Electrical generation and C02 reduction

The 'Renewables' and Nuclear Power

A note by R.F Jackson CBE. MA. FREng

Summary

Our commitment to the Kyoto agreement to reduce our C02% release from electricity generation by 10% by 2010 - and more later - is inviting a review of our future generation policy including particularly the possible contribution of the 'renewables', and by implication a review of our nuclear generation policy which at present provides 25% of our power generation free of CO_2. This note, while supporting a modest programme of renewable development - particularly wind and in due course photo-voltaics and biomass, questions whether, without some nuclear power, our reasonable expectation of electricity demand growth, and our CO_2 reduction agreements and expectations, can be sustained without a too high commitment to natural gas - 60%+ - whose availability and price must be increasingly uncertain over the next 20+ years. It also notes the possible problems of secure Grid System control and supply if too much of the generation programme had large uncertainties of load capacity, timing and location such as might be the case for a too large proportion of renewable energy.

It considers that the present nuclear generation programme has been most reliable, and is generally accepted by the public, and recommends that it should be maintained at about its present 25% generation level both as our principal contribution to CO_2 reduction, and as a reliable alternative to the diminishing supply of fossil fuel world wide. It recognises the need to solve the perceived public anxiety about waste disposal and recommends an early decision to build and demonstrate a 'retrievable' waste store.

UK Electric Generation

The total UK generation for 1999 of 37 GWye was split between coal/oil-30%, gas 38% and nuclear 25%, with a very small contribution from hydro and others of 3% and an import of 4% - probably French nuclear. The recent average load factor has been 54%, and the maximum demand 82%, of installed capacity

The annual demand growth rate over the past 30 years has averaged about 1.6% - or ~0.4 GWyey. This suggests an annual demand of about 44 GWye by 2010, and 50 GWye by 2020 - though such a forward estimate must be uncertain.

CO_2 release to the environment

The chemical composition of coal and oil together with the average generation efficiency of 36% for the coal/oil generating stations results in the release of about 7.5 Mt of CO2 per GWye of electrical generation for coal fired stations and about 6.5 Mt of CO2 for oil fired stations.

The rather lower carbon content of natural gas - essentially methane-per unit calorific value, taken together with the much higher thermal efficiency of the CCGT cycle results in a much lower CO2 release of about 2.6 Mt CO2 per GWye of CCGT generation.

The latest (1999) generation data indicates, within a total demand of 37 GVVye, a CO2 release of the following order:

	Gwye	%	Mt CO2
Coal/Oil	11	30	77
Nat. Gas	14	38	36
Nuclear	9.5	25	___
Hydro, etc	2.5	7	___
Renewables	___	___	___
Total	37	100	113

This presentation enables the effect of a change in the energy mix on CO2 discharge to be easily seen. Thus a 1 GWye switch from coal/oil to CCGT would cause a 3% reduction in CO2.

10 – 20 year targets for reduced C02 discharge

The Government have set a target for reducing the present discharge of 002 from electric generation by 10% - 11 Mt - by 2010, and - by implication - a further reduction by say 2020. To contribute to this they have initiated a very positive programme of 'renewable energy' development.

However during this 10-20 years most of the nuclear stations, which at present contribute 25% of generation -free of CO2, are due for closure. If they are not replaced by a new generation of nuclear plant then the electricity demand - which may grow from the 1999 total of 37 MWye to perhaps 44 GWye by 2010 and 5OGWye by 2020 - will need to be met by a further increase in the use of CCGT using gas whose availability and cost will be increasingly uncertain and by renewables - yet to be demonstrated on a substantial national scale.

While it is difficult to predict an exact pattern over the next 20 years in the event of a nuclear closure the following two estimates illustrate the problems.

	Year 2010 – 44 GWye			Year 2020 – 50 GWye		
	GWye	%	MT CO2	GWye	%	MT CO2
Coal/Oil	6	14	42	4	8	28
Nat. Gas	23	50	60	30	60	78
Nuclear	7	16	___	2	4	___
Hydro/Imports, etc	4	9	___	4	8	___
Renewables	4	9	___	8	20	___
Total	44	100	102	50	100	106

Thus in 2010 with some nuclear remaining and assuming a small increase in Hydro, others-CHP etc and imports, and with renewables providing nearly 10%, the 10% reduction in CO2 could just be held with an increase in natural gas use to 50% of total energy.

By 2020 however, with nuclear nearly decommissioned - probably 2 AGRs still just in operation - it would require 60% from natural gas and 20% renewable energy to maintain the system. Even then the 2010 CO2 target would not be reached - let alone a tighter target for 2020.

But both these forecasts assume a considerable increase in - reliance on - the supply and cost of natural gas, and a fairly optimistic view on the ability of 'renewables' to provide a large –guaranteed - part of the supply- 20% by 2020. It is in this context that the development and application of the renewables and the case for a continuation of safe and effective nuclear power will be discussed.

The "renewable" Energy Options

Of the several 'renewable' energy options under discussion and at some level of development there are probably three with good short/medium term prospects - wind energy, photo-voltaics and biomass

Of these wind energy has the most potential and is already being well developed and tested on a world scale, over 14,000MW world wide, including some 9000MW in Europe, and doubling every 3 years. Unit sizes have increased to 2+ MW so that a wind farm of 100 units now has a maximum output comparable with a base load power station. Such wind farms can be built on land or off shore, though many 'on shore' sites will face planning objections of noise and damage to the environment. Off shore sites will be more acceptable, but be more expensive. The very high towers may also initiate some risk/objection.

However the average wind conditions will generally lead to an average generation of about 1/3 of the maximum rating, and very high wind may require the plant to be shut down to protect the mechanism. So the availability and output of a particular wind farm will be uncertain in the context both of its NETA commitment and perhaps more important in the context of Grid Control planning. While inputs from a number of farms geographically distributed may reduce the Grid uncertainty overall it may require additions to the HT grid to ensure power transfer capacity. Occasionally weather conditions may lead to a minimum output from a high proportion of the wind generators.

Because wind energy is essentially 'free' energy it will generally be sensible to maximise the use of wind energy, but this will create costing problems within the total generation system. A wind energy surplus will require other plant - fossil or nuclear - to run at reduced output at a potential higher cost per unit delivered. Conversely a very low wind condition may require more 'stand by' plant to come on line, and the availability of such plant must be a cost on the system as a whole. A national programme to supply even 5% of the annual demand by wind by 2020, based on a probable average generation of 33% of rated output would imply the construction of 8GW+ of wind power and the ability of the Grid System to maintain - and pay for - at least 6GW of more conventional plant to be available at short notice for operation or stand by. While real experience over a period of several years of wind generation across the country as a whole might show this to be a rather pessimistic view, wind power clearly presents significant planning, distribution and pricing problems.

The primary application of photovoltaics will be their local use in buildings of all sorts, industrial, commercial and domestic, connected in such a way as to provide for a much of the building load as is possible during the hours when photovoltaic power is available. The present world manufacture of solar cells is about 150MW per year. However this is increasing rapidly and it is probable that when, in a few years this is trebled, the cost will fall to a figure at which a solar installation would provide local power at the same cost as domestic electricity.

Photovoltaic power is therefore principally generated at the point of use and will therefore reduce demands on central generation, though hopefully in a way which is capable of fairly accurate forecasting on a day to day basis. It is unlikely to have much effect of central generation policy for several years when some small reduction in maximum demand may result. While solar 'farms' of 100MW could be built it is unlikely that a central generator would fund such an uncertain asset. (A solar farm built in the tropics could be used to generate hydrogen if that seemed to have a transport use.)

Solar power for domestic heating also has useful potential, but, like photovoltaics, requires southerly roof space and may meet building planning objections.

Biomass energy relates principally to the combustion of biological material which has fairly recently absorbed its ration of CO_2 in the photosynthesis process by which it was formed. Unlike wind, and nuclear power, which actually avoid CO_2 production, the energy recovery by combustion and the release of CO_2 is therefore neutral on the environment over the short period involved. Biomass energy includes the energy recovery from the combustion of deliberately grown short rotation crops (SRC) such as shrub willow etc, from the discard from other crops - sugar cane etc, from wood chips etc from manufacture and from Municipal Solid Waste - MSW

Biomass is thus an alternative fuel whose 24 hour availability could permit power generation on a continuing 24 hour basis and would thus fit into a planned generation network. The engineering/ combustion technology (Circulating fluid bed - CFB) for energy recovery from short rotation crops or wood waste is now quite highly developed, several plants have been built at 100MW+ and a Finnish wood chip plant of 250 MWe is now completed. The possibility of short rotation crops fitting into a revised UK agricultural policy will presumably be considered.

Its application to energy from Municipal Solid Waste - Energy from Waste – EfW - has potential. Although an electric output of about 500 KWhe/ton of waste is possible is a modern plant, only 10% of UK MSW is currently subject to electrical energy recovery - corresponding to an annual electrical generation of about 0.2 GWye out of a total UK EfW potential of perhaps 1.8 Gwye. Plant sizes would probably be about 50 MWe, but involve a double benefit, not only is energy recovered but, perhaps more important, the need for increasingly scarce landfill sites reduced. Such EfW plants would however probably create greater planning uncertainties than for clean biomass, both with respect to location and public perception of risks such as dioxin, though this is well controlled in modern plant design. Biomass may also include the recovery of methane etc from landfill waste sites.

The other renewable options include more hydro power and the development of tidal, current and wave power.

More hydro power in the UK is limited by opportunity. The addition of another 0.5GWe to the existing 1.5 GWe is possible.

Tidal power clearly can work well - the Rance scheme - but sites are very limited. The Severn estuary is possible, very large, but probably with serious environmental objections. The technology will remain very site specific.

'Current' power is clearly possible-particularly in the multi tidal conditions of the UK. However would the scale of application warrant the effort involved?

Wave power seems particularly at risk from the extreme weather elements. Scope for application in the UK would probably concentrate most in Scotland. But the weather risk, the costs of connection to a reliable network and the subsequent transmission of any significant power to where it was needed by the present Grid could be significant.

All the schemes involving sea energy will probably have less development potential in the 3rd world than wind energy and their development seems less commercially viable.

Although Combined Heat and Power – CHP - is not itself an alternative energy system it's potential contribution to total energy saving and hence to CO2 remission is real. It has therefore been given 'renewable' status and encouragement, and while major industry will generally have already adopted appropriate CHP where this was economic, small industry and commercial premises are now being encouraged to look at small schemes. Such schemes will probably have the smallest inputs in the 'renewable,' contribution and will usually contribute at the regional or local level as 'embedded' generation.

The effect of renewables on Grid system control

Prof M.Laughton F R Eng ,has recently drawn attention to the new problems of Grid System control and management which could develop progressively over the next 20+ years if 20%+ of generation is from renewables and CHP, some embedded in lower voltage networks, and if the 20-25% of base load nuclear generation is retired and not replaced with equally reliable base load plant

To maintain a Grid System compatible with the needs of a highly computerised modern industrial economy, such changes would require a major overhaul of the method of Central System Control, which, depending on the distribution and dependability of future generation might also require major extensions to the grid system to ensure new power sources, located further from demand, could reach existing customers.

Probable growth in electricity demand

Electricity demand has been growing fairly steadily at about 1.8% pa. If however the CO2 release per unit of generation can continue to be reduced – CCGT - renewables and nuclear power - then it could become an even more attractive alternative for some of the purposes for which fossil fuels are at present used such as domestic heating - perhaps by motor driven heat recovery units - and looking more to the future, for medium distance battery operated motor vehicles - the 'second' car - and even further ahead for hydrogen production for fuel cells etc - both to reduce CO2 and the other local pollution of the internal combustion engine. It would therefore seem prudent to assume that environmentally clean electricity has a probable growth future in which CO2 free nuclear power must play a lead role.

Energy saving

Energy saving, whether in the context of CO2 reduction or of world reserves of energy, is clearly an increasingly important activity. It is however one for which the energy supply companies do not have direct interest - they sell energy! Energy saving in industry seems to be going well - 40%reduction in the last 30 years - presumably driven by balance sheets and improved technology.

On the other hand domestic consumption has risen by 25% over the same period - probably due to higher wages. Wall and loft insulation standards for domestic property should be mandatory in new construction and gas suppliers should be encouraged to give simple quantitative advise to customers on heating energy management in the home. Similarly electricity suppliers should give help and advise - perhaps by the offer to supply long life low energy bulbs.

Transport has shown the largest 30 year rise of 90% to 48M tons. Within this total Aviation fuel increased by nearly 300% to 10M tons. Petrol remained fairly static at, about 21 M tons while Derv increased by 400% to 15 M tons. While there is no obvious alternative to aviation fuel, petrol usage could be reduced by smaller engined cars - already tax assisted - and possibly by the battery operated second car - and in due course by fuel cell technology - mentioned above. Derv demand could be reduced by more rail transport for bulk goods, perhaps assisted by slicker rail-road interfaces for the final part of the journey, and by fuel cell development

The New Electricity Trading Arrangements

The new arrangements, NETA, which are aimed at making the electricity market more price responsive to end users than to generators, requires generators to enter into supply contracts with users, either large industrial users, or 'suppliers' - area boards etc which will define the quantity, timing and pricing of the power to be supplied.

The distribution of this power, except for small amounts of local – embedded - generation, will continue to be the responsibility of the National Grid Company for maintaining a high quality national power supply within statutory limits of voltage and frequency. The NGC must therefore be fully informed of all the agreements in time and quantity for transmission of power through the National Grid

However a generator who fails to meet his agreed generation supply (and a user who fails to use his agreed demand) will be fined through the Balancing and Settlement Code by the National Grid Company - as System Operator. This will lead – has already led - to penalties being imposed on weather dependant renewables. While there could be some case for imposing rather smaller penalties on renewables for failure to meet their commitments due to unanticipated weather conditions it would be unfair if excessive short term - favourable weather - renewable generation led to other generators being underpaid for generation they had committed. NETA therefore poses some questions for renewables whose generation is weather dependant.

Energy storage

Energy storage clearly has a part to play in any system in which consumption and potential generation do not match hour by hour, or in emergency to avoid some crisis. The present Dinorwig scheme allows base load nuclear to be stored overnight and used at peak and/or in emergency. A new electro-chemical energy storage system – Regenesys - presently being built and tested on a 15MW prototype scale - can provide both energy storage and an immediate response to a power network instability. Such additional storage could enable the weather dependant 'renewables' to optimise their power market, or for a 'power market trader' to purchase power at periods of minimum demand and sell at peak demand. The cost of such options is not yet clear. There may yet be a case for another Dinorwig scale scheme for maximising the use of wind power without the complication of too much conventional or nuclear 'stand by' power.

The case for Nuclear Power

Nuclear power was developed as an alternative - and possibly cheaper - energy source to the rather fortuitous deposits of coal oil and gas that had initiated the industrial revolution. Nuclear power now generates 20% of the world's electricity and the World Energy Council anticipate this will need to increase as the world population and the gross domestic product doubles world energy demand by 2050. By this time nuclear generation in parts of Europe and the Pacific rim may well reach 50% and we would be well advised to maintain this option - as part of our contribution to the new problem of C02 restraint coupled with the earlier recognition that new energy resources will be required to replace the diminishing and increasingly politically controlled fossil fuel reserves, such as natural gas on which we will otherwise be very dependant.

The Royal Society/Royal Academy of Engineering report on Nuclear Energy and Climate Change of 1999 fully supported the Trade and Industry Committee's report of 1998, which recommended that for the purpose of long term planning further nuclear power should be presumed necessary in the next two decades.

Of course the present thermal nuclear cycle is not a final energy solution - economically mined natural uranium in the ground is limited - perhaps 100+ years, but other fuel cycles involving U233 and Plutonium are also possible, and could extend the nuclear power timescale by an order of magnitude. However wind and solar PV, together with energy storage may provide a larger proportion of the world demand. Fusion may yet work sooner than we think. But meanwhile we need also to continue with a technology we are sure of - and our present 25% of nuclear generation is an anchor we should not lightly let go.

Public perception of nuclear power

The public seem fairly relaxed about the present UK Power Reactors and the

Sellafields chemical plant which they have learnt to live with and no longer regard as potential nuclear bombs. There have been no nuclear fatalities in the UK and only one accident of any significance - that at Windscale - not a power reactor - 45 years ago. Only one nuclear power accident – Chernobyl - has left people dead - about 45 staff - and this was an accident on a reactor which would not have been considered for construction in the West. It is interesting that, while a large area of land adjacent to Chernobyl is still out of bounds for food production, the flora and fauna is thriving.

Some may still be persuaded by Greenpeace logic that nuclear energy is inseparable from nuclear war, regardless of the fact that a nation can build weapons without - having a civil power programme - and vice versa. Some may still be worried by the Greenpeace publicity that all radiation is dangerous - an overstatement which the ICRP have quantified and provided the simple understanding that for most people the risks are either so low as to be of no concern or are actually probably zero.

There has been very reasonable anxiety about the 'decommissioning' of the large nuclear installations - particularly power reactors. However now that decommissioning of some of the early Magnox reactors is well underway it is proving easier and less costly than had been expected. Sites could be left with a quite safe minimum reminder of their earlier purpose and/or could become the sites for new reactors where the existing services and probably the familiarity of the local population would be a bonus.

The final hurdle to the public acceptance of nuclear power is now that of the final 'safe' disposal of nuclear waste. This may either be unreprocessed fuel or the concentrated fission products and plutonium from a fuel reprocessing plant - such as Sellafields. In spite of the fact that to 'bury' this at a great depth in a very stable part of the earth’s crust is probably considerably easier with today's drilling technology than is the management of activity in the working conditions of a chemical plant, the ‘public', perhaps assisted by Greenpeace, emphasise the 'risk' to future generations of any 'leak' of radioactive material to the surface. They argue that 'burial' must be accompanied by the ability to inspect and, if necessary to remove and allow a further process to occur.

The recent - May1999 - National Consensus Conference on Radioactive Waste Management was satisfied that a deep retrievable store was a potentially responsible solution and should be built and tested. It now seems essential to build such a prototype store with appropriate public information and advice. Only when a real facility is built, used and open to public understanding and comment will this final phase of the public acceptance - even approval - be complete. The Government should give this it's highest backing and priority, for this has to be done anyway to deal with existing waste, but when it is done it may dispose of the final objection to continuation of nuclear 'clean air' energy.

Risks and environmental costs of conventional power

A major new EU Research Study – "EXTREME" has recently analysed the various health hazards associated with conventional energy and is concluding that if all the environmental costs associated with energy production from fossil fuels - particularly including gas - such as to health and crop yield etc - were to be allocated it would put up the real cost of these fuels by as much as 30%. It considers nuclear power adds very little uncosted risk to the environment, and that wind and hydro add the least.

While the Study considers that to charge energy technologies for damage to the environment would be very difficult, it might be easier to subsidise - or at least give formal encouragement to the development of cleaner technologies - which would include nuclear power.

A recent Swiss study of energy related accidents over the past 30 years records that accidents with over 5 fatalities have totalled 18,000 deaths roughly distributed between oil, hydropower, coal and gas.

Costing and longevity of nuclear power

Nuclear power plants have the potential for long life due to the essentially clean conditions of their closed circuits coupled with their design for reliability to meet the safety criteria. Calder Hall is now 45 years old and has approval for 50 years, Wylfa, now 35 years old is running very profitably at 85% availability. Many other plants in Europe and the USA show similar potential for long life and high availability. Meanwhile nuclear fuel costs, backed by good material supply and manufacturing capacity, should remain linked to the industrial price index - or even fall with larger throughput. In the UK the future costs of decommissioning and waste management are included in the cost of plant operation and fuel processing.

The now clearly demonstrated quality of reliability and long life, coupled with fuel cost stability, should now enable the slightly higher capital cost of nuclear to be committed with confidence. A recent analysis of a 4X600 MW Westinghouse PWR recently certified by the US Regulatory Commission, suggests that such a unit, embodying the latest design and technology could be built in 6 years, and at a discount rate of 10% and a load factor of 90%, would generate at 2.3 d/unit. At this discount rate and at today's gas price it would only be about 0.3d/unit higher than CCGT. The current European PWR design suggests similar costs. Other alternatives may soon be possible, such as the proposed South African small, high temperature, naturally safe, pebble bed reactor.

However ETSU suggests that oil and gas prices could increase - perhaps double - in real terms over the next 10-20 years. If nuclear fuel prices remained linked to the cost of living, as seems likely, this could lead to price equality - or better. In the event that such a reassessment of the short term future of nuclear generation was unattractive to conventional finance suggests an arrangement under which the private sector might undertake to design, fund and operate new nuclear plant provided the Government found some appropriate 'balance' in cost/unit which represented the difference between the present cost of gas and the cost at which it was agreed the generating cost of nuclear would be about equal with gas. The country would have assured a continuation of reliable ‘no CO_2' generation, funded and managed by a private corporation, and would only have to subsidise this for as long as gas prices remained low - which may not be long.

Retention of Nuclear skills

With the possible exception of BNFL, there has been a slow run down in nuclear technology both in industry and education in response to a lack of future reactor design intent. If we are to recover and retain our reputation as a 'nuclear' industry then the Government must decide that nuclear power is a desirable national objective and must give this policy visible approval in terms of quick decisions or approvals for planning and siting applications etc. Industry and education will then respond.

Conclusion

Even if no new nuclear power was initiated UK generation could probably meet the 2010 target of 10% CO_2 reduction by greater use of CCGT s together with 10% of renewable - if guaranteed at peak periods - though at some risk of the cost and availability of the increased demand for natural gas.

However in the event of nuclear run down, then, beyond 2010, the increasing demand growth could probably not be met without even more CCGT a further development of guaranteed peak period renewables to 20% - a very challenging target, and with the probability that even the 2010 CO_2 target of 10% would not be met. This does not seem satisfactory and suggests a continuing nuclear programme is essential.

But if this is to be effective in 2010, and if our nuclear skills are to be retained and updated, the decision on a continuing nuclear power programme must be taken now.

However 'renewables' are a very worth while target and should be actively pursued having regard to the need for reliable supply at an economic cost .This may require the joint attention both to supporting energy storage and to the Grid Control and Supply to ensure that renewable energy can be used when and where it is needed.

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