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SCOTLAND'S ENERGY FUTURE

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1. Electricity Supply in Scotland

1.1 Although some aspects of electricity supply are peculiar to Scotland, as for example the Scottish Government's powers to grant or withhold Planning Consent, National Grid is the controlling agency for the whole of the UK System and it is likely to remain the case that electricity supply must be considered in the context of the UK.

1.2 Prior to privatisation in 1991 the two Scottish Boards were responsible to the Secretary of State for Scotland who in turn was required to ensure that energy policy, as defined by the UK Government, was implemented in Scotland. The emphasis in Scotland at that time was on using electricity supply as an inducement for industrial development with the lowest possible tariffs linked with high standards of security of supplies. Electricity costs were one of the lowest in Europe and this facilitated profitable trading with the industry in England and Wales to the benefit of Scottish consumers.

1.3 To ensure costs were minimised, generation, being the largest single element, was planned with the optimum mix of base load, mid merit and peaking plant for Scotland as a whole with the costs then allocated to each Board reflecting their demands on the generation.

1.4 Later, following privatisation, National Grid assumed responsibility for scheduling generation operation throughout the UK and this at first continued on the basis of 'order of merit' of running costs but with an additional element to recognise the part played by the provision of capacity (MW) in ensuring the security of supplies. However this system was not immune to gaming by generators who could hold back capacity and thus increase the level of capacity payments. To counteract this Government, through OFGEM, introduced NETTA (later modified to BETTA which included Scotland) and which allowed generators to sell their output direct to Suppliers. National Grid retained its responsibility for scheduling additional generation, the output from which had not been sold, in order to maintain security of supply and control grid system loadings, frequency and voltage.

1.5 Since privatisation there has been no attempt at planning new generation to achieve minimal overall generation costs, it being left to individual generators to assess whether any particular project was likely to be viable for them. However as the operation of every generator on the system is affected by the operation of other generators and there being no way of guessing what new projects might or might not be constructed in the future, any investment in new despatch-able generation became something of a lottery. This situation was aggravated as Government policy was concentrated on reducing CO_2 emissions as a primary aim with the construction of large numbers of wind generators and photovoltaic installations (both subsidised by consumers) and which are given running priority on the system. Thus the business case for new despatch-able generation, essential to back up wind and solar, became even more uncertain with generators withholding investment, leading to an unacceptable risk to security of supply. *

* see www.iesisenergy.org/agp/Aris-Gibson-paper-security.pdf

1.6 Recognising this situation Government again intervened, inviting tenders for new generation through 'Contracts for Difference' and later ' Capacity Contracts' which guaranteed firm prices for output for a term of years. While this was successful for some new nuclear (although at a high cost) as it can expect high load factors of operation it was less successful for other plant such as mid merit CCGT, where its operating load factor over its life time is uncertain.

1.7 The Capacity Contract Tendering process was even less successful in receiving offers for 'Demand Management' where consumers are paid for reducing their demand at times when the system is under stress. This is hardly surprising in that for the vast majority of commercial or industrial consumers any saving in electricity costs would be small in relation to the value of lost production. This may well have lessons for the unrealistic 'Smart Meter' programme whereby all householders are encouraged to have these meters installed (at a National cost of some £ 13bn) in the belief that this will lead to widespread time of use tariffs and a reduction in National Peak demand. Householders have other things to do than to continuously monitor their electricity usage as is confirmed by experience in the US where large numbers of such meters have been installed to no effect.

1.8 While it is possible that the Capacity Contracts system may attract some new despatch-able generation (at a cost), no attempt been made by Government to carry out total system cost studies, essential in planning for a minimum cost system, before deciding to which types of plant contracts should be awarded.

2. System Operating Criteria

2.1 Post privatisation, new renewable generation is located where there are suitable wind conditions and planning consents can be obtained so that minimal consideration is given to the effects on the transmission system. The National Grid 'Use of System' tariff does include a zonal component dependent on the marginal costs of transmitting the power. Thus generators in say the north of Scotland where there is sometimes an excess of power from wind farms, pay a higher transmission charge than those located closer to the National load centre in the English Midlands. Conversely generators located in the South of England where their output will reduce the transmission requirement are credited with a negative payment. Nevertheless only some 23% of total transmission charges are levied against generators (although they have more options to locate generation) whereas the remaining 77% is paid by supply companies which have little or no choice in the location of their loads.

2.2 It is well recognised that electricity systems, having very limited short term energy storage (typically 5 KWSecs per KVA provided by the inertia of the synchronous generating plant), must achieve a close balance of power input and load at all times. Moreover without adequate inertia a short circuit on the transmission will result in a loss of synchronism and system collapse. It is less well appreciated that it is equally essential to maintain a close balance in reactive power (MVAR)) which is consumed by a heavily loaded system and generated by a lightly loaded network). Unlike MW which can be balanced over the system as a whole, MVAR must be in reasonable balance in each individual part of the system. An inadequate supply of MVAR will lead to lower local voltages preventing the transmission of power (and risking instability) while a surplus will result in excessive voltages and damage to equipment. Unlike traditional synchronous generating plant, wind and photovoltaic generators do not provide inertia or control MVAR.

2.3 Where there is insufficient synchronous generation available, MVAR can be provided to or extracted from the system by the provision of shunt and series connected reactors and capacitors which can be individually controlled as required. These are now being installed extensively on the long inter-connectors over the Border and, apart from being costly, are not without their problems, as for example generating sub-synchronous resonance leading to failure of large generator shafts. Moreover none of these contribute to the essential inertia.

2.4 All power systems must cater for the rapid re-establishment of supplies following a complete shut down. This requires that the country be divided into regions with each region developing a plan to re-establish supplies using only its own resources. Scotland is one of the five such zones in the UK and until recently relied on the rapid starting capability of the Cruachan pumped storage scheme supplying power via its directly connected EHV transmission to the large centrally located Longannet station. With the closure of Longannet it is necessary to examine other possibilities. (It should be noted that nuclear is ineffective in this role, the reactors being poisoned out for some 24hrs following a trip and also the new 2000MW HVDC inter-connector (see below) will be ineffective requiring as it does an established supply at its receiving end to allow valve commutation). The most likely plan will entail using the small hydros in conjunction with Peterhead but this will take some 36hrs or more to re-establish supplies. Reliance on re- establishing the system using supplies from England would take even longer, especially if it is also suffering disruption of supplies.

<u>3. Generating Plant in Scotland</u>

3.1 The present generating capacity on the grid in Scotland comprises:-

Hunterston	1000MW
Torness	1200
Peterhead	400
Hydro	1000
Pumped storage	750
Wind	6000 (approx)
Total	10350 MW (of which 4350 is despatch-able)

3.2 While the majority of renewable capacity in connected to the HV grid system a significant amount of wind and solar (probably approaching 30% of the total) is connected at lower voltages and so is seen by National Grid only as a variable reduction in demand. This capacity is therefore not included in the above figures. Max demand in Scotland is assessed as some 5000MW and is expected to remain about this level for several years

3.3 The UK Government have set a target in the light of the Mastricht agreement of 30% of electrical energy from renewables by 2020 although there have been recent signs of modifying this commitment in the light of their high costs and the effect on electricity bills. The Scottish Government has adopted a target of matching the total of Scotland’s electricity energy use in full by 2030. Discussions with Government confirm there has been no analysis to support this objective or to examine the implications. It would however require a large increase in renewable installations mainly wind, to some 10,000MW.

4. Cross Border Exports and Imports

4.1 Generating capacity in Scotland is presently some twice maximum demand.. However wind output is highly variable with output less than 30% for 2/3rds of the time and below 10% for 1/3rd of the time; this taken with the fact that output from both hydro and pumped storage is limited by water availability means that Scotland, while exporting heavily to England when wind output is high, is already dependent on imports from South of the Border when nuclear output is reduced as for example for maintenance or refuelling.

4.2 Cross border transmission comprises two DC (double circuit) 400KV lines together with a limited capacity 132KV circuit. This will provide a firm export capacity of some 4000MW (with a lower import capacity of 2500MW) when present works are completed. A 2000MW HVDirect Current (HVDC) submarine cable connection, shortly to be commissioned between Deeside and Hunterston, will increase export capacity and initial discussions are taking place to establish a further DC 400KV connection via Dumfries and Sellafield (which inter-alia would cater for the projected nuclear station, thus reducing export capacity from Scotland). Extensive works, such as these, required to accommodate the large amounts of renewable generation comprise a large part of National Grids capital expenditure, some
£2.5 bn per annum at present, and are a direct charge on consumers.*

5. Costs to Consumers

5.1 DECC figures show that electricity costs to domestic consumers in the UK are now the highest in Europe (some 50% above the average) and those to industry even higher (at 90 %). These high costs stem directly from the emphasis on high cost renewables to which have to be added the costs for integration into the system, increased transmission losses, inefficient operation of thermal plant to provide flexibility and increasingly the ‘constrained off’ payments when high renewables output would otherwise cause overloading of the transmission system. None of these costs are incurred when existing conventional plant is replaced with new generation on the same site.*

5.2 It should be noted that the practice of quoting costs as energy only (£ /MWhr) is misleading and unduly favourable to non despatch-able generation as it takes no account of the need to have sufficient capacity to meet demand when output from wind or solar is low.

5.3 Government statistics show that some 40% of all consumers in Scotland are now quoted as being in fuel poverty and the question needs to be asked if the present policy of concentrating on renewables is effective whether in containing costs, maintaining security of supply or reducing CO_2 emissions. **

* 45% of the £712 bn investment in electricity in 2016 was on networks.(Ofgem figures)
** The Climate Change Committee has in the past pointed out that allowing for CO_2 from increased imports (excluded from Government figures) UK missions actually increased.

6. Planning for the future

6.1 With its present structure relying on market forces, the electricity system is clearly not working in consumers' interests but continues to demand increasing interventions (micro management) by Government incurring ever high costs while failing to achieve its major objectives.* To achieve these will require more attention to costs, to security of supply as well as the application of sound engineering and organisational principles. For example it cannot be right that National Grid, whose profits are related to their investments, should be responsible for designing, owning and operating the EHV transmission system.

6.2 Furthermore the current generator loading regime in which all generators in each half hour loading period are reimbursed at the highest accepted bid (which bears no relation to the costs of other generators) means that the system is largely a lottery and discourages much needed investment in new generation while encouraging gaming when plant margins are low.

6.3 We suggest that these fundamental weaknesses could be addressed by a limited restructuring in which a new body (The Commission) is charged with planning, design and operation of the system (including generation loading) whilst leaving ownership and asset management of the EHV system with National Grid. The Commission, which would require a strong engineering capability, would invite tenders from approved generation companies for new generation for defined loading regimes based on total system cost studies. The accepted capital and running costs (with appropriate escalation provisions) would then form the basis of an order of merit loading system to achieve minimum costs. This would be to consumers' advantage while ensuring a proper return for generators. This structure has parallels with the successful Central Electricity Board of the 1920's.

* Renewables installed over the 10years to 2016 increased from 6000MW to 35000MW

7. Recommendations

7.1 Scotland needs to plan now to provide new base load generation to be in place by the time the nuclear plant is decommissioned. This is required for the security of supplies, to back up renewables for the many times when output is low and to provide the inertia essential to allow the system to ride through system faults as well as facilitating rapid recovery in the event of failure of the system.

7.2 In the timescales available this can only be some combination of nuclear (using an existing proven design such as the Westinghouse / Toshiba APWR) and CCGT burning natural gas. Both the existing nuclear sites at Hunterston and Torness can accommodate new developments (the Planning Enquiry at Torness sought consent for this in principle)

7.3 The promotion of new nuclear will necessarily involve Government intervention whether directly or through modifying the licences of the major generation companies to require them to take shares in the projects, much as is done already with renewables.

7.4 The construction of new CCGT plant will require secure and economic sources of gas supply; there is no good reason why the development of the apparently large scale Scottish deposits by fracking should not be part of this plan.

7.5 The future planning of the system should be based on whole system cost studies with the interim results made available for political and general consultation. These would also give full details of estimated CO2 emissions for alternative plans.

7.6 To achieve these objectives some limited restructuring of the Industry is essential with the planning, design and operation of the system (using staff largely transferred from National Grid) concentrated in a new Commission and given the necessary powers as outlined above.

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8. Apppendix

8.1 The history of energy use has been to harness the benefits of increasingly intensive sources resulting in wider availability, lower costs and higher standards of living. Seen in this light the wholesale reversion to lower energy density sources such as wind is a retrograde step and it should be no surprise that it is resulting in significantly higher costs and a reduced security of supply.

8.2 It is entirely possible that if a fraction of these extra costs had been spent on developing new technological solutions we should now be in on firmer ground as regards our electricity supplies while reducing CO2 emissions and boosting our manufacturing sector and economy. We give below a shorthand version of our assessment of the energy sources which could be considered for deployment within the planning horizon.

9 Energy Storage

9.1 As the difficulties from large amounts of non-despatch-able renewable generation have increasingly impacted on the system there has been frequent references to storage mechanisms, pumped storage, batteries (including those in electric cars), hydrogen from electrolysis of water and even gravity (a train running up and down a hill). However all of these fail on grounds of cost, efficiency and practicability, not least that of matching the system’s large energy requirements for several hours not to mention the periods of a week or more when renewable output is low.

10. Tidal (and wave)

10.1 The power available in a moving fluid is proportional to its weight and also the cube of its velocity. Thus although water is some 1000 times the weight of air the relatively low tidal velocities mean that the energy density seen by a tidal turbine is similar to that of a

wind turbine. Add in the enormously greater difficulties of working at sea, the peaking nature of the power output (the result of the cube rule and the diurnal cycle), the greatly reduced output for most sites during much of the bimonthly cycle and it is clear the prospects of achieving an economic and reliable power source are extremely low if not negligible.
Work done by Robert Gordon's University has demonstrated that unlike wind turbines that can be located in a field pattern without substantially reducing the output from downstream machines, a single line of tidal turbines reduces the stream velocity for machines located whether up or downstream. Based on this work an analysis conducted by consulting engineers Black and Vetch for DECC has estimated that even if all the developable tidal resources in UK waters from the Pentland Firth to the Channel isles were to be utilised they could not provide more than 5% of our electricity energy. As the bulk of marine energy is located in the Pentland Firth and the Channel isles which would both involve every high costs in transporting the energy to market, it is high time the considerable grants for marine power development being awarded by Governments were put to better use.

10.2 Wave power is clearly even less attractive, its output being subject to the vagaries of wind (complicated by changes in direction over preceding periods) but with the added difficulties of operating in extremely aggressive conditions.

11. Nuclear

11.1 This has a good record in Scotland,. Hunterston A held the world record for performance for many years while both Hunterston B and Torness were built substantially to time and cost. At peak over 2/3rds of Scotland's electricity was produced by nuclear and at costs even lower that the Longannet 2400 MW coal fired plant. The operating lives of the two AGR plants have been extended to the mid 2020's.

11.2 Following years of neglect, Government now recognises nuclear has a vital part to play and has invited proposals for four or more different designs from overseas contractors. This multiplicity of designs risks repeating the mistakes of the early years of the UK nuclear programme when Government insisted on 5 (later consolidated into three) different contractors. For an economy the size of the UK, experience would suggest concentrating our resources on no more than two different designs.

11,3 Much has been made in recent years of the claimed advantages of small scale reactors (factory built and located close to the loads). But the advantages claimed are generally overstated; the reactor accounts for only some 35% of the station costs, the plant will still need to be sited near major sources of cooling water (the sea) and away from built up areas, the large gains from the benefits of scale would be lost, the likelihood of series production is low and a multitude of reactors raises questions of proliferation. Nevertheless a mid sized development of say 450MW, as is being promoted by Rolls Royce, would seem worth pursuing.

11.4 Other designs of reactor as for example thorium fuel with molten salt coolant may have advantages in the longer term but these are well beyond the present planning timescale. However there seems to be no prospect of a privatised and market led electricity industry voluntarily embracing nuclear power even with Government guaranteed funding and firm capacity contracts, so some form of further Government led intervention will be essential.

12. CCGT

12.1 The combined cycle gas turbine technology exhausting its hot gases to a steam raising boiler is well established and produces about 50 % of the CO_2 of a coal fired plant of comparable rating. There has been pressure on Government to fund a demonstration of CO_2 capture and disposal to an exhausted oil well reservoir in the N sea but the high cost of the washing process together with the loss of some 25% of power output has discouraged progress.

12.2 Nevertheless it remains possible that a different technological approach may make CO_2 separation practicable in the medium term. One such is the Allam CO_2 cycle, developed by a British engineer and now the subject of a 50 MW demonstration plant under construction in the US. The liquid CO_2 (pressurised) working fluid offers a higher efficiency than the conventional steam cycle and allows excess CO_2 to be bled off as required for long term disposal. The saving resulting from the small size of the turbine and its higher efficiency is claimed to balance the extra cost of separating oxygen from air to burn the fuel. A further advantage is that there being no nitrogen in the combustor means there are no NOX emissions.

13. International Interconnections

13.1 Present interconnections with the Continent using HVDC links to France and Holland have a capacity of some 4000MW and at present would seem to be importing heavily for a high proportion of the time, mainly from French nuclear generation. However these imports, not being backed by firm contracts do not provide firm power (see Nat Grid Ten Year Statement) so there is no compensating reduction in UK investment in generating plant. At 80% load factor and a cost of say £50 /MWhr the cost to the UK economy currently amounts to some £1.5bn per annum.

13.2 Ofgem, apparently confident in forecasting the future of energy pricing in the UK and Europe for decades ahead, have accepted further interconnection capacity (bringing the total to 11,300 MW) mainly under their Cap and Floor scheme. This provides that the economics of such schemes are to a substantial extent underwritten by the UK consumer for periods of 25years. In addition there is a further 6,200MW under consideration.

13.4 National Grid who clearly have an interest in interconnections as a potential revenue source are currently carrying out a consultative operation in which the interconnection capacity could be further increased during the next few years up to 20,000MW.
