AN ENGINEERING APPRAISAL OF
THE POLICY AND INNOVATION UNIT'S

ENERGY REVIEW

Memorandum prepared by
The Royal Academy of Engineering
for
Mr B. Wilson MP, Minister of State for Energy and Industry

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Executive Summary

The Royal Academy of Engineering welcomed the initiative by the Government to embark on a review of national energy policy. However, it was disappointed by the eventual report which focused on a small, albeit significant, area of energy supply and demand – electricity. Other areas of similar concern (both in terms of energy usage and emissions to the environment) warrant the same degree of consideration. Further, the assessment was theoretical yet the problems to be addressed are very much of a practical engineering nature.

The Academy welcomed the invitation from Mr B. Wilson MP, Minister of State, to furnish an engineering appraisal of the PIU Energy Review. This report has been compiled by the Fellows of The Academy and whilst addressing issues raised in the PIU report, states the need for an in-depth holistic study of all aspects of energy supply and demand including financial modelling and those economic drivers which will cause change in society's behaviour.

The UK is confronted by rapidly maturing trends related to energy supply requiring a wide appreciation of many issues. The country is emerging from an era of cheap energy with near self-sufficiency in coal, oil and gas supplies. Energy policy recently has to an extent been overshadowed by environmental policy and emissions reduction. Now as an imminent net importer of energy with a growing reliance on a limited number of external suppliers, security of supply will rise in importance relative to environmental, competitiveness and social aims.

For these reasons and others the Academy welcomes the DTI's intention to establish a Strategy Unit in its Energy Group.

This response addresses several of the issues raised in the PIU Review, notably that of electricity generation and makes a number of specific recommendations. Here the central question is seen as the future contribution to energy supply from gas, renewables and nuclear power.

The Academy notes that in the recent initial response to the Government's consultation on UK energy policy, Lattice Group plc stated that the PIU was wrong to assume that there appear to be no pressing problems connected with increased dependence on gas, including imported gas from overseas. The Academy agrees with this appraisal. The absence of a suitable enabling pan-European infrastructure, coupled with lack of interconnectors between the European and UK distribution systems and of adequate storage in the UK, was not appreciated by the PIU. To correct this will require major investment. As a consequence, gas is not necessarily the cheap and secure source of energy for electricity generation, as depicted in the PIU Report. It would clearly be unwise to expect gas to supply 70% of electricity generation by 2020.

It is recommended that:

> The Government should, with the EU Commission and other EU governments, address the strategic questions surrounding the planning, funding, regulation and capacity allocation for the enabling pan-European gas infrastructure.
>
> The Government should consider appropriate measures to ensure that sufficient gas storage capacity be constructed as required to provide insurance cover for unusual and relatively rare events that would not otherwise attract investment in a liberalised market based on the sale of energy.

Renewables are not seen as the only tool available for reducing emissions and enhancing security of supply. Renewables can make a significant contribution to electrical energy supply but because of their intermittent nature, especially the random intermittency of wind, cannot provide a reliable source of power. The PIU recommendation of 20% of electrical energy by 2020 to be derived from renewables, with installed wind capacity to be of the order of 17 – 25GW, would not replace the need for an equivalent capacity of conventional plant. If, say, 22 GW were installed, as mooted by the PIU, then 16 – 19 GW, would have to be available in the form of conventional plant capacity in order to provide back-up power when wind is light or absent. The fixed capital costs of this partly used plant would have to be borne by the consumer – possibly of the order of £1billion in the above case and for this reason the economic viability of renewables has to be questioned.

If renewables cannot deliver the levels of power anticipated in the Review, there will be only two remaining options to provide reliable, secure generation open; either to build large new coal-fired stations with their attendant environmental problems, or new nuclear build. Either option would require a decision to go ahead within the next few years if they are to provide the additional capacity by 2020. Initial build would need to start in about six to eight years from now.

For nuclear to progress, however, considerable work will be required to convince the public that nuclear energy is indispensable for tackling both the climate change problem and for providing security of electrical power supply. An early decision by the UK Government would be helpful to the UK industry in maintaining and enhancing skills by participating in the substantial nuclear build programme planned elsewhere in the world. This will ensure that the UK nuclear industry is not left behind on several grounds, including those dealing with safety and environmental concerns as well as the issues of commercial return.

Advances in reactor design mean that if the entire UK nuclear capacity was replaced, the volume of nuclear waste from all sources requiring treatment (including decommissioning the waste from existing and new plant) would increase only marginally over the next 40 years (the life of the new plant).

Transport's share of total energy use has increased rapidly; it currently accounts for 42% of total energy use in the UK[1] and overwhelmingly depends on petroleum. Road transport accounts for 75% of UK petroleum demand with air transport accounting for nearly 15% and growing very quickly. In the field of transport, the Government should consider the benefits in emission reduction of further electrification schemes for public transport including railways and urban systems. With fuel cell technology expected to make an impact in this area over the next two decades major Research, Development & Deployment support should be given to hydrogen production, storage (including chemical storage) and delivery systems whether for transport purposes or for electricity generation. Such developments should be given at least the same priority as the Government's renewable energy and emission reduction policies.

[1] Digest of UK Energy, DTI, 2000

Summary of Recommendations

Policy Framework

1. The policy instruments employed to reduce CO_2 emissions should be based on the actual amounts of carbon dioxide emitted and not energy consumed.

2. The Government should place security of supply as central to its energy policy whilst the various economic, social and environmental objectives should be weighed against the economic benefits that derive from low energy costs.

Security of Supply – Primary Fuels

3. Given the limitations of the existing gas supply networks in Europe, the envisaged scale of the future operation, the engineering effort and the level of investment demanded, the Government should with the EU Commission and other EU governments address the strategic questions surrounding the planning, funding, regulation and capacity allocation for the enabling pan-European gas infrastructure

4. The Government should reassess the limitations of the market and market mechanisms as the basis for planning and funding new capacity that would lead rather than lag the needs of the network users, e.g. re-examine the effectiveness of capacity allocation market mechanisms, and the signals and revenues from them, as the basis for planning and funding the future development of transmission infrastructure.

5. The Government should consider appropriate measures to ensure that sufficient gas storage capacity be constructed as required to provide insurance cover for unusual and relatively rare events that would not otherwise attract investment in a liberalised market based on the sale of energy.

Security of Supply – Nuclear

6. The government should establish the real benefits of nuclear energy to the economy in terms of its climate change objectives, security of supply and the provision of reliable supplies of electricity at ensured long-term stable prices. (This has not been done before).

7. The nuclear industry should be invited to indicate to Government the national requirements in terms of skills required and manufacturing capability for "keeping the option open". The cost of losing this ability and the feasibility of rescuing the industry at a later date should be determined.

8. The UK should enter into international Joint Certification programmes to reduce the regulatory burden on the nuclear industry.

9. The planning process should be streamlined to avoid unnecessary delays and cost particularly as the industry is proposing any new build be on existing sites.

10. A decision must be made on the management of radioactive waste rather than the prevarication that is damaging our ability to replace nuclear with nuclear at the expense of increasing CO_2 emissions to the environment.

Security of Supply – Renewables

11. Intermittent generation provides energy over time, but in the UK system does not replace the need for (conventional) generation capacity. Detailed engineering studies should be undertaken urgently before policy decisions relying on high levels of intermittent renewable generation are taken.

12. The study should determine the full costs of employing high levels of intermittent renewable energy sources (including the provision of standby plant, energy storage, upgrading of the transmission and distribution systems) and identify the impact on the electricity prices.

13. It has been argued that traditional fossil fuel based electricity generators should incorporate the costs of environmental pollution into their pricing and that this process would make renewable generators appear more competitive. Likewise renewable generators should incorporate into their pricing the cost of maintaining and running reserve capacity required for grid stability and for covering demand when intermittent generators are not available.

Electricity Supply

14. Consideration needs to be given to the consequences of insecure gas supplies with particular reference to the necessity of secure power supplies.

15. Given the increasing penetration of gas in the electricity generation market, a thorough risk analysis should be completed on the various causes of gas supply interruptions and the effects on electricity supply.

16. Consideration needs to be given to the consequences of increasing gas supply prices with particular reference to the viability of other technologies and fuel supplies including nuclear.

17. Given the reservations concerning the limitations imposed by the direct connection of intermittent renewable energy sources to the public electricity supply system, greater emphasis should be given to the importance of developing and deploying energy storage technologies.

18. Ministers should consider the alternative scenarios for electrical energy production by 2010 and 2020 to protect against the situation where renewable energy does not become available at the desired rate.

19. With limited system compensation capacity between England and Scotland the Scottish electricity system needs further study in view of the planned timetable of closures of major coal and nuclear stations. If replaced then decisions need to be taken in the near future. The substantial development of new randomly intermittent renewable wind and wave resources is not seen as a practical engineering solution.

20. More generally a comprehensive engineering appraisal needs to be carried out to determine the tolerable level of distributed generation from intermittent sources within the systems of Scotland and England and Wales and to explore the opportunities of greater connectivity with the Norwegian grid.

21. Given the Government support for CHP development an engineering appraisal should be carried out into the state of development of micro-CHP devices

including fuel cell based systems and their prospects for installation and operation as envisaged.

Transport

22. The Government should consider the benefits in emission reduction of further electrification schemes for public transport including railways and urban systems.

23. Major Research Development & Deployment support should be given to hydrogen production, storage (including chemical storage) and delivery systems whether for transport purposes or for electricity generation. Such developments should rank as being at least as of equal significance as the Government's renewable energy and emission reduction policies.

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1. Introduction

On the 26th April, 2002 Mr Brian Wilson MP, Minister of State for Energy and Industry invited The Royal Academy of Engineering to carry out an engineering appraisal of "The Energy Review" prepared by the Performance and Innovation Unit of the Cabinet Office. This report constitutes the Academy's response to that request and has been prepared with the awareness of the impending Government White Paper on Energy. It does not attempt to set policy but to inform the policy making process. It considers the issues from a practical engineering standpoint. During the preparation of this paper it soon became apparent that the answers to many of the questions were not immediately available; we have therefore had to draw on whatever was accessible and in some cases have indicated that further studies need to be carried out.

The PIU report can be thought of as having two main thrusts: security of supply, and reduction of carbon dioxide emissions to the environment. It focussed mainly on electricity generation yet this is only the smaller part of the problem. It concentrated on a small number of large generators of electricity or emitters of Carbon Dioxide and not the task of amending the habits of millions of home and road users yet the effect on the environment of one gram of Carbon Dioxide is the same irrespective of its origins.

To illustrate the point the DTI Digest of Energy Statistics 2001 states (table 1c) that in 2000 the Industry, Transport and Domestic consumption of primary fuels was 25%, 27% and 30% respectively (others accounting for the balance). In particular, secondary electricity (i.e. excluding nuclear, natural flow hydro and imports) represents 18% of the energy consumed by all users. When considering CO_2 emissions, electricity generation accounts for 28%, transport 24%, and the remaining 48% arrives from industrial combustion, domestic use and a small amount of "other". Hence, whether considering energy supplied or CO_2 emitted, there is an urgent need for an in-depth and holistic consideration of the nation's energy supply and demand. An additional consideration is that this area is one where there are many fiscal and economic influences. The existing economic instruments are unlikely to secure the changes which should be demanded of all energy users, not only electricity generators, to improve the efficiency of energy use (e.g. in buildings). A financial model must be considered along side that of energy usage since it is the fiscal instruments which will cause change to occur.

The following report attempts to identify the engineering issues across the whole of the spectrum of energy supply and use.

2. Policy Framework

Much of the treatment in the Review, although sound, is theoretical given the assumptions from which it is worked.

The liberalised energy market does seem to have worked well and has over the years reduced prices in real terms. It should however be noted that the market situation is constantly evolving with regulatory and external changes and it is therefore too early to draw concrete conclusions. There is still little empirical evidence that the market will respond correctly to capacity needs; so far, because of high reserve margins, the availability of gas and stagnant demand, the tendency has been to build for energy cost savings. It would therefore be dangerous to expect market forces alone to bring about the implementation of any recommendations particularly as Government interventions are not without precedent. However, there is no real reason to jettison the liberalised market solution. In fact there is a case for working to ensure the same level of liberalisation within European markets as currently exists in the UK.

The Review quite rightly identified carbon valuation as fundamental to any systematic attempt to manage climate change. It would therefore be sensible to base any policy instruments designed to reduce emissions on actual amounts of carbon dioxide emitted rather than the current, arbitrary basis of the Climate Change Levy (CCL) which is based on energy used and the origin of that energy. This could be achieved with a tax or other fiscal instrument based on the mass of carbon in primary fuels used, as this would be proportional to the CO_2 in the emissions. Such a tax should be designed so as not to affect industrial competitiveness and should have similar mechanisms as those introduced in the CCL to make it revenue neutral. Thus it would then encourage energy efficiency and fuel switching to genuine low-carbon alternatives.

The Review proposes that environmental objectives should take precedence over economic and social objectives: this is an odd simplification. It is only recently that environmental issues have come to the fore and it is still unknown as to what extent they will take precedence in the public's or industry's perception. If there were serious energy shortages or costs became very high then the public might not be so concerned for the global environment. In the US, industrial competitiveness already takes precedence over environmental issues. It may be unwise to specify a priority amongst these objectives, but it will be important to keep a watching brief on how industrial competitiveness is affected over time.

The analysis is very UK centred. The UK is a relatively small player (only amounting to 2.5% of Global Primary Energy consumption and around 3% of reported global CO_2 emissions). There is a need for much more attention to how the UK should work, especially within Europe, to promote solutions. There is also a neglect of the influence of developing countries and their likely future impacts on markets, especially gas: e.g. China, Russia, SE Asia, and also a neglect of the possibilities of saving carbon in these and other economies at much lower costs than can be achieved in industrialised economies such as the UK's. The Clean Development Mechanism (CDM) within the Kyoto Protocol is available specifically to promote this type of cross border investment.

With the energy supply scene changing in the UK after some thirty years of self-sufficiency, a number of issues in energy policy have to be faced in the future that have hitherto not been high on the agenda. Security of supply, for example, will rise in importance relative to environmental concerns, regulation and liberal market mechanisms, competitiveness and social aims. In this respect The Academy strongly supports the recommendation to establish a Strategy Unit in the DTI with an overall responsibility for the larger picture.

Recommendations

The policy instruments employed to reduce CO_2 emissions should be based on the actual amounts of carbon dioxide emitted and not energy consumed. Such instruments should be revenue neutral to industry to protect global competitiveness.

The Government should place security of supply as central to its energy policy whilst the various economic, social and environmental objectives should be weighed against the economic benefits that derive from low energy costs.

3. Security of Supply

3.1 Background

Energy policy has to consist of a number of separate aims that, at times, may be in conflict with one another. These main concerns can be summarised as: security of supply, environmental, competitiveness and social. As far as is possible, a holistic energy policy will balance these aims but be flexible enough to respond to changing market conditions.

The UK has for many years been a net exporter of natural gas and oil with significant reserves in the North Sea and Morecambe Bay. Recently, demand has outstripped supply and the UK is facing the likelihood of becoming a significant net importer relatively quickly. At the same time, UK oil and gas discoveries are slowing and are not keeping pace with rising demand.

As an imminent net importer of energy with a growing reliance on a limited number of external suppliers, security of supply has risen in importance relative to environmental, competitiveness and social aims.

Ensuring an adequate supply of energy for the UK from both indigenous and foreign sources requires management of both the supply and demand sides of the market. The UK has been at the forefront in developing a free market for energy, a situation that has been brought about by the break-up and sale of large nationalised utilities in the coal, gas and electricity sectors. For the most part, this market now operates on a commercial basis providing competitively priced energy in a competitive market. The mix of fuels used is determined by the market mechanism but also influenced by political decisions e.g. the 1996 moratorium on combined cycle gas turbine (CCGT) build.

Commercial pressures have led to certain fuel sources being economically more attractive than others and, from time to time, the fuel mix changes according to the world market situation. The ability of UK industry to react to these pressures by altering the overall fuel mix quickly is a major advantage in terms of security of supply. However, where the choice of suppliers is limited, such as with natural gas from Russia and oil from OPEC countries, there is a significant role for Government in ensuring politically stable long-term relationships with foreign suppliers. Where cross-border trading is required there is a similar role for Government in ensuring that legal and regulatory systems are compatible and do not hinder that trade.

Each potential fuel source has its own set of advantages and disadvantages. These must be balanced against security of supply, environmental and fuel poverty policies. Security of supply is affected by the risk of disruption, so can be enhanced either by diversity of fuels or by diversity of sources. These issues will be expanded upon and recommendations made in the following sections addressing each of the main primary fuel sources available to the UK.

3.2 Primary Fuels

The existing energy supply is largely based on traditional primary fuels. This report considers the current situation with primary fuel usage in the United Kingdom in a broad sense, considering nuclear and renewables in this category. Each is analysed in terms of security of supply and environmental goals separately from their uses in the economy.

The main shape of a policy addressing these goals is determined today by the views taken of the future availabilities, prices and technical possibilities concerning oil, gas, nuclear, renewables and energy efficiency. Within the PIU Review there are five core assumptions about these issues:

- Oil will continue to be readily available and to retain a price advantage in transport
- Over the same period gas will be plentiful and cheap; hence in a liberalised electricity market gas will dominate power station construction and electricity supply
- Renewables can be developed to supply 20% of electrical energy by 2020
- Substantial gains in energy efficiency can be achieved by 2010 and again by 2020
- Nuclear costs are high and based on previous UK experience, not current global experience.

The first two assumptions, taken from paper DTI EP68, dominate the shape of energy policy emerging from the Review.

3.3 Oil

The International Energy Agency (IEA) noted recently, as have many others including the European Commission[2], that mature oil reservoirs in OECD countries will soon peak and decline and consumers will grow increasingly dependent on a small number of oil suppliers in the Middle East.

There is a body of informed opinion that the peak in world oil production will occur before 2020. Similar forecasts have been made before and have not been realised. Whether as a consequence of a return to monopolistic pricing arising from a concentration of production or of a genuine rise in the supply curve following depletion, it cannot be excluded that the price of oil will rise substantially in the next two decades. This alternative view at least requires that assumptions on oil prices must be rigorously scrutinised and carefully questioned lest they become, as presented in the PIU Review, the basis of over-optimism, especially with regard to transport policy.

Technology in oil production continues to make previously uneconomic reserves exploitable, but ecological concerns may ensure that many reserves such as those in Alaska remain out of reach.

In terms of security of supply, oil will be available for the foreseeable future, and certainly over the period considered by the PIU Review, at a price. However, as prices increase, oil as a chemical feedstock will become more important as price elasticity for this sector of industry is probably higher with fewer alternatives available.

The infrastructure for oil is mature with refineries and a delivery network in place. Most important is the vast delivery network devoted to the transport sector with around 12,200 petrol forecourts on the roads of the UK. This figure has dropped from about 18,000 in 1991 due to consolidation and commercial pressures on small

[2] "Towards a European Strategy for the Security of Supply", COM (2000) 769.

retailers[3]. The sheer scale of this enterprise means that real change in the transport sector will require concerted effort.

3.4 Gas

3.4.1 EU demand growth

The assumptions concerning gas availability and price in the PIU Review are far more important than those for oil with respect to the electricity supply industry. The implications of this are dealt with under section 4 on Electricity Generation.

The EU Energy Directorate view as per June 2000 indicates demand exceeding supply from around 2008 although, as the Directorate mentioned in March 2002, this may occur as soon as 2005. This situation is illustrated in Figure 1.

Two-thirds of the increase in European gas consumption will be associated with electricity generation. The European Commission has stated that up to 600 Gigawatt electric (GWe) of the installed capacity deemed necessary in Europe by 2020 has yet to be built. In addition to an additional new capacity of 200-300 GWe, 300 GWe of existing capacity will have to be replaced over the next 20 years to replace power stations that have reached the end of their lives[4]. By 2020 the UK will have to replace 35 GWe of retired generation or 60% of current capacity.

New supplies of gas will have to be found coming from more distant fields. Potentially the British and Continental European markets have access to ample reserves of gas from remote sources such as Russia (Siberia), North Africa, the Caspian Region, and – in the form of LNG – the Middle East and Nigeria.

There have been some concerns about a "too high" import dependency on gas and both the EU and member states have expressed a desire to achieve a balanced energy portfolio with regard to fuels and regions[5]. Should such policies prevail, they are likely to curb gas imports. However, Russia is expected to double its gas exports to the EU over the period 2000-2010[6] which would make it more difficult for a

[3] http://www.ukpia.com
[4] (European Commission, 2000a).
[5] European Commission. 2001. EU/Russia Energy Dialogue: An Overview. 1 June 2001. http://europa.eu.int/comm/energy-transport
[6] Europen Commission. 2001. EU/Russia Energy Dialogue: An Overview. 1 June 2001

liberalised and competitive market to properly consider issues of security of supply over short term business needs. Such a scenario would only be sustainable if EU-Russia relations were stable in the long-term.

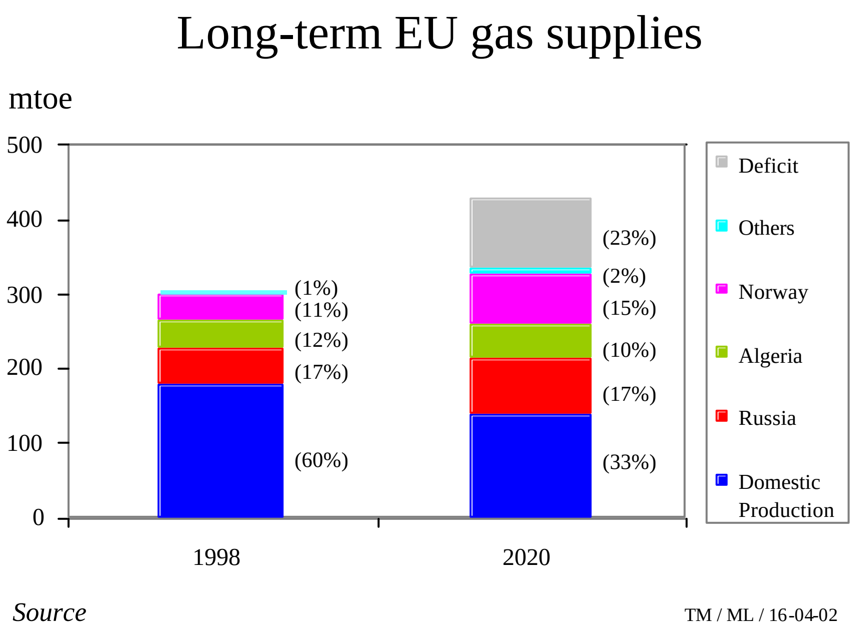

Figure 1 The EU Energy Directorate view of the European gas supply situation

3.4.2 Gas supply infrastructure

The Academy notes that in the recent initial response to the Government's consultation on UK energy policy, Lattice Group plc and its principal subsidiary, Transco,[7] state that the PIU was wrong to assume that there appear to be no pressing problems connected with increased dependence on gas, including imported gas from overseas. The consequences of the British gas market, like the rest of the EU, becoming increasingly dependent on imports from remote sources need to be addressed urgently. Furthermore, there is a failure to recognise the crucial nature of the supply infrastructure.

By 2010 a third or more of Britain's total gas requirement will need to be imported. Already winter supplies need to be supplemented with imports, as well as gas from

[7] http://dms.lattice-group.com/files/documentFiles/final_draft_consultation.doc

storage, even at average levels of demand. By 2020 the UK might need to import between 55% and 90% of its gas requirements[8].

In practical terms, for imports of 90% of requirements the equivalent of about five new pipelines each with the capacity of the existing Zeebrugge to Bacton interconnector would be needed (capital cost approx. £500m each), a nontrivial and expensive undertaking that also has to be coordinated with the rate of decline of domestic gas production. The Joint Energy Security of Supply Working Group (JESS)[9] first report predicts that with the current investment timetable, the UK could experience gas shortages from 2004/5 if a one-in-twenty peak winter demand condition was encountered.

Gas may be available to the EU from more distant sources, but with a need for a rapidly-increasing UK requirement for transit capacity across Continental networks at the same time as all EU countries are becoming more dependent on imports from remote sources, the construction of a considerably expanded pan-European gas transmission and distribution network is crucial.

Being on the Western extremity of Europe's gas transmission networks, the UK would be particularly exposed to inadequacies of such an infrastructure, but as yet no clear and coherent consensus exists on the key questions surrounding the planning, funding, regulation and capacity allocation for the enabling pan-European infrastructure.

The Government has an essential role in ensuring that the infrastructure planning and investment plus operation of the evolving European gas network reflects the expanding needs of the UK in the future years for secure supplies.

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[8] *"Review of Energy Sources for Power Generation"*, DTI Consultation Document, 25 June, 1998. Summary of report by Wood Mackenzie, Annex 3, (http://www.dti.gov.uk/enrev/3annex.htm)
[9] Joint Energy Security of Supply Working Group (JESS) First Report, June 2002. DTI and OFGEM

3.4.3 Storage

The UK's gas supply infrastructure was designed to meet a one-in-twenty peak winter demand. It is not a system designed against annual energy requirements. In the latter type of system gas storage is an essential support for security of supply. At present the UK has about one fifth the level of storage capacity needed judged by the levels required in Germany and France whereas in many continental countries typically some 25% of annual gas import demand is stored at the commencement of winter.

The Rough and Hornsea facilities operated by Dynegy Inc, which comprise about 80% of UK capacity, are already fully utilised. This situation arose because supplies from the North Sea fields have been able to provide the extra cushion needed by manipulating the production levels. Further studies need to be carried out to ascertain the minimum storage capacity required of the industry over the coming years, but using the 25% of import rule, a capacity of approximately 20 billion cubic metres would be required by 2020.

The estimated cost of large gas storage facilities (in the region of 100 million m^3) ranges from £0.25 to £0.65 per m^3 according to a 1999 UN/ECE[10] study; thus a total investment of £5 – £13 billion has to be considered to be necessary over this period. The concern is that storage provision to cover unusual and relatively rare events would not attract investment in a liberalised market based on the sale of energy. It is thus important that Government considers appropriate measures to ensure that storage capacity is constructed as required.

3.4.4 Liquefied Natural Gas (LNG)

From a security of supply point of view, there are a significant number of gas fields around the world where pipeline connection to the UK is not feasible and others where oil is the primary product and any gas produced has no market. With increased capacity to import LNG, the UK could take advantage of these supplies and thus be less reliant on imports through interconnectors where supply may be diminished by upstream demand.

[10] 'Underground Gas Storage in Europe and Central Asia - a study of the United Nations Economic Commission for Europe (UN/ECE)', by R.Sedlacek. 'Oil Gas European Magazine', 4, 1999, pp19-22.

Because of the abundance of North Sea gas, the UK has little infrastructure for LNG. While the economics of LNG are not currently attractive, the ability to import given further terminal facilities could be important to security of supply especially considering the current lack of interconnector capacity for importing natural gas from Europe.

Recommendations

Given the limitations of the existing gas supply networks in Europe, the envisaged scale of the future import demands, the engineering effort and the level of investment demanded, the Government should, with the EU Commission and other EU governments, address the strategic questions surrounding the planning, funding, regulation and capacity allocation for the enabling pan-European gas infrastructure

The Government should reassess the limitations of the market and market mechanisms as the basis for planning and funding new capacity that would lead rather than lag the needs of the network users, e.g. re-examine the effectiveness of capacity allocation market mechanisms, and the signals and revenues from them, as the basis for planning and funding the future development of transmission infrastructure.

The Government should consider appropriate measures to ensure that sufficient gas storage capacity be constructed as required to provide insurance cover for unusual and relatively rare events that would not otherwise attract investment in a liberalised market based on the sale of energy.

3.5 Nuclear

While nuclear power is often considered under electricity generation, in the context of security of supply, it is appropriate to consider it as a primary fuel.

As has been mentioned earlier, it appears that the PIU Review based its assumptions on the cost of new nuclear capacity on current installed capacity rather than new current modular designs which will show considerable economies of scale for a programme of new building. That there is added potential for evolutionary and new designs of reactors appears to have been acknowledged by recent announcements from the DTI. Efforts to reduce the regulatory burden involved in certification of new reactor designs are welcome and joint certification programmes with other nations would be a significant benefit increasing the potential sales for a given design and driving down unit costs. However, it is important that safety standards and principles developed in the UK over many years are not diluted in the process.

The PIU Review stated that there are advantages in *"keeping the nuclear option open"* in the light of the planned closure of about 9 GWe of nuclear capacity in the period to 2010. It is important to understand exactly what this phrase means since the necessary skills base and manufacturing capability are quickly lost without orders for new plant or the expectation of orders in the foreseeable future. The current DTI study on the Nuclear Skills Shortage is welcome, but the rate of loss of expertise means than action rather than studies is required sooner rather than later if the UK is not to rely on other nations maintaining their nuclear design and fabrication facilities so that at some time we may make a purchase from them. The Review also concedes that *"current licensing and planning procedures could add much to cost and be lengthy"* and that *"regulatory risk needs to be minimised wherever possible to ensure private finance"*. While a reduction in the regulatory burden would be welcomed by developers, the key to encouraging new nuclear build will be the unification of licensing standards over as wide a geographical area as possible to ensure that economies of scale can be achieved by commissioning as many as possible facilities to the same standards.

Expertise in the UK in building and commissioning nuclear plants will continue to diminish over time and it is conceivable that the UK will, at some point, be incapable of initiating a programme without relying on designs which are unfamiliar to the UK. The Westinghouse design which is being proposed by BNFL, the AP1000, has its roots in the US, and the other concept, currently being evaluated by British Energy, is the AECL Candu design from Canada. It should also be stressed that the current UK regulatory regime is unique, and so bringing in expertise from overseas inevitably means a significant "learning curve" must be climbed. Skills shortage, although acute in the field of nuclear engineering, will also be felt eventually in all areas of power engineering. In reality the UK will become a turnkey operator in an important field with all the limitations that entails.

The Review states in paragraph 7.81 *"There is no requirement, in system terms, to replace any particular generation technology with the same type of generation".* As environmental issues are an integral part of system considerations, it is essential that non-CO_2 emitting technologies be replaced fully with similarly non-CO_2 emitting technologies over and above any artificial targets for renewables. Otherwise, the replacement of nuclear capacity will lead to, at best a zero net gain in terms of emissions, and at worst be entirely replaced by gas generation.

There is a strong reliance in the conclusions of the PIU Review on scenario modelling and within these scenarios assumptions are made about the growth of demand and the rate at which technological solution will become available. The *Nuclear Option* is held in reserve to meet requirements should none of the main scenarios be realised.

Apart from the erosion of nuclear skills detailed above there is, of course, the issue of nuclear waste. The PIU Review does not envisage any new nuclear build until the nuclear waste issue has been resolved and accepts the Government's seven year timescale for this as set out in a recent DEFRA Consultation[11]. This arbitrary timetable will further handicap the industry's ability to provide the insurance envisaged. As an issue this is, in part, separate from the decision to commission new nuclear facilities as the major effort will be dealing with a legacy of old waste (currently stored on the surface) and decommissioning waste. Any decision to commission new nuclear plant, to compensate for missed renewable targets or otherwise, must be taken within the next few years. The time required to plan and build any large power station is significant and the value of nuclear power as an insurance will be lost if new plant are not online at the time that the possible short fall in generation capacity is experienced.

It should be emphasised that the technical aspects of waste management are not the issue here - it is the political, regulatory and perceptual issues which lead to difficulties. Dealing with nuclear waste is necessary irrespective of any decision on new build, but much progress has been made in this area. A decision to replace the whole of the current UK nuclear capacity with a fleet of new AP1000 units, for

[11] *Managing Radioactive Waste Safely, Proposals for developing a policy for managing solid radioactive waste in the UK*, September 2001, Department for Environment, Food and Rural Affairs, Department of the Environment, National Assembly for Wales, Scottish Executive

example, would add only around 10% to the existing volumes of waste requiring treatment over the 40-year design lifetimes of the reactors. Such are the improvements in waste generation which have been achieved in moving to such designs.

Recommendations

The government should establish the real benefits of nuclear energy to the economy in terms of its climate change objectives, security of supply and the provision of reliable supplies of electricity at ensured long-term stable prices. (This has not been done before).

The nuclear industry should be invited to indicate to Government the national requirements in terms of skills required and manufacturing capability for "keeping the option open". The cost of losing this ability and the feasibility of rescuing the industry at a later date should be determined.

The UK should enter into international Joint Certification programmes to reduce the regulatory burden on the nuclear industry.

The planning process should be streamlined to avoid unnecessary delays and cost particularly as the industry is proposing any new build be on existing sites.

A decision must be made on the management of radioactive waste rather than the prevarication that is damaging our ability to replace nuclear with nuclear at the expense of increasing CO_2 emissions to the environment.

3.6 Renewables

There are many different sources and many still unproven technologies considered under the umbrella of Renewable Energy. At present clearly hydro, wind and waste combustion have proven potential for making significant contributions to alternative energy supplies in the short to medium term. Biofuels might enter the picture in the longer term, especially in the transport sector.

For power generation, however, the picture for other technologies is unproven. Short rotation coppicing requiring 10% of the farmed area in the UK to be planted could ultimately support 9,000 MW, but it is unlikely that more than 1000 and 2000 MW could be achieved during the next ten years, i.e. 6.1 - 12.2 TWh (British BioGen) enough to satisfy only 1.5 to 3% of demand at that time. It would require the whole of Kent to be covered with coppiced willow, for example, to replace the output of Dungeness B power station on the Kent coast. The economic transport limitations on the size of the area of harvested land surrounding each power station would further restrict the size of the stations to between 40 – 70 MW (i.e. Dungeness B is equivalent to 17 to 30 small coppice willow-fired power stations).

With the exception of biomass and to some extent hydro sources, all renewable generation available in the UK is intermittent. This intermittency must be compensated by output from other generating plant or from storage systems. Other than in some hydro schemes it is not at present possible to store electricity in large quantities. There is a possibility that novel storage systems may be developed that would reduce somewhat the costs of stand-by, but it is likely always to be a significant factor in the economic performance of intermittent plant. For the moment these technologies are not available and it would be a serious risk to assume that they will become available at low cost. The DTI has initiated a study to ascertain the effects of high contributions from renewable energy sources to the electricity supply system and this initiative is to be commended.

Small variations can be met from balancing plant available to the National Grid Company (NGC) and the figures quoted in the PIU Energy Review (0.1p/kWh) refer to the additional operating cost needed to support the short-term hourly variations for 5-10% of energy being contributed by intermittent supply on the distribution network

(Table 7.1 of the PIU Review) based for the most part on retaining existing conventional generating plant. The UK currently has a good reserve capacity so a certain amount of intermittency can be accommodated, but if the Review recommendation of "*…a firm target of 20% of electricity to be supplied from renewables for 2020,* i.e.*… a further 39TWh"* is realised then with most of this target supplied by intermittent sources, the reserve plant fixed plus operating costs per unit of energy supplied increase substantially.

Wind generation is singled out in the PIU Report for major expansion. For onshore and offshore wind, the PIU recommends installation rates of 1-2 GW per year (name-plate capacity rating) for the period 2010-2020 (i.e.3 - 6 MW per day for ten years!). Taking into account the 7.5 GW capacity possibly constructed by 2010 the implication is that 17-25 GW of wind power capacity will be connected to the grid by 2020, supplied by perhaps between 10,000-15,000 wind turbines (the precise figure would depend on the size of turbines installed).

It is noted that a very considerable building programme would be required to commission windfarms at the rate recommended in the Review and questions remain as to whether the perceived environmental impact would be tolerated by the public or whether the Ministry of Defence would tolerate the implications for air safety, communications disruption and radar interference. The infrastructure necessary to fabricate, install and commission let alone collect and transmit the power is not trivial and much of it does not exist at this time. The costs of constructing and commissioning a wind turbine onshore are well known, but the transition to offshore installation introduces many additional demands and a significant increase in cost.

These are serious difficulties that need addressing. To assume that such a policy is feasible and desirable prevents serious consideration of realistic alternative policies.

Apart from these reservations a major problem is shown up in the wind data records covering the whole of mainland UK. Regardless of the capacity installed, there is a sizeable probability of no or very little wind blowing across the entire country. Figure 2 illustrates the situation where a hypothetical wind power capacity of 7,300 MW installed throughout the country is correlated with actual Met Office wind data. The most likely power output nationally is seen to be less than 200 MW.

If, say, 22,000 MW were installed, as mooted by the PIU, then this figure would rise to only approximately 600 MW. Perhaps as much as 75 – 85% of this wind capacity, i.e. of the order of 16,000 – 19,000 MW, would have to be available in the form of conventional plant capacity in order to provide back-up power when wind is light or absent. The fixed capital costs of this partly used plant would have to be borne by the consumer – possibly of the order of £1billion in the above case.

There are even higher probabilities of parts of the country being without wind for several hours, e.g. England, Wales or, less frequently, the whole of Scotland. With small levels of penetration, this would not be serious, but for large levels of wind capacity, these extra system costs would push the additional cost of wind generation substantially above levels quoted in the Review.

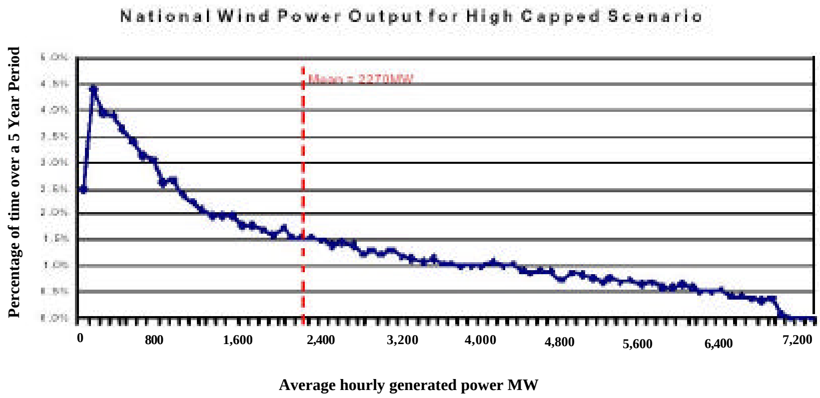


Figure 2 **Hourly Power generated v Percentage of time over five years from a hypothetical GB wind power capacity of 7300 MW installed over the whole country**

High levels of wind power capacity in the system could also cause severe stability problems as they have in Denmark, even though Denmark has the advantage of being stabilised by the connections to Norway, Sweden and Germany. On the assumption that the mainland UK system continued to be "stand-alone" all such large-scale alternative reserve balancing capacity would have to be installed in the UK and paid for in full. The analysis is complex but should be undertaken urgently before policy decisions relying on high levels of intermittent generators are taken. It cannot be emphasised too strongly that for the UK system intermittent generation capacity does not replace the need for conventional generation capacity, even though within the limits imposed by intermittency there is a degree of replacement of electrical energy produced.

A number of reports have suggested that using excess electricity at times of low demand to produce clean hydrogen could mitigate the intermittent nature of wind generation. This hydrogen could then be used directly as transport fuel or stored and used to power fuel cells to compensate when wind generation is not available. This scenario is theoretically attractive but will not be of any practical use until the UK has properly developed a hydrogen economy. Hydrogen as a potential fuel is discussed under section five on transport.

Tidal power is a technology that has been demonstrated in France for over 30 years, but not without problems (including environmental and cost) and only recently proposed elsewhere. It is an intermittent power source, but the power delivery of the tides is highly predictable and a barrier type installation gives some flexibility as to when electricity is generated within the tidal cycle. Although an expensive project, with attendant environmental questions, the Severn Barrage Project could, if built, contribute 17TWh of renewable electricity annually, or 6% of UK demand. A purely commercial case has yet to be made for a large tidal barrier such as the Severn Project, but current studies show that with a capital cost of around £9 billion, it could generate electricity at 5.5p/kWh. As a renewable source, this would avoid approximately 18million tonnes of CO_2 emissions *per annum*. A number of other smaller sites have been identified for tidal schemes such as the Humber and the Mersey. Additionally, serious consideration should be given to incorporating tidal electricity generation into future flood protection projects such as the replacement for the Thames Barrage.

Although at an earlier stage of development, tidal flow generation and wave power should not be written out of the picture.

Photovoltaics could, with encouragement, make a contribution to the UK's renewable energy target and the recent announcement that Government grants would be available for up to half the cost of installation is welcome. The nature of photovoltaics is that they are best suited to use on individual buildings and as such have an additional benefit of reducing stress on the local electricity grid. The UK significantly lags behind countries such as Germany on the roll out of photovoltaics but there is no reason why Germany's success could not be repeated here. Government support for photovoltaics and solar water heating could be signalled by encouraging their use in refurbishment of public buildings under Agenda 21.

Recommendations

Intermittent generation provides energy over time, but in the UK system does not replace the need for (conventional) generation capacity. Detailed engineering studies should be undertaken urgently before policy decisions relying on high levels of intermittent renewable generation are taken.

The study should determine the full costs of employing high levels of intermittent renewable energy sources (including the provision of standby plant, energy storage, upgrading of the transmission and distribution systems) and identify the impact on electricity prices.

It has been argued that traditional fossil fuel based electricity generators should incorporate the costs of environmental pollution into their pricing and that this process would make renewable generators appear more competitive. Likewise renewable generators should incorporate into their pricing the cost of maintaining and running reserve capacity required for grid stability and for covering demand when intermittent generators are not available.

4. Electricity Supply

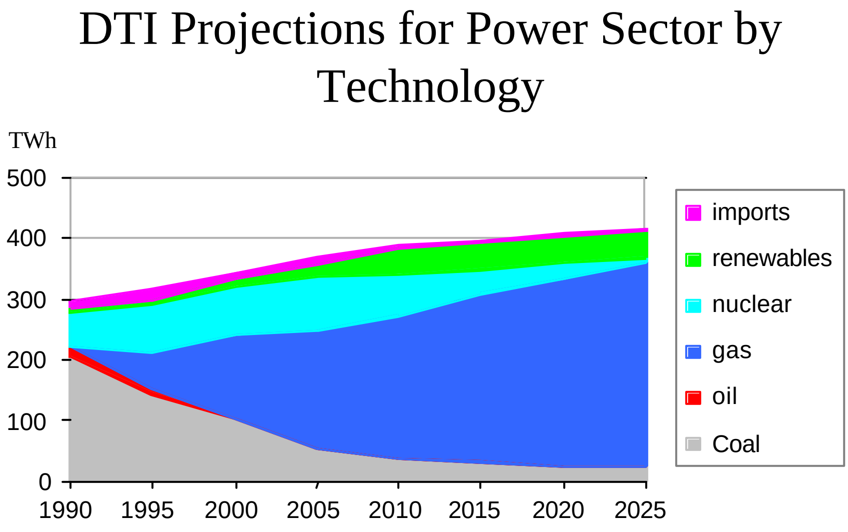
4.1 The DTI / PIU Scenario

In the UK by 2020 it will be necessary to replace 35GW of retired generation or 60% of present capacity. If renewables are able to take up 20%, the very optimistic target of the PIU report, there will still be a deficit of 40%. If gas is to replace the nuclear and coal stations at the end of their lives then CO_2 emissions will inevitably rise.

The "Business as Usual" scenario used in the PIU Energy Review leads to the division of electricity production shown in Figure 3. If this state of affairs is realised, electricity supply would be subject to a single fuel dependence to a degree never before experienced, being extremely reliant on stable gas supplies and thereby vulnerable to international market price behaviour and gas availability. An apparently comparable dependence on coal in a past era was mitigated by the availability of stocks of coal, which came from a domestic industry. Paragraph 3.4.2 has already expressed concerns over the availability of imported gas in the event of a 1:20 severe winter where supply could be cut to electricity generators at quite an early stage and paragraph 3.4.3 has identified the need for a significant increase in available gas storage. The amount of storage necessary to provide confidence of meeting such a demand needs to be determined and costed.

It is difficult to see how gas prices can remain low when the industry has such a large investment to make to satisfy demand growth. A doubling of today's prices appears the minimum needed to support the infrastructure. This uncertainty is key to the need for a long-term policy framework if a sensible balance between environmental, economic, security and social issues is to be maintained.

This scenario also represents the virtual end of nuclear generation for base load operation by 2025. Energy from renewables might appear to compensate partially for carbon neutral generating energy lost as nuclear stations are retired, but as discussed above renewable capacity does not replace nuclear capacity. As a result of the assumptions made concerning gas in particular, the nuclear question does not arise and is not debated in the PIU Review. Coal-fired stations would be phased out, although they may be necessary for stability and standby purposes. It is not a scenario developed with a full analysis of risk, alternative options or the technical requirements of operation. It is a market driven approach to electrical energy supplies coupled with a minimum development of renewable generation, i.e. a 10% limit by 2010 according to the Government plans.



Source: DTI's EP68 CL data - extended slightly to 2025

Figure 3 Sources of electricity generation based on PIU assumptions

The increasing dependence on gas means that electricity generation in the UK carries an extra risk with the nation's gas industry already no longer able to meet peak demand in a harsh winter. In such circumstances, possibly within five years[12], areas of the UK would be without power due to increasing reliance on imported gas and inadequate storage facilities. Under Lattice's emergency procedures set by safety regulations, power stations and large consumers would be the first to be cut off from gas supplies with domestic users the last to be affected. Gas-fired power stations in the South of England most distant from the main gas infeed points, which are at present in the North, would be the first to lose supply.

The reservations expressed by Lattice / Transco[13], however, concerning the future supplies of gas across an expanded pan-European infrastructure for delivery coupled with the considerable sums of investment needed over the next few years, including

[12] Financial Times, 15 April 2002
[13] http://dms.lattice-group.com/files/documentFiles/final_draft_consultation.doc

that for adequate storage in the UK, refutes the forecast of predicted growth of gas within the generation mix shown in Figure 3. This contribution to the debate based on expert knowledge of the gas industry is of great importance. If gas is not to be the secure and cheap supply of fuel for the next few decades, what will replace it as the mainstay of electricity supply let alone much CHP plant? Renewables such as wind cannot replace conventional plant in providing a reliable and secure power supply. At present with the environmental limitations placed on coal-fired stations plus the ending of oil-fired capability, new nuclear build is the only viable option available. In these circumstances the case for new nuclear build is seen as a necessity rather than an option.

Recommendations

Consideration needs to be given to the consequences of insecure gas supplies with particular reference to the necessity of secure power supplies.

Given the increasing penetration of gas in the electricity generation market, a thorough risk analysis should be completed on the various causes of gas supply interruptions and the effects on electricity supply.

Consideration needs to be given to the consequences of increasing gas supply prices with particular reference to the viability of other technologies and fuel supplies including nuclear.

Given the reservations concerning the limitations imposed by the direct connection of intermittent renewable energy sources to the public electricity supply system, greater emphasis should be given to the importance of developing and deploying energy storage technologies.

4.2 Electricity Supply Technologies

Because the emphasis of this paper is on security of supply, Nuclear and Renewables have been considered above in the context of primary sources and will not be discussed further here.

The PIU Energy Review appears to believe that economies of scale in the roll out of new gas powered generation will continue to be apparent. This is not necessarily the case. The revolution in technology that led to the building of CCGT power stations over the last ten years began in the early 1980s. The plant was forced into the market place before the development work had been completed and consequently there were problems with vibration, plant integrity and reliability that took a further ten years to solve. For this reason such gas turbines have not been designed beyond the current maximum output of some 250MW. This is a real demonstration that new technology needs a development period.

Most technologies require five or more years over which developments occur before the quality and performance demands necessary for power supply are met. This situation applies equally to renewable energy exploitation where many new engineering and environmental conditions have to be understood in establishing the design and maintenance requirements. Offshore wind, wave, tidal stream, photovoltaic, biofuel and micro-CHP generating plants are but examples where many new challenges have been, or will be, identified. Likewise large stationary fuel cell systems which promise access to different fuel sources such as hydrogen will need several more years of development.

The PIU Report assumes that the cost of wind generators will continue to fall as the technology develops. This assumption is based on rather simple extrapolation of performance in the past. Wind turbines are relatively simple devices and the scope for continually falling costs over the long-term must be speculative. To count on this continually improving performance is to run a substantial risk. As the best sites are developed so the output from a given design will fall and though the cost of the turbine may remain the same, the specific cost of the output will rise.

4.3 Carbon Sequestration

Given the concern over climate change, it is surprising the Review gave little regard to carbon sequestration either as a technology in its own right or as an additional cost for energy in the future. Carbon sequestration would be most effective in conjunction with large, single point emitters, so would be more applicable to the electricity generating sector than, say, transport. The cost of CO_2 sequestration was quoted in the Review as being in the order of 3-4.5p/kWh before any possible benefits from enhanced oil recovery are taken into account. A number of organisations have recently been questioning the long- term viability of geological sequestration, and more research should be carried out on this area. It should also be remembered that the process of sequestering the carbon involves significant energy use thus reducing overall efficiency. Carbon sequestration therefore has environmental benefits only being counterproductive to security of supply aims.

On the world stage, coal is likely to remain an important primary fuel. With the benefits of potential exports through the Kyoto Protocol Clean Development Mechanism (CDM) and security of supply benefits in the UK, research into and demonstration of clean coal technology could be of significant benefit.

Recommendations

> **Ministers should consider the alternative scenarios for electrical energy production by 2010 and 2020 to protect against the situation where renewable energy does not become available at the desired rate.**

4.4 Electricity Supply Infrastructure

4.4.1 Summary of developments

Developments in the electricity sector from 1990 onwards, from the power pool through to the more recent New Electricity Trading Arrangements (NETA), have transformed relations between the different players in the electricity market. The transformation has brought huge benefits in terms of costs to consumers. However, it has relied on an existing infrastructure built up over the period 1965-1985, designed by and for the use of a publicly owned monopoly. The transmission and distribution (132kV and below) systems were designed for large centralised generation. The move to a distributed generation system including CHP and renewables with large numbers of small generators being connected to the distribution and not the transmission system poses additional problems which have to be solved if the quality and security of supply expected by the consumer are not to deteriorate. It is noted that the DTI and OFGEM are working together to address the issues of distributed generation. The quality of supply is particularly important when operating modern electronic systems. The cost of upgrading the existing infrastructure to meet these new demands is believed to be significant but needs to be quantified.

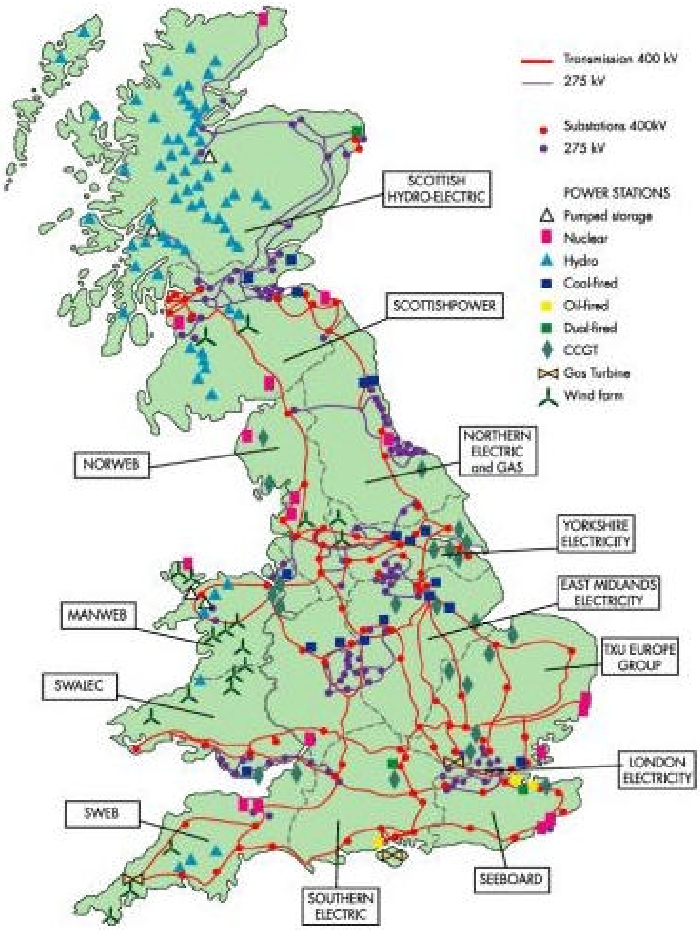
4.4.2 High-Voltage Grid

The PIU Energy Review identified infrastructure provision as a key issue. In the long-term, as noted above, hydrogen could become an important energy carrier, with major infrastructure requirements for storage and distribution. Equally, the large-scale development of smaller scale distributed electricity generation, including renewables, will be enabled only by substantial reinforcement of the electricity transmission and distribution network. Arguably, the liberalisation drive has resulted in the relative neglect of infrastructure issues. As we move beyond liberalisation, and seek step changes in the energy system, infrastructure will move up the agenda.

Figure 4 illustrates the lack of transmission infrastructure in the North-West of Scotland where the largest wind and wave resources in Europe are to be found. With the demand for power being highest in the south, the need for greater transmission capacity linking Scotland to England is also apparent. These problems are well recognised as are those associated with embedded generation in local distribution networks.

The Scottish electricity transmission system needs further study, because it is here that the Danish wind problems (instability in the grid arising from lack of control on the numbers of generators and hence unfettered penetration of the market) will probably occur first in the GB system. The question of the tolerable maximum penetration level of distributed generation in the UK market needs to be answered. With plans to exploit the Scottish wind and wave resources over the next few years coupled with the planned closures of large coal and nuclear stations before 2011, the additional question arises of the installation of reliable base capacity to replace that which is to be withdrawn, or other answers found (e.g. energy storage on an unprecedented scale).

The treatment of the electricity distribution system by the PIU Energy Review appeared to be concerned purely with its operation as part of a liberalised market. Although it was acknowledged that additional transmission capacity might be needed between Scotland and England, the only concern appeared to be over regulating access to a new interconnector with little concern as to how such a strategic project could be funded without placing undue burden on consumers or transmission companies. If there were an objective to reach a given amount of renewable generation, it would be perverse to wait for the price of electricity to rise to such an extent that such strategic projects become financially viable.



Source: UK Electricity Association's website

Figure 4 The GB Electricity Grid

4.4.3 Storage

There is very limited potential for "electricity storage" with pumped water storage schemes such as Dinorwig currently being the only available technology in the UK although compressed air schemes have been demonstrated in Germany. Fuel cell or chemical storage, such as that being developed by Innogy, will course become available in due course but at a significant cost.

While "electricity storage" is in its infancy as a technology, the current electricity system does not require it except for rapid response to peak demands. However, as more intermittent generators are added to the system it is conceivable that it will become an indispensable part of the system and research should be continued.

As discussed under renewables (para 3.6), there could be scope for the generation and use of Hydrogen as an energy vector in the context of a hydrogen economy. Hydrogen generated using excess electricity from intermittent generators at times of low demand could either be used as a transport fuel or stored and used to generate peak shaving electricity.

4.4.4 Interconnectors

Experience on the Continent, especially in Denmark, has shown that grid stability can be adversely affected when the penetration of intermittent renewables reaches about 15%. This grid stability (frequency and voltage) is to some extent a separate problem to that of security of supply and will be exacerbated by the proliferation of smaller, distributed generators.

The UK Electricity system is, apart from one interconnector to France, currently isolated and under these conditions has to control its own stability without the luxury of being able to "lean on" neighbouring systems.

A number of additional interconnectors are being proposed and investigated, in particular with Norway and the Netherlands. Synergy between the UK System and Norway's is high in that base load can be exported to Norway to preserve the potential of Norwegian large hydro plant and peak shaving hydro can be imported to the UK when required. Although a potentially expensive project, the synergy means that it would have benefits for both countries beyond pure security of supply issues.

Recommendations

With limited system compensation capacity between England and Scotland the Scottish electricity system needs further study in view of the planned timetable of closures of major coal and nuclear stations. If replaced then decisions need to be taken in the near future. The substantial development of new randomly intermittent renewable wind and wave resources is not seen as a practical engineering solution.

More generally a comprehensive engineering appraisal needs to be carried out to determine the tolerable level of distributed generation from intermittent sources within the systems of Scotland and England and Wales, and to explore the opportunities of greater connectivity with the Norwegian grid.

4.5 Combined Heat and Power (CHP)

In order for CHP schemes to be viable, they must be situated close to a customer for their heat output, heat usually being the more important output. Electricity is thus a by-product and is valued as spill under the New Electricity Trading Arrangements (NETA). Generally electricity generation efficiency is compared with that of electricity plus heat generation in a CHP plant, an error made also by the PIU. The real energy conversion efficiency of modern combined cycle gas turbine (CCGT) plant plus heat-only boilers can be in the region of 65 -75%, a figure comparable with many CHP plants.

CHP is a generic technology that can be employed with almost any fuel source although natural gas tends to be the fuel of choice. There are already security of supply concerns attached to natural gas, so although expanded use of CHP has environmental benefits, the security of supply benefits are not so clear.

There are currently significant obstacles to the implementation of CHP schemes in the UK. Grid and Distribution Code obligations concerning response requirements can force the generation off the system without regard for the consequences to the steam or heat customers. Despite Government encouragement of “good quality” CHP, CHP has been disadvantaged by NETA and low wholesale price of electricity which NETA encouraged. According to DTI figures reported in the Financial Times (July 11th 2002), installation of new CHP capacity fell to just 38MWe in 2001 from more than 800MWe in 2000. There are benefits to industrial users for installing and using CHP, but after Climate Change Levy Agreements have been taken into account, the cost of energy to industry as a percentage of overall costs has been so low, that the investment in CHP has not been commercially viable. In short, CHP is not adequately rewarded for its benefits at this time.

Micro CHP in an individual building or dwelling has potential in the UK for both improving buildings' overall efficiency and reducing stress on the local electricity supply network. However, this is a relatively new technology where not all the technical problems have been solved and the industrial base has not yet been developed to supply and maintain the potential mass market.

The Government's Strategy for Combined Heat and Power to 2010 Public Consultation Draft recently published by DEFRA, acknowledges that micro-CHP will only make a minor contribution to Government targets over the period to 2010. However, the levels of penetration that are envisaged, ("1 million systems could be installed by 2010") is, given the current state of the industry, unrealistic. In fact, the micro CHP industry is currently little more advanced than a technological cottage industry and might even struggle to supply the 6,000 units required for trials by 2003.

The PIU Energy Review made few recommendations concerning CHP beyond minor modifications to market regulation to provide a more favourable environment for CHP. Whilst this recommendation is welcome, the core problem for commercial investors in CHP appears to be the fact that the profit from electricity sold back to the grid is not high enough to justify the additional cost of CHP over traditional plant. Market mechanisms and regulation have simply added a further burden. The PIU Energy Review's recommendation that "*consideration should be given to locating responsibility for energy efficiency and CHP policy with the other aspects of energy policy*" (para 8.19) is welcomed as is the recommendation that an Energy Research Centre be set up (para 8.21).

Recommendations

Given the Government support for CHP development an engineering appraisal should be carried out into the state of development of micro-CHP devices including fuel cell based systems and their prospects for installation and operation as envisaged.

5. Transport

5.1 Energy use

The average annual distance per person travelled increases with increasing wealth. As wealth increases people choose faster modes of transport. Travel in the UK has increased exponentially over the last 50 years and this trend is likely to continue with minor bumps due to short-term economic fluctuations. Significant improvements in engine efficiency have been negated to a certain extent by additional safety and personal options, which have increased the weight of the vehicle and increased the demand for extra power.

Transport's share of total energy use has increased rapidly and currently accounts for 42% of total energy use in the UK[14] and overwhelmingly depends on petroleum. Road transport accounts for 75% of UK petroleum demand with air transport accounting for nearly 15% and growing very quickly. It is therefore surprising that so little was said by the PIU Energy Review on such a dominant energy user, and so few issues were raised for discussion in the Key Issues for Consultation recently published by the DTI.

Sustainable mobility is fast becoming a key political issue and motorists a strong lobbying group.

5.2 Transport Technologies

Alternative renewable energy sources appear to have very little to contribute to the transport scene which is likely to be liquid hydrocarbon dominated for the foreseeable future. The 'technological window' (the time from first introduction into service to replacement of the fleet) for substantially changing the technology in road vehicles, is about 10 years for automobiles, and about 40 years for trains: in the latter case a successful marriage with appropriate infrastructure is critical if improved performance is to be achieved. In the case of the automobile industry, a huge infrastructure now exists to provide fuel from the pump and this aspect is addressed below under Transport Infrastructure.

Blending of biofuels such as alcohol with petrol has been investigated and could technically be accommodated at levels of up to 10%. Alternative fuels made from

[14] Digest of UK Energy, DTI, 2000

agricultural products could be a compulsory component of motor fuels in the European Union under recent proposals made by the European Commission. The proposals would ensure that, from 2005, at least 2 per cent of fuel used in transport came from biofuels, made from plants oils, sugar beet, cereals and even domestic waste. The mandatory minimum would rise to 5.75 per cent by 2010.

While biofuels have the advantage of being domestically made and less environmentally damaging, they remain expensive to produce. The Commission calculates the additional cost of biodiesel over conventional oil-based diesel at about €300 ($270) per 1,000 litres, with an oil price of $25 a barrel.

Although the Commission has recommended the reduction of duty on such biofuels to increase their market penetration, critics of such programmes including the UK Petroleum Industries Association[15] have argued that the potential energy content of crops suitable for production of biofuels is low in comparison to other energy crops that can be grown in the UK. Other countries, such as Brazil, are better placed as producers of transport biofuel.

5.3 Transport Infrastructure

As was mentioned above, the "technology window" for changing the current fleet of road vehicles would be about ten years. If a move towards a new fuel such as hydrogen were advocated then the additional time and engineering costs of converting the fuel supply infrastructure must also be considered. Currently, hydrogen is an expensive fuel that is mostly derived from the reformation of hydrocarbons. While the technology for a hydrogen-powered car is available, the industrial capacity to produce the required hydrogen from non-CO_2 emitting sources is not. Clean hydrogen production is linked to electricity generation and could form the basis of energy storage coupled with intermittent renewable generators and this aspect is addressed earlier in the paper. At present the main motivator for a move to a hydrogen economy - the drive to reduced CO_2 emissions - is dependent on a carbon-free source for the power needed to generate the hydrogen. This means using all the carbon-free power the UK can muster - nuclear and renewables together - particularly since a hydrogen economy would imply a major increase in the overall demand for electricity.

[15] http://www.ukpia.com/pdf/Biofuels%20RIA%20-%20UKPIA%20response.pdf

As far as Energy Policy is concerned, there would be an argument for promoting high speed rail links and rail electrification in conjunction with low or non-carbon electricity generation. However, this is probably an area where Transport Policy should be complementary to Energy Policy rather than the other way around. Provision and planning of road infrastructure would fall into a similar category.

The PIU Energy Review appears to accept fuel switching, probably to hydrogen, as inevitable in the long term but is unwilling to recommend early action or signalling that this is the Governments preferred solution. It acknowledges the *"chicken and egg"(para 7.97*) situation between vehicle manufacturers and the fuel supply industry but, like many other papers on the subject, places a strong emphasis on the development of fuel cells as a precursor to widespread use of hydrogen. If equal emphasis were placed on the use of intermediate technology, such as hydrogen burning internal combustion engines, the fuel suppliers would be more likely to provide early hydrogen infrastructure. Indeed, as hydrogen becomes more available, it could quickly replace the current intermediate technology of compressed natural gas use in transport.

Recommendations

The Government should consider the benefits in emission reduction of further electrification schemes for public transport including railways and urban systems.

Major Research Development & Deployment support should be given to hydrogen production, storage (including chemical storage) and delivery systems whether for transport purposes or for electricity generation. Such developments should rank as being at least as of equal significance as the Government's renewable energy and emission reduction policies.

Annex 1: Group Membership

This report was prepared by the following group of Fellows and approved for publication by The Academy's Standing Committee for Engineering.

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