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**Clean and Secure Energy for the 21st Century
by**

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“Are these the shadows of things that Will be, or are they the shadows of things that May be only?”

Charles Dickens, A Christmas Carol

Introduction

The twin problems of Global Warming and Security of Energy Supply have related solutions. Global warming is primarily the result of steadily rising carbon dioxide concentrations in the atmosphere, they have risen from 270ppm in pre-industrial times to 380ppm and are still rising inexorably. This is the result of the global population's insatiable demand for more and more energy; demand is expected to double between now and 2050 even on a constrained growth scenario. Over 80% of this demand is expected to be provided by fossil fuels unless draconian measures such as universal carbon taxes are put in place. It is predicted by optimistic “green” commentators that carbon emitting fossil fuels will be replaced by clean renewable energy, although responsible organisations such as the World Energy Council and the International Energy Agency make it clear that 25% of world energy demand is the most that can possibly be provided by 2050. Perversely, the advocates of renewable energy are often opposed to nuclear power, which is the other major, carbon dioxide-free, energy supplier (7% of world energy last year, about the same as hydro-electric power). Countries such as Sweden and Germany have been persuaded to phase out their nuclear stations; unfortunately, replacing them with gas-fired stations only increases carbon dioxide emissions and, in most cases where this is proposed, it will make it impossible for those countries to meet their Kyoto obligations. In the UK emissions are already rising again after a period of decline.

In the medium to long term world supplies of oil and natural gas will go into decline. Recent work using commercial data on proved and possible reserves show production will start to decline somewhere between 2005 and 2010. This is already happening with North Sea supplies. In the longer term coal, with much larger reserves, could come to replace oil and gas with unfortunate environmental consequences. The UK is beginning to understand the folly of not having a depletion policy in the North Sea. The market-led free-for-all has done little ensure to supplies into the future.

Nuclear Power

There have been a number of calls in the last couple of years asking for nuclear power to be reassessed. World-wide, nuclear power has reduced carbon dioxide emissions by around 8 per cent, about the same as hydropower. This environmentally friendly aspect of nuclear power has dumb-founded the “green” anti-nuclear lobby, who find themselves unable to come to terms with the environmental arithmetic. Not so the Royal Commission on

Environmental Pollution in its 1999 report, where the call to reduce carbon dioxide emissions in the UK by 60 per cent by a 2050 was made. This was necessary to limit the concentration of carbon dioxide in the global atmosphere to 550 parts per million, twice the pre- industrial figure. Nuclear power was expected to play a large part in two of the four scenarios presented. The report assumes no increase in energy demand over the 50 years in one scenario, a reduction of 36% in two others and a 47% reduction in the final scenario. This contrasts starkly with the doubling of energy demand anticipated in the Royal Society/Royal Academy of Engineering report on Nuclear Energy published in the same year. The UK government is signed up to reducing carbon dioxide emissions by 20 per cent of 1990 values by 2010. Until recently it seemed on track to achieve this but recently carbon dioxide emissions have started to rise again, the result of higher gas prices causing more coal burn. Increased outage of ageing nuclear stations and the inexorable rise in the number of cars on the roads, have added to the problem. If the closure and decommissioning of all but two of the UK Magnox stations goes according to plan and they are replaced by gas-fired stations, carbon dioxide emissions will rise by 15 million tonnes. This is just about the savings anticipated from the climate change energy tax and associated measures introduced by the government. As the Red Queen remarked to Alice in "Through the Looking Glass", when they had been running very fast "Here, you see, it takes all the running you can do to stay in the same place; if you want to get somewhere else you have to run at least twice as fast as that". The carbon dioxide reduction of 20% is beginning to look fragile despite the rhetoric of government ministers.

Energy is the lifeblood of civilisation; without it society soon spirals down into anarchy. This is particularly true of the information technology-dependent developed countries of the West and Asia. A crash of the computer systems in the stock exchanges of the world, or at a major airport, or in the banking system shows just how vulnerable we all are. A power failure in the underground in London or New York at rush hour swiftly becomes intolerable. A foretaste of these dangers has arisen in California and Brazil, causing President Bush, in the US, to introduce a National Energy Plan. The Bush-Cheney plan strongly endorses nuclear power as part of a balanced generation portfolio. The thrust of the plan is to ensure "security of supply" rather than "protection of the environment". The European Union has recently published a Green Paper on security of energy supply with a plea that the nuclear option is not ignored. Nuclear power has also surfaced, albeit hedged around with caveats, in the UK. Prime Minister Blair announced, on the 25th of June, the setting up of an energy strategy review. "The aim of the review will be to set out the objectives of energy policy and to develop a strategy that ensures current policy commitments are consistent with longer term goals". The scoping note, which accompanies the announcement, emphasises security of supply and also, amongst other things, reduction in carbon dioxide emissions with a recognition of the important role nuclear power plays in reducing UK figures. The very mention of nuclear power is a political turn-around for the Labour Party in the UK and a recognition, at last, of the reality of nuclear power's role. The stark horror of the events of 11th September

point, amongst other things, to the danger of terrorist attacks however motivated, which could hit at imported energy supplies of oil and gas.

The two-pronged approach in the UK strategy study suggests a possible future role for nuclear power in reducing dependence on imported gas from Russia, Norway and the Middle East (as much as 70% of UK electricity could be generated using imported gas by 2020 if coal and nuclear stations are closed) and keeping carbon dioxide emissions low. If this strategy is found to have merit we could see a resurgence of nuclear power in the UK. Similar realisations may develop in Germany, Sweden and other nuclear averse countries. The US is driven by the awful prospect of lights going out elsewhere than in California; as for natural gas, supplies are running out as prices quadruple although demand is predicted to rise by 50% by 2020 and, in twenty years time, the US will be importing two out of every three barrels of oil. So it's coal and nuclear power to fuel the future, or is it?

Renewable Energy

Renewable energy technology is still in its infancy, other than hydropower, that is. A huge increase in renewable energy is strongly advocated by some environmental groups such as Friends of the Earth who call for a doubling of the 10% renewable electricity target for 2010 in the UK, for example. But energy arithmetic reveals the difficulty, if not impossibility, of such proposals. If all the wind farms currently operating in the world were all concentrated, say, on the South Downs in the UK, they would only supply 10% of **United Kingdom electricity**. Or, to replace the two nuclear power stations that supply 50% of Scotland's electricity would require 10,000 of the wave power generator newly installed on the island of Islay. The World Energy Council's most optimistic scenario for renewable energy suggests it could provide just 20% of world energy by 2050.

By far the biggest renewable source, other than firewood,(which is now running out in Asia and Africa), is hydroelectric power, which provides around 19% of world electricity, cutting carbon dioxide emissions by about 8%. Expansion of this resource is possible, although environmental groups have pronounced large scale hydro as unsustainable. They object particularly to the 18,000MW Three Gorges Dam now being built in China. There is an air of unreality about some environmental groups' plans for the future. How can renewable energy replace nuclear power and dwindling fossil fuel resources and, at the same time, provide double the current energy demand in 2050?

Future Strategies

But if there is to be a resurgence in nuclear power, with life extension and new build and not just a "silly season" brief flowering of interest before the idea withers on the vine, how will it be achieved?

The industry has been developing a new generation of "inherently safe" designs, primarily light water reactors, building on the very successful current technology. The Westinghouse AP600 (already licensed in the US) and the larger AP1000 are ready to go; there is the EPR built by Siemens/Framatome, the ABB Boiling Water Reactor, the second generation CANDU reactor now

using enriched uranium and light water coolant and a number of Japanese designs, some of which will use mixed oxide fuel. Looking further ahead, the Pebble Bed Modular Reactor of Eskom/BNFL/Exelon and other high temperature reactors using helium as coolant will become available. In Russia there is the prospect of the BS800 Fast Reactor based on the long operating BS600. A move to fast reactor technology which uses the uranium fuel 60 times more efficiently than today's thermal reactors, would make world electricity supplies secure for 500 years.

It has to be appreciated by politicians eager for a "quick fix" that nuclear stations take, in general, 10 years to build and a medium length strategy has to be adopted. The same is true of expansion of renewable power generation. But that means starting new programmes in the next couple of years to achieve security of supply and carbon dioxide emission control post 2010.

The Achille's heel of the nuclear industry is the problem of radioactive waste management, widely perceived as being unsolved. Although the engineering of both the reprocessing route and the dry store method is well understood, the identification of dry, geological structures, which can contain the waste, is still not in place. In the US continuing arguments over the Yucca Mountain site and in the UK the suggestion that there is no hurry and that waste can be stored safely for 50 years above ground whilst a suitable site is found, are unacceptable. Finland leads the way with the approval of the construction of an underground rock facility at Olkiluoto and the near ordering of a new nuclear station.

Despite the logic of expanding a technology with green credentials and huge potential, particularly the fast reactor, the future growth of nuclear power is problematical. Public perception of the industry is allegedly averse although a poll in Time magazine in 2000 asking what technology would replace hydrocarbon fuels, gave 82 per cent of the poll as favouring nuclear power over renewables.

The growth of renewable energy is also problematical for different reasons. It is widely perceived as benign and, like nuclear power, does not put carbon dioxide into the atmosphere or is, at least, carbon dioxide neutral (biomass and the like). But it is expensive, has high up front costs, again like nuclear. The Severn Barrage scheme would cost £12bn to build but would provide 7 per cent of UK electricity and last for 120 years. Growth in renewable electricity, especially wind power, has been spectacular but that is from a very low base. It is also dilute, that is the energy flux available from wind or solar power is orders of magnitude less than from a steam boiler burning oil or coal. The consequence is that enormous numbers of wind generators or solar collectors are necessary to provide useful amounts of energy. 1,800, 2MW wind turbines would be required to replace one 1,200MW power station, the nameplate figure must be divided by 3 because of the limited availability of wind). Nevertheless government policy in many countries is to find ways of growing renewable energy and particularly electricity. The EU plans to double its renewable energy portfolio from 6 per cent to 12 per cent by 2010.

Energy Policy

In the UK 10 per cent of electricity must be renewable by 2010 (5 percent by 2003). The figure is currently 2.8 per cent. If suppliers fail in this they will be fined £30/MWh on the shortfall. Suppliers are encouraged to produce renewable energy by a series of incentives and grants but the price suppliers can charge distributors of renewable electricity is perversely capped at 3p above the market price, ie less than 5p/kWh. This makes many of the emerging technologies such as wave, tidal stream and probably offshore wind unviable. In fact, strong regulation of the industry has forced the market price of electricity down so far that it inhibits investment in new generating equipment.

It could be said that UK energy policy is particularly paradoxical and anomalous. Embedded sources of generation, particularly renewables and Combined Heat and Power (CHP), the two areas the government is relying on for future growth, are actually disadvantaged by the new electricity trading arrangements (NETA). The so-called climate change levy, introduced earlier this year, which is really an energy tax is, inexplicably applied to large scale hydro-power and nuclear, two technologies which do not produce carbon dioxide. A Carbon Tax is the logical way of curbing the use of fossil fuels and encouraging renewables and nuclear which both produce "clean energy". There is a symbiosis between these two technologies which should be encouraged. The way that some protagonists of renewables seek to set their technologies against nuclear as though it is an "either or" situation is particularly unhelpful and counterproductive in terms of both carbon dioxide emissions and security of supply.

The Way Ahead

The way ahead must be to promote "clean energy" which derives from non-fossil fuel sources. In the UK we will need as much energy as we can generate using both renewable and nuclear energy and moving to the 60x more efficient fast reactor as oil and gas supplies decline later in the century. If fusion power can be made to work on an industrial scale, that will be a bonus.

The distribution of electricity via grid networks will have to be modified to accommodate "embedded" generation such as wind power and CHP; it will be expensive. Additional gas and electricity inter-connectors to enable more energy to be traded in a trans-European network must be constructed to improve security of supply. However, the prospect for Europe of increasing its energy imports from the current 55 per cent to 70 per cent by 2030 under a "business as usual" scenario" indicates the imperative of acting now to ensure security of supply in the future. The current intentions of Russia and Norway to join the OPEC group in controlling supply of oil to ensure prices remain high, points to future cartel formation. It does not require much of a leap of imagination to foresee control of oil and gas supplies being used as a strategic weapon by disaffected groups in politically unstable parts of the world.

Transport on land, sea and in the air is as big a polluter as the electricity generation industry. It is difficult to see a non-hydrocarbon substitute for kerosene as aviation fuel but hydrogen-powered fuel cells have already been

demonstrated in cars and could be used in locomotives and ships. Ideally the hydrogen would be produced by the electrolysis of water using renewable electricity but an engineering assessment showing a maximum provision of 25 per cent of world energy from renewables by 2050 constrains this possibility. Renewables cannot take on the burden of replacing transport fuels, in addition to providing a high proportion of electricity generation. Nuclear power is the only possibility if we are to move to a hydrogen economy.

Supply and Demand

It is often stated that attention is focussed on the energy supply technologies and the demand side is neglected. This is true and made worse in the UK by separating departmental responsibility, so that the Department of Trade and Industry looks after supply and the Department of the Environment, Food and Rural Affairs deals with demand, leaving Transport in yet another Department. A coherent approach would be obtained by reinventing the Department of Energy.

There is no doubt that striking savings in energy use could be effected but this seems only likely if the price of energy is substantially increased, not reduced as the regulators seem determined to do. A fiscally neutral carbon tax would help here as in other areas. This highlights a sociological observation. Despite clear evidence of the financial benefits of more efficient energy use, industrialists and householders alike will not invest in more energy efficient equipment. They will also not give up their motorcars, despite paying lip service to the importance of protecting the environment and reducing the emissions of greenhouse gases. Changing these entrenched attitudes has proved well nigh impossible, although some small progress has been made. This points inescapably to technical solutions to these intractable problems as the way ahead. The ingenuity of scientists and engineers to find solutions to the continuing and increasing supplies of energy and its more efficient use has been demonstrated time and time again. What is required is far-sighted, political will to implement the technical advances that are already available.

Conclusions

The future lies with "Clean Energy"; that is, renewable and nuclear energy together. Post-2050 fast reactor technology will be required to close the energy gap. It is impossible to "square the circle" of future energy supply without including nuclear power.

As fossil fuels go into serious decline in the second half of the 21st century coal will regain some of its former dominance, but only if clean coal technologies are developed. Removal of carbon dioxide from the flue gas and injecting it to provide tertiary recovery for declining North Sea oil wells, will increase recovery by up to 15 per cent and sequester the carbon dioxide.

A carbon tax would encourage this process, amongst other benefits.

The problem of transport emissions will be at least partially addressed by using fuel cell powered vehicles running on hydrogen. The only large scale, clean source of hydrogen will be nuclear power.

Energy strategy cannot be left to market-driven systems if the environment is to be protected and secure energy supplies ensured. The postulation that "10 per cent of UK electricity will be renewable" is an example of sensible

intervention, the process could be extended to include percentages for nuclear, gas and coal.

This presages a move to a “post-market economy”!

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