Energy issues for Scotland

A joint Institute of Physics and Institute of Physics in Scotland response to a Royal Society of Edinburgh stakeholder consultation

A full list of the Institute's responses and submissions to consultations can be found at http://policy.iop.org/Policy/public.html

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Institute *of* **Physics**

Dear Dr Rands

RSE Inquiry into Energy Issues for Scotland

The Institute of Physics is a leading international professional body and learned society, with over 37,000 members, which promotes the advancement and dissemination of a knowledge of and education in the science of physics, pure and applied. The Scottish Branch of the Institute, known as The Institute of Physics in Scotland, has some 2400 members drawn from all sectors of Scottish life.

The Institute welcomes the opportunity to respond to this important consultation document, and is pleased that the Royal Society of Edinburgh has taken the lead in addressing the crucial issue of the supply and demand of energy in Scotland.

The attached annex highlights some key issues of concern to the Institute and these have been linked to the general themes of the consultation document.

If you need any further information on the points raised, please do not hesitate to contact the Institute.

Yours sincerely

Professor Sir John Enderby
President
Institute of Physics

Professor David Saxon
Chair
Institute of Physics in Scotland

RSE Inquiry into Energy Issues for Scotland

1. General

It is essential that a secure and sustainable supply of energy be maintained to ensure Scotland's future economic development and prosperity. Energy, and in particular electricity supply is, however, susceptible to economic, political, security, environmental and technological threats, and poses similar associated risks.

In order to manage and minimise these risks and threats, and to ensure security of a sustainable supply of electricity for at least the next 30 years, it will be necessary to maintain a mix of fuels/technologies for power generation. Within this time frame the current mix of: nuclear fission; coal; hydro; gas; renewables other than hydro; and oil, in descending order of present capacity, are the only options for electricity generation on a commercial scale. Beyond this timescale nuclear fusion and other technologies may begin to have significant impact.

Included in the 'renewables other than hydro' element of the mix above are photovoltaic panels and fuel cells, which not only should be available within a 15-year time frame for distributed generation applications, but may also be directly applicable for transport applications.

Within an approximate five-year time frame there are likely to be significant reductions in both coal-fired and nuclear fission capacity coupled with a further reduction in nuclear fission capacity within the 15-year time frame. As a consequence, despite reductions in energy demand resulting from better energy efficiency measures and an increase in renewables capacity, there will be a shortfall in generating capacity. This will also be impacted by the intermittent nature of the primary near-term renewable energy sources.

This shortfall can initially only be addressed by the construction of additional capacity from existing technologies. Such capacity must, however, be consistent with meeting the commitment for reduction in greenhouse gases and carbon dioxide emissions. Policy and regulatory regimes must also ensure that both sustainability and diversity of supply are assured and that Scotland does not become overly dependant on imported oil or natural gas.

2. Energy Supply

The major features and associated issues regarding the different elements of current energy generation technology mix, as above, together with emerging technologies, and the key issues surrounding the development of Scotland's electricity transmission and distribution systems, are seen as follows.

2.1 Nuclear Fission

Nuclear fission has a major role to play in lowering carbon dioxide emissions, as it can meet base-load electricity demands and is practically a zero carbon dioxide emitter. Given that most EU nations are poorly prepared to meet their respective Kyoto Protocol emissions targets, the Institute believes that new nuclear power plants need to be commissioned to replace current plants as they reach the end of their lives. If new nuclear power plants are not constructed, then by 2020 there will be a power void which will most probably have to be filled by fossil fuel electricity generation resulting in more, not less carbon dioxide emissions.

The Institute has in recent years welcomed both the UK Government and the Scottish Executive's various initiatives to tackle carbon dioxide emissions such as the renewables obligation and the climate change levy. However, the Institute feels that the nuclear industry has been severely disadvantaged by not being exempted from the climate change levy, since nuclear power does not contribute to carbon dioxide emissions.

The Institute wholeheartedly agrees with the UK Government's Chief Scientific Advisor, Professor Sir David King, that in order for the UK to meet its international targets to reduce carbon dioxide emissions, it must inevitably revive its nuclear power plant building programme.

Unless there is new nuclear build, the reliance on fossil fuel energy generation will be unabated. Renewables energy technologies alone will not enable the UK to meet its current Kyoto Protocol targets, or satisfy Scotland's demand for electricity generation, as the decommissioning of nuclear plants in Scotland will result in the loss of approximately 55% of its current electricity generating capacity by around 2020. New nuclear plants are required in order to maintain and improve not just the UK's, but the EU's current diversity, security and environmental balance of electricity supply.

With a 10-year minimum lead-time for the development of a nuclear plant from initial concept to power on the grid, a decision on new nuclear build needs to be urgently made. Continuing delays in making a firm commitment to new nuclear build will lead to the further haemorrhaging of both Scotland's and the UK's nuclear skills base, which will adversely affect the development of new nuclear plants. It is imperative that a firm decision is taken soon that does not keep the nuclear industry on tenterhooks, while the UK waits for the renewable industry to bridge the gap. Nuclear capacity should be increased to fulfil the immediate need arising over the next 10-15 years, and this time can then be utilised in the development of other low carbon technologies such as renewables and nuclear fusion.

In order for the nuclear option to remain open in the UK, clear commitment from both the UK Government and the Scottish Executive and strong leadership at Ministerial level are required to provide a climate in which a new nuclear power station can be sponsored by the private sector and can be consented and built within a 10-year programme. The following Government actions are urgently needed:

- a clear statement that is supportive of new nuclear generation, to reduce the perceived risk to potential investors;

- provision of mechanisms and incentives for investors and vendors to participate in the preparatory, pre-construction phases of a new nuclear build programme;

- establishing via effort from vendors, operators and regulators the acceptability of internationally approved designs as candidates for UK licensing. This will also help (i) maintain critical capability required to select and license designs and (ii) assess generic licensing issues;

- developing the current licensing and approvals process to ensure timely and predictable delivery of all regulatory clearances and planning consents within a five-year time frame;

- providing appropriate market mechanisms to encourage investment in long lead time plant and low carbon generating capacity. These might include measures to enable nuclear generation to compete on a 'level playing field' with other low carbon forms of generation, and to enable long-term electricity markets, at prices which will encourage new base-load capacity;

- setting a policy framework and implementation strategy for long-term radioactive waste management; and

- Government funding to support and encourage research into reactor technology and waste management, including continued UK participation in international fission R&D projects.

While the popular perception in Europe and North America is that nuclear power is an industry in decline, the reality worldwide is the reverse. Over recent years there has been a wave of new nuclear plant construction in the Far East, most notably in China. In addition, Finland and France are constructing new nuclear plant.

The Institute's technical report, *The future of fission power - evolution or revolution?,* published in April 2004, highlights the technical advances that are being made in reactor designs worldwide. New modular reactors are being developed, which have lower capital costs, are more efficient, safer to operate, produce significantly less radioactive waste and generate electricity at a lower cost unit than the current fleet of reactors.

The report reviews both evolutionary and revolutionary reactor designs. Evolutionary designs capitalise on existing technology and introduce system simplifications that improve safety while, at the same time, reducing costs. For example, the AP1000 design, a pressurised light water reactor from Westinghouse, already licensed in the US, and the European Pressurised Water Reactor (EPR), which is the design adopted by both Finland and France, are both ready to seek licensing in the UK.

Revolutionary designs reviewed in the report include the development of High Temperature Gas Reactors and Pebble Bed Modular Reactors, which represent the first of a class of 'revolutionary' systems. These revolutionary designs will be inherently safer and more efficient than the evolutionary class. The Pebble Bed Modular Reactor (PBMR) is being developed in South Africa by an international consortium. Key benefits of PBMR include the fuel's ability to withstand very high temperatures, and the fact that the concept is of a simple modular construction with consequential low capital cost of units, which may be produced in substantial numbers ensuring economy of scale.

However, the report concludes that both types are needed. The evolutionary designs are needed to plug the gap left by the retirement of current nuclear plants, and to avoid the sizable increase in carbon dioxide emissions in the near future. One of the key problems in fission's future in the UK could be the lack of a skilled work force. The construction of these plants will also keep alive the knowledge and expertise that has been built up and keep the nuclear option open. Revolutionary designs can then follow, delivering safe, long-term competitive and sustainable energy.

The report also makes reference to work which is jointly being carried out co-operatively by a number of countries on the US Department of Energy's Generation IV programme. This activity is aimed at developing advanced reactor systems and fuel cycles for deployment circa 2030. International collaborative work has selected candidate systems to be developed that further improve the economics, safety, environmental impact and security in order to meet the stringent challenges of sustainable development energy generation in the 21st century.

With regards to the issue of managing radioactive waste, it is fundamental to separate the issue of dealing with radioactive waste and the construction of new nuclear plants. It needs to be understood by policy-makers and the general public that the problem of managing radioactive waste is largely a legacy from the past. Even if a decision were made not to construct new nuclear plants, the problem of managing nuclear waste produced as a consequence of past and current electricity generation and plant decommissioning will remain. The new nuclear plants, highlighted in the previous paragraphs, will generate significantly lower amounts of waste (estimated to be between 7-10% of the legacy waste) which will be much easier to deal with, and neither Scotland nor the UK should use the difficult challenge of dealing with legacy wastes as a basis to delay the decision for a new nuclear build programme.

<u>2.2 Coal</u>

The Institute has no specific comments relating to coal-fired electricity generation other than to note the DTI's continuing evaluation of the Cleaner Coal Technology programme and expressed interest in a Carbon Abatement Technology programme.

<u>2.3 Hydro</u>

The Institute has no specific comments on hydroelectric schemes other than to note that whilst these currently provide for approximately 11% of Scotland's electricity demand, there is limited potential for additional capacity due to environmental constraints. Given the pressing need for storage capacity to support all of the near-term renewable technologies, Scotland's hydroelectric expertise might best be exercised in developing additional pumped storage capacity, possibly based on existing hydro schemes.

<u>2.4 Gas</u>

Natural gas is expected to provide over two-thirds of the UK's fuel consumption by 2020. Such a dependence on what will increasingly become an imported resource is a major concern. The Institute published a report last year, *Gas supplies to the UK – a review of the future,* which clearly highlights the risks associated with a dependence on importing natural gas, to meet the UK's need for energy.

The report concludes that from 2006 the UK will become a net importer of gas, which has implications for the UK's security of supply, in terms of:

- potential threats to supply arising from political instability in gas-producing nations;

- price disruptions arising from risks associated with the supply and demand of gas; and

- concerns relating to the transit of gas and the facilities through which it is delivered.

The report also comments that a greater demand across the EU for natural gas is forecast, with increased competition for the same gas resources as nations attempt to meet their own carbon and pollutant-reducing targets. Even though carbon dioxide emissions from gas-fired generating plants are significantly less than from previously dominant coal-fired plants, gas-fired electricity generation alone will struggle to help meet the UK's future climate change targets. Additionally, there are concerns over gas leakage during transit along long pipelines.

Gas-fired generating plants currently offer the cheapest method of generating base-load electricity. However, nuclear power and renewable options become more competitive when fuel price fluctuations and future carbon dioxide emission allowances are taken into account.

2.5 Renewables other than Hydro

The Institute supports R&D into new renewable energy technologies which potentially, may eventually reduce the UK's dependence on fossil fuel electricity generation. Renewables are an essential part of the future energy mix, but there is a need for increased research and innovation in the relevant R&D sectors, in order for Scotland and the UK to be in a position to respond to the challenges of the medium to long-term future.

The Institute notes that the UK Government's Energy White Paper, *Our energy future - creating a low carbon economy*, aspires by 2020 to double the UK's renewables' share of electricity from the 2010 target of 10%. The equivalent targets for Scotland are 18% by 2010 and 40% by 2020.

The Institute is of the view that the current UK target of 10% itself is somewhat unrealistic, as renewables presently suffer from various barriers to exploitation, which in themselves demand greater R&D. These include: the power density required by the UK making the use of renewable sources problematic; disadvantages of renewables with respect to base-load capacity and the inflexibility of their supply; high economic costs in comparison to fossil fuel technologies; and they can have environmental impacts which may be reduced only through substantially greater capital investment.

The White Paper states that in the absence of new build or life extensions, nuclear power's share of electricity production will shrink from its current level of around 25% to less than 4% by 2025, when there will only be one reactor (Sizewell B) left in operation, following decommissioning. Whilst it is anticipated that renewables will become a more significant source of electricity as the UK seeks to tackle the threat of climate change, it has been noted that five thousand of the largest windmills currently available would be needed to replace the nuclear reactor capacity that will be lost between 2010 and 2015 – equivalent to commissioning 10 new windmills every week as of now. Indeed, it has been noted that even if all of the world's wind-generating plant were located in the UK it would only just meet the 10% target for renewable energy exploitation, which shows the extent of the challenge.

The situation in Scotland is, however, somewhat different. The additional 1,000MW of new capacity required in order to attain the 2010 target should be achievable from planned onshore wind developments. Environmental concerns at this level of capacity, which would require the deployment of 700-800 turbines, are unlikely to represent an insurmountable constraint. It does, however, equate to the commissioning of a new turbine every week for the remainder of the decade. The technology is proven and, although arguably not yet fully mature, should not represent a risk. Associated reinforcement of the transmission network infrastructure and an upgrade of the Anglo-Scottish Interconnector, to both maintain current market access for generators, and to cater for the detrimental effects that wind turbines using induction type generators have on transient stability are required. Provided these are undertaken, the target could be met.

However, the additional capacity necessary for Scotland to generate 40% of its energy from renewable resources within the 2020 time frame will increasingly have to be sourced from marine technologies (offshore wind, wave and tidal or a combination thereof). All of these represent relatively immature technologies with offshore wind, although representing huge potential, the most mature with five to 10-years' exploitation on a commercial scale. Wave and tidal technologies have yet to be demonstrated on a commercial scale although valuable operating experience is currently being gained from the Limpet Mk2 device on Islay. Storage systems will also be required in order to accommodate variations in generating capacity with the weather; periods of low or zero wind conditions inevitably occur at times of peak demand. Currently, only pump storage technology is proven and mature on a commercial scale. There are also significant attendant transmission network issues resulting from the geographical locations for offshore wind generators relative to consumer demand. It is considered therefore unlikely that by 2020 Scotland could be in a position to generate 40% of its electricity from renewable resources.

Only a small fraction of the energy currently used is generated from solar cells and it is questionable whether solar power will be in a position to supply energy for increasing base-load demand within the next decade due to the low power density (the power generated per unit). However, ongoing research into thermophotovoltaic (TPV) cells has shown that they could have the potential to yield a power density greater than 300 times that of a standard solar cell.

The main problem with solar power is cost. Currently the cost per unit generated is several times more than conventional means of generating electricity. The costs need to be reduced, and the efficiency of the solar cells increased, if solar power is going to make the desired impact.

Indeed the problem facing renewables and other low carbon generating technologies is that following the liberalisation of the UK energy market, the current price of electricity is so low, that it is not economically viable to develop and introduce new generating technologies to the market, unless they can be developed at a low cost and can provide electricity at competitive wholesale prices. The solution to date has been to subsidise research, development and demonstration (RD&D); renewables have benefited from Government support for RD&D and, in the absence of any other solution, this will need to continue.

The Institute has commissioned AEA Technology Environment to prepare an in-depth report, setting out the challenge facing renewable energy technologies, the important role of RD&D in meeting this challenge and areas where physicists currently, or could in the future contribute to this RD&D. The report will be published in the autumn, but we are happy to forward a copy of the final draft, on request.

2.6 Oil

The Institute has no specific comments relating to oil-fired electricity generation.

2.7 Emerging Technologies

2.7.1 Nuclear Fusion

Nuclear fusion has long been hailed as the ultimate energy source, mimicking on Earth the processes which take place deep inside the Sun and other stars, where light elements are fused to form heavier ones, releasing huge amounts of energy. Harnessing this energy on Earth would provide a virtually inexhaustible energy source with no greenhouse gas emissions.

The Institute is of the view that nuclear fusion potentially has an important role to play in low carbon energy generation in the long-term future. Despite the fact that commercial electricity generation from nuclear fusion is not likely before 2040, its benefits as an energy source for the long-term future are significant.

Fusion research is finally coming of age. Results from large machines like the Joint European Torus (JET), the world's largest magnetically confined fusion facility, mean that physicists have a deep understanding of the processes that will make fusion a reliable system for large-scale base-load electricity generation. The UK Government and their international partner Governments commitment to the International Thermonuclear Experimental Reactor (ITER), which it was recently announced is to be built in Cadarache, France, will hopefully lead to a demonstration of fusion energy production on a 20-30 year timescale.

2.8 Scotland's Bulk Electricity Transmission and Local Distribution Systems

If Scotland is to realise its full electricity generation capacity potential, especially in order to accommodate renewable technologies, it will be necessary to significantly strengthen the grid. The study commissioned by the Scottish Executive's Renewable Energy Network Study Group prepared jointly by Scottish and Southern Energy plc and Scottish Power, published in October 2001, assesses the available capacity of existing transmission network and the impact of additional renewable generation on the network in the context of the 2010 target. It also takes account of likely additional capacity required to service the potential demand from suppliers to England and Wales for Renewables Obligation Certificates.

A further study is required to assess the impact of potential additional renewables capacity in the 2020 time frame. The study will need to address and cost alternative scenarios for the mix of technologies providing the additional capacity and, in particular, the issues associated with distributed resources and the potential 'grid connected market'. The concept of a 'grid connected market' requires a radically different approach to management of the transmission network and current trading arrangements. Such information, together with any additional network associated maintenance and security costs is a prerequisite for calculating the cost of energy produced.

A study is also required into security (continuity) of supply in the context of changes in employment patterns with the predicted increase in the number of SMEs being established in rural areas and a general increase in teleworking. The current relative fragility of the network in terms of supply to rural communities during poor weather conditions will become increasingly unacceptable with the increasing dependence on IT and technology in general. It may of course be possible for distributed resource to be used to service 'grid disconnected' consumers where such systems are available.

If Scotland were to become a net importer of electricity, the security of supply and capacity implications of this will need to be assessed in relation to the Anglo-Scottish Interconnector.

The Institute broadly supports the findings of the October 2001 study referred to above and notes with particular concern:

- system transient and voltage stability will be affected by the introduction of large volumes of renewable generation in Scotland. These new generation sources may displace existing conventional generation that historically has provided the necessary response characteristics to maintain the overall transmission system integrity. Further work is therefore required to assess the impact of renewable generation on stability;

- the effect of renewable generation on Anglo-Scottish Interconnector capacity requires detailed assessment. Initial indications are that wind turbines using present induction type generators will have a detrimental effect on transient stability which will lead to a reduction in the Anglo-Scottish Interconnector transfer capability; and

- the development of suitable computer models for the various types of renewable generators is essential to understanding how the introduction of large volumes of renewable generation will change the characteristics of the transmission network planning and operation. New technologies for wind turbines in particular are presently being developed and introduced without an understanding of how they will interact with the local network or the wider transmission network.

3. Energy Demand

The Institute wholeheartedly agrees with the statement contained in the Energy White Paper, that energy efficiency could play a major role in lowering carbon dioxide emissions, if the problem of waste in energy usage could be tackled with changes in the style and use of energy. Reducing energy demand by increasing energy efficiency may in the short-term appear to be a more viable option than the implementation of low carbon energy sources. There is undeniably a need for a step change in the way we create and use energy and materials, if we are to limit further catastrophic effects on the environment. However, it must be appreciated that such changes in energy usage will require a significant cultural change.

The Energy White Paper placed an emphasis on the implementation of a low energy culture, not just in the public and private sector, but also on households. In the public and private sector, regulation such as the EU emissions trading scheme, will be the main driver. However, with the general public and their households it can only be brought about by education and public understanding coupled with incentives and taxes.

It must be noted, that measures towards reducing energy demand and promoting efficiency must recognise the particular needs of vulnerable citizens, such as, the poor and the elderly.

4. Environmental and Social Issues

4.1 Planning Policy and Constraints

As with the deployment or application of all new or emerging technologies, models used to either estimate or determine energy costs should be continually reviewed in the light of experience gained. For example, understanding of the effects of dams and reservoirs, a mature technology, on ecosystems continues to evolve. Studies in Canada have suggested that decaying vegetation, submerged by flooding in the large reservoirs created behind hydro-dams, may give off quantities of greenhouse gases equivalent to those from other sources of electricity. If this were to be substantiated, new hydro-electric facilities created by flooding large areas of land might prove to be contributors to global warming, and cost models would have to be adjusted accordingly.

The Institute recognises that the National Planning Policy Guideline NPPG6; Renewable Energy Development, addresses social, environmental and other constraints. The Guideline should, however, be subject to periodic review to both ensure and assure that it reflects changes in Government policy resulting from the reconciliation of conflicting policy interest. The review process should also capture experience gained, and incorporate lessons learnt, particularly as renewable energy systems are progressively deployed. The Guideline should not become primarily driven by, or relaxed to meet, progressively higher targets for generating capacity.

In particular, there is a need for financial models to determine the total cost of energy produced, taking into account the whole lifecycle (raw materials, manufacture, installation, running costs, servicing and maintenance, any security measures required, distribution, decommissioning and disposal or recycling). These models should also address the environmental impact ‘costs’ of the energy produced, over the same whole lifecycle, including: the footprint of the power generation, storage and distribution system on the land during the lifecycle of the power system; permanent or long-term damage which persists after decommissioning; risks to people and other fauna and flora (due to waste heat, radioactivity, corrosive chemicals etc); and importantly the net greenhouse gas emission. Assessment of environmental impact ‘costs’ is implicit on a common understanding by all stakeholders’ of the monetary value of what, in many instances, are essentially subjective issues.

Following publication of the Scottish Executive’s recent White Paper on Modernising the Planning System and the current public debate on third party right of appeal, there is concern that any Energy related projects of ‘national strategic significance’ contained in the next National Planning Framework, anticipated in 2008, may not be subject to full public scrutiny.

There is also concern that public statements by senior politicians and Scottish Executive Ministers advocating the use of the Scottish planning process to frustrate the build of new nuclear generating capacity in Scotland are premature given the current lack of informed debate.

4.2 Public education

A key component in any policy that needs public support or attempts to influence human behaviour is the need to enhance the public's understanding of the underpinning science and technology. Individuals must be able to understand in a broader sense what terms like 'global warming' mean and also comprehend the issues relating to matters such as energy efficiency. Only with such understanding are they likely to change their actions and behaviour in respect to the environment and climate, both directly and indirectly. It is essential that education and information in this area is provided in a co-ordinated and balanced way, spanning primary education through to the adult population. It is vital to include those involved in legislation in order to ensure that decisions are based on a proper understanding of the issues.

4.3 Supply of scientists

Without a good supply of highly skilled and trained science graduates, especially physicists, being nurtured and supported, the UK could end up in the position of either having to import the skills needed to help create the much coveted low carbon society, or risk being left behind as its main competitor nations press ahead with the advancement of low carbon technologies. For instance, the UK has a world leading scientific community in the field of climatic and environmental modelling, which is predominately peopled with physicists, who can play a crucial role in influencing the international scientific community and through them, global behaviour. With the recent number of low entries to Higher, Advanced Higher and A-level physics and undergraduate physics degrees, coupled with university physics department closures, there is a genuine concern that the UK's ability to provide the number and quality of physicists needed to help deal with the low carbon challenges that lie ahead will be adversely affected.

5. References

*1) Physics World (*July 2002)

Focuses on energy challenges for the 21st century, including reviews on technologies from fuel cells, wave and wind power to new nuclear reactors and featuring an article on the role of physics in energy supply. An electronic version of Physics World may be viewed at http://www.physicsweb.org/toc/world. A paper copy is available on request.

2) *Institute of Physics briefing papers on energy and climate change*

Hard copies of the following briefing papers are available on request, and downloadable from the Institute's website at http://policy.iop.org/Policy/HE/index.html

- *The future of fission power - evolution or revolution? (2004)*

- *Gas supplies to the UK - a review of the future (2004)*
- *Climate Change Prediction: A challenging scientific problem (2005)*

The Institute of Physics is a leading international professional body and learned society, with over 37,000 members, which promotes the advancement and dissemination of a knowledge of and education in the science of physics, pure and applied

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