemical decomposition of the introduced feedstock by heat in a reduced oxygen atmosphere, also known as 'destructive distillation'. The process principles have been in industrial use for many years and are still widely used in the modern petro-chemical industry.

The GEM® gas converter works on the principle of a closed-circuit system with no oxygen present and no escape to atmosphere. It runs at high temperatures.

When the small prepared particles enter the chamber they are instantaneously converted to a high energy gas – this taking place in a fraction of a second. The particles are continuously fed into the chamber, dropping to the base by gravity. Small deposits of ash are discharged, resulting in the production of a very clean gas, free from any solid particles.

With no oxygen present, no combustion takes place so there is no major clean up process. The gas is immediately piped to a blast cooler for rapid cooling. So quick is this process that there is insufficient time for a chemical reaction to allow the formation of dioxins and furans.

The solids residue amounting to some 2% for biofuel (as opposed to some 25% with incineration) contains an amount of carbon which can be re-used, leaving only a small percentage of ash. The ash is non-toxic and can be used in the manufacture of building blocks or for other building purposes.

Benefits of the GEM system include:

- Uses prepared biofuels to produce a gas similar to natural gas.
- High energy conversion efficiency.
- Clean gas conversion process in the absence of oxygen (a non-combustion process).
- Rapid conversion and cooling (no harmful dioxins or furans).
- No emissions to atmosphere.
- Small scale modular plant to facilitate proximity principle available in 5MW and 10MW thermal output units.

Energy generation

The biofuel and contaminated packaging available from this project will produce approximately 30 Megawatts of thermal energy output in the form of electricity, steam and hot water. A high proportion of the fuel produced will be of organic origin, attracting Renewable Obligation Certificates.

The energy output from the process is split into approximately 10MW of electricity with the majority of it eligible for Renewable Obligation Certificates (ROCs), 10MW of high grade steam, and 8MW of hot water with 2MW of losses.

The thermal energy in the form of steam and hot water is available for the processing of the food waste to biofuel or energy return to the client's site. This energy is derived from the exhaust of the engines with heat recovered from the Inetec and GEM process.

So the process moves from waste received, to biofuel production, to gas conversion, to electrical generation and energy return, to the Inetec biofuel preparation process.

Summary

By moving to the Inetec system for the treatment of food waste and packaging contaminated with food residues, Greencore will considerably reduce the environmental impact of its operations, and divert a large proportion of its waste away from landfill. Combined with waste minimisation and improved recycling, this solution will present a significant move towards an environmentally sustainable waste management system for all our UK manufacturing facilities.

The combined process offers substantial benefits to Greencore through removing the need for complex waste treatment or segregation systems on food manufacturing sites (other than those established to support reduction and recycling), meeting all of the requirements of the Animal By-Products Regulations and the forthcoming Landfill Directive, and potentially providing a significant reduction in carbon footprint through the utilisation of renewable energy, generated from its own waste streams. Let's hope more companies follow suit.

◆ For further information, contact James Cherry: email james.cherry@greencore.com

ENERGY FUTURE: JUST DESERTS?

The ingenious use of mirrors and DC electrical grid technology could provide a significant new source of power from desert sunlight. GERRY WOLFF explains

Every year, each square kilometre of hot desert receives solar energy equivalent to 1.5 million barrels of oil. Multiplied by the total area of deserts world-wide, this is nearly a thousand times the entire current energy consumption of the world.

Given our concerns about energy supplies and the need to cut CO_2 emissions, these rather startling statistics seem to be a cause for optimism. But, you may very reasonably ask: Can we tap into this enormous source of energy at a reasonable cost? Can we get it to where people are living? And, if those things are possible, what other snags or problems might there be? The purpose of this article is to describe some answers to those questions and suggest that one's initial sense of optimism may be something more than just a mirage.

The key technology for tapping into the solar energy of desert regions is 'concentrating solar power' (CSP). This is not some futuristic possibility like fusion nuclear power. It is the remarkably simple idea of using mirrors to concentrate direct sunlight to create heat and then using the heat to raise steam to drive turbines and generators, just like a conventional power station. However, in some variations, the heat is used to drive a Stirling engine that drives a generator.

A useful feature of CSP is that it is possible to store solar heat in melted salts (such as nitrates of sodium or potassium, or a mixture of the two) so that electricity generation may continue through the night or on cloudy days. This overcomes a common objection to solar power: that it is not available when there is no sun.

CSP is very different from the better-known photovoltaic panels and, with current prices for PV, it can deliver electricity more cheaply in situations where lots of direct sunlight is available. However, PV may become cheaper in the future and methods for storing PV electricity are likely to improve – so the balance of advantage may change. Just to confuse matters, CSP is sometimes used in conjunction with PV, to minimise the amount of PV that is required.

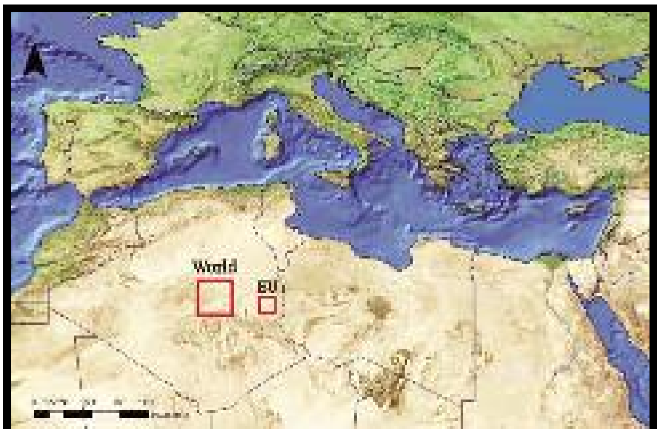
The relative merits of different technologies and different versions of CSP will, no doubt, be the subject of study and debate for years to come. The key point for present purposes is that the technology works, it is relatively mature and has been generating electricity successfully in California since 1985. Currently, about 100,000 Californian homes are powered by CSP plants, new plants came on stream recently in Arizona and Spain, and others are being planned or built in various parts of the world.

Getting the energy to where it is needed

Given that, with a few exceptions, desert regions are not places where many people choose to live, it is natural to ask how all this plentiful supply of energy is to be used. One possibility is to move energy-intensive industries such as aluminium smelting to desert areas. But even if all such industries were relocated, there would still be a need to transmit electricity to towns and cities elsewhere.

The high-voltage AC transmission lines with which we are all familiar work well over relatively short distances, but they become increasingly inefficient as distances increase. Fortunately, it is possible to transmit electricity efficiently over very long distances using high-voltage DC (HVDC) transmission lines, a technology that has been in use for over 50 years. With transmission losses of about 3% per 1,000 km, it would for example be possible to transmit solar electricity all the way from North Africa to London with only about 10% loss of power. When one considers that the 'fuel' is free, this level of loss compares very favourably with the 50% to 70% losses that have been accepted for many years from conventional coal-fired power stations, where the fuel is far from being free.

To meet the need for this kind of long-distance transmission of solar power, the 'TREC' group of scientists,



The larger red square on the map shows a 254 km × 254 km area of hot desert that, if covered with concentrating solar power plants, would provide electricity equivalent to the current electricity consumption of the whole world. The smaller square shows a 110 km × 110 km area that would meet the electricity demands of the European Union (25 countries).

engineers and politicians[1] propose the development of an HVDC transmission grid across all the countries of Europe, the Middle East and North Africa (EUMENA). Apart from long-distance transmission of solar power, there are other good reasons to build such a grid. For example, if there is a surplus of wind power or hydropower in one area, it is very useful to be able to transmit that electricity to places where there is a shortage. Without that facility, the surplus power is simply wasted! And although wind power may be quite variable in any one location, it is much less variable across a large region such as Europe or EUMENA. Large-scale grids are also needed to take advantage of large-scale but remote sources of renewable electricity such as offshore wind farms, wave farms, tidal lagoons and tidal stream generators.

For these kinds of reasons, the wind energy company Airtricity has proposed a Europe-wide 'Supergrid' of HVDC transmission lines and others have proposed a world-wide HVDC transmission grid. Interestingly, Airtricity proposes that all the HVDC transmission cables can be laid under the sea, thus simplifying construction and avoiding the visual intrusion of transmission lines over land.

How much will it cost?

While fossil fuels are artificially cheap (using the atmosphere as a free dumping ground for CO_2) and until CSP costs are reduced via economies of scale and refinements in the technology, it is likely that there will be a need for price support via direct subsidies or market mechanisms such as 'renewable obligation certificates'. Then, according to the 'TRANS-CSP' report commissioned by the German government,[2] CSP is likely to become one of the cheapest sources of electricity in Europe, including the cost of transmitting it.

Others take an even more positive view of costs. The legendary venture capitalist Vinod Khosla has suggested that CSP is poised for explosive growth, with or without public support.[3] In a report in *Business Week*,[4] the CEO of Solel is quoted as saying 'Our [CSP] technology is already competitive with electricity produced at natural-gas power plants in California.'

CSP bonuses

One of the most fascinating aspects of concentrating solar power is the potential that it has for producing other benefits besides plentiful supplies of pollution-free electricity.

Perhaps the most interesting possibility is that waste heat from steam turbines (used in the production of electricity) may be used to desalinate sea water. This could have a major impact in alleviating shortages of water in drier parts of the world, a problem that is likely to become increasingly severe with rising global temperatures – as has been highlighted by Sir David King, Chief Scientific Advisor to the UK government. Waste heat from electricity generation may also be used for air conditioning.

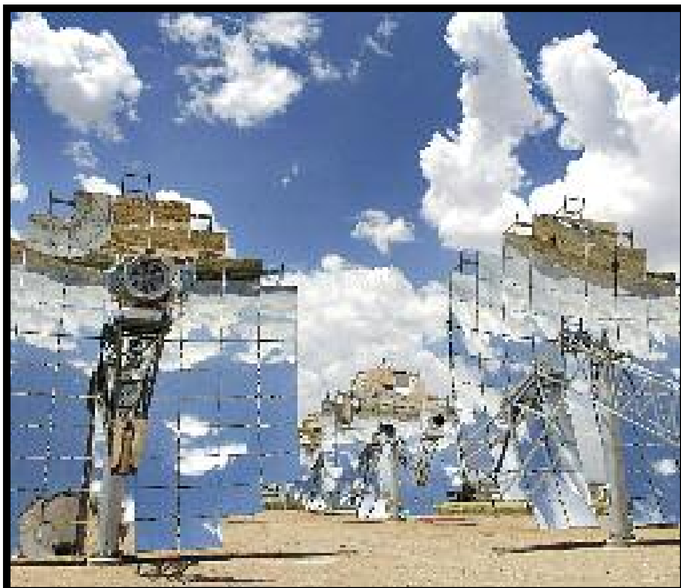
Another interesting side-effect of CSP is that the area under the mirrors of a solar plant is protected from the harshness of direct tropical sunlight. These shaded areas may be useful for many purposes including living space, stables for animals, car parks and so on. Although the area under solar collectors is in shadow, it should still receive quite a lot of light, quite sufficient for growing plants and without the damaging effect of direct tropical sunlight. Thus land that would otherwise be useless for any kind of cultivation could become very productive. An obvious problem is that plants need water and that is not plentiful in hot deserts. But desalination of sea water may provide the fresh water that would be needed for 'CSP horticulture'.

CSP has the potential to become a large new industry in the world with many benefits in terms of jobs and earnings. Many of the world's hot deserts are in countries that are relatively poor so we may suppose that concentrating solar power could be a particularly welcome new source of income via taxes or earnings from the sale of electricity.

Plentiful and inexpensive supplies of electricity from CSP would open up many interesting possibilities for taking fossil carbon out of transport by road and rail. For example, the latest generation of plug-in hybrid electric vehicles (PHEVs) – with relatively large batteries – can, for many journeys, be run largely on renewable electricity from the mains. Batteries may also be topped up from photovoltaic panels on each vehicle's roof. Railways can be electrified and run on renewable electricity. CSP also provides a means of avoiding the many disadvantages of nuclear power (see www.mng.org.uk/green_house/no_nukes.htm).

More generally, CSP can alleviate shortages of energy, water, food and land and reduce the risk of conflict over those resources (a risk that is likely to increase as climate change takes hold, as highlighted in a speech to the UN by Margaret Beckett when she was UK Foreign Secretary). And the development of a CSP collaboration among the countries of EUMENA is a positive way of building good relations between different groups of people, with potential advantages over the more aggressive policies that have been pursued in recent years.

1 'TREC' stands for the Trans-Mediterranean Renewable Energy Cooperation (www.trecers.net).
2 See www.trec-uk.org.uk/reports.htm or www.dlr.de/tt/trans-csp. Also relevant is the earlier MED-CSP report (see www.trec-uk.org.uk/reports.htm or www.dlr.de/tt/med-csp).
3 You may listen to his talk at the Solar Power 2006 conference in California via links from www.trec-uk.org.uk/resources.htm.
4 'Israeli Solar Startup Shines' by Neal Sandler, *Business Week*, 2006-02-14.



Left: Sun-tracking parabolic dish reflectors, each with a Stirling engine and electricity generator at its focal point.
Right: Close-up view of a parabolic trough solar mirror with a pipe at its focus containing heat-collecting fluid.

Possible problems

It is rare for any technology to be totally positive in its effects, without any offsetting disadvantages. That said, I believe that there are good answers to most of the queries or doubts that may be raised about CSP.

Security of supply

If Europe, for example, were to derive a large proportion of its energy from CSP, people would naturally wonder whether supplies might be suddenly cut off by the action of terrorists or unfriendly foreign governments.

In the scenario up to 2050 described in the TRANS-CSP report, there would be an overall reduction in imports of energy, an increase in the diversity of sources of energy, and a corresponding increase in the resilience and security of energy supplies. Imports of solar electricity would be an exception to the rule of reduced imports and would, in any case, be not more than 15% of European energy supplies.

Compared with sources of supply for oil and gas, there is a relatively large number of locations that have hot deserts. So in principle no country need be overly dependent on any one source of CSP. HVDC transmission grids can be designed to be robust in the face of attack, in much the same way that the internet was designed to carry on working even if part of it is damaged. Transmission cables can be buried underground or laid under the sea where they would be relatively safe from terrorist attack.

Isn't this just another smash and grab by rich countries upon the poor?

One may wonder whether CSP might become another case where rich countries take what they need from poorer countries leaving little for local people, except pollution.

There are reasons to think otherwise because several of the benefits of CSP are purely local and cannot easily be exported or expropriated. These include local jobs and earnings, local availability of inexpensive pollution-free electricity, desalination of sea water, and the creation of shaded areas with the kinds of uses mentioned above.

The ecology of deserts

From at least as far back as Walt Disney's *The Living Desert*, wildlife films have made us aware that hot deserts have their own vibrant ecology. If the world's hot deserts were all to be covered with CSP plants, there would indeed be cause for concern about the animals and plants that live there. But less than 1% of the world's deserts would meet current world demands for electricity and even in pessimistic scenarios, it seems unlikely that more than 5% would ever be needed in the future. It should be possible for CSP plants and wildlife to co-exist.

Conclusions

There is no doubt that planet Earth's ability to support humanity is being put at risk by a combination of inappropriate technologies, huge and increasing material demands, and the sheer weight of population. CSP is not a panacea but it can be a useful plank in the new ways of living that will be needed if we are to survive and prosper in the future.

◆ This article first appeared in *Scientists for Global Responsibility Newsletter*, No 34, Summer 2007, www.sgr.org.uk/ and is reproduced with permission.

RIDING THE WAVES

The ever-moving waters that surround us are teeming with energy. Modern technologies allow us to harness the potential of this mass movement. **RACHEL BOWES** of Pelamis Wave Power Ltd gives us a brief

Building on technology developed for the offshore industry, the Pelamis Wave Energy Converter has a similar output to a modern wind turbine. The Pelamis is a semi-submerged articulated structure composed of cylindrical sections linked by hinged joints. It works by hydraulic rams pumping high-pressure oil through hydraulic motors via smoothing accumulators. This acts to resist the wave-induced motion created by hinged joints.

The hydraulic motors drive electrical generators to produce electricity, and the power produced in the joints is fed down a single umbilical cable to a junction on the sea bed. Several devices can be connected together and linked to shore through a single seabed cable.

A novel joint configuration is used to induce a tuneable, cross-coupled resonant response, which greatly increases power capture in small seas. Control of the restraint applied to the joints allows this resonant response to be 'turned-up' in small seas where capture efficiency must be maximised or 'turned-down' to limit loads and motions in survival conditions. The machine is held in position by a mooring system comprising a combination of floats and weights which prevent the mooring cables becoming taut. It maintains enough restraint to keep the Pelamis positioned but allows the machine to swing round in order to face oncoming waves. Reference is achieved by spanning successive wave crests.

The Pelamis is best positioned moored in waters approximately 50-60m in depth (often 5-10km from the shore). This would allow access to the great potential of the larger swell waves but it would avoid the costs involved in a longer submarine cable if the machine was located further out to sea.

Three Pelamis machines will form the initial phase of the world's first commercial wave farm located off the Northern coast of Portugal, and further projects are planned for 2008-09. These include the Wave Hub project off the coast of Cornwall and the recently announced station off Orkney, supported by the Scottish Executive, where four machines will have a combined output of 3MW.

In the future we envision that a typical 30MW installation would occupy a square kilometre of ocean and provide sufficient electricity for 20,000 homes. Twenty of these farms could power a city such as Edinburgh.

The Pelamis undergoing sea trials

LUNAR ENERGY AND THE ROTECH TIDAL TURBINE

Tidal power is renewable and reliable. **ANDREA TYRRELL** of Lunar Energy explains how they can bring the sea into our everyday energy life

There are many advantages of generating electricity using tidal stream energy. The resource, and therefore the amount of power extracted from it, is completely predictable far into the future and some technologies are completely invisible from above the surface of the ocean. Moreover, it is environmentally benign, and the technology design is based on existing experience of the offshore environment; so it is also an excellent diversification opportunity for the oil and gas sector.

Lunar Energy Limited commissioned Rotech Engineering Limited to develop the technology, known as the Rotech Tidal Turbine (RTT), which Rotech has patented. Lunar Energy has an exclusive, worldwide in-perpetuity licence to commercially exploit it.

The RTT has added benefits over other tidal stream schemes. In guiding the development of this technology, Lunar Energy has focused on generating electricity for the commercial market at a realistic target price, in the region of 2.5 to 3.5p/kWh. To achieve this earlier in the commercial cycle than would normally be expected, this concept deliberately incorporates known, proven and relatively simple, technology, thereby keeping to a minimum operation and maintenance costs and facilitating accelerated development timescales. From the beginning, all development activity has been commercially focused.

Not wishing to 'reinvent the wheel', Lunar's philosophy has been to collaborate with partners who add value by contributing to the project commercially proven design, components, or procedures. Overseen by Rotech, the companies now collaborating or contracted to the 1MW demonstration project, which is to be deployed in the Orkney Islands, include Atkins (structural design); ABB (generators); Hägglands and Bosch Rexroth (hydraulic pumps, motors and circuits); SKF (Bearings); Wichita Clutch (brake) and Garrad Hassan (control algorithms and hardware).

The technology

The RTT comprises a ducted rotor which extracts the tidal-flow energy and drives hydraulic pumps and motors which in turn drive a generator housed within the sub sea unit. As well as obviating the need for a conventional mechanical gearbox, the use of hydraulics allows all the electrical components to be located in an airtight chamber with no rotary seals, and allows long periods between servicing. This configuration effectively removes the risk of water leaks into the generation compartment and the loss of hydraulic oil out of it.

The ducted rotor is bi-directional and the turbine blades are symmetrical. Use of the duct makes the device insensitive to off-axis flow of up to 30 degrees. This completely removes the need for a complicated yawing mechanism to rotate the device at the turn of each tide and to keep it pointing directly into the flow, which would be expensive to design, build and maintain. It also removes the need for blade pitch control. The venturi shaped duct accelerates the fluid through the turbine, increasing the energy that can be captured by turbine blades of a given diameter. This keeps the size and hence manufacturing, operation and maintenance costs of the complex moving components to a minimum. The turbine is designed to rotate at around 20 rpm.

The environment in which tidal turbines are required to survive is technically challenging. Mechanical devices do not generally like to be exposed to seawater, and electrical equipment is by its nature averse to moisture of any kind. The high density of water means that tidal turbines can be exposed to large forces acting on their structures from both the movement of the tides and the effects of surface waves. And, of course, by definition tidal turbines must be installed in areas with high current velocities. The number of visits to service the units must be kept to a minimum because of the costs associated with accessing off shore devices, and the initial design lifetime of the devices must be of the order of 25 years or more.

The Rotech Tidal Turbine on the sea bed

With this in mind, a central focus of the RTT design is to achieve maximum simplicity and ruggedness. The use of a ducted turbine is key to this philosophy. The duct captures a large area of the tidal stream and accelerates the flow through a narrowing channel into the turbine. Thus, a smaller turbine can be used for a given power output, or alternatively, a larger amount of power can be generated by a turbine of given blade diameter. Moreover, complex systems such as yawing and variable pitch mechanism and mechanical gearboxes are deliberately not used. The RTT will only be accessed for maintenance once every four years.

Atkins structural design

Atkins, who has extensive worldwide experience and success in designing large structures that stand on the seabed and survive harsh off-shore environments (www.atkinsglobal.com), was contracted to undertake the structural design of the RTT. Using standard oil and gas industry design codes to calculate stress and fatigue loads on the operating structure, Atkins initial design incorporated a duct held by a tubular support structure. Once this initial design process was complete, Atkins and Rotech, in consultation with the supply chain, took the design to the pre-commercial stage, being focused on cost reduction and unit mass production. This design incorporates the same 3-point-of-contact gravity foundation concept, used to ensure the base has no instability by catering for local undulations of the seabed, but uses steel cans instead of a steel (or concrete) box structure. In both designs the overall weight required to prevent the unit sliding across the seabed is largely made up by the use of cheap ballast, held in cavity spaces within the base structure. The duct is now load-bearing and self supporting. The removable cassette design concept (see below) has remained the same throughout the design iterations.

The dimensions of the 1MW EMEC (European Marine Energy Centre) unit are: 15 metre duct intake diameter (the base of which stands 8 metres above the seabed), 10 metre turbine diameter, and a unit length of around 25 metres.

Installation, operation and maintenance

The evolution of the installation, operation and maintenance processes are ongoing. The EMEC 1MW device is to be installed in a one-go heavy-lift procedure with little or no seabed preparation being required. It is likely that later variants of the RTT will incorporate internal buoyancy, reducing considerably the initial lift requirement.

All the moving parts and electrical components are situated in a central cassette. It is removed using proven North Sea remote extraction techniques and does not require the routine use of divers or ROVs. When a cassette is removed, it is taken to shore for servicing and another unit replaces it, thereby keeping generation downtime to an absolute minimum; no expensive offshore servicing is required. All the electrical and moving parts are contained in the cassette and when it is removed, only a ‘dumb’ steel structure remains. A hermetically sealed cylindrical container houses all the generation equipment and sits on top of the cassette.

Removable cassette

The initial design specification of the RTT allows for it to be left unattended for many years at a time. This is achieved because of the inherent simplicity and reliability of the design and because the components are operating at atmospheric pressure in a leak-free environment (for which they were designed). The RTT system design uses a predictive rather than reactive O&M philosophy where servicing is required only on an infrequent periodic basis (initially four years).

Because little or no seabed preparation is required, the installation process will take less than 24 hours. Similarly, the cassette removal will take place during one slack tide period. Therefore, ship costs are kept to a minimum.

Support and funding

The UK Department of Trade and Industry (DTI, now BERR) has been a supporter of this technology from an early stage. Awarding Lunar Energy grants totalling almost £3.5m to date, it has monitored the development and design of the RTT in a scrupulous way, calling for frequent diligence checks on the economic as well as the technical developments by an independent oversight panel.

Environmental considerations

Invisible from the surface and having a significant depth of clear water above the top of the unit (around 20 metres for the 1MW unit in Orkney), the RTT will have little, if any, impact on shipping or marine usage. A DTI feasibility study for the development of tidal turbines in Orkney and Shetland concluded that the environmental impact on fishing, transport routes, Ministry of Defence property and other environmental factors would be minimal.

The UK Environment Agency in its position statement: *Generating Electricity from Tidal Power* (2005) acknowledges that ‘tidal power technologies could play an important role in reaching renewable energy targets and limiting climate change’. It states that they are committed to helping limit and adapt to climate change; want to avoid unnecessary regulatory barriers; expect the impacts of tidal stream generation to be relatively mild; wish to ensure that environmental impact studies are conducted; and are supportive of further research and development of tidal stream devices.

Lunar Energy commissioned an environmental impact assessment by Robert Gordon University which indicated that the RTT is likely to have limited effect on marine life and then only in a localised area of the seabed. It said: ‘Overall, with respect to present knowledge it can be concluded that the system in question has no significant detrimental environmental impact.’ Scottish Natural Heritage’s policy statement on marine renewables concludes that tidal stream devices will have less impact than shoreline wave devices, offshore wind farms or tidal barrages.

The impact of bio-fouling and anti-fouling coatings has been considered with advice from QinetiQ (formerly the UK Defence Research Establishment). Depending on specific site conditions, it is possible that most of the RTT will not require anti-fouling coatings. It is expected that the RTT will be removed from the seabed at the end of its useful life.

Lunar is working closely with EMEC to offer a robust monitoring package that will show the RTT’s effects on the local environment. Video and high definition sonar monitoring equipment will be incorporated on the EMEC RTT unit which will record flow though the duct and the turbine. Also, Lunar Energy is currently in talks with manufacturers of advanced, highly sophisticated acoustic monitoring devices capable of tracking the movements of marine life around the installed unit.

Commercial development

After the 1MW unit has completed its proving and optimisation phase, Lunar Energy together with its partner E.ON UK, will commission and deploy an array of up to eight devices, funded partly by the government’s Marine

Renewable Deployment Fund – a fund of £50m to encourage early deployment of pre-commercial arrays of marine devices in the UK. The money received by developers will take the form of both capital grant and revenue support (£100 per MWh of electricity produced).

The Electric Power Research Institute, a USA-based research organization funded by more than 100 utility and other organisations with interests in the electrical generation sector, has conducted a far reaching assessment of tidal stream technology (2005-06). The study included technology assessment, the identification of pilot development sites in the seven principal states and provinces in North America that enjoy a significant tidal stream resource, and matching of chosen technologies to those sites. Lunar's RTT was identified as one of only two technologies currently viable for transmission-level projects and indeed was identified as ideal technology to be developed in five of the seven EPRI sites (the others were preselected before the study started and were considered too shallow for the RTT and for significant power extraction).

After the 1MW demonstration at EMEC, Lunar will commission the 2MW unit design.

◆ www.lunarenergy.co.uk

TIME TO REACTIVATE?

JOHN MCNAMARA of the Nuclear Industry Association says 2007 will be remembered as a truly momentous one for the UK's civil nuclear industry – and for the climate change debate in general

This year marks a crucial turning point for nuclear energy in the minds of industry leaders, politicians, media and to some extent the British public. In a broader context, but still very much linked to the nuclear debate, the issue of an individual's carbon footprint has started appearing increasingly in national newspapers. And this is not just in *The Guardian* or *Observer;* even the *Sun* and *News of the World* began to offer tips on how to do your bit for the environment and cut carbon. This truly is a step-change in environmental consciousness.

As far as the nuclear debate is concerned, interest has soared to unprecedented levels, with all angles of comment taking part in a wide-ranging and inclusive discussion.

Last year important developments included the long-awaited recommendations to the UK government for long-term disposal of nuclear waste. Then came the eagerly-anticipated Energy Review itself, where nuclear's contribution to the UK's energy mix was underlined by government ministers. The headlines kept coming. Along with government's acknowledgment of the need for nuclear, the year was also marked by Gordon Brown's endorsement of a balanced energy mix – including nuclear.

The range of academics, scientists and high-profile climate change commentators who have also felt compelled to make a case for a new generation of nuclear power stations has helped fuel the debate. This has encouraged newspaper editors to cover an area they left well alone just a couple of years ago. Whatever one might think, the nuclear option is now impossible to ignore.

Climate change is now a 'top three' issue with editors – a universally-recognised hot topic with never-ending opportunities for coverage, comment, debate and conflict.

The move towards a low-carbon electricity mix which can heat and light our homes and drive the fifth largest economy in the world is news – and will continue to be news. So is the chilly realisation that we are moving rapidly towards a dependency on foreign imports of power to keep us warm. How can the media ignore these issues? How can the politicians or the general public?

The Nuclear Industry Association (NIA) is the representative voice of Britain's civil nuclear industry and has been at the forefront of the national debate surrounding these issues.

The NIA is a trade association representing more than 130 companies including the main operators of nuclear power stations, those engaged in decommissioning, waste management, nuclear liabilities management and all aspects of the nuclear fuel cycle. With trade union support, it also campaigns for the future of some 40,000 nuclear workers in the UK.

The association warmly welcomed the government's conclusion in the Energy Review that nuclear energy should continue to play a major part in supplying the country's needs. The review gave clear recognition that nuclear, alongside renewables and much-improved energy-efficiency, can make a major contribution to tackling climate change and lead to a sustainable low-carbon economy.

The review also confirmed the NIA's position that nuclear offers reliable, secure and affordable low-carbon electricity for the benefit of both consumers and the environment. It also revealed the government's intention to introduce carbon-pricing and to streamline the planning and licensing processes for nuclear and other energy infrastructure projects. We are confident this will help lead to private sector investment to build new nuclear power stations in the UK. The major pan-European utilities, including EDF, E.ON and RWE all have new nuclear build in the UK firmly in their sights.

The NIA's submission to the Energy Review and subsequent nuclear consultations has centred around nuclear's benefit of being carbon-free at point of generation while delivering base-load generation (up to 20% of the UK's electricity) from within the UK. These points tally with Gordon Brown's 'twin pressures' of the impending energy gap and the potential for over-reliance on imported energy, and the need to combat climate change and move towards a low-carbon economy.

The facts are clear. Year-on-year, our demand for electricity in the UK is rising by 1-2%.[1] Carbon emissions are also rising. Figures released (rather quietly) earlier this year by David Miliband show the UK's carbon emissions rose by 1.25% in 2006.[2] This demonstrates a very considerable distance between political rhetoric surrounding our commitments to Kyoto (now very important to the voters) and the reality of our situation in the UK.

This I think is why nuclear is so firmly back in the debate. Nuclear energy is a reliable and economic source of large-scale low-carbon electricity. One nuclear power station like Sizewell B produces enough electricity for the daily domestic needs of 2 million people (3% of all the UK's electricity) – without carbon emissions. The nuclear industry supports a balanced energy mix, including development of all low-carbon technologies. But, to put that into context, it would take 1,200 wind turbines to equate to Sizewell B's output, and maybe three times as much again situated in different locations when you factor in Sizewell B's record-breaking 480 consecutive days at full power, which only ended with a statutory maintenance shutdown last November.

In just ten years from now there could be just three nuclear power stations still running in the UK (based on current closure dates). Nuclear's percentage contribution to the energy mix will be in single figures. Surely nuclear, wind-farms, solar, wave power, clean coal and energy efficiency are all needed to combat climate change? If you erase nuclear's 20% from the low-carbon balance sheet, you play catch-up for decades. Where's the environmental gain in that?

For critics who say that nuclear isn't low carbon, a host of studies conducted in countries like Finland, Sweden and across the EU looking at cradle to grave carbon emissions point to a rather different conclusion which will surprise many people. These studies take into account mining of uranium through to building the nuclear plant, areas where of course carbon is emitted. But carbon is also emitted when fabricating wind turbines, building sub-stations and installing onshore and offshore wind farms. The studies show clearly that nuclear emits a fraction of the carbon that coal and gas installations do over the life cycle. What may surprise many people is that, megawatt for megawatt, nuclear is also less carbon intensive than even wind power over the lifetime of the plant.[3]

As far as climate change is concerned, nuclear is part of the solution, not the problem. World-renowned environmentalists like James Lovelock agree. So do many respected academics and scientists, including the government's own chief scientific advisor, Sir David King.

Recent BBC programmes by Sir David Attenborough[4] looked closely at how we can tackle the dangers of climate change. Sir David's findings were that we must protect the rainforests, educate and legislate for total energy efficiency, while carrying out research and development into all forms of renewables, as well as the use of safe, reliable nuclear energy, which at point of generation is carbon-free. More than that, Sir David concluded that globally we need a 'three-fold increase' in the amount of low-carbon nuclear energy. There are strong signs that this massive global nuclear renaissance has already begun.

The UK nuclear industry has the experience, the skills and the capability to deliver a programme of new modern reactors to maintain nuclear energy's contribution to a low carbon energy mix, and to safely decommission plants that have reached the end of their working life.[5]

In as little as 20 years the UK could be counting on gas to supply 70% of our electricity. Of that, 90% will need to be imported.[6] Britain will be at the very end of a long pipeline. Anyone who took an interest in last year's stand-off between Russia and the Ukraine, when Putin decided to settle a squabble with his near-neighbour by cutting off all gas supplies during the winter, will need to hope the UK keeps up very good relations with its suppliers. Reliance on imported energy is a risky strategy.

All indicators show public opinion is changing towards

1 www.berr.gov.uk/energy/statistics/publications/dukes/page39771.html
2 www.defra.gov.uk/news/2007/070329a.htm
3 This relates to several studies conducted over the life-cycle of plants, including mining of uranium, construction and decommissioning. The two main ones the nuclear industry quotes in detail are by the Parliamentary Office for Science and Technology (POST report) and one conducted for British Energy – based on Torness power plant. This one was carried out for them by nuclear consultants and is featured on their website – www.british-energy.com.
4 Are We Changing Planet Earth?
5 'UK is currently safely and efficiently decommissioning 5 first-generation Magnox plants at Hinkley, Dungeness, Sizewell, Trawsfynedd, and Chapelcross. Overseen by the Nuclear Decommissioning Authority.' – www.nda.gov.uk/
6 Figures from DBERR

nuclear. Many of these arguments and issues have been played out in the media over the past two years. The industry is helping to foster an open debate as well. It has also been heartening to see parliamentary support grow. In a recent Ipsos MORI poll[7] commissioned by the NIA a major swing towards positive attitudes to nuclear was revealed among some 108 MPs questioned.

The nuclear consultation being held by the government closes on 10 October.[8] It is concerned about the UK's future energy needs (30% of our current power stations, including coal and nuclear, will be closed down in the next 20 years, so we desperately need to start building something new) and concerned with security of supply. And it is also giving the public the chance to have their say.

We recognise that some are uncomfortable with the idea of nuclear energy. But in the UK we have used it for 50 years to heat our homes and power our industry, without harming the environment. The issue of nuclear waste is often cited as a main blocker to acceptance. But nuclear waste has always been stored and managed safely. And now that we are moving towards a long-term underground repository, the case for new-build is strengthened. It's worth remembering a couple of unavoidable truths here. Nuclear waste is currently safely contained. It is not damaging the atmosphere and causing havoc and uncertainty for all future generations, like the waste from the fossil-fuelled base-load provider is. Secondly, in terms of physical quantity, the amount of waste we have from 50 years of nuclear energy in the UK is less than the amount of domestic waste we throw out for landfill in just one day. That's one day's domestic waste volume = 50 years of secure low-carbon electricity powering our hospitals, trains and machinery.

The NIA will continue to work to ensure that the case for nuclear energy is made strongly and the voice of the nuclear industry is heard, and we look forward to nuclear remaining a key part of the solution to Britain's future energy needs.

7 www.ipsos-mori.com/polls/2007/niauk.shtml
8 http://nuclearpower2007.direct.gov.uk/

MANAGING RADIOACTIVELY CONTAMINATED LAND

KANAN PURKAYASTHA looks at ways we can safeguard against the possible dangers of nuclear and other potentially harmful wastes

An extended statutory regime[1] for the identification and remediation of contaminated land came into force from 4 August 2006. This extended regime consists of Part 2A of the Environmental Protection Act 1990 as originally introduced on 1 April 2000, together with changes intended to address land that is contaminated by radioactivity. For this purpose Radioactive Contaminated Land (Enabling Powers) (England) Regulations 2005 (SI 2005/3467), the Radioactive Contaminated Land (Modification of enactments) (England) Regulations 2006 (SI 2006/1379) and Contaminated Land (England) Regulations 2006 (SI 2006/1380) have also been made.

Generally speaking, the objective of the extension of Part 2 A is to provide a system for the identification and remediation of land where contamination is causing lasting exposure to radiation for human beings and where intervention[2] is justified. The reason for setting up such an objective is to ensure that the UK complies with its obligations to transpose and implement articles 48 and 53 of the Basic Safety Standards Directive. This directive introduces the basic safety standards for the protection of the health of workers and general public against the dangers arising from an ionising radiation.

This article will provide some flavour of managing radioactively contaminated land under the extended statutory regime.

Sources of radioactively contaminated land

Defra (Department of Environment, Food and Rural Affairs) has produced an industrial profile that delineates the industrial activities that may lead to radioactive substances

1. Extended statutory regime comprises several documents. These are as follows:
Radioactive Contaminated Land (Modification of Enactments) (England) Regulations 2006.
Radioactive Contaminated Land (Enabling Powers) (England) Regulations 2005.
Contaminated Land (England) Regulations 2006 (SI 2006/1380).
The Environmental Protection Act 1990 (Isles of Scilly) Order 2006 (SI 2006/1381).
Defra Circular 01/2006 Environmental Protection Act 1990: Part 2A Contaminated Land (revised statutory guidance).
Further information regarding the extended regime is available on Defra's web page (www.defra.gov.uk).
2 See Defra briefing guide, September 2006

in land.[3] Some of the industrial activities are as follows:
- Rare earth metal refining.
- Radium luminising works.
- Waste management industry, such as landfill sites where radioactive substances have been disposed of.
- Production of gas mantles.

Decision making process

Local authorities have retained the lead regulatory role in the extended regime. In case of radioactively contaminated land, decision making processes via inspection can only start if there are reasonable grounds[4] for believing that a particular land might be contaminated by radioactivity.

Section 78A(2) of Part 2A of the Environmental Protection Act 1990 is modified in case of radioactively contaminated land:

> *Contaminated land is any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that –*
> *(a) harm is being caused, or*
> *(b) there is a significant possibility of such harm being caused.*

An important point to note is that controlled water pollution is not considered as a receptor in the case of radioactively contaminated land. But land which has radioactive contamination would be considered as a 'special site'.

In terms of radioactively contaminated sites, 'harm' is defined as 'lasting exposure to any person resulting from the after-effects of a radiological emergency, past practice or past work activity'.

The next decision making step is to see whether harm is actually being caused. In this regard, Defra circular 01/2006 states that harm is being caused where lasting exposure gives rise to doses that exceed one or more of the following:
- an effective dose of 3 millisieverts per annum;
- an effective dose to the lens of the eye of 15 millisieverts per annum; or
- an equivalent dose to the skin of 50 millisieverts per annum.

These criteria are referred to as the 'A41 Criteria'. In practice, one criterion is related to another criterion, because it is unlikely that the criterion for the lens of the eye would be exceeded without the other criteria also being exceeded.

The third decision making step is to understand whether the possibility of harm being caused is significant. Here, first of all we need to focus on two issues: 'possibility' and 'significant'. The term 'possibility' is referring to a measure of the probability or frequency of the occurrence of circumstances which lead to lasting exposure being caused. The term 'significant' is referring to a situation if the potential annual effective dose from any lasting exposure multiplied by the probability of the dose being received is greater than 3 millisieverts. However this test will applied to scenarios where –
- the potential annual effective dose is below or equal to 50 millisieverts per annum; and
- the potential annual dose equivalents to the lens of the eye and to the skin are below or equal to 15 millisieverts and 50 millisieverts respectively.

If site condition is different than what is mentioned above, then local authorities, in order to determine whether the possibility of harm being caused is significant, need to take account of the following issues:
- the potential annual effective dose;
- any non-linearity in the dose-effect relationship for stochastic effects;
- the potential annual equivalent dose to the skin and to the lens of the eye;
- any deterministic effect associated with the potential annual dose;
- the probability of dose being received;
- exposure duration and timescale within which the harm might occur;
- any uncertainities.

It is clearly evident in the above-mentioned decision making process that one needs to understand the nature of effects from the radioactively contaminated land – that means whether the effect is 'stochastic' or 'deterministic'.

Where the likelihood of radiation-induced health effects which may be assumed to be linearly proportional to the radiation dose over a wide range of doses, and where the severity of the health effect is not dependent on the level of the dose, then such types of health effect can be depicted as stochastic effects. As with, for example, radiation induced cancer. The type of health effect which occurs following a dose of radiation above a certain level, with the severity of the health effect dependent on the level of the dose, is known as deterministic effect. As, for example, radiation-induced cataract of the eye.

When the question of selection of the appropriate remedial measures arises, the authority might ensure that the achievable benefit through a remedial measure is greater than any harm caused or cost incurred. That is a test of justification. The authority also should ensure that

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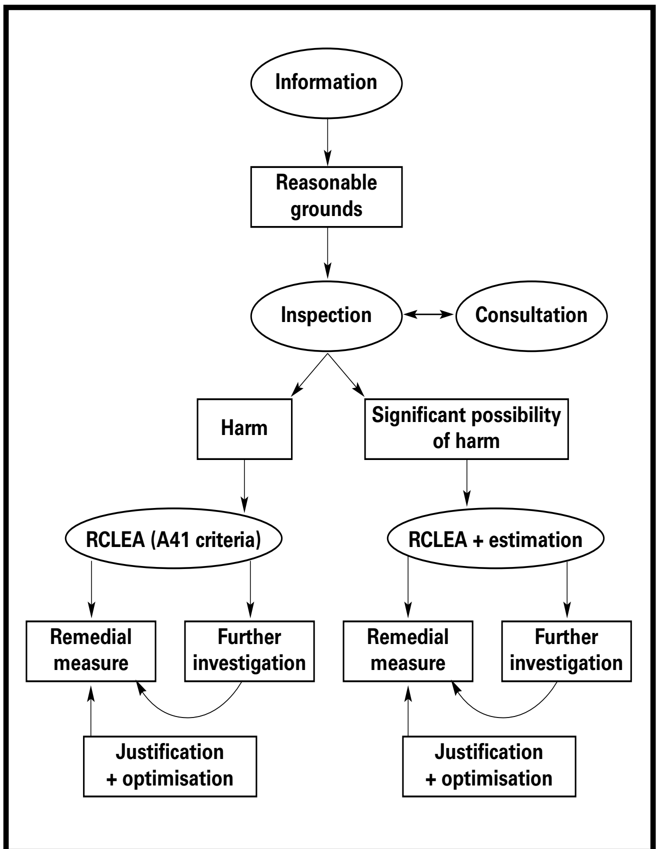
3 Defra publication *Industry profile: Industrial activities which have used materials containing radioactivity* is available at www.defra.gov.uk/environment/land/contaminated/pdf/industryprofile0603.pdf

4 Reasonable grounds are decribed in Defra circular 01/2006 para B.17A and B.17B. In a nutshell, the following test/tests can be applied:
Where authorities have knowledge of information relating to land use, past practice, or past work activity that can cause lasting exposure or levels of contamination present on the land arising from a past practice and past work activities.
Where information is held by the local authorities or received from other regulatory bodies.

the form, scale and duration of the intervention are such that it maximises benefits. This is a test of optimisation.[5]

The general process flow diagram for decision making can be presented as shown below. (A square shape indicates a decision making step and an elliptical shape indicates an activity step.)



Decison making flow diagram

Role of RCLEA in decision making processes

Defra has recommended an approach for the exposure assessment of a site under the extended regime known as RCLEA (Radioactively contaminated land exposure assessment).[6] The methodology is based on a set of mathematical models and data that calculate radiation doses from radionuclides in soil. Using measured concentrations of radionuclides, RCLEA calculates potential doses for comparison with regulatory criteria. Another use of RCLEA is to calculate 'guideline values' for a radionuclide. Site specific calculation is also possible using RCLEA. It is important to note that the dose calculated with RCLEA can be compared with the criteria which apply for radioactivity under the extended Part 2A regime, provided the scenarios and assumptions are appropriate. That means RCLEA has been designed for situations where the contamination is evenly dispersed over a relatively large area. Where contaminants give rise to localised exposures, RCLEA methodology is not suitable. RCLEA does not include consideration of potential exposures resulting from the migration of radionuclides in surface water or groundwater. Another important point to note is that one can use RCLEA methodology for A41 criteria in relation to 'harm' but it cannot be used on its own to establish 'significant possibility of harm'. Later scenarios requires an estimate or calculation of probability that a person is exposed.

In this context, the decision making process relies on the fact that if radionuclide concentrations are known with some certainty, and the RCLEA scenarios and assumptions are applicable, then the site can be eliminated for further consideration if:

- concentration of a single radionuclide < RSGV
- sum of the individual radionuclides ratio to their respective RSGV < 1

where RSGV is the guideline values of a radionuclide.

Some of the characteristics of RCLEA methodology

The methodology relies on some assumptions, data requirements and modelling approaches:

- Providing direct estimates of harm in terms of estimated radiation dose.
- Exposure pathways are inhalation, ingestion, external irradiation at a distance and direct irradiation of the skin.
- The contamination is assumed to be uniformly distributed through soil to a depth of 1 metre from the surface.
- Not applied to buried contamination without separate measurement or calculation of radiation dose rates above the buried contamination.
- Potential exposure scenarios are described in terms of land use such as residential, allotment and commercial/industrial use.
- Several site-specific options can be used, such as age and sex of exposed person, building type, duration of exposure and atmospheric dust concentration. If the optional information is not specified the RCLEA will automatically use worst-case assumption.
- The annual intake is determined from an intake rate combined with the exposure duration.
- The annual radiation dose from ingestion and inhalation is calculated using internationally recommended 'dose coefficients' which are age and

5 More information regarding 'justification' and 'optimisation' is available in Defra Circular 01/2006 p119-120 (Para C.43B-C43I and para C.43I-C.43J).

6 More information is available from CLR 13 document entitled 'Using RCLEA - the Radioactively Contaminated Land Exposure Assessment Methodology' (October 2006). The document is in draft stage but will be published shortly.

pathway dependent.

- The radiation dose from the external irradiation of a person is calculated using the radionuclide concentration in the soil, the exposure duration and dose coefficients for external irradiation.
- RCLEA does not adopt distributional approaches, but rather a single value drawn from the distribution is considered.
- It includes data for 47 different radionuclides, which can be assessed separately or in combination.

Conclusion

Radioactively contaminated land management and a related decision support tool (RCLEA) have been discussed here. Local authority's duty to act can only arise if there are reasonable grounds for believing that a particular land could be contaminated by radioactivity. At the remedial stage of the management of such land, the principle of justification and optimisation approach should be followed.

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FUSION AS A FUTURE ENERGY OPTION

Fusion scientists **CHRIS LLEWELLYN SMITH** and **DAVID WARD** give us a glimpse of a high-powered future

Fusion powers the sun and stars. The Joint European Torus (JET), which is the world's leading fusion facility, has produced 16MW of fusion power and shown that fusion can be mastered on earth. The advantages of fusion power are that it will be environmentally responsible and intrinsically safe, and the supplies of fuel are essentially limitless.

The main disadvantage of fusion power is, of course, that it is not yet available, and will not be available as soon as we would like. A fusion power station could be built, and it looks as if the cost of fusion power will be reasonable. However time is needed to further develop the technology in order to ensure that it would be reliable and economical, and to test in power station conditions the materials that would be used in its construction.

Assuming no major surprises, an orderly fusion development programme – properly organised and funded – could lead to a prototype fusion power station putting electricity into the grid within 30 years, with commercial fusion power following some ten years later. Studies are ongoing looking at how to speed up this development, if required.

What is fusion?

Reactions between light atomic nuclei in which a heavier nucleus is formed with the release of energy are called fusion reactions. The most effective reaction for power production uses two isotopes of hydrogen, deuterium and tritium, which produce helium, a neutron and very large amounts of energy.

To initiate the fusion reaction a gas of deuterium and tritium must be heated to over 100M°C – ten times hotter than the core of the sun – in order to allow the fuel particles to fuse rather than just bounce off each other's electrical charge. The challenges are therefore to

- Heat a large volume of fusion fuel to over 100M°C, while preventing the plasma from being cooled (and polluted) by touching the walls: this has been achieved using a toroidal 'magnetic bottle' known as a tokamak.
- Make a container with walls sufficiently robust to stand up, day-in day-out for several years, to bombardment by the neutrons produced in the fusion reactor.

Fusion fuel

The tiny amount of fuel that is needed is one of the attractions of fusion. The release of energy from a fusion reaction is 10 million times greater than from a typical chemical reaction, such as burning a fossil fuel. Correspondingly, while a 1GW coal power station burns 10,000 tonnes per day of coal, a 1GW fusion power station would burn about 1kg of fuel per day.

Deuterium is stable and is found in natural hydrogen at the level of 1/6700: it can easily be extracted from water: there is enough deuterium for many millions of years of world energy supply. Tritium, which is unstable and decays with a half-life ~12 years, occurs only in tiny quantities naturally. But it can be generated in-situ in a fusion power plant by using neutrons from the fusion reaction impacting on lithium compounds.

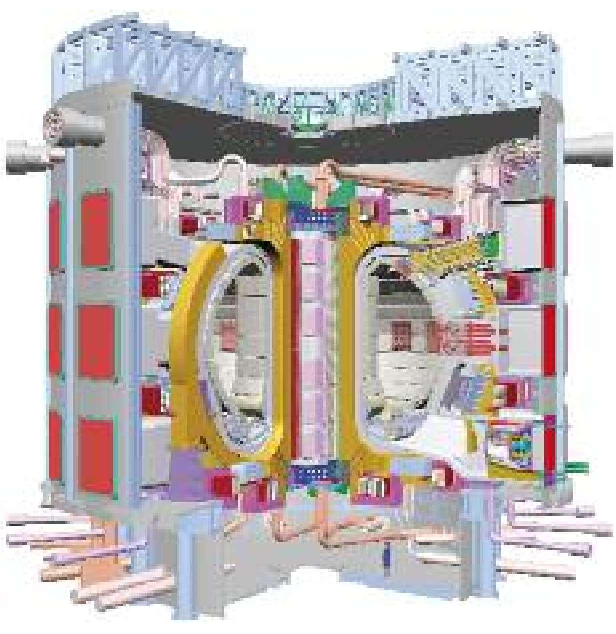
The raw fuels of a fusion power plant would therefore be lithium and water. Lithium is a common metal, which is in daily use in mobile phone and laptop batteries. Used to fuel a fusion power station, the lithium in one laptop battery, complemented by deuterium extracted from 45 litres of water, would (allowing for inefficiencies) produce 200,000 kWh of electricity – the same as 70 tonnes of coal: this is equal to the UK's current per capita electricity production for 30 years. There is enough known lithium reserve for thousands of years of world energy supply.

Advantages and disadvantages

The advantages of fusion are
- essentially unlimited fuel;
- the potential to be a major, low carbon, option for future energy supply;
- passive safety;
- costs of generation that look reasonable when plants of 1GW or above are constructed.

A key fact is that, although it will occupy a large volume, the amount of tritium and deuterium in a fusion reactor will be tiny: the weight of the hot fuel in the core will be about the same as ten postage stamps. Because the gas will be so dilute, there will be no possibility whatsoever of a runaway reaction. Furthermore, there is not enough energy inside the plant to drive a major accident and not much fuel available to be released to the environment if an accident did occur. These facts are the basis of the passive safety of the device.

What are the potential hazards? First, although the main product of the fusion reaction, helium, is not radioactive, the blanket will become activated when struck by the neutrons. However, with the correct choice of materials, the radioactivity decays away with half-lives of around ten years, and all the components could be recycled within 100 years. There is insufficient heat generation in the walls to lead to melting even in the event of complete failure of the cooling circuit. Second, tritium is radioactive, but again the half-life is relatively short (12 years) and the hazard is not very great, particularly because so little fuel is used and available for release in an accident.



The ITER project, ready for construction, is designed to produce 500 MW of fusion power.

Status of fusion research

Combining developments in science, technology and engineering, fusion research has made enormous progress over the last few decades, over which time the fusion power levels produced have increased from less than 1W up to a maximum of 16MW in JET. These developments, successfully achieved in laboratories around the world, have given the confidence to build a machine, called ITER, as a global collaboration.

The aim of ITER is to demonstrate integrated physics and engineering on the scale of a power station. The design goal is to produce at least 500MW of fusion power, with an input ~50MW. ITER will include superconducting technology which will allow operation for tens of minutes at a time and will also contain modules that, for the first time, will test features that will be necessary in power stations, such as the in-situ generation and recovery of tritium. ITER, although an experimental device, will be about the size of a fusion power station whereas the largest existing experimental fusion device is JET, about half the size (in linear dimensions) of ITER.

ITER, like JET, will use a combination of magnets and a current flowing through the fuel to hold the hot fuel away from the wall and provide thermal insulation. The current also heats the fuel up to 30M°C but requires additional heating methods to push the temperatures up to the 100M°C required for fusion. The heating systems use either radio-frequency waves, rather like a microwave oven, or banks of small accelerators to provide beams of very fast neutral particles. These serve the dual purpose of heating the fuel to the required temperature and maintaining the current flowing round the machine.

Prototypes of all key ITER components have been fabricated by industry and tested. Construction of ITER will cost €5 billion – an annual expenditure of around 5% of world energy R&D or 0.01% of the world energy market – and be undertaken by a consortium of the European Union, Japan, Russia, USA, China, South Korea and India. ITER is to be built in Cadarache in France.

Materials

The structural materials close to the fuel in a fusion power station will be subjected to continuous bombardment of neutrons. This will be a very hostile environment and, even though tests so far show that appropriately chosen materials may be reliable, it is only by reproducing the real environment of a power station that this can be fully explored.

The only way (other than building a power station) to reproduce the fusion environment, is by constructing an accelerator-based test facility that has become known as IFMIF. IFMIF will consist of two deuteron accelerators which will be focused on a liquid lithium target to produce neutrons with energies matching those generated in fusion. The international design effort for IFMIF is now ongoing.

The route to fusion power

In determining how to get from where we are today to fully functioning fusion power stations, we are naturally driven to look at design concepts for real power stations. Such design studies are carried out around the world and there now exist designs for a spectrum of possible plants, covering the range of scientific, technological and material possibilities. The designs range from water cooled plants made of steel through to a helium cooled plant which incorporates silicon carbide composites to allow high coolant temperatures, up to 1000°C.

The cost of fusion generated electricity is dependent primarily on the capital cost of the machine and this depends on the details of the assumption of the study. Typical values for cost of electricity, assuming that the 1.5GW_e power stations are successfully built and operated, lie in the range 5-10 €cents/kWh; comparable to projections for other low carbon energy sources.

On the basis of where we are today, and the target for fusion power stations, studies have been carried out to produce a critical path analysis and plan for the development of fusion, in order to i) prioritise future research and development, and ii) motivate support for, and drive forward, the rapid development of fusion power. Using technical targets derived from power plant conceptual studies (especially the dependence of the cost of electricity on power station parameters), issues are identified that still need to be resolved, and which will be resolved by existing devices, ITER and IFMIF.

The next step is to identify information that will be needed to finalise the design of the first prototype fusion power station, which has become known as DEMO (for Demonstrator). Assuming just-in-time provision of the necessary information, this leads to the construction timetable for DEMO (planned to be operational in less than 30 years) and feed-through of information from ITER, IFMIF and DEMO to the first generation of commercial fusion power stations (although this is obviously much more speculative). This is not the place to elaborate further on this schedule, but three points should be made:

- It should be stressed that such models yield technically feasible plans, but do not constitute predictions. Meeting a specific timetable will require a change of focus in the fusion community to a project orientated 'industrial', approach, accompanied of course by the necessary political funding and backing. (In general, the dramatic decline in energy R&D expenditure over the last two decades must stop and be reversed if we are to achieve a major change in our energy systems).
- The derived timetables reflect an orderly, relatively low risk approach. It could be speeded up if greater risks were taken, e.g. starting DEMO construction before in-situ tritium generation and recovery have been demonstrated.
- Reduced risks and faster development could be achieved through the use of other devices run in parallel to the main programme. These could be devices similar to ITER, IFMIF or DEMO, or other smaller devices targeting earlier attainment of specific strategic information.

Concluding remarks

Given the remarkable progress that has been achieved in recent decades, we are confident that fusion will be used as a commercial power source in the long term. We are less confident that fusion will be available on the time scale of 30 years, which would require adequate funding of a properly focused and managed programme, and that there are no major adverse surprises. However, given i) the magnitude of the energy challenge, ii) that fusion is one of very few candidates for large scale CO_2-free generation of baseload power, and iii) the relatively small investment that is needed on the $4 trillion p/a scale of the energy market, we are absolutely convinced that focused development of fusion power would be fully justified.

Acknowledgment

This work was funded by the UK Engineering and Physical Sciences Research Council and Euratom.

Further reading

General information on fusion can be found in the recent book, *Fusion, the energy of the Universe*, G McCracken and P Stott, Elsevier (2005), ISBN 0-12-481851-X, or on our web site www.fusion.org.uk

More information on the engineering aspects of fusion can be found at www.iter.org and in the EU studies of fusion power plant concepts, summarised in *A conceptual study of commercial fusion power plants*, D Maisonnier *et al*, EFDA-RP-RE-5.0 (2004) www.efda.org/downloading/efda_reports/PPCS_overall_report_final.pdf

The analysis of a development path for fusion is given in *Accelerated development of fusion power* by I Cook *et al*, February 2005, UKAEA FUS 521, available at www.fusion.org.uk/techdocs/ukaea-fus-521.pdf

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SCANNING THE ENERGY HORIZON: MIRACLE OR MIRAGE?

Humanity has proved to be very destructive to the biosphere. It also has the facility for seemingly endless invention. While some proposed new methods of energy production look promising, others sound like the visions of LSD-fuelled science mavericks. **DAVID HAWKINS** examines a few

Our tour of the creative or crazed commences with the Atmospheric Vortex Engine (AVE) invented by Canadian Louis Michaud. This would harness the power of an artificially induced tornado, enabling a large amount of reliable energy to be produced. A column of air would be heated within a cylindrical wall while a system of vents would induce convection currents to begin their natural flow. It has been suggested that the whirlwinds above these AVE stations could be extended up to significant heights, even as far as the tropospause, and generate power between a projected 50 and 500 Megawatts, much greater than the capabilities of conventional horizontal wind turbines. Apparently, we would need have no fear of the twister ripping free as it would be properly 'anchored'. (See: http://vortexengine.ca/index.shtml)

The Maglev Wind Turbine is a magnetically levitated device which could generate up to a Gigawatt of power, at a going rate of less than one US cent per Kilowatt hour, with output boasting energy generation over 20% higher than with traditional turbines. The blades of this machine, which run vertically, are suspended on a cushion of air. It is able to utilize low wind speeds, even as low as 1.5 metres per second, and is highly efficient. One already on trial in China seems to be having success. And you can't miss it – though hard to tell from extant information, it seems like a Maglev turbine is approaching 200 metres in height! (http://magturbine.com/)

Then we have Magenn's Air Rotor System. With this the company plans to have helium-filled blimps suspended at altitudes of between 180 to 300 metres where they will harness the power of the wind, sending what they gather back to earth via a (strong!) cable. Aerodynamic fins on the blimps will cause them to rotate, transferring power to generators inside. Other companies plan to raise energy crafts far higher into the atmosphere, where they can draw in power from the jet-stream. Could we one day see our skies filled with clouds of such things, grazing the high winds like floating energy cows? (www.magenn.com/technology.php)

It seems that radical ways of harnessing the wind are coming from all quarters. A student at Arizona State University has come up with a way of catching the rush of air from traffic. His proposal is a retrofitting of the horizontal steel-tubing over freeways which hold signage. Turbines would be built into these, feeding power into the grid or providing local services. Apparently turbulence created by passing vehicles is more than adequate to make this economically viable. (www.archinect.com/schoolblog/entry.php?id=55756_0_39_0_C)

Enviromission in Australia are using German technology for a solar thermal tower, which will give a projected 200MW of power annually – enough for 200,000 homes. Again, convection currents will be the source, as air flows are channelled in to drive 32 turbines set in the base of the tower. If built this will be the largest engineered structure ever – 1000 metres high! Will this huge power finger deep in the outback point the way to the future? (www.enviromission.com.au – artist's rendition of the solar tower video is recommended.)

One of the more outlandish proposals for energy generation has come from space. Solar power satellites orbiting the earth or solar arrays on the moon would transmit the energy they gather back to substations on the ground via microwave beams. The costs of transport and transmission for this method would be very high, but the advantage of space energy is that it is constant – up there the sun shines all the time, never obscured by clouds or night. However, fears have been raised that misdirected microwaves could accidentally cook a city.

Closer to home, energy chances from burning biomass are being exploited by the company Infinis. Organic waste from supermarkets and a variety of other sources is being sized-up for conversion into ready power at a new plant by the company, which already supplies the national grid via landfill methane. 100,000 tonnes of waste from supermarkets goes into the ground every year. Clearly this quantity of waste is far too high, but for now the least we can do is make some use of it. Ultimately, Infinis would like to use waste from food processing companies and farmers too. (www.infinis.com)

Irish company Steorn recently hit the news with claims of being able to produce an endless supply of 'free, clean and constant energy' with its Orbo technology. This is based around magnetic fields, which they claim engender a sort of perpetual motion in stable bodies when things are arranged appropriately. They also acknowledge that this energy without a source is a scientific 'heresy' and that with it they have been forced to 'effectively slap science in the face' as they go against the basic principle of the conservation of energy. Due to this skepticism and controversy they have invited anyone willing to test their designs.

This 'process of validation' is still underway. The unfortunate failure of their machine at its latest public display was blamed on heat from the cameras of the assembled media. Aside from all the talk of heresy, we also must not fail to overlook what the implications of extremely cheap and limitless energy actually are. (www.steorn.com)

Three fish farmers in Wales have come up with a way of producing a second-generation biofuel from genetically modified algae. They have designed a box ('Greenbox' technology) which can be fitted to cars and other vehicles to capture exhaust fumes. The carbon dioxide from these can then be used to feed the algae, which are in turn broken down into a bio-oil and then converted to form of biodiesel. In this way, their company Maes Anturio Ltd plans to significantly reduce emissions and produce useful energy at the same time. (www.maesanturio.org)

Hydrino Theory, developed by Randell Mills, goes against the physics of Quantum Theory. The idea is that, with the use of a catalyst, the electron in a hydrogen atom can reach an energy level below the ground state of quantum mechanics, thus releasing a great deal of energy while the hydrogen is converted to a 'hydrino'. Despite rejection by the scientific community, his business Blacklight Power, Inc has raised a large amount of venture capital to fund its research. Mills has linked his technology to cold fusion and written a 2,000-page book on the subject: *The Grand Unified Theory of Classical Quantum Mechanics*. But is this epic just a work of science fiction? (www.blacklightpower.com)

Meanwhile, new mega-battery technologies from the likes of Scottish company Plurion are increasing the possibilities of storage from intermittent renewable energy supplies such as wind and solar, allowing greater long-term power reliability in these fields and giving further options as Peak Oil approaches.

There are several other technologies not mentioned in this journal which are already in use around the world. Most salient are further forms of tidal power, along with geothermal and the advance of nanotechnology. There are also future possibilities in hydrogen, fuel cells and perhaps even superconductors. But as well as finding new ways to make clean energy we need to reduce our consumption and increase energy efficiency. Only a combination of these approaches will pave the way to a truly sustainable world.

INTERVIEW: GEORGE MONBIOT

GEORGE MONBIOT is well known as a campaigner for global justice and as a strident voice in the fight against climate change. His book *Heat* is a detailed and lucid examination of Britain's energy potential that demonstrates how emissions can be reduced by 90% in every sector. He speaks to David Hawkins about expansion and issues a call to arms for environmental scientists

It's clear that a paradigm-shift in our energy system is needed. Some have proposed a concerted move towards microgeneration, but you seem to advocate an expansion of the grid, perhaps using HVDC transmission cables. How feasible is this?

■ I would love to be able to advocate microgeneration myself, because it ties in with the localised small-scale economy that I'm inherently favourable towards. But, unfortunately, the physics militate against it. Where people live in Britain there is simply not enough wind, and we have problem with sunlight as well because at times of peak demand sunlight isn't available. So first of all you have a problem with generation, then you have a problem with storage. And resulting from both of those problems you have a very major problem with expense. It seems to me that we have to use limited resources as well as we possibly can. So if you can produce five times as much energy with a pound spent one way and not another way, then you should be spending it the first way, not the second way.

Unfortunately, as a major solution to the problem, microgeneration falls down on all counts. The first one being that there is not enough ambient energy in the places where people live in the UK. The second is that there is not enough diversity of ambient energy in the places where people live, which you require if you are to overcome the variability problem. The third one is that it is an extremely expensive means of generating electricity, because you can't tap into economies of scale and because you need separate systems for every house or for every small collection of houses.

Now, what we look for if we are to have a chance of a very high proportion of our electricity coming from renewable sources is the greatest possible diversity of supply. By that I mean not just different sources of renewable energy, but also different places from which renewable energy can be extracted. Because, of course, if you obtain all your wind power from one place and the wind stops then you lose all your wind power. But if you obtain it from places which are very far apart then there's a very high chance that if the wind stops in one place then it will still be blowing in another place. And the wider the geographical range from which you draw your wind power, or indeed your wave power or sunlight or any other source of ambient energy, the less the variability of that power. The great problem of microgeneration is that you're confined to one site.

So, theoretically, if we were to see an expansion of the grid (as, for instance, the TREC group have suggested) might it be possible actually to generate all of our energy from renewable sources? Because in *Heat* you reached the domestic conclusion that we could only get 50% of our energy from renewables…

■ Well, that was a guesstimate, and had to be so, because at the time of writing there had simply been no studies showing anything beyond 30%, which was incomprehensible. Or I suppose comprehensible, when you see how the tail was wagging the dog as far as the research was concerned, because the government had said 'our target is 20%, find a way of delivering it'. Rather than what it should have been saying which was 'what's the maximum we can deliver and how could it be done?' And so the research agenda was distorted by the government's commitment.

Since writing the book there have been several studies published which show you could potentially go way beyond 50%. One of them was done by Mark Barrett at UCL[1], another was the one sponsored by the German government and the most recent one is by the Centre for Alternative Technology, called *Zero Carbon Britain*[2]. All of them suggest that you could go way beyond 50%. The German study suggests 80%, Mark Barrett suggests up to 95% and the CAT, a little over-optimistically perhaps, suggests 100%, and they do this principally by changing the way we think about energy storage, as well as talking about this greater diversity of supply. I think these papers are all very interesting indeed. But the CAT paper also contains one very pessimistic condition, which is that all the electricity must come from within the UK. There is no reason at all why that has to be the case; we do not have to be an electricity island by any means. The German DSP study shows with a great deal of force that you can draw energy in Europe from a very wide range of sources across a very wide geographical area. So I think it is reasonable now to be able to say that deploying the full range of techniques of both generation and storage and using this far more efficient means of transmission – which is I think the key to all of this, interestingly everyone's concentrated on generation, nobody's thought very hard about transmission – we can produce between 80-90% of our energy in Europe by renewable means, but through very large scale generation, quite the opposite end to microgeneration.

And this is where the HVDC cables would come in as a more efficient means…

■ Right, because over long distances they lose less electricity and they are considerable cheaper than alternating current.

Yes, and these are at a level where they can be employed now? You mention that in the Democratic Republic of Congo there is a very long one.

■ It's 1,800 kilometres, which is probably about as long as any we would need. But I'm told by one person in the industry that the technical maximum is 4,500 kilometres, which is potentially interesting because we can then start to think about a global grid – if that's true. Unfortunately again there's been very little work into what the maximum distance might be. One disappointing thing I found when researching *Heat* was how many enormous research gaps there are, how many unanswered questions, how many questions which haven't even been asked. So, for example, at the time of writing (and I don't know whether it's changed now) there was no research whatsoever showing whether it makes sense, in carbon terms, to keep old houses going and trying to improve their efficiency or to be demolishing and rebuilding them. There was simply no research which allowed you to say which option was the best option, and yet this is a critical issue, a huge issue. And I think again, a lot of it is an artefact of the way the government pitches the thing. Because most of the funding for research is going to come from government, if the government's not asking the question then the question isn't going to be asked by researchers. There's a real problem there, and I was shocked by how many unanswered questions there were.

So, anyway, as far as HVDC is concerned, we know that the technology would allow us to build a European supergrid, possibly it would allow us to build a global supergrid. The global supergrid has tremendous advantages, because it taps into resources, obviously, all over the world, and you get even greater reliability than you would get within Europe alone, or within Europe and North Africa.

1 www.cbes.ucl.ac.uk/projects/energyreview/Bartlett%20Response%20to%20Energy%20Review%20-%20electricity.pdf

2 www.zerocarbonbritain.com

Now this is something of a philosophical question, but do you think, on a conceptual level, if we were to build a global supergrid might we begin to see some problems with the way the world would be if there was a constant supply of essentially limitless energy? How might that affect consumption?

■ It's a very interesting question; and to try to answer the philosophical question we require a philosophical answer. The problem which all environmentalists confront, whether they're fully aware that they're confronting it or not, is the fundamental problem that our economic system is based on growth, and the system collapses if growth stops. And yet, perpetual growth on a finite planet is a physical impossibility. So, either we have to devise a growth free system – and so far no-one has succeeded in doing that in a way which is able to persuade the most powerful forces in society that that's the way to go – or, we have to find means of accommodating the existing economic system while causing as little damage as possible, and preventing that growth from causing complete destruction of the biosphere for as long as possible. Again, as an environmentalist, I would much prefer us to have an alternative; I'd much prefer us not to be relying on a system which requires perpetual growth, because that simply cannot be reconciled to any environmental objective. Unfortunately, that's not a likely option in the very very short timescale that we've got when dealing with the issue of runaway climate change. We have to fall back on the second option which is to say: how do we reduce the damage that that growth is going to do? Given that it's going to happen anyway, whichever energy sources we make use of, let's find one which causes as little damage as possible.

So this is sort of the mitigation of the inner climate change battle against ourselves which you talk about in your book…

■ That's right, and unfortunately in the very short timescale we've got that's what we have to rely on. What distinguishes climate change from other political challenges is that it is effectively irreversible, certainly as far as lifetime scales are concerned, and we've got a very short time in which to prevent irreversible runaway climate change from taking place. We don't have the luxury that other political campaigns have of slow evolutionary change; we have to have a drastic step-change.

So it's reached a tipping-point of its own in a sense… We've been talking about future possibilities, now I'd like to ask a couple of more political questions. The government's Sustainable Development Commission have just given a nod to the proposed Severn Barrage development – what are your ideas about that? Meanwhile some environmental campaigners have been advocating a series of smaller tidal lagoons instead…

■ I'm much more sympathetic to tidal lagoons. I know that estuarine environments are becoming increasingly scarce; they're very vulnerable to destruction. I've seen how, for instance, the Cardiff Bay Barrage completely wiped out a rich estuarine environment.

But do we have to have a trade-off between a localised (albeit extensive in this case) environmental impact for the sake of the wider environment as a whole? Is it a case of just deciding where some inevitable destruction is going to be wrought, or is there a way of avoiding impacts of this kind?

■ I think there is a way of avoiding these major impacts. I would much rather that investment went into very large-scale, very far offshore wind farms where the environmental damage is minimal. In fact you can actually start creating some pretty good habitats for marine organisms as a result of creating more structural heterogeneity. The very concrete pilings themselves are going to be good places for invertebrates to hang out, for fish to hunt those invertebrates, and to disrupt commercial fishing, which has got to be a good thing.

What's your reaction to the government's recent Energy Review, which has been heavily criticised (again)?

■ Well, it's a complex series of reactions… Just to pull out one particular issue: the government seems to be doing everything it can to allow the coal industry to sustain itself. This keeps coming up. It's buried in a succession of documents starting with the Energy Review, and carrying on through the Energy White Paper and various other government papers, where we see a sort of stealthy reintroduction of coal as a major power source. Of course coal has been a major power source in this country for a very long time, and it hasn't gone away. But the government is trying to find ways of rehabilitating it. I find this extremely worrying. What it's quite successfully done is to muddle the public mind with this term 'clean coal'.

'Clean coal' actually means three completely different things, which are conflated when it's convenient for the government to conflate them. The first one is: more efficient coal burning power stations, where efficiency is raised from around 37% to a maximum of 44% or thereabouts. The second is flue-gas desulphurisation. In order to meet new European rules you have to reduce the sulphur content of your exhaust gases. The third one is carbon capture and storage. Now, when people say 'clean coal' what they generally mean is steps 1 or 2, but the impression they try to create in the public mind is step 3. It can be extremely misleading. I often found in government documents a deliberate conflation of those three processes. The problem is that even if you have a more efficient coal burning power station it's still less efficient than any gas burning power station. When you fit flue-gas desulphurisation, which is necessary to prevent acid rain and local pollution, you actually make it less efficient than it was previously, especially if you use a lime-gypsum process which not only consumes energy but also produces CO_2 as part of the chemical reaction. So you actually increase the carbon intensity of coal. But if you're creating the impression that you're getting rid of the carbon emissions, that 'clean coal' is about CCS, then you're seriously misleading the public. This is what the government has done as part of its PR offensive to permit coal-fired generation to continue. And I don't know if you are aware that there are several planning applications in the pipeline now for new coal-burning power stations.

Do you think that modern politicians are capable of the kind of long-term, joined-up thinking that is essential for the switch to sustainable energy production and consumption?

■ I think not. To give one small example, small hospitals all over the country are being closed down and their facilities consolidated into bigger hospitals generally on the outskirts of towns on greenfield sites. At no point in the discussions over that shift was there any mention of the impact of carbon emissions caused by the increase in transport trying to get people to those hospitals. Even when you have a much more direct situation, for instance, when they were negotiating this 'Open Skies' agreement between the Europe and the USA, there was virtually no discussion at all about the fact that an increase in flights was going to cause an increase in carbon emissions. It was put in a completely separate box. What I see throughout government is that people either accidentally or deliberately leave out the environmental implications of many very major decisions.

You've discussed the problem of a lack of scientific understanding in the media particularly. What would you suggest are some of the courses of action that environmental scientists can take to help bridge this communicative gap?

■ There definitely is a gap. I've often come up against it myself when, for instance, a radio or television programme has got in touch with me and said, 'we need someone to explain a particular scientific issue to do with climate change, who would you suggest?' And I suggest a number of people and they say, 'oh we've tried them, but they don't know how to speak on a radio programme.' They really struggle to find people who are good at that sort of thing, who are good at presentation in the media. And not many scientists are – not necessarily for bad reasons, often for good reasons, because they're not tuned in to that rather shallow soundbite approach to the issues which they rightly take very seriously. However, it's absolutely necessary that more scientists learn how to survive in that difficult media environment because we desperately need people to explain these ideas. What we often find is that the climate change deniers have been put through expensive media courses by their sponsors, and are very good at handling the media. Whereas, the climate scientists who have not got that experience are very bad at handling the media, and actually come off worse in discussions with the deniers even though the science is on their side.

Unfortunately you need to acquire a command of shallow rhetoric in order to do well in a combative radio or television programme. I would really like to see a lot more climate scientists learning how to get through a situation like that. For far too long scientists have relied on environmentalists to fight their battles for them. In fact, a couple of years ago a bunch of us wrote a letter that was published in *Nature*, saying 'where the heck are you all? Why is it being left to us to defend your science?' Things have improved a little since then, but not enough. It's still the case that I get called on to defend climate science, and that shouldn't be happening. The media shouldn't be coming to me to do that. The media should have a large pool of climate scientists who it can turn to being confident that they can, number one, master the soundbites, and, number two, that they are prepared to engage in some pretty fierce hand-to-hand fighting with their opponents.

At the moment a lot of climate scientists are guilty of what James Hansen calls 'scientific reticence'. This means not only that they have perhaps an excessive tendency to emphasise the doubt, which is great in science but not so great in the media, but also a lot of scientists are afraid of getting their hands dirty by having directly to confront their opponents. And it's bloody out there, it really is. I'm sure you're aware of the viciousness of the rhetoric of some of the climate change deniers, the way they smear people, the lies they're prepared to tell, and the enormities they're prepared to promulgate about climate scientists who do stick their necks out. But we have to be tough about these things. These people, if they have their way, will allow the biosphere to be destroyed, or at least those biospheric functions which permit human civilisation to persist. We have to stop them, and if that means sometimes abandoning our restraint and our reticence, then I'm afraid that has to be done.

For example, until I did that investigation of David Bellamy's glacier claims[3] he'd got clean away with it. They weren't exposed and no-one had discovered where they'd come from. But it was actually very important to do that. However, it seemed utterly ridiculous. Part of me, while I

3 See *Heat*, pp 24-25.

was doing it, thought, 'why am I bothering with this? This is too stupid for words, I shouldn't even have to be writing this.' But actually it was necessary, it had to be done.

The refutations have to be there.

■ I commend the people at realclimate.org who do this very effectively nowadays. But we need to see British scientists on the media, doing the same sort of thing, much greater numbers of them.

Would you advocate a sort of scientific 'rapid response team' for when bunk gets put out there in the media?

■ I did precisely that about three years ago. One of the problems here, and it's a very odd problem, is that some of the main public interfaces of science and the media became colonised by this weird group of anti-environmentalists who came from the remnants of the Revolutionary Communist Party. The Science and Media Centre and the Association for Sense about Science were entirely staffed by former members of that party, and other anti-environmentalist organisations. I've no idea how people like Susan Greenfield and John Madden allowed these organisations to be taken over in this way. But for years they flatly refused to do anything about climate change. And in fact you had people like Dick Taverne, who founded Sense about Science, who is or was a climate change denier. So a lot of scientists relied on those organisations to do the job for them, but they didn't do the job.

We've talked about the crucial need for a step-change in power generation, consumption and transmission. Peak Oil has almost become a sort of mythic demon which people invoke, and there are many conflicting views on when it might happen. Do you think there is a way we can turn this on its head and go a bit Leonardo DiCaprio (in *The 11th Hour*), making humanity's greatest challenge into its finest moment? Can we maintain a sanguine perspective?

■ There are two dangers implicit in the Peak Oil situation. (I do subscribe to the idea that global oil supplies are going to peak, though I haven't the faintest when it's going to happen.) The first is that people say, 'so oil is going to peak, then we don't need to worry about climate change!' What they're doing there is confusing oil for fossil fuels in general. The real danger of oil peaking is that we switch to synthetic fuels made from coal. Synfuels made from coal are far more damaging even than crude oil.

This is the liquefied coal amongst others…?

■ Exactly, the sort of thing done by Sasol in South Africa. And we're now hearing many people talking about a worldwide solution to Peak Oil. So this other problem associated with Peak Oil is that when you look at governmental answers to it they're not saying, 'therefore we have to massively increase fuel efficiency'; they're saying 'we have to find other sources of fuel'. The three sources they turn to are, number one, biofuels, and we all know the problems associated with those now; number two, synfuels made from coal; or, number three, unconventional oil – which means tar sands or oil shale. So they're shifting to even worse sources of energy than those we're using at the moment. So far from Peak Oil delivering us from evil it could cause even greater climate change than petroleum does.

So it's absolutely essential we get the right paradigms in place now to pre-empt that sort of situation.

■ Precisely.

> Real energy policy also points the way to real climate policy. You can put it like this:
>
> - Climate is an energy issue.
> - Energy is an infrastructure issue, not a commodity issue.
> - Therefore climate is an infrastructure issue.
>
> To get climate right, we have to get energy right. To get energy right we have to start by changing the way we think about it. We have to explain this change, with its profound and exciting implications, to the politicians, financiers and journalists that still fail to understand it. If we are serious about tackling energy security and climate change, if we are serious about keeping the lights on, we have to start by getting energy right.
>
> – From *Keeping the Lights On: Towards Sustainable Electricity* by Walt Patterson, published by Earthscan, 2007; www.earthscan.co.uk

OBITUARY: DR JACOB 'JOHN' ROSE

We are sad to report the death of Dr John Rose, who died on 3 August 2007 at the age of 91. At the Institution of Environmental Sciences he will be remembered as the founder who guided it through its early years, until its secure establishment as a professional association. This role was recognised in a letter from Patrick O'Sullivan, Professor of Architectural Science at the Welsh School of Architecture, who as early as 1971 described him as the 'guiding light' behind the IES. Without his ideas, connections and sheer determination, the Institution would not be here today.

Although he was later able to hand over the administrative functions he carried out for the Institution from his base at Blackburn College of Technology and Design where he was Director, he never gave up his interest or commitment. Looking back through the minutes of Annual General Meetings and Council, John attended regularly throughout the 1970s, 80s, 90s and into the new millennium. He continued as an active committee member, raising money and running programmes until very recently. It is a record unlikely ever to be equalled. The Institution and the environmental professions more widely owe a huge debt of gratitude to John; however, it is characteristic of his modest style that relatively few are aware of his exceptional contribution.

The Institution's archives testify to John Rose's vision and determination in bringing about the foundation of a new professional institution in what was then a tentatively emerging vocational field. Acting as Editor of the International Journal of Environmental Studies in 1971, he began approaching leading academics, heads of organisations and peers of the realm about the concept of a professional body for environmental sciences. Lord Burntwood proved particularly helpful, becoming the Institution's first Chairman, and his active support undoubtedly helped John Rose to attract that of others.

By July 1971, a group of 38 influential people representing a variety of institutions and organisations were working on a constitution. Within three months, the constitution was almost complete and the Institution was ready for inauguration. The purposes of the Institution were agreed and remain largely the same today.

By November the putative Council had expanded to a rather unwieldy 53 members including representatives from 14 societies and academics including three Fellows of the Royal Society. Evidence that the time was right for such an Institution came in March 1972 from Dr Turner, Associate Medical Officer of Health at the London Borough of Tower Hamlets. Turner wrote, 'I am so convinced of the need for what the Institution proposes to do that the sooner it can be brought into operation the better, before splinter movements can milk away money…'

The early days of the Institution were not always unproblematic. In May 1972, John received the Certificate of Incorporation but had only two weeks to find a registered office and company secretary. It was at this point that another name well known to IES members started to become prominent – Dr John Potter at Farnborough College of Technology, who took the role of Secretary for the Institution over the next decade.

In July 1972 a strong letter from Lord Molson to Lord Burntwood suggested that the IES should be dissolved because of its similarity to another organisation, the Professional Institutions Conservation Group, later to become known as CoEnCo. John Rose wrote in characteristically forthright terms to assist Lord Burntwood's defence of the specialist role of the Institution, pointing out the differences to Lord Molson and inviting him to become a member.

One of his latest sources of satisfaction was to see the Institution's members and fellows able to become Chartered Environmentalists. This was a vision he held of the Institution from the very start. In 1971 in a letter to Alex Gordon, President of the RIBA he was already mentioning the possibility of a Royal Charter, prior even to incorporation of the Institution.

Directing Blackburn College, editing an academic journal and setting up a successful professional body would be quite an achievement for one lifetime. However, John was active in many areas and frequently those benefiting from his interest and contributions in one area knew little or nothing of his activities elsewhere. Fleeing Poland to escape the Nazis, John lost most of his family in the Holocaust; his only surviving close relative was his elder brother. During the Second World War he served in the British Army prior to starting a career in Further and Higher Education.

He was founder and editor of seven international journals, author or editor of more than 50 books spanning interests in chemistry, cybernetics, automation, biomedical computing, medical biotechnology and, of course, environmental issues.

Even after his retirement from Blackburn College, he continued working. He was Director of Dainichi-Sykes, the company that supplied the first generation of robots to Jaguar Cars. He was appointed Research Professor of Robotics at the University of Salford and the University of Central Lancashire. He continued editing academic journals until well after normal retirement age, and only relinquished the last one at the age of 89.

The Institution will be marking John Rose's outstanding contribution to the IES and to environmental sciences through the presentation of an award in his honour at the Burntwood lecture on 14th November.

John Baines, IES Vice-President
Carolyn Roberts, IES Chair

IES: NEW MEMBERS

The Institution of Environmental Sciences is pleased to welcome the following new members and regrades:

Miss Abiodun Adeyemi	MSc Graduate (A)
Ms Eman Albanna	Environmental Consultant (M)
Mrs Candice Aliasgar-Sankoomar	Environmental Specialist (M)
Mr David Anderson	Geoenvironmental Engineer (A)
Mrs Katherine Armstrong	Environmental Scientist (M)
Miss Angela Baje	Postgraduate Student (A)
Mr Christopher Barrett	Senior Environmental Consultant (M)
Dr Wasim Bashir	Post Doctorate Research Fellow (M)
Dr Jack Blumenkrantz	Retired (Af)
Dr Christine Braban	Post Doctoral Research Associate (A)
Dr Leigh Brewin	Environmental Scientist (M)
Miss Chantal Brown	Environmental Educator (Af)
Mr Benjamin Burfoot	Lead Officer/Project Manager (M)
Miss Judith Chan	Environmental Scientist (A)
Ms Winnie Chu	Principle Environmental Consultant (F)
Miss Jane Clark	Environmental Scientist (A)
Mrs Clare Cutler	Senior Environmental Consultant (M)
Mr Hugh Datson	Senior Environmental Scientist (M)
Ms Angela Flowers	Policy Officer (A)
Mr Patrick Froggatt	Air Quality Consultant (A)
Dr Andy Fryer	Environmental Scientist (Af)
Miss Noelia Garcia-Martin	Student (Af)
Mr Dino Giordanelli	Environmental Scientist (M)
Miss Lyndsay Glanfield	MSc Student (Af)
Dr Scott Hamilton	Environmental Scientist (A)
Dr Sherif Hassan	Environmental Consultant (M)
Dr Darren Hawkins	Support Officer (A)
Mr Jameel Hayat	Principal Consultant (M)
Miss Christy Ho	Consulting Engineer (M)
Miss Sarah Horrocks	Senior Environmental Consultant (M)
Mrs Michelle Latimer	Senior Geo-Environmental Consultant (M)
Mr Peter Lee	Consultant (A)
Dr Lakhumal Luhana	Principal Consultant Air Quality (M)
Mr Ewan McLellan	Environmental Consultant (M)
Ms Helen Murphy	Senior Geoenvironmental Scientist (M)
Professor Noel Nelson	Senior Scientific Adviser (M)
Mr Jonathan Newman	Student (Af)
Mr Clive Nightingale	Environmental Engineer (A)
Miss Ruth O'Brien	Sustainability Officer (M)
Mr Christopher Ochulor	Regeneration Research Officer (M)
Mr Jaime Ortiz	Graduate (A)
Mr Steven Philp	Environmental Tutor (A)
Mr Samuel Pollard	Senior Environmental Scientist (M)
Mr Oliver Puddle	Environmental Scientist (A)
Dr Chuansen Ren	Postdoctoral Research Associate (M)
Mr Paul Shearer	Environment Protection Officer (M)
Dr Lesley Sloss	Principal Environmental Consultant (F)
Mr Andre-Karl Smit	Senior Environmental Scientist (M)
Dr Toby Smith	Environmental Scientist (M)
Miss Katie Squires	Geo-Environmental Engineer (M)
Dr Lorraine Stewart	Environmental Health Surveillance Scientist (M)
Miss Lindsay Sullivan	MSc Student (Af)
Mr Bence Tarnai	Expert Co-worker (A)
Dr Mark Todman	Business Development Manager (A)
Mrs Eloise Travis	Environmental Scientist (M)
Mr Matthew Whitehead	Evaluation Manager (Energy Efficiency) (M)
Mr Phil Wilkes	Research Assistant (A)
Mrs Hayely Wood	Environmental Lecturer (M)
Mr Wai Yu	Project Manager (M)

KEY:

F = Fellow **M = Member** **A = Associate** **Af = Affiliate**