REF
RENEWABLE ENERGY FOUNDATION

Response of the RENEWABLE ENERGY FOUNDATION to the 2006 Energy Review

Our Energy Challenge

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List of Contents

LIST OF CONTENTS **2**

THE RENEWABLE ENERGY FOUNDATION **3**

ABOUT THIS RESPONSE **4**

SUMMARY OF RESPONSE **4**

1. THE ELECTRICITY SUPPLY INDUSTRY **9**

2. THE CLIMATE CHANGE POLICY OF THE UNITED KINGDOM IN INTERNATIONAL CONTEXT **12**

RENEWABLE ENERGY AND GERMAN CLIMATE CHANGE POLICY 12

3. FLAWS IN THE UK'S RENEWABLES OBLIGATION **19**

4. GERMAN AND DANISH EXPERIENCE OF WIND ENERGY **25**

GERMANY 25
Key Challenges Presented by Wind Energy *25*
Wind Energy Cannot Replace Conventional Power Stations to Any Significant Degree *26*
Wind Forecasting is Inaccurate *27*
Grid Expansion is Required *28*
Conclusion *29*
DENMARK 29

5. ARE GERMANY AND DENMARK RELEVANT TO THE UK? **33**

THE SUSTAINABLE DEVELOPMENT COMMISSION ON WIND POWER 33
GRAHAM SINDEN, THE UNITED KINGDOM'S WIND RESOURCE 35
UNITED KINGDOM ENERGY RESEARCH CENTRE 40
Capacity Factor and the Likelihood of a Distributed Wind Carpet *42*

6. REALISM WITH REGARD TO RENEWABLE ENERGY FUTURES **45**

7. CONCLUSION **48**

APPENDIX 1: MICHAEL LAUGHTON, "RENEWABLE ENERGY AND THE POWER MARKET BOTTLENECK" **49**

INTRODUCTION 49
SYSTEM LOAD FACTOR 50
RENEWABLE ENERGY AND A VARIABLE SYSTEM POWER DEMAND 51
CONCLUSION 52

APPENDIX 2: MICHAEL LAUGHTON, "OBSERVATIONS ON THE UKERC REPORT ON 'THE COSTS AND IMPACTS OF INTERMITTENCY'" **54**

The Renewable Energy Foundation

The Renewable Energy Foundation (REF) is a registered charity which aims to raise public awareness of the issues surrounding renewable energy and to encourage the creation of a structured energy policy for the United Kingdom which is both ecologically sensitive and effective. We recognise that global circumstances make it increasingly difficult for the government to create favourable conditions to facilitate market provision of clean, economically priced energy with adequate and diversely sourced supplies. By contributing a diversity of technologies to an overall portfolio that is itself balanced renewable energy could have a very important part to play in ensuring that the United Kingdom is buffered as far as is possible against future crises. **The Foundation wishes to ensure that our national energy debate leads to a diverse application of renewables within a balanced system of energy provision.**

REF is able to draw on a very wide range of expert industry and academic advice, both formally and informally, but synthesizes this from a perspective which is independent of any commercial or political interest.

However, our position is principled, and we are part of a growing consensus that the current Renewables Obligation subsidy system is flawed, and far from bringing on a range of technologies is actually constricting growth and innovation in all but a few areas, areas which, in fact, are no longer in need of subsidy support.

REF has contributed to recent debate by commissioning and publishing reports from leading consultancies and experts thus providing an independent and authoritative source of information. We have been particularly prominent in ensuring that evidence from Europe on the deployment of renewables is better known, and we draw particular attention to our submission to the Stern Review of the Economics of Climate Change.[1] We have also disseminated information from E.ON Netz, the major grid operator whose experience of large scale wind carpets is unmatched. In addition the Foundation has supported definitive research on the performance characteristics of the wind carpet in West Denmark.[2] The Foundation has an ongoing research programme, which is now maturing and gathering pace. In the coming year we intend to commission major studies ranging across topics including portable biomass generation for remote areas, the application of energy storage to mitigate extreme spiking from offshore wind, energy from waste, non-transport applications of biodiesel, and the application of domestic renewables (for example solar thermal appliances) in conjunction with energy saving and efficiency projects that will bring rapid and manifest benefits to householders.

In all these areas we are endeavoring to ensure that our policy recommendations are grounded in realistic projections which avoid the understandable but often

[1] Available from the Foundation's website: www.ref.org.uk.
[2] For further information please see the Foundation's website: http://www.ref.org.uk

counterproductive overexcitement which is attendant upon this rapidly growing and extremely important sector.

About this Response

In view of the very large numbers of responses likely to be submitted to the Energy Review, the Foundation has restricted itself to a document commenting only on those areas in which it believes its views should carry particular weight. These areas bear heavily on several of the questions outlined in the consultation,[3] and as appropriate we shall make reference to these issues, but we shall not attempt to address all the matters outlined in the DTI's document. An outline of our position, but drawing further inferences, is given below in the "Summary of Response". Further discussion of relevant issues, explaining the background to our Summary, is provided in the six sections which follow.

Summary of Response

1. In view of the fact that the United Kingdom produces only 2% of the world's emissions, a proportion which is falling due to growth in the developing world, it is axiomatic that **our climate change policy should aim to provide a <u>qualitative</u> rather than a *quantitative* example**.
2. It is only by providing an ***economically*** compelling lead that we can hope to draw the developing world with us, and consequently **security of supply and affordability must be the foremost goals of our policy**. <u>Self-harm in the United Kingdom will be a poor advertisement for clean energy.</u>
3. Premature or idealistic deployment of renewables will fail to contribute to an economically compelling example and will also fail to ensure a healthy future for the renewable energy sector.
4. There is an optimistic tendency at present, prevalent amongst non-engineers and the environmental lobby, to claim that a predominantly or wholly renewable energy future awaits us, and consequently that our current task is to find an interim solution. This view is particularly widespread in relation to electricity. However, it is extremely unlikely to be correct. **The scope for renewable energy, particularly in electricity, will almost certainly be severely constrained either technically or economically, or both.**
5. Misrepresentations of the role of renewables are causing widespread public misunderstanding of the issues facing the government in its energy review. **The Foundation judges that renewables are being asked to deliver more than is feasible, and that the sector is being set up for inevitable failure.**
6. We urge the government to do everything in its power to ensure that the public understands that while renewables are desirable, and indeed essential

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[3] DTI, *Our Energy Challenge: Securing clean, affordable energy for the long term* (Feb. 2006), 7.

(particularly in heat and transport), their contribution in the short term can only be modest, however valuable, and is likely to remain so.

7. The popular "renewables v. conventional energy" debate is grounded in a false dichotomy. Renewables, even firm generating renewables, including very large projects such as the Severn Barrage,[4] cannot obviate the need for conventional generation in strategically significant quantities in the short, medium and probably longer term.
8. Unreasonable and aspirational visions of a **predominantly or wholly renewable energy future should not be permitted to distort contemporary policy by encouraging the belief that our present need is to construct a short-term or bridging strategy.** On the contrary, as a matter of social responsibility the government should aim to produce an energy system which is *robust in the long term* and thus insures the UK and its people against risk. Renewable energy will play a part in this portfolio, and the UK should certainly be in a position to take advantage of breakthroughs in the sector, but **there is nothing to be gained for the UK and its people, or for the world at large, by exaggerating the likely role of renewables or banking on rapid technological progress**.
9. The Renewables Obligation system of indirect subsidy for renewable electricity is flawed, is in a state of protracted failure, and is resulting in a significant misallocation of resources. **The RO's principal defect is that it hyper-incentivises low capital cost renewable technologies irrespective of intrinsic merit**. Thus, investors are almost exclusively focused on onshore wind at the expense of higher merit technologies such as
    i. Biomass, which is fully dispatchable.
    ii. Tidal stream and tidal barrage and lagoon systems, which are predictable with a high degree of certainty, and in the case of lagoons could offer some degree of energy storage.
    iii. Offshore wind, for which capacity factors are much higher and for which locations in proximity to centres of load can be more readily found. **We fully endorse the finding of a recent report for the British Wind Energy Association that a "New Policy Impetus" is needed to ensure that offshore projects fulfil their potential.**[5]
10. The intention of the Renewables Obligation is to levy a subsidy on the consumer to fund support for immature technologies that would otherwise not be brought forward to market. However, it has provided excessive and to some degree undeserved support to two near-market technologies, namely:

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[4] The Foundation acknowledges ecological concerns with regard to the Severn Barrage concept, and believes lagoons may be a viable way of realising this resource without damaging environmental consequences.

[5] BVG Associates and Douglas Westwood, for the BWEA and Renewables East, *Offshore Wind: At a Crossroads* (April 2006). Available from http://www.bwea.com/pdf/OffshoreWindAtCrossroads.pdf.

  i. Landfill Gas (though this is not a growing problem since available sites are now largely developed), and
  ii. Onshore wind, which in good locations, can now generate electricity at costs of the same order of magnitude as conventional plant.[6]

11. **The degree of over-support for near-market renewable technologies is significant in degree,** and is tending to suppress growth in other renewable technologies, some of them capable of firm generation.

12. Oversupport for onshore wind is still more undesirable since wind is, relative to firm renewables, a lower merit technology, a fact now richly evidenced in empirical data from Germany and Denmark. This evidence shows that:
    i. The degree to which wind power can replace conventional capacity is very low (German grid operators estimate that 48,000 MW of wind will replace only 2,000 MW of conventional plant), with implications for overall system costs.
    ii. Large scale expansion of the grid is required solely to mitigate grid balancing difficulties consequent on wind.

13. Achieved capacity factors for onshore wind in the UK are not promising, and suggest very significant regional variations, with important implications relating to the likely concentration of the UK's wind carpet, and its remoteness from centres of load.

14. Theoretical arguments proclaiming the irrelevance of German and Danish experience are misleading, and exaggerate the distinctions between the UK wind resource and the likely behaviour of the UK wind carpet. We note with concern that several of the most misleading of these studies have been issued by government-funded organisations, or with the DTI's imprimatur, or accompanied by press releases including approving statements attributed to the Rt Hon Malcolm Wicks, MP, Minister for Energy. In our view and that of many other expert analysts, these documents are potentially misleading.[7] We are deeply concerned that the Minister has been drawn unwittingly into false and risk-prone positions. **If these studies are allowed to direct policy the resulting energy future for the United Kingdom would be both sub-optimal and prone to deliver unpleasant surprises.**

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[6] PB Power, *Powering the Nation: A review of the costs of generating electricity* (Mar. 2006), pp. 18-21.

[7] We are particularly concerned by the quality of guidance currently being inferred from the following studies: 1. Sustainable Development Commission, *Wind Power* (May 2005); 2. Graham Sinden, *Wind Power and the UK Wind Resource* (Environmental Change Institute (for the DTI): Oxford, 2005). 3. Graham Sinden, "Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand", *Energy Policy* (2006); 4. Robert Gross, et. al., *The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network* (UK Energy Research Centre, Apr. 2006).

15. Realism with regard to renewables, and other technologies, is crucial since **an energy policy which is not manifestly grounded in practical self-interest will deter global investment in the United Kingdom's economy,** with disturbing implications for employment and the well-being of the population.
16. Renewables in general are, unfortunately, a relatively expensive means of reducing CO_2 emissions, and applications are necessarily limited in scale. The United Kingdom's climate change policy must take precedence over its renewable energy policy, and therefore **it is of vital importance that we concentrate on planning an economically compelling system of clean and efficient conventional energy provision, particularly in electricity, and with that foundation assured then, and only then, seek to add as much renewable energy as can be economically and sustainably generated.**
17. The Foundation acknowledges widespread public concerns with regard to the operation of nuclear power stations, and the safe disposal of waste, but believes it irresponsible and unhelpful to propose renewable energy as an alternative. It is a matter of practical logic that if the UK chooses, after public debate, and via the democratic process of parliament, to reject the nuclear option, the country's future electricity system will have to depend on a portfolio of conventional plant overwhelmingly comprised of gas and coal. Irrespective of the amount of wind added, this conventional system cannot be smaller than peak load, plus ten per cent safety margin.[8] Firm renewables such as biomass and tidal would be able to reduce the coal and gas fleet in this scenario, but their contribution would be necessarily limited.
18. In order to enhance the contribution from non-firm renewables **we urge government to ensure that developers are encouraged, by variable reward within the subsidy system, to design electricity storage into their plans for stochastically intermittent or variable renewable**s, thus providing "in house smoothing" of output for projects such as offshore wind, which, as noted above, have intrinsic merits such as high capacity factor and potential location in proximity to demand centres.
19. Regardless of whether the UK decides to renew the nuclear build or not, coal and gas will be a major component in our portfolio for many decades to come. This, and the prospect of very rapid growth in fossil fuel electricity generation in the developing world, indicates that **the United Kingdom would contribute powerfully to global climate change policy by ensuring that it contributes vigorously to the application of carbon capture and sequestration technologies**. This is a position that the Foundation has advocated from its inception.

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[8] Michael Laughton, "Power Supply Security with Intermittent Sources: Conventional Plant Capacity Requirements", *Power in Europe*, 460 (10 Oct. 2005).

20. Resulting from the Renewables Obligation distortions and misdirections of resources within the renewable electricity sector are having a spill-over effect on the rest of the portfolio, where there is little incentive for conventional plant development upon which the future prosperity of the UK will depend.

21. The excessive incentive of the Renewables Obligation has also resulted in undue concentration on electricity generating renewables and has drawn investment away from renewable and innovative alternative technologies for heat and transport.

22. We welcome the publication of the recent DTI strategy document on microgeneration,[9] and trust that this heralds a period of novel emphasis on combining renewable and alternative energy generation with energy saving and low-energy innovations throughout our society. **If approached with realism and prudence microgeneration technologies can make significant contributions to reducing national and personal energy consumption in the long term, thus enhancing competitiveness and domestic prosperity**.

23. Alternative electricity generation which lies outside the Renewables Obligation, such as Energy from Waste, is comparatively neglected. Given the future challenges of waste disposal and the potential generation from Municipal Solid Waste alone (ca. 25 TWh of firm electricity) this is as regrettable as the suppression of firm renewables.

24. **The Renewables Obligation is harming the United Kingdom, weakening its climate change policy, and blighting the future of the renewable energy sector. As a matter of urgency the RO must be revised**.

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[9] DTI, *Our Energy Challenge: Power from the People* (March 2006). Available from http://www.dti.gov.uk/energy/environment/microgeneration/strategy.shtml.

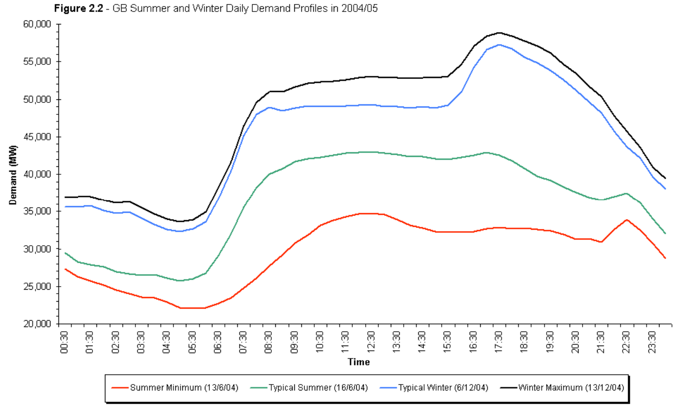
1. The Electricity Supply Industry

Many areas of the energy supply industry, such as coal, oil, liquid transport fuels, and biomass resemble straightforward commodity markets with a tangible physical product which is delivered to the customer by simple physical transport and then converted by the customer into work or services. The product can be stored, repackaged, and delivered in a variety of ways, and once delivered to the customer the rate of consumption is the responsibility of the consumer and of no further relevance to the supplier. Gas, when supplied via the gas grid is somewhat different in that pressure must be maintained at stable levels to meet customer demand. The supplier thus must monitor demand, and retains an interest and is under a continued obligation. However, gas can be stored in meaningful commercial volumes, and any pressure drop in the grid met by a rapid call on reserves.

In contrast to gas, electrical energy cannot currently be stored on the commercial and industrial scales relevant to grid balancing. The electricity supply industry must continually track and follow demand on an instantaneous basis with very little variation in voltage and system frequency. The precision of these demands may be gauged by the fact that NGT is required to maintain the latter to within 1% of 50hz.[10]

The curves representing maximum and typical daily demand in winter and summer are represented in the following well-known chart taken the NGT *Seven Year Statement*.

Figure 2.2 - GB Summer and Winter Daily Demand Profiles in 2004/05



The special relationship between the electricity supply industry and its customers makes the provision of electrical energy more akin to a *service* than a standard system of commodity provision, and this has a powerful bearing on our evaluation of proposals to add plant to the system.

The most salient and heavily weighted of these is the quality differential between:

i) Plant types which can provide a very strong guarantee of power provision (i.e. energy at a certain rate) and

ii) Plant types which, either individually or in aggregate, can provide only a weak guarantee of power provision.

[10] http://www.nationalgrid.com/uk/Electricity/Balancing/services/mandatory/

Within the first category we find most conventional thermal plant (coal, gas, oil, biomass for examples), nuclear, and hydro. For certain aspects of the service there is a gradient of quality according to the degree to which such plants can economically and conveniently follow fluctuations in demand. The current generation of nuclear plant in the United Kingdom, for example, is relatively inflexible. Coal plant is relatively flexible, but has a longer response time than Combined Cycle Gas Turbines, which in turn are less responsive than Open Cycle Gas Turbines.[11] Since the matching of supply to demand requires load following in different timescales, these differences determine the suitability of plant for any particular purpose. However, taken together “dispatchable” power plant forms the backbone and bulk of our electricity system at present. For some time now, baseload power has been provided for the most part by nuclear generation. Coal has followed load in recent years, because of price signals making it the marginal plant, but gas is increasingly used for this purpose, partly because of its flexibility. Due to rapid price increases in recent months gas is probably the principal load following plant at present and is very likely to be the dominant load following plant for the foreseeable future.

While it is common to say that we have an energy problem, in the electricity supply sector it is at least as appropriate to say that we have a “power” problem, in the technical sense of “power”. The UK portfolio of dispatchable electricity generating plant is ageing, and must be replaced. Estimates of this decline vary, but one prominent figure offered by the DTI is that just over 20 GW of coal and nuclear will have closed by 2025.[12] or some 25% of the current fleet Other commentators indicate that the problem has dimensions additional to simple closure:

> *Much of the generation capacity is old and becoming obsolete. A combination of internationally agreed environmental regulations and increasing costs will force the closure of most of the steam plants within the next 10 years. By 2020, only one nuclear power plant – the almost 30-year-old Sizewell B – will still be in operation, the oldest of the steam plants will have been working for five decades and the first generation of CCGTs will be approaching their 30th birthday.*[13]

On both estimates there are serious shortfalls in dispatchable *power* provision. While the renewable sector may in some, in fact questionable, theoretical sense be able to partially fill the “energy” gap, the currently dominating renewable technologies are largely intermittent and, or, variable, some stochastically: They are consequently unable to give a high probability guarantee to deliver their energy when required and at a specified rate. This fundamental point is often overlooked in discussions of the potential

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[11] Oxera, *The Cost of Flexibility Provision by Electricity Generators* (Nov. 2003), 4.

[12] Presentation by Clare Dobson, Assistant Director, Energy Review Team, “The 2006 Energy Review”. See also the Energy Review consultation document, *Our Energy Challenge*, p. 40.

[13] Hugh Sharman, 'Why the UK should build no more than 10 GW of Wind Capacity', *Proceedings of the Institution of ICE: Civil Engineering* 158 (November 2005), 164.

for renewable energy, but it governs the policy recommendations of the Renewable Energy Foundation, and should, we believe, play a much larger part in the government thinking.

2. The Climate Change Policy of the United Kingdom in International Context

RENEWABLE ENERGY AND GERMAN CLIMATE CHANGE POLICY

Renewable Energy is widely believed to have a significant role in tackling climate change. However, the extent and character of this role is often misunderstood, with the result that public expectations are both unrealistic and likely to encourage deployment of renewable energy in ways which are sub-optimal. In rethinking the nature of the United Kingdom's role we would be well advised to draw upon the experience of our European neighbours, who have made extensive experiments aimed at reducing emissions via the means of renewable energy technologies.

To bring these matters into sharper focus, the Renewable Energy Foundation commissioned a brief report from Dr Wolfgang Pfaffenberger, Professor of Economics (European Utility Management) at the International University of Bremen, and Director of the Bremer Energie Institut.[14] The report has been separately published elsewhere, and has been submitted by the Foundation to the Stern Review of the Economics of Climate Change.[15]

Professor Pfaffenberger indicates that German endeavours with regard to emissions reduction, particularly via renewable electricity, have been unsatisfactory in a number of regards, a fact which is now increasingly widely recognised in Germany itself.

The report may be summarised as follows:

1. Subsidy support for renewable technology in Germany has encouraged the production of renewable energy, but it has sheltered renewables from the disciplines of the market, resulting in unbalanced development. In Professor Pfaffenberger's words:

> *To promote market introduction would require that renewable energy producers regularly become responsible for marketing their product by themselves. It would require that they produce the balancing services necessary for a marketable product and combine these services with their renewable product. The present system is clearly a system where the renewable energies are outside of the market whereas on the other hand of course they influence the market.*

We believe that this comment applies with equal force in the United Kingdom, where the Renewables Obligation has the superficial appearance of a free market instrument, but has created an artificial, indeed a "hothouse", situation, with all the undesirable results that such a forced growth entails.

2. Renewable electricity is, relative to other means, an expensive method for the reduction of greenhouse gas emissions. (We note that this the findings of the National

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[14] http://www.iu-bremen.de/directory/02826/

[15] http://www.hm-treasury.gov.uk/Independent_Reviews/stern_review_economics_climate_change/sternreview_index.cfm

Audit Office report on *Renewable Energy* published earlier this year,[16] the remarks of Ofgem in response to the DTI's RO review (quoted above), and also endorses the views expressed in the House of Lords Report, *The Economics of Climate Change*[17]). Professor Pfaffenberger writes:

> *Whereas the promotion of renewables in Germany was definitely effective in the sense of increasing capacity and production it was certainly not cost effective in the sense of getting the highest effect per Euro in terms of greenhouse gas reduction or production from renewable sources.*

This is a very important conclusion for the United Kingdom, and suggests very strongly that our own climate change policy, which we regard as a matter of great importance, is not on track.

3. Because of difficulties in balancing the grid due to the presence of stochastic wind generation Germany is now faced with the need for costly and *largely unanticipated* measures to ensure stable supplies. These increases in cost have implications for industry, as Professor Pfaffenberg indicates:

> *A system of national support for renewable energy in the way the German system has been designed definitely changes the competitive position of any industry that works for the international market.*

There is no compelling evidence that the situation in the United Kingdom is significantly different. Indeed, in-so-far as the UK's grid is islanded, as opposed to being richly interconnected as is the case in Germany, balancing problems and associated costs are more probable here (for comments on this matter we refer to the articles by Hugh Sharman in *Civil Engineering*,[18]). Furthermore, in some respects the regulatory framework in the UK is less favourable to industry. For example, Professor Pfaffenberger writes that while intensive energy users in Germany are granted partial exemption from the impact of renewable energy laws, cost increases have still resulted in a crisis in these industries. In the United Kingdom, of course, far from being sheltered to any degree, industry is exposed to increased costs via both the, now index-linked, Climate Change Levy, and the Renewables Obligation.

4. The introduction of renewables has not necessarily had a positive net effect on the economy. In a crucial passage Professor Pfaffenberger writes (the emphasis is ours):

> *Part of the motivation for promoting renewable energy is to substitute local generation for imported energies and in this way promote economic activity*

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[16] National Audit Office, *Department Of Trade and Industry: Renewable Energy*, report by the Comptroller and Auditor General, Hc 210 Session 2004-2005, 11 February 2005. Available from http://www.nao.org.uk/

[17] House of Lords Select Committee on Economic Affairs, *The Economics of Climate Change*, July 6th 2005, Chaper 5.

[18] Hugh Sharman, 'Why Wind Power Works for Denmark', *Proceedings of ICE: Civil Engineering*, 158 (May 2005), 66-72; and 'Why the UK should build no more than 10 GW of Wind Capacity', *Proceedings of the Institution of ICE: Civil Engineering* 158 (November 2005), 161-169.

> *and employment. A number of studies have been carried out during recent years to investigate the effects of the promotion of renewables in this respect. The results are not very encouraging (see Häder, 2005 and Hillebrand, 2005). Basically, of course, investing in renewable energy plants creates employment in industries producing these investment goods. On the other hand the extra cost of renewables adds to the cost of energy and in this way destroys purchasing power that otherwise could have created demand and indirectly employment in other areas.* ***Whereas the gross effect of spending money on renewables is always positive, the net effect may be negative.***

We draw attention to this last point because it bears with considerable weight on the way in which the United Kingdom conceives of renewables within its climate change policy. Any climate change policy which is economically deleterious for the proposing state will fail to encourage emulation at international level, and thus will fail in relation to climate change, since it is only by carrying the developing world in the direction of lower emissions that a domestic policy can achieve significance. The United Kingdom emits approximately 550 million tonnes of CO_2 per year.[19] This is just over 2% of the global total of 24,000 million tonnes.[20] It should be immediately apparent that the United Kingdom has no quantitative role in global climate change policy, but instead can only contribute by:

- Demonstrating and exporting good practice
- Providing an economically compelling example.

Rapid growth in the developing world further emphasises this point, and may be conveniently indexed via electricity. China is at present approximately four to five times the size of the UK electrically, with an installed capacity of about 357 GW, generating approximately 1,800 TWh[21]. The UK has an installed capacity of approximately 80 GW and generates just under 400 TWh per year.[22] By 2020 it is estimated that China will need to generate some 11,000 TWh, with an installed capacity of approximately 2,400 GW.[23] The following chart shows this growth in relation to current electricity generation in the UK, Europe, and the USA.

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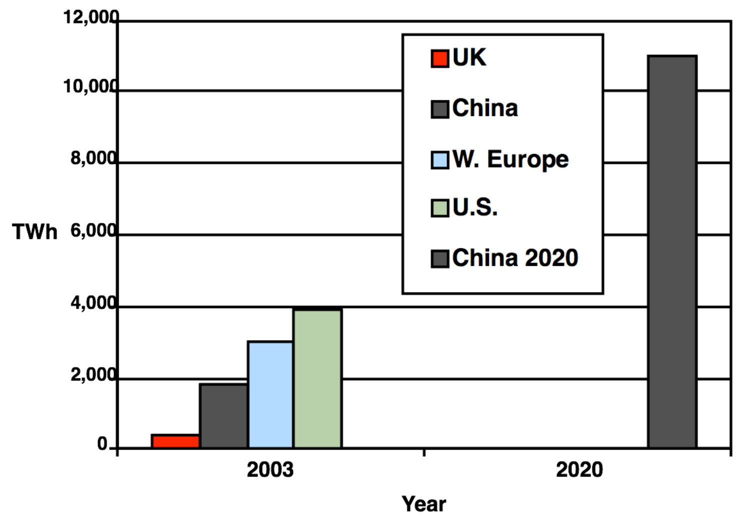
[19] For latest emissions data see DEFRA: http://www.defra.gov.uk/environment/statistics/globatmos/gaemunece.htm

[20] Current estimates can be obtained from the Energy Information Administration of the US Dept. of Energy: http://eia.doe.gov/.

[21] See International Energy Annual data on: http://www.eia.doe.gov/emeu/iea/

[22] See DTI, *DUKES 2005*, Table 5.5.7 (Plant Capacity – United Kingdom), and Table 5.5.2, Electricity supply and consumption. Both available from http://www.dti.gov.uk/energy/inform/energy_stats/electricity/index.shtml.

[23] See statements by Zhang Guobao, vice-minister of the National Development and Reform Commission quoted in the *China Daily*, 19 Oct. 2004: http://www.china.org.cn/english/BAT/109757.htm



2003 Electricity generation for the UK, China and Western Europe compared with projected Chinese generation in 2020.

In other words, by 2020 China will have grown six-fold electrically and be some 30 times the size of the UK in this sector. While nuclear and hydro-electrical power will provide a considerable portion of this energy, the bulk is expected to come, necessarily, from coal and gas.

Seen against such a backdrop, it is obvious that the United Kingdom climate change and energy policies will be at best futile unless they are *economically* attractive and sufficiently practical to induce emulation in China. Consequently, as we have emphasised in our 2005 Manifesto,[24] it is essential to recognise that the goals of the 2003 Energy White Paper must be prioritised correctly, even though this resequencing may seem counterintuitive.

It is widely agreed that energy must demonstrate favourable credentials in a number of areas, which should be reflected the following order:

- Secure
- Reliable
- Economical
- Clean
- Sustainable

However, it should be noted that **these are qualities which should be characteristic of the overall energy portfolio**. It is not enough that the various component

[24] Manifesto 2005, *Renewable Energy – the Need for Balance and Quality,* Published by the Renewable Energy Foundation, January 2005

technologies of our portfolio should demonstrate them individually. Each technology must manifest these qualities in such a way that:

- The ability of other technologies to deliver their benefits is not impaired.
- The value of the energy sector as a whole is not seriously compromised.

The Renewable Energy Foundation has repeatedly suggested that the criteria above should be arranged in the sequence given, reflecting their priority and consequence. The logic of this sequence can be explained as follows:

- If security of the primary sources cannot be guaranteed, then reliability at the point of use is questionable;
- If security and reliability of supply are compromised, then our economy will be damaged;
- If our energy supplies are insecure, unreliable, and unaffordable we will be unable to maintain and develop the high technological economy necessary to support our social aims and control the emissions of a large urban and industrial society.
- If the energy system in its total sense is unclean, as is seen in the CIS countries and parts of the developing world, then our social aims will be compromised by ill health in our population.
- And finally, if we cannot achieve any of the foregoing aims, our overall energy policy will be unsustainable, and the well-being of the United Kingdom and its people will be poorly served in the short, medium, and longer term.

This sequencing and logic differs radically from that found in the *Energy White Paper*.[25] **In particular we note that the *White Paper* foregrounds emissions abatement as the principal goal, and allows other goals to settle into subordinate positions in no particular order.** In criticizing this framework, we are not suggesting that emissions abatement is unimportant, but, rather, that placing it centre-stage is likely to compromise our ability to reach other essential objectives outlined in the policy.

Views such as these are now beginning to become evident in remarks offered at the highest levels of government. We would draw the Review's attention to a recent letter from the Prime Minister to the umbrella environmental group Stop Climate Chaos:

> *We also have to understand that, important as it is to reduce our own greenhouse gas emissions, the bigger battle against climate change will be international. This is not trying to shift the blame. It is about looking at the facts.*
>
> *At the moment, the UK accounts for something like 2% of greenhouse gases. By 2020 as the world economy continues to grow, this proportion will*

[25] See, for example, *Energy White Paper: Our Energy future: Creating a Low-Carbon Economy* (Dti: London, 2003), pp. 7ff.

> *have fallen to 1.5%. Even the most extreme and unrealistic action taken in the UK will have only a tiny impact on global climate change. Even more crucially, it would do nothing to protect us from its worst effects. I am afraid that, in this case, being virtuous alone will not bring much reward.*[26]

This is a credible and sober view of the scope available to the United Kingdom. The question which the Prime Minister leaves pending is how to ensure that we are not left in the position of being "virtuous alone". However, we can say with absolute confidence that it is unlikely that anything other than an economically compelling example will gather a crowd.

We have been drawn to conclude that the Renewables Obligation has created sub-optimal investment patterns in renewable technologies. If we are to avoid the solitary tokenism that the Prime Minister very rightly warns against then significant revision, learning from the experience of Germany and Denmark, is required. The Renewable Energy Foundation has consistently drawn government's attention to publications revealing evidence from Denmark and Germany now confirming that wind energy is at best a fuel saver, and offers only a very low "capacity credit" (the ability to replace "firm" capacity in the portfolio), as evidenced for example in the E.ON Netz *Wind Report 2005* and the recent articles by Hugh Sharman.[27]

From these documents, and from Professor Pfaffenberger's report, we conclude that the UK's current policy is heavily over-dependent on wind energy. This imbalance is largely the result of the simplistic structure of the Renewables Obligation, which is "unbanded", and makes no distinction between the intrinsic merits of various technologies. The consequence has been an investment scramble for the least capital intensive ticket to the RO subsidy stream (initially land-fill gas, now wind), regardless of the value of the technology adopted to the subsidising consumer. This is doubly unfortunate, since the overemphasis on one technology has resulted in the neglect of others, such as tidal and biomass systems, which have more to offer in terms of secure and firm energy provision. While wind power will undoubtedly form part of the UK's future portfolio, the current levels of proposed development, particularly in Scotland and Wales, are irrational from a national perspective and do not constitute a wise use of scarce capital.

From the above analysis we conclude that there is no *necessary* conflict between the two major goals of any UK energy policy:

- Configuring energy provision to serve our own economic needs, and

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[26] The Rt Hon Tony Blair, MP, to Stop Climate Chaos, 28 Feb. 2006. Available from http://www.number10.gov.uk/output/Page9107.asp.

[27] REF's abstract of the E.ON report is available from www.ref.org.uk, and the full report http://www.eon-netz.com. Hugh Sharman's papers, 'Why Wind Power Works for Denmark', *Proceedings of ICE: Civil Engineering*, 158 (May 2005), 66-72, and 'Why the UK should build no more than 10 GW of Wind Capacity', *Proceedings of the Institution of ICE: Civil Engineering* 158 (November 2005), 161-169.

- Fulfilling the United Kingdom's international responsibilities in relation to climate change.

Indeed, **if the energy policy promises economic disadvantage it will by the same token be ineffective as a climate change policy** because it will fail to carry the developing world in the same direction. Thus, we conclude that:

> **Economic viability and attractiveness is the first and fundamental test of any climate change policy for the United Kingdom.**

In view of the analysis above, we arrive at the view that in relation to the UK's role in tackling climate change "Less is More" provided that a superior economic result is achieved. However, the Renewables Obligation is so structured as to offer dramatic margins of profitability to technologies regardless of intrinsic merit, and this is unlikely to produce the sort of "example" required if the UK is to have a catalytic international role. As explained in the next section in more detail, revision of the Renewables Obligation is mandatory. Projects which offer firm, dispatchable power, and emissions reductions at an attractive cost, should be rewarded according to their merits. Failure to recognise this key issue will result in the continued transmission of motivating signals to the development market which are counterproductive since they incentivise the misdirection of capital.

3. Flaws in the UK's Renewables Obligation

There is growing concern amongst analysts that the Renewables Obligation is seriously defective and is failing to deliver value for money. In its response to the DTI's Renewables Obligation review consultation Ofgem wrote:

> *[…] Ofgem notes that one of the stated objections of the Obligation is to "assist the UK to meet national and international targets for the reduction of emissions including greenhouse gases". Ofgem has estimated that the implied cost of carbon to the consumers for the Obligation is £198-515/tC, much greater than the £40-50/tC estimated for the allowance price under the EU-ETS based on recent higher prices. While this is not a like-for-like comparison and both schemes are relatively new, it does indicate that the RO costs are likely to be higher than might be needed to achieve similar carbon reductions. This would suggest that the Obligation is not as efficient a mechanism for achieving carbon reductions.*[28]

Similarly powerful criticisms are made in greater detail in the report by the National Audit Office, and the consultants' reports on which it is in part based.[29] These documents not only summarise the system in admirably clear terms, but also provide trenchant criticism of the operation of the Obligation. From the present perspective, the most relevant conclusions are that:

1. Onshore wind is very significantly over subsidised. The NAO says that a buyout price of £15 would be sufficient to support most projects, and thus we can conclude that the subsidy stream is in excess of needs by at least 33%.[30]
2. The Renewables Obligation is a very expensive way to save CO_2.[31]
3. The RO is faulty in so far as it does not distinguish between technologies of varying merits.[32]

These observations are correct in our view. We note in particular that the excessive subsidy offered to onshore wind development has drawn developers even to sites where the wind resource is very weak, and the environmental impact severe. It is very much to be hoped that the NAO's criticisms will be absorbed by the DTI in their review of the Renewables Obligation. In doing so, corrective measures should be taken not least because as things stand at present renewable electricity projects of higher capital

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[28] Steve Smith (Managing Director, Markets, Ofgem) to Megan Bingham Walker (Renewable Energy Policy, DTI), 23 June 2005, forming part of Ofgem's formal response to the Consultation, and available from http://www.dti.gov.uk/energy/consultations/pdfs/Ofgemresponse1.pdf

[29] National Audit Office, *Department Of Trade and Industry: Renewable Energy*, report by the Comptroller and Auditor General, Hc 210 Session 2004-2005, 11 February 2005, p. 15. Available from http://www.nao.org.uk/

[30] NAO, *Renewable Energy*, p. 5, and p. 41.

[31] NAO, *Renewable Energy*, p. 6.

[32] NAO, *Renewable Energy*, p. 41.

intensivity, but with higher intrinsic merit, are quite simply starved of investment. Such concerns are now widespread within the renewable energy industry itself. For example discussions internal to the Renewable Energy Association (formerly the Renewable Power Association) have produced an extremely interesting internal document citing with deep concern the mounting criticism in the UK. One paragraph deserves citation here:

> *Many of those most closely connected with the DTI have received the message that it is politically unsustainable for the RO to continue in the form originally envisaged, with quotas continually rising to 2027 and with all technologies equally eligible for ROCs.*[33]

As the REA observe on the first page of this document, the fundamental ground of the criticism is that "some technologies get more support than they need", a view taken, the REA note, not only by the NAO, but also by the Committee for Public Accounts, and most significantly by the European Commission, whose major report "The support of electricity from renewable energy sources", was published in December 2005.[34] This document is of very considerable importance, both for its content and its origin. We can begin with the following quotation as an introduction for two of its most significant charts:

> *Figure 4 and figure 6 show the generation cost of wind energy and the level of the supported prices in each country. Support schemes for wind vary considerably throughout Europe with values ranging from €30/MWh in Slovakia to €110 per MWh in the UK. These differences – as seen in Figures 4 and 6 – are not justified by the differences in generation costs. Generation costs are shown in a range based – in the case of wind – on the different bands of wind potential.*[35]

Figure 4., reproduced below, represents for the EU-15 the relation between the minimum and average costs of onshore wind generation (a range indicated by blue bars) and compares this with the average to maximum support offered by subsidy or infeed tariff or tax credit (red dot and line). As will be noticed the UK offers the highest level of support, with very little difference between average and maximum levels, and, most importantly, the very largest distinction between cost and support levels. This latter interval is the margin enjoyed by the developer.

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[33] Renewable Energy Association, "Moving the debate forward: The future of the RO draft 2", p. 2.
[34] European Commission, "The support of electricity from renewable energy sources" (Brussels, 7.12.2005) COM(2005) 627 final. SEC(2005) 1571:
http://europa.eu.int/comm/energy/res/biomass_action_plan/doc/2005_12_07_comm_biomass_electricity_en.pdf
[35] European Commission, "The support of electricity from renewable energy sources", 27.

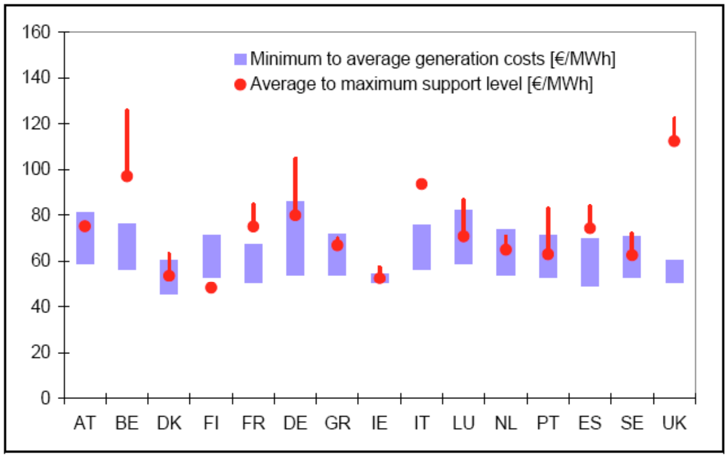


Figure 4:
Price ranges (average to maximum support) for direct support of <u>wind onshore</u> in EU-15 Member States (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs). Support schemes are normalised to 15 years.

The purpose of the EU report is to compare the impact of the various national support mechanisms on various technologies. For present purposes we will select only a single representative example, that of biomass electricity from forestry residues:

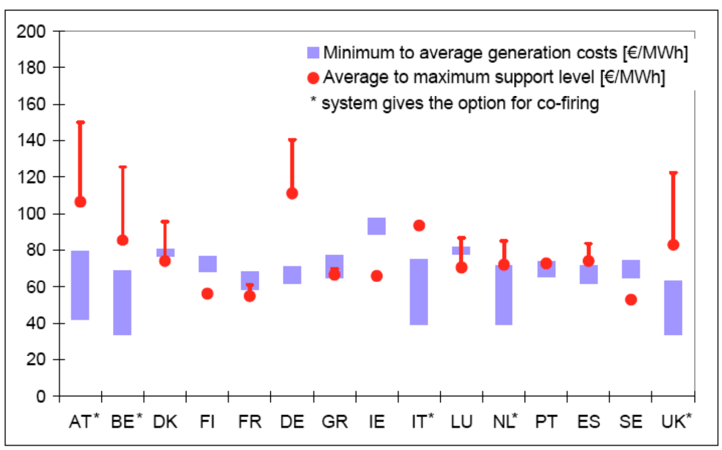
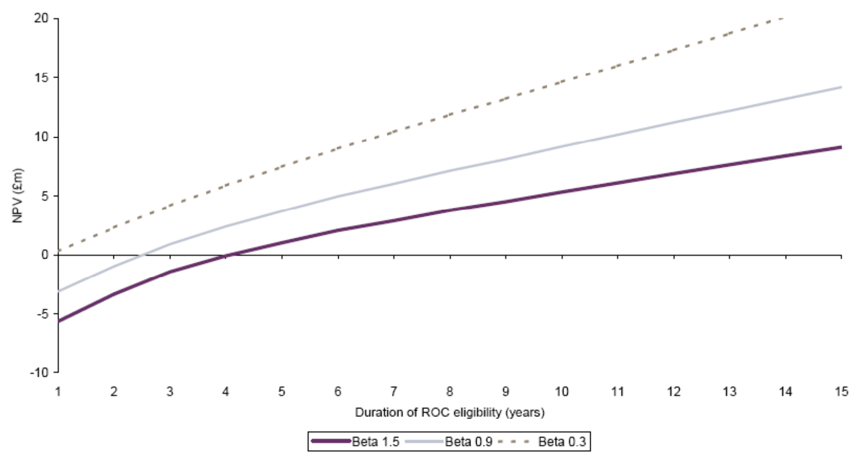


Figure 12:
Price ranges (average to maximum support) for supported <u>biomass electricity</u> production from <u>forestry residues</u> in EU-15 member states (average tariffs are indicative) compared to the long-term marginal generation costs (minimum to average costs).

From the red bars it can immediately be seen, while the maximum support offered is comparable to that provided for onshore wind, the margin of average-to-maximum support over generation costs for forestry residue biomass is very much smaller, and is therefore less attractive to investors. Yet biomass is capable of providing firm generation, and is therefore a technology of higher intrinsic merit from the point of view of the subsidising consumer.

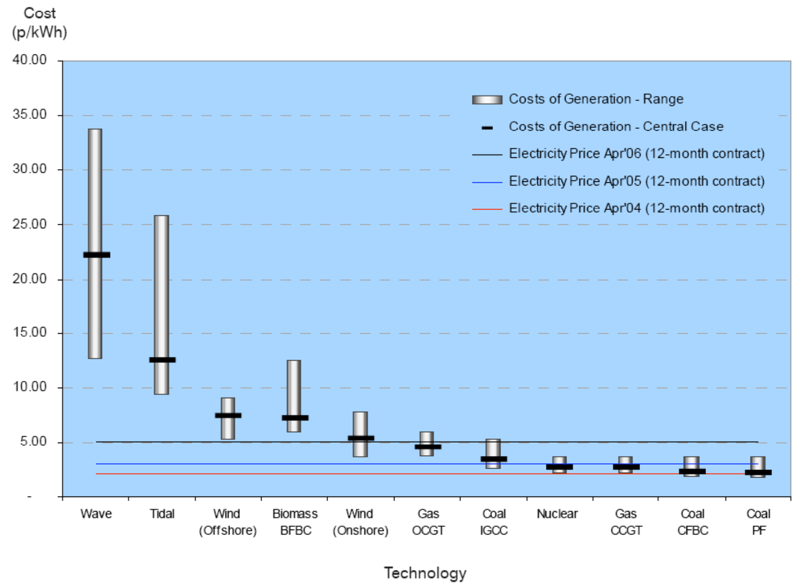
The degree of this excess reward will vary from location to location, with sites in high wind areas such as NW Scotland being over-supported to a greater degree than those in other locations. The recent and important report by Oxera for the DTI, *What is* *the impact of limiting ROC eligibility for low-cost renewable generation technologies?,* suggests that such locations are probably not in need of full RO support, and perhaps do not require any support.[36] As a sample we reproduce below figure A3.15 from that study. which shows Net Present Value (NPV) for a high wind location with a £60/MWh offtake Power Purchase Agreement (PPA), a contract which does not seem unattainable with current fossil prices:

Figure A3.15 NPV for a 30MW onshore wind site at 8.5m/s with £60/MWh PPA



Viewed as an industry sector, the costs for onshore wind are now in the same order of magnitude as those of other industries, though slightly more expensive. In its recent and important study for the Royal Academy of Engineering, PB Power offers the following chart:[37]

[36] Oxera Consulting Ltd, *What is the impact of limiting ROC eligibility for low-cost renewable generation technologies?* (August 2005), p. 10. Commissioned by and available from the DTI.
[37] PB Power, *Powering the Nation: A review of the costs of generating electricity* (Mar. 2006), 18.



We draw particular attention to the fact that the range of costs for onshore wind in the UK is narrow, and that the central case is very close to the 12 month contract electricity price for April 2006, with a good portion of the range being below that price – suggesting that much onshore wind would be viable even without RO support.

It should be observed that these costs are exclusive of overall system cost increases brought about by the addition of wind to the portfolio, but they are extremely relevant from the point of view of estimating whether subsidy support for an investor is justified. The intention of the Renewables Obligation was to assist immature and costly technologies in advancing towards the marketplace, and as can be seen clearly from PB Power's chart, and from the EU Commission's work, onshore wind is not such a case. The Foundation suggests that **the work of Oxera, and PB Power confirms that the costs of onshore wind are now of the same order of magnitude as conventional generation, and no longer deserve full or any subsidy support**. Unless this hyper-support is removed it is inevitable that funds will flow towards onshore wind and away from those technologies that were the intended recipient of the support.

This flaw is compounded by the fact that, as we will show in the next section, wind is a low merit technology, and onshore wind particularly so because of low capacity factor.

In this context we draw the Review's attention to situation in Ireland, and refer the reader's attention to the EU Commission chart above, where it is shown that subsidy support in Ireland is close to and only just above the cost of generation. Indeed, the power power price for wind in Ireland is roughly €54/MWh or £37.26, less than the RO support alone for UK wind. Nevertheless, development in Ireland has been in some senses impressive. At the end of 2005, almost 500 MW of wind had been installed on-shore in Ireland. A proportional installation in the UK would be roughly equivalent to 7,500 MW. In spite of the low level of subsidy support projects which had managed to secure financing are producing up to 20% IRR on their wind properties with a load factor in excess of 35%. The rapid increase in gas price now makes the price of raw wind power less than the cost of electricity from gas-fired MWh and therefore less than the average forward power for electricity in the UK.

The Irish case demonstrates that the increases in the cost of “black power” can render viable wind in suitable locations, even with feed-in prices as low as €54/MWh. In point of fact, the so-called “Gate Two” round of applications in Ireland has attracted some 2,400MW of wind power connection applications.

We therefore conclude that while the Renewables Obligation might remain in force for those technologies that require support, onshore wind is not a deserving recipient. We have suggested other methods of revising the RO to address this issue, including banding,[38] but it is at least interesting to speculate that another method would be to remove onshore wind from the RO, and transfer it to a system providing a low fixed feed-in tariff such as that operating in Ireland. We urge the DTI to examine the Irish experience and consider revisions to the RO in the light of that material.

While the precise nature of revision to the RO is a matter for further economic analysis, it is abundantly clear that revision of some kind is now absolutely necessary if we are to ensure the creation of a diverse and effective portfolio of renewable generation. The current structure is not producing adequate returns on consumer subsidy, and is in very important respects actually counterproductive.

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[38] Renewable Energy Foundation, “2005–2006 Review of the Renewables Obligation”, submitted to the DTI, and available from http://www.ref.org.uk.

4. German and Danish Experience of Wind Energy

The largest body of empirical information relating to the value of wind generation is found in Europe, and in the following two sections we shall summarise significant studies of wind power in Germany and Denmark.

GERMANY

E.ON Netz GmbH is a major German grid operator serving a population of 20 million people living in 40% of the country's land area. It runs 32,500 km of high-voltage and extra-high voltage power lines, and is responsible for integrating 7,000 MW of wind power, nearly half of all that installed in Germany.

Germany's 16,394 MW of wind power produced 26,000,000 MWh, which is around 4.7% of Germany's gross demand (p. 5), and is operating at a capacity factor of approximately 0.19 (calculated from figures on p. 5). It should be borne in mind when reading the present summary that the 2010 UK renewable energy target is for 10% of electricity supplied, with the Government's expectation being that three-quarters of this will be from wind. The targets for 2015 and 2020 are 15% and 20% respectively.

The extreme difficulties reported by E.ON Netz have much significance since the company knows more about the practical realities of managing a large wind carpet in a modern grid than any other organisation in the world. E.ON publishes their experience in annual reports in English, the second of which, the *Wind Report 2005*, has been issued together with a speech by the CEO of E.ON Netz, Martin Fuchs.[39]

The E.ON reports have created intense interest within the energy sector, and demonstrate conclusively that many national policy expectations for wind energy, particularly those of the UK, are currently unrealistic.

Key Challenges Presented by Wind Energy

E.ON Netz identify three key operational challenges.

- Wind energy cannot replace conventional power stations to any significant degree
- Wind forecasting is inaccurate, and in spite of heavy expenditure on improvements, will remain so.
- Because the wind resource is geographically concentrated very substantial expansion of the grid is required to transport power to areas of demand and to stabilise the grid.

All three points are highly relevant to the United Kingdom. We will comment on each in turn.

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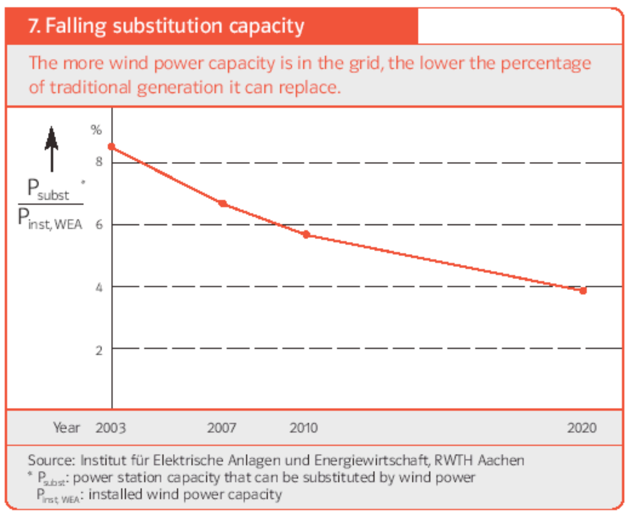
[39] Downloadable from http://www.eon-netz.com. Hard copies may also be ordered.

<u>Wind Energy Cannot Replace Conventional Power Stations to Any Significant Degree</u>

E.ON Netz state this matter so clearly that verbatim quotation is appropriate:

> *In order to guarantee reliable electricity supplies when wind farms produce little or no power, e.g. during periods of calm or storm-related shutdowns, traditional power station capacities must be available as a reserve. This means that wind farms can only replace traditional power station capacities to a limited degree.* (p. 9)

The degree to which wind-power can obviate the need for conventional power in the overall portfolio is called its "capacity credit". E.ON reports the results of two independent studies that reveal that at present the Capacity Credit of wind power is <u>8%</u>. This is so low that it is, in macro planning terms, <u>effectively zero</u>.



7. Falling substitution capacity

The more wind power capacity is in the grid, the lower the percentage of traditional generation it can replace.

Source: Institut für Elektrische Anlagen und Energiewirtschaft, RWTH Aachen
* P_{subst}: power station capacity that can be substituted by wind power
$P_{inst, WEA}$: installed wind power capacity

Moreover, E.ON shows that this figure will decline as more wind power is added to the system. As E.ON comments:

> *In concrete terms, this means that in 2020, with a forecast wind power capacity of over 48,000 MW (Source; Dena grid study), 2,000 MW of traditional power production can be replaced by these wind farms. (p. 9)*

This is a disastrously poor result, and reveals, finally and conclusively, that wind-power will do nothing to reduce the UK's need for reliable, "firm", generation.

That is to say, however much wind power is built, we will still be faced with the need to ensure that we have adequate conventional generation to meet our peak demand independently of any wind resource. Thus, the "Wind v. Fossil" or "Wind v. Nuclear" debates are shown to be vacuous. **Wind is not an <u>alternative</u>, it is at best a <u>supplement</u>.**

This point bears further emphasis: **E.ON's experience shows conclusively that those who expect wind-power to prevent a nuclear rebuild, or reduce the need for gas and coal stations, have been seriously misled.**

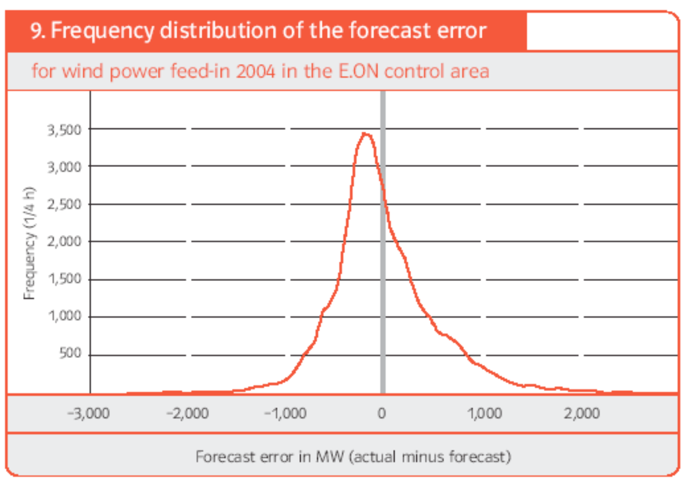
The Renewable Energy Foundation has argued that the E.ON report supports our arguments and those of others, namely, that we need a radical rethink of contemporary renewables policy, which must be altered to favour technologies such as tidal and biomass, which have higher capacity credits and thus more to offer to the UK's need for stable *power* (energy when and as it is needed).

Wind Forecasting is Inaccurate

Because electrical energy cannot be stored commercially on an industrial scale, the grid must be balanced on a second by second basis. Wind input, as Martin Fuchs, CEO of E.ON Netz states in his speech, suffers from various drawbacks to a grid operator:

> *"1. The wind blows, when it will.*
>
> *2. The wind blows as it will – despite increasingly accurate forecasts, it is difficult to predict its actual strength.*
>
> *3. The wind blows, where it will – and sadly, it does not blow where large quantities of power are required."*

In order to mitigate this unreliability E.ON Netz has invested heavily in wind forecasting. In spite of this, large errors are still common, ranging from 2,532 MW *less* to 3,999 MW *more* than predicted, which is equivalent to 36% and 57% of the installed wind capacity. E.ON concludes that "there are natural limits to the quality of the wind power forecast" (p. 11). The error rate in the forecast is illustrated by the following chart:



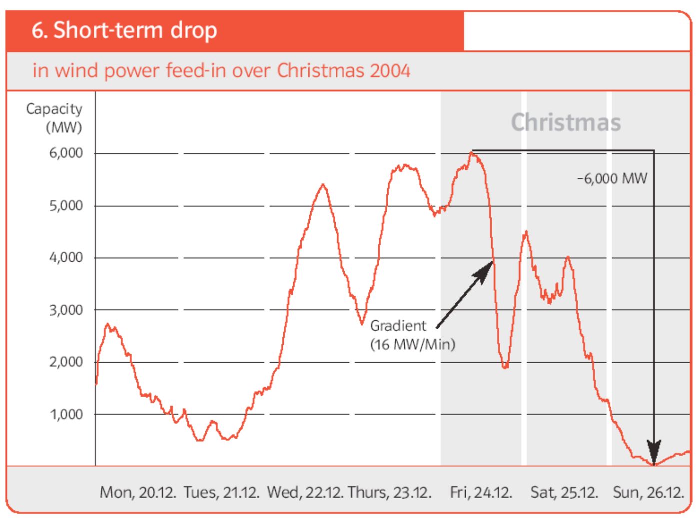
In order to put the scale of error into perspective, it should be borne in mind that a modern coal power station is capable of generating 1,000 MW, and that the UK's national all time peak load is around 59,000 MW. While very large errors are relatively infrequent, the grid operator must be ready for *all* errors. The chart therefore shows that the grid operator must **at all times** be able to deal with the unexpected absence or presence of large, **nationally significant,** quantities of power, several power stations' worth, on a regular basis during the year. Maintaining such a state of preparedness is costly.

<u>Grid Expansion is Required</u>

Wind resources are not evenly distributed in Germany, with most being concentrated in the northernmost part of the country. Consequently, very substantial grid expansion is required to carry this energy down to the centres of load, and to permit immediate import and export of energy to cope with the rapid fluctuations of wind power. The seriousness of these fluctuations is made clear in Martin Fuchs' speech:

> *On 12 September, wind power supplies covered up to 38% of our grid power requirements at times. This was the highest value achieved during the past year. On 30 September, on the other hand, this figure was down to 0.2 % – the lowest value of the year.*
>
> *Maximum wind power output in our control area was achieved on the morning of 24 December, with an absolute figure of 6,024 MW (compare this with the 2003 maximum power supply of 4,981 MW and the top figure of 3,546 MW for 2002)*
>
> *However, the supply on Christmas Eve 2004 fell to under 2,000 MW within just ten hours. By Boxing Day – on 26 December – the figure had slumped to under 40 MW, a negligible value to all intents and purposes.*

Mr Fuchs' point is illustrated in the following chart:



<u>Balancing such erratic and uncontrollable flows of energy presents severe challenges, and a very extensive and robust grid infrastructure is essential.</u> By 2020 E.ON Netz estimates that Germany as a whole will require 2,700 km (1,700 miles) of new or reinforced grid, of which 1,900 km (1,200 miles) will need to be on new routes at a cost of 3 billion Euros.

The scale of this expansion is breathtaking, and its relevance to the UK is obvious. NGT has disclosed that most wind power is being proposed in Scotland.[40] This is unsurprising. A recent study by Oxera for the DTI has concluded that even with the very strong subsidy support currently available, which can account for 50% to 70% of a wind-farm's income, wind-farms in medium and low wind areas such as those found in most of the UK, will struggle to be economic. Canny investors are looking towards the NW of the British Isles, and in fact some 17,000 MW of wind, more than is currently installed in the whole of Germany, is now applying for grid connection in Scotland.[41] The grid expansion needed to support this expansion will cost, according to NGT, some £250,000 per MW. If all 17,000 MW were built this would entail grid enlargement costing over £4 billion in Scotland alone.

It is worth noting that even if Germany succeeds in expanding its grid, it is not clear that this will result in anything more than an export of the problems caused by large fluctuations in wind output. As Martin Fuchs notes, currently:

> *[...] in times of strong winds, the majority of the energy produced between Oldenburg and Rendsburg sloshes southwards in waves. In accordance with the laws of physics, it seeks the path of least resistance, also escaping eastwards and westwards into neighboring European grids. Thus German wind power is increasingly taking Dutch and Polish grids to the limits of their capacity; complaints have already been made in this regard.*

E.ON's practical experience undermines previous theoretical assertions that the UK, with its effectively islanded grid,[42] can economically manage a large wind-component, and indeed raises deeply troubling questions with regard to its feasibility.

Conclusion

The E.ON Netz wind report is required reading for those wishing to determine whether wind power is a prudent choice in order to realise the UK government's current renewable energy and emissions reduction policy.

The inescapable conclusion to be drawn from the German experience is that the unsophisticated nature of the UK's Renewables Obligation, coupled with the lack of any strategic planning guidance for installations, is driving us towards an irrational over-commitment to an unreliable and expensive energy source with a large and deep environmental footprint.

DENMARK

While Germany has the world's largest wind carpet, Denmark's 2.4 GW makes it the world's most wind intensive state, with an installed capacity of 0.88 kW per head of

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[40] Lewis Dale (Regulatory Strategy Manager, NGT), 'The Energy White Paper - Will it Deliver?', IEE seminar, 19 May 2005, at the Royal Society.

[41] Lewis Dale, 'The Energy White Paper - Will it Deliver?'.

[42] The UK currently has only one link to the European grid, a 2 GW connector to France.

population. It is therefore a crucial case, but has hitherto been poorly understood outside Denmark. However, last year two major articles in *Civil Engineering* outlined the lessons which the UK could learn from this unique experience.[43] The author, Hugh Sharman, is a leading energy consultant and an authority on the operation of Danish wind.

At peak output the Danish wind carpet can account for nearly 64% of Danish peak power demand, but this does not always occur when it is needed, and the power swings occur over relatively short timescales, as the following chart from the article demonstrates:

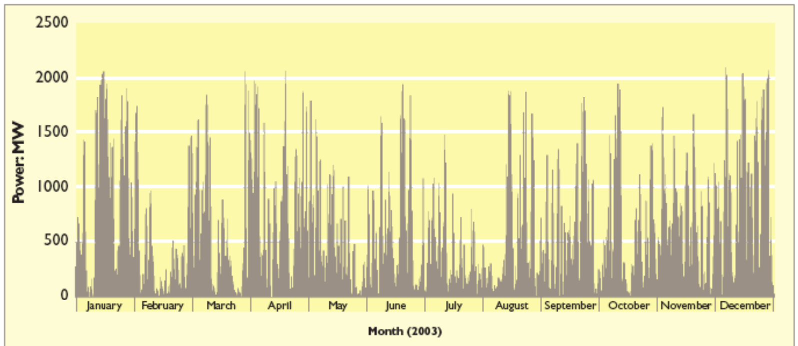

Fig. 8. Wind power production in west Denmark exceeded 2000 MW nine times during 2003

Furthermore, as Mr Sharman remarks:

> *On other occasions it delivers no energy when demand is high. There were 54 days in 2002, for example, when wind supplied less than 1% of demand (Fig. 9). On one of those days (16 August 2002) the wind power system steering requirements exceeded wind output and the wind carpet consumed more power than it could produce. In other words, the wind carpet became a net energy consumer. There was also a whole week in February 2003 when virtually no wind power was generated in west Denmark.*[44]

The following chart demonstrates this weak correlation with demand:

[43] Hugh Sharman, 'Why Wind Power Works for Denmark', *Proceedings of ICE: Civil Engineering*, 158 (May 2005), 66-72; Hugh Sharman, 'Why the UK should build no more than 10 GW of Wind Capacity', *Proceedings of the Institution of ICE: Civil Engineering* 158 (November 2005), 161-169.

[44] "Why Wind Power Works for Denmark", 69.

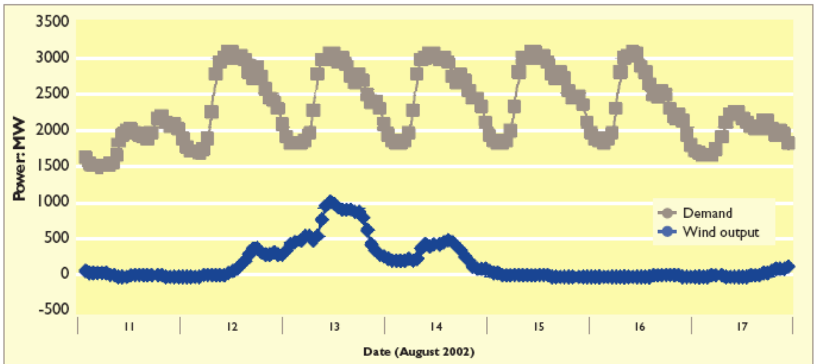

Fig. 9. Wind power during the week of 11–17 August 2002 fell a long way short of overall demand

Denmark is sometimes cited as a state producing a large proportion, some 20%, of its electrical energy from wind power. Mr Sharman shows that this is a half-truth. While Denmark does indeed generate a parcel of energy equivalent to 20% of its annual consumption, this energy is not comfortably integrated into the Danish grid, but nearly 80% of it is sold to its neighbours, Norway, Sweden and Germany. Perhaps the most striking chart in these two articles is the chart showing net trades on the European grid:

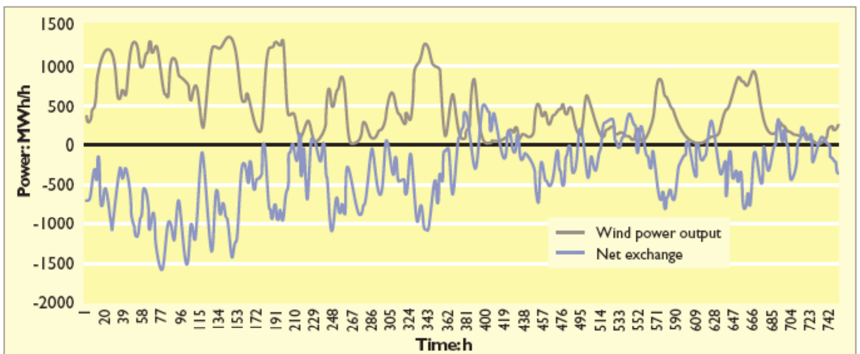

Fig. 13. West Denmark's wind power output compared to net power outflow to neighbouring countries in December 2003—the amounts are closely in balance

This net exchange is financially disadvantageous for Denmark, since wind electricity generation is heavily subsidised, but must be sold at distressed prices on the open market. It is estimated that this results in a net exchange of wealth of around £100,000,000 a year.

Since these papers are readily intelligible to the lay reader we do not intend to summarise them further here, but will note that they forcefully confirm the findings of E.ON Netz, and demonstrate without any doubt that the United Kingdom cannot expect significant "firm" capacity from even a large wind carpet. Mr Sharman's laconic conclusion is worth quoting in full:

> *There are considerable and often rapid output variations throughout the day and throughout the year. Accurate forecasting of wind speeds is still difficult and output rarely matches demand, sometimes dropping below zero as stalled wind turbines still require power for their steering systems. The*

> *variations, which are inherent in any wind energy system, can be readily accommodated in west Denmark because there are very strong electrical connections to the much larger grid systems of Norway, Sweden and Germany that can absorb these variations, particularly due to their reliance on rapid-reacting hydropower. Countries such as the UK, which operate an 'island' grid, will find it difficult to do this with slower-reacting thermal power stations and may thus have to limit their reliance on wind power.*[45]

Far from dismissing wind altogether, though, Mr Sharman emphasises that it is only through realism with regard to the merits of the technology that we will be able to ensure that we make the most of what it can actually provide, *supplementary* energy (as opposed to power). Mr Sharman argues that the UK's island grid will be unable to support more than, at the outside, some 10 GW (12.5% of current capacity) of wind, and that this would be best provided in offshore locations, since the wind speeds are higher (giving higher capacity factors), the environmental impacts can be more adequately handled, and the plant can be brought into closer proximity to the centres of load, such as London. In this connection we may note that the proposed London Array offshore windfarm would offer 1 GW of wind, and the Greater Gabbard proposal off the Suffolk coast a further 500 MW. Consequently it is clear that the maximum tolerable wind carpet could be readily located offshore.

In conclusion, though, we must note that the evidence from Germany and Denmark conclusively demonstrates that wind is a low merit generator - views which are increasingly frequent amongst power engineers. It is appropriate at this juncture to draw the attention of the Review to an article by Professor Michael Laughton, Emeritus Professor of Electrical Engineering at the University of London, and now Visiting Professor at the Centre for Energy Policy and Technology, Imperial College, London. This article, "Power Supply Security with Intermittent Sources: Conventional Plant Capacity Requirements" appeared in *Power in Europe* in October 2005. On the basis of data and analysis published by National Grid Professor Laughton concludes that:

- *Irrespective of the amount of wind installed in the system, the conventional capacity required will never be less than the peak load. Indeed the 20% conventional plant margin needed without wind will never be reduced, regardless of the added wind capacity, to less than 9 or 10%.*
- *Much otherwise uneconomic conventional plant will need to be retained or replaced either running on low or minimum output or be replaced by plant capable of frequent rapid start and ramping characteristics such as (aeroderivative) OCGT generators*[46]

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[45] "Why wind Power Works for Denmark", 72.

[46] Michael Laughton, "Power Supply Security with Intermittent Sources: Conventional Plant Capacity Requirements", *Power in Europe*, 460 (10 Oct. 2005).

5. Are Germany and Denmark Relevant to the UK?

The Foundation, in common with many other analysts, believe that European experience is relevant to the United Kingdom's deployment of wind. However, as is well known, the DTI is also currently receiving prominent and influential advice that this is not the case. This view is implicit in the work of the Sustainable Development Commission, and explicit in the views of Mr Sinden of the Oxford Environmental Change institute and of the United Kingdom Energy Research Centre. The Foundation believes that all three documents are potentially misleading, and require critical comment. We will discuss each in turn.

THE SUSTAINABLE DEVELOPMENT COMMISSION ON WIND POWER

The Sustainable Development Commission (SDC) report *Wind Power in the UK*[47] was published in May 2005 and has been prominently covered by the press and television. The SDC itself is distributing copies of both the full document, and a shorter pamphlet, *Wind Power: Your Questions Answered*. These documents are attractively produced, and apparently authoritative. However, closer examination from an informed perspective reveals these documents to be deeply flawed across a broad range of issues. So much so in fact that it should be given very little weight in any consideration.

As a representative critique indicative of the low regard in which this study is held by expert analysts and engineers we need only turn to a study 'Wind Power in the UK: Has the Sustainable Development Commission Got it Right?',[48] by Mr Malcolm Keay, one of the UK's leading energy analysts, currently a Senior Research Fellow of the Oxford Institute for Energy Studies.[49]

Mr Keay's opening statement is a fair summary of his criticism's overall tenor:

> *The current state of the debate about wind power presents many [...] unwelcome symptoms – exaggerated claims; confused arguments; strong emotions; neglect of the practicalities and risks. In this climate an authoritative and neutral examination of the issues would have been a helpful corrective. This is what the latest report of the Sustainable Development Commission (SDC) seems to promise. The Report, entitled "Wind Power in the UK" describes itself as "a guide to the key issues" surrounding wind power development, providing information to help "considered decisions to be made". Unfortunately, but perhaps predictably, the Report fails to do so. The Commission ends up as just another cheerleader for wind power, using the Report to argue that "wind power must be made to work" because it is a*

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[47] Sustainable Development Commission, *Wind Power* (May 2005). Available from www.sd-commission.org.uk.

[48] Malcolm Keay, 'Wind Power in the UK: Has the Sustainable Development Commission Got it Right?', Oxford Energy Comment (May 2005). Available from the Oxford Institute for Energy Studies: http://www.oxfordenergy.org/.

[49] http://www.oxfordenergy.org/keay.php

> *"critically important part of the overall energy mix". In its bullish (not to say bull-headed) approach, the Commission is repeating the errors of the early advocates of nuclear: underestimating the likely* ***costs****; minimising the* ***practical problems****; overstating the* ***benefits****; and dismissing the* ***alternatives*** *– in a report which, at many points, shows a poor grasp of the issues.*

As can be inferred, the core of his criticisms hinge around the report's *overselling* of wind power, its selective use of data favourable to its own case, and its trite dismissal of both other sustainable and conventional alternatives for electricity generation. Far from providing information for 'considered decisions to be made' it is a case of special pleading.

For example, the SDC report claims that 'the generated cost of wind is quite accurately known', but as Keay points out, the SDC have not only chosen costings that are especially favourable to wind, and have failed to factor in 'system costs' such as the need for grid strengthening, but have then 'cherry-picked' the data to unfairly bolster their case. Other independent studies suggest that the true cost of offshore wind will be at least 55% higher than the SDC claim of 5.5p/kWh. If the costs are truly as low as the SDC claim, then, as Keay notes, 'onshore wind energy is clearly being subsidised too much, not too little'.

Mr Keay is also critical of the use of an assumed 35% capacity factor by the SDC (i.e. the amount of electricity delivered by a wind turbine relative to its theoretical maximum). Nowhere in Europe has such a figure been achieved and, curiously, the SDC dismisses the DTI's own figures for the UK stating that 'the figures in the UK of under 25% in 2002 "and a number of other years" are untypical'. Rather than being 'untypical', there is evidence that the UKs wind resource is currently on a decline and that even the 25% may be an over-estimate for future projections[50]

With regard to the need for fossil fuel support (i.e. firm generation), Keay considers the SDC thinking confused: Based on the SDC's own calculations, it is pointed out that for 'a system with around 20% wind in 2020, significantly more total capacity will be required (105 gigawatts as compared with 84GW) than without the wind element'.

Even when discussing possible benefits the SDC is opaque. It claims that by 2020 a 20% wind penetration will save 7.8 million tonnes of carbon each year (equivalent to 28.6 million tonnes of CO_2). This is greatly at variance with the Government's own estimate of a 2.5 million tonnes of carbon saved annually by 2010 from a 10% wind penetration. The best statement the SDC can come up with is that 'the social benefits of having 20% wind **might** outweigh any costs' (my emphasis). This is hardly a sound basis on which to found a major plank in our energy policy.

In conclusion, Keay writes (my emphases):

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[50] Prof. Em. Peter Cobbold. *Ocean-driven changes to the UK's weather systems threaten failure of wind power generation in winter.* March 2006.

> *One should not expect the SDC to come up with a coherent overall approach to energy and the environment. However, **it is fair to ask it to present a properly argued case for wind power** if it wants unwilling communities across the country to suffer the environmental consequences (and unknowing consumers to bear the cost). **It has not done so.***
>
> *The fundamental problem remains that all forms of energy generation have environmental impacts, and that any form of generation employed on a large scale has large scale impacts. Wind power is no exception to this rule (any more than hydro or nuclear proved to be). Instead of pretending that wind is a "silver bullet" providing the unique way out of the quandary, and should therefore be "made to work", the SDC should help in the effort to consider wind on a rational basis along with other sources, **balancing the advantages and disadvantages in particular situations**. In many cases, wind will clearly come out well, and it certainly has a part to play in the future energy system, but that role should not be exaggerated.*

It should be noted that this statement is entirely consistent with the position taken by nearly all opponents of onshore wind applications. It is accepted that wind will have a role, in certain locations, mostly offshore, but that in the vast majority of other onshore areas the balance of impact to benefit is unfavourable.

Mr Keay's view that 'overselling any technology damages, above all, the technology itself' is clearly correct. Indeed, this is a significant factor in the rising tide of resistance to insensitively sited wind farms all over the UK. Mr Keay concludes that "**Wind power deserves better than the SDC's boosterism**". This is strong language, but fully justified, as can be seen by anyone taking the trouble to read the SDC's report in its entirety.

While Mr Keay confines himself to consideration of the technical engineering aspects of the SDC report it should be noted that selective and misleading handling of information is pervasive, and that many of the other sections, for example those on environmental impact and noise problems, fail to provide an objective and informed perspective, and are frequently little better than a compendium of wind industry sales talk.[51]

Far from being an important contribution to the debate, the Sustainable Development Commission's report is so flawed that it should be given very little weight in any review of the United Kingdom's energy provision.

GRAHAM SINDEN, THE UNITED KINGDOM'S WIND RESOURCE

Much reliance is currently being placed by DTI and United Kingdom Energy Research Centre on work by Mr Graham Sinden a DPhil student at the Oxford Environmental

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[51] Subsequent to Mr Keay's article a request under the Freedom of Information act revealed that Mr David Milborrow, the retained consultant of the British Wind Energy Association, and a former board member, was a principal technical consultant on the SDC's document.

Change Institute.[52] The principal of these, "Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand",[53] has been summarised in an unrefereed study *Wind Power and the UK Wind Resource* commissioned from Mr Sinden by the DTI.[54]

Our concerns are as much with the use made of this document as with the research itself, and we will begin the former. We note with some concern that *Wind Power and the UK Wind Resource* was published by the DTI and announced in a press release that quoted the Energy Minister, the Rt. Hon Malcolm Wicks MP as saying:

> *The only sensible debate about energy is one based on the facts. This new research is a nail in the coffin of some of the exaggerated myths peddled by opponents of wind power.*
>
> *We have a vast and dependable wind resource in the UK, the best in Europe. Over the past year there's been the biggest increase in wind power yet, as we move towards our target of 10% of electricity coming from renewable sources by 2010.*
>
> *This new research shows that UK wind power delivers more energy at times of peak demand, and that claims that calm conditions regularly occur throughout the UK in winter are without foundation.*
>
> *It also shows that it's misleading for opponents of wind in the UK to cite problems from elsewhere in Europe as valid here. Our wind resource is far better even than Germany and Denmark where wind power is currently most widespread.*
>
> *While the 'wrong' leaves may fall on our railway tracks and we hear people in the water industry talk about the 'wrong' kind of rain, we have the best wind - and that's official!*[55]

We are shocked that the DTI staff and press office should have prepared such an intemperate and unscientific utterance for a Minister of State on such an important matter. Even if the research announced were conclusively persuasive, which it is not, these remarks would be inappropriate in their extremity and the cocksure assumption of bad faith on the part of those holding different views. However, in the actual context, which is that of an ongoing and unconcluded technical debate in power engineering, they are highly injudicious and needlessly expose the Minister to embarrassing correction at a later date. In fact, there are two substantive claims here which are incorrect or confused, and cause serious misgivings as to the adequacy of the way in

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[52] http://www.eci.ox.ac.uk/lowercf/renewables/index.html

[53] Graham Sinden, "Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand", *Energy Policy* (2006).

[54] Graham Sinden, *Wind Power and the UK Wind Resource* (Environmental Change Institute (for the DTI): Oxford, 2005).

[55] DTI Press Release, "Research Blows Away Myths", 14 Nov. 2005. http://www.gnn.gov.uk/environment/detail.asp?ReleaseID=177588&NewsAreaID=2&NavigatedFromDepartment=False

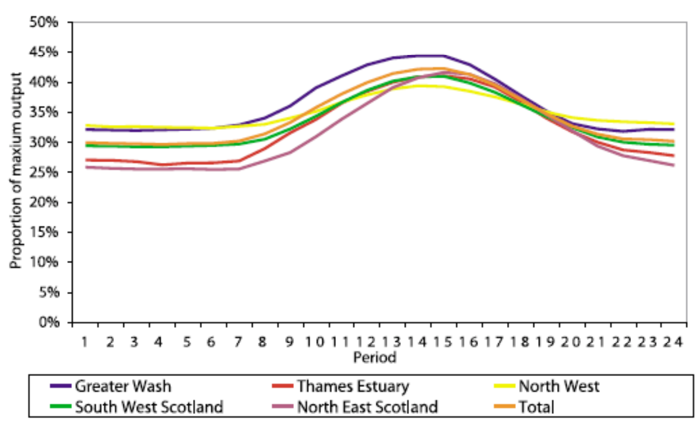
which the data from Mr Sinden's research, and the overall debate itself, has been represented to the Minister and perhaps more widely within government.

We deal with these two claims first before passing on to certain general comments of Mr Sinden's work and the statements attributed to the Minister. Paragraph three makes the very strong claim that "wind power delivers more energy at times of peak demand". This claim is only defensible in relation to timescales which are not strongly relevant to grid management. While it is perfectly true that the winter months are windier, and that peak load tends to occur in those months it is false to suggest that wind output coincides well enough with the diurnal schedule to justify a strong claim such as that made in the Minister's press release. German and Danish data richly confirm this fact, but since the relevance of this data has been called in question (though unjustifiably in our view) we refer to the 2003 study by Oxera of historical wind-speed data over a period of twenty years. Oxera concluded:

> *[…] the peaks in wind generation are generally not fully coincident with electricity demand – i.e. wind generation is not necessarily available at times of demand. Table 1 illustrates the impact of this second conclusion. The table shows the number of hours in a year in which defined levels of demand and wind capacity are available. It indicates that on average, wind generation is only producing at peak for five days of the year, only eight hours of which coincide with the period when demand is at its peak.*[56]

Elsewhere in their study Oxera reproduce the following chart, which represents the hour output of five theoretical wind sites:[57]

Figure 4.2: **Daily variation**



Source: OXERA calculations using Met Office data.

This result is broadly similar to that reported in Mr Sinden's work,[58] namely that wind output is very roughly correlated with the daily demand curve.[59] However, the

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[56] Oxera, *The Non-market Value of Generation Technologies* (June 2003), i-ii.

[57] Oxera, *The Non-market Value of Generation Technologies* (June 2003), 14.

correlation is not strong. Oxera combined data regarding annual, monthly, and daily variations in output and, tabulating the results, state (the emphasis is ours):

> *The overall pattern in Table 4.2 is constructed by combining all these patterns together, and comparing the output of the wind portfolio against demand for electricity. This table has been derived from 10 years of hourly UK electricity demand data and 10 years of simulated wind generation data, with each actual hour of wind speed matched to each actual hour of demand.* ***The results reveal that there are significant periods in an average year when demand is high and wind output is low.*** *For example, in a typical year there will be 23 one-hour periods when the output from wind turbines for the whole of Great Britain is less than 10% of declared net capacity, and demand is between 90% and 100% of peak demand. Similarly, there will be 186 periods when wind output is between 10% and 30% of capacity, and demand is between 80% and 90% of peak demand.*

Table 4.2: **Coincident hours**

Percent of maximum output	Percent of peak demand: 40%	50%	60%	70%	80%	90%	100%
10%	0	276	517	399	339	88	23
20%	0	123	420	437	472	140	23
30%	0	73	264	348	396	186	55
40%	0	39	177	263	338	174	29
50%	0	27	103	196	259	161	34
60%	0	17	74	205	201	181	38
70%	0	7	61	201	214	230	33
80%	0	1	46	125	152	161	21
90%	0	0	14	87	86	103	17
100%	0	0	1	30	39	43	8

[60]

There is nothing particularly surprising in this result, and Mr Sinden's more recent work does not suggest that it is incorrect. Indeed, Mr Sinden confirms it. In the second of his papers he writes:

> *These results do not imply that all demand hours will experience the average capacity factor figures presented in Fig. 9 - there remains considerable variability in the hourly capacity factor occurring during these times, as is*

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[58] See Graham Sinden, *Wind Power and the UK Wind Resource* (Environmental Change Institute (for the DTI): Oxford, 2005), 3; and Graham Sinden, "Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand", *Energy Policy* (2006), Fig. 4.

[59] See NGT chart reproduced above in section 1.

[60] Oxera, *The Non-market Value of Generation Technologies* (June 2003), 14-15. (A typographical error has been corrected in this table.)

> *demonstrated by the low correlation coefficient between hourly electricity demand and wind power output of 28% (Pearson's r).*[61]

This point is reiterated in the Abstract where he writes "wind power output in the UK has a weak, positive correlation to current electricity demand patterns".

Where there is a distinction, however, is between Oxera's emphasis on the examination of the micro structure of the data, and Mr Sinden's leaning towards a macro or coarser-grained analysis in his conclusions, a tendency which has been exacerbated in the DTI press release and ministerial statement. However, as should be sufficiently obvious to anyone familiar with the electricity supply industry, it is the micro texture of the data that is significant in this case. Regrettably the recently published UKERC Report has made no reference to the Oxera work – presumably because it did not agree with the conclusions they sought to make.

Thus we can see that the statement prepared for Mr Wicks was very significantly exaggerated, and has placed him in a potentially embarrassing position. Unfortunately, this is also true of other aspects of the statement, namely that the occurrence of widespread calms or large storms are irrelevant to the issue of wind intermittency, or that the superiority of the UK wind resource is overwhelmingly significant. This is unacceptable, and it is hard to see how such misrepresentations could have become current within the DTI, let alone published as the observations of a Minister of State.

We have so far concentrated on erroneous inferences drawn from Mr Sinden's work. We will now turn to general concerns about the studies themselves, which are theoretical examinations of the likely wind output characteristics of a distributed wind carpet. Mr Sinden has taken a large body of empirical Met Office data regarding wind speeds at a number of locations around the UK, and then on the basis of various assumptions, has inferred the probable output of wind turbines. The principal aim is to examine empirical wind data over long periods, and attempt reasoned estimates of the "capacity credit" attainable by a distributed wind carpet in the United Kingdom. They are being extensively used to suggest that continental experience of wind power gives only a limited insight into its likely behaviour in the UK.

Specifically, Mr Sinden argues that the superior wind resource of the UK will enable a geographically dispersed wind carpet to achieve an improved capacity credit, and to avoid many of the difficulties experienced elsewhere. However, the improvement in capacity credit that Mr Sinden outlines is in fact very modest ("17% of the installed wind power capacity"[62]), and yet would come at the expense of subsidising wind development across a very broad geographical distribution including areas where it was fundamentally uneconomic in the extreme. This latter cost issue is not tackled by Sinden's work, and the absence of this consideration must be regarded as a significant weakness. Overall, indeed, it is the narrowness of scope and lack of the relevance of

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[61] Graham Sinden, "Characteristics of the UK wind resource: Long-term patterns and relationship to electricity demand", *Energy Policy* (2006), para 5.2.

[62] Graham Sinden, *Wind Power and the UK Wind Resource* (Environmental Change Institute (for the DTI): Oxford, 2005), 6.

these papers to the debate that raises concern, rather than outright defects. As Professor Michael Laughton has remarked in correspondence:

> *Graham Sinden's work covers the same periods as Grubb and more, but is more to do with wind statistics and thus potential power generation without any real contribution to probabilistic security of supply and capacity credit. Sinden does not have an engineering background and so in one sense his work is limited; however I have no difficulty with his results which should be seen simply as a contribution to a parallel subject.*[63]

Nevertheless, there are technical flaws in Mr Sinden's work, and these are currently being investigated by various researchers. G. P. van den Berg, whose work has already been cited in relation to the SDC's study of wind turbine noise, is one of Europe's leading experts on atmospheric stability and wind-speed. Van den Berg wrote:

> *Sinden extrapolates the 'surface wind speed' to hub height (without mentioning how, so he must have used the usual logarithmic wind profile), then converts it to wind power. The result, an average over 34 years and 66 sites all over the UK, shows a clearly diurnal pattern (fig. 4), which must be a direct consequence of night-time stability alternating with daytime instability […]. But at higher altitudes the diurnal variation will be less or even inversed, so Sinden's estimate of diurnal variation in UK wind power is wrong.*[64]

Mr Sinden's theoretical work can therefore be regarded as in large part irrelevant to the issues raised by the mass of empirical data contained in the E.ON report, deficient in economic analysis, and in other respects methodologically questionable. Overall, while interesting, it must be regarded as *sub judice*.

UNITED KINGDOM ENERGY RESEARCH CENTRE

The United Kingdom Energy Research Centre (UKERC), which was founded in 2004, has recently published the first document from its "Technology and Policy Assessment Function". This report, *The Costs and Impacts of Intermittency*, claims to be a definitive study of the impact of the cost impacts of adding intermittent or stochastically variable renewables to the generation mix.[65] Incongruously, for such an ambitious project, the work was announced by the UKERC under the unfortunately sensationalistic press release title "UK Energy Research Centre Dispels Myths Surrounding Intermittent Renewable Energy".[66] This release attributes the following words to the Minister:

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[63] Professor Michael Laughton to Professor Infield, 3 March 2006, email copied to me by Professor Laughton, 6 March 2006

[64] G. P. van den Berg to John Constable, 28 Feb. 2006.

[65] Robert Gross, Philip Heptonstall, Dennis Anderson, Tim Green, Matthew Leach, Jim Skea, *The Costs and Impacts of Intermittency: An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network* (UK Energy Research Centre, Apr. 2006).

[66] http://www.ukerc.ac.uk/content/view/259/952

> *Our target is to have 10% of the UK's electricity produced from renewable sources by 2010 and a significant proportion of that will come from wind power. Suggestions that it is excessively expensive, or that traditional power stations are needed to back-up the energy produced by all our wind farms, are just two of the myths that have been peddled by their opponents. The UK Energy Research Centre's study demonstrates that these claims have been exaggerated.*

As with the press release accompanying Mr Sinden's report for the DTI, these vulnerable statements that expose the Minister to criticism. Setting aside the unfortunate tone of this utterance, the principal problem here is the tendency to represent a complex issue in such simple terms that it becomes misleading, and has apparently misled the Minister. This is clearly the case in the Minister's remark on "back-up". While it is perfectly true that the addition of *n* GW of wind does not require the addition of a *further n* GW of conventional plant to support it, it is equally true that the addition of *n* GW of wind cannot *reduce* the conventional capacity by *n* GW. In fact the UKERC report itself states *'Wind turbines do not displace fossil generating capacity on a one-for-one basis'* (p.iii), and again *'Intermittent generation increases the size of the system margin required to maintain a given level of reliability', (p. v).* In point of fact, the "capacity credit" of stochastically renewable generators such as wind is very low, and decreases proportionately as the total installed capacity grows. As can be seen from the remarks of E.ON Netz quoted above, the capacity credit of very large installations is strategically close to zero. This impacts severely on the Government's targets for CO_2 abatement as the best that can be obtained from wind power is a reduction of fossil fuel usage and very little from the actual closure of fossil fuel power stations. We refer again to the very recent review of NGT data and analysis by Professor Michael Laughton:

> *Irrespective of the amount of wind installed in the system, the conventional capacity required will never be less than the peak load. Indeed the 20% conventional plant margin needed without wind will never be reduced, regardless of the added wind capacity, to less than 9 or 10%.*[67]

It is in this sense that critical analysts have commented on "back-up", and it is very unfortunate that Ministerial comments should confuse the issue, and give false reassurance. Professor Laughton has written a short statement on this matter, which we reproduce in this report as Appendix 2 below. The Minister's confidence with regard to pricing is also mistaken, and in large part for the same reason.

Examination of the UKERC report shows that it has contributed to the Minister's error by providing such a narrow frame of investigation that it has failed to grasp the principal issues at stake in discussions of intermittency. We will summarise our criticisms of UKERC's work:

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[67] Michael Laughton, "Power Supply Security with Intermittent Sources: Conventional Plant Capacity Requirements", *Power in Europe*, 460 (10 Oct. 2005).

- In spite of its title the Report does not cover the problem of “impacts” on the overall system.
- The calculations of cost are incomplete, and, or, too narrowly defined. They fail to consider:
    i. Increases in overall system cost due to wind’s low capacity credit, requiring dispatchable conventional capacity at least equivalent to peak load.
    ii. Increases in need for large scale investment in enhanced grid to ensure balancing and to transport energy from remote locations, which the SCAR report estimated as adding 50% to overall costs.
- Premature and imprudent reliance is placed on the work of Mr Sinden, leading to several over-optimistic assumptions of key importance.
- Certain important preceding studies are unjustifiably omitted, while undue weight appears to be given to work from within the wind industry, and to dated and now questionably relevant studies.
- A strong smoothing effect is premised on the optimistic and improbable assumption of the construction of a widely distributed wind carpet.
- The study is throughout marred by an unjustified minimisation of the relevance of the two largest bodies of empirical data regarding wind generation, namely those from Denmark (which has more wind power per head of population than any other nation) and Germany (which has the world’s largest installed wind carpet, at approximately 17,000 MW).
- The choice of external reviewers is puzzling. It is unfortunate that the comments of specialists in the USA and Finland were not correlated with remarks from the Danish grid authorities, or with the German grid company E.ON Netz, whose statements on the difficulties of wind integration are amongst the most trenchant recent publications.

The UKERC was set up by government to provide accurate technical analysis to guide policy. In this report we feel, however, that it has failed to adequately fulfil this role. Far from being “definitive” the report is inadequate in certain regards, and potentially misleading, as is shown by the fact that it has in fact misled the Minister.

Capacity Factor and the Likelihood of a Distributed Wind Carpet

A key assumption in both the UKERC study and that of Graham Sinden, and underlying some of the views of the SDC, is that wind development will be distributed around the United Kingdom to take advantage of some degree of “smoothing”, and that this, when combined with the more favourable overall wind resource, will result in an enhanced “capacity credit”. The precise extent of this smoothing is questionable, and probably limited, since **the UK does not possess several areas of <u>uncorrelated superior</u>**

wind. In fact, the UK possesses a superior wind regime in Scotland, principally in the North West, and mediocre and inferior wind regimes in the rest of the country.

The following map, taken from Hugh Sharman's recent and authoritative study of the performance of Denmark's wind carpet, is based on the European Wind Atlas, and gives a broad-brush insight to the available wind resource.[68]

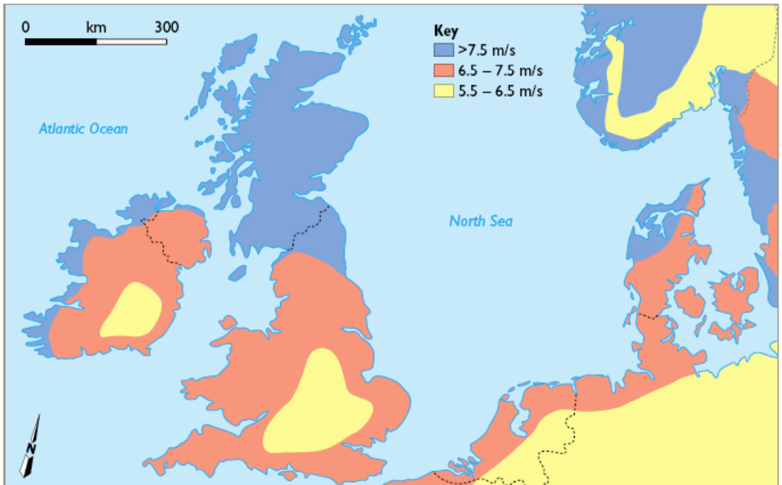

Fig. 5. Britain and Denmark have similar wind regimes (source: European Wind Atlas[2])

More detailed insight is available form empirical data. We refer to the important regional capacity factor analysis recently published in *Energy Trends* for March 2006 in a study jointly conducted by the DTI and by Future Energy Solutions.[69] Table 1 from this analysis is reproduced below (where insufficient data was available the relevant cell is filled with two dots):

Table 1: Regional capacity factors

	1998	1999	2000	2001	2002	2003	2004	Average 1998-2004
East of England	0.23	..	..	..	..	0.23	0.26	**0.24**
North East	..	..	..	..	0.23	0.19	0.22	**0.21**
North West	0.30	0.29	0.27	0.23	0.27	0.24	0.26	**0.27**
Yorkshire and The Humber	0.32	..	..	..	..	0.28	0.27	**0.29**
South West	0.30	..	..	..	..	0.24	0.24	**0.26**
England	0.30	0.28	0.27	0.23	0.27	0.24	0.25	**0.26**
Northern Ireland	0.40	0.39	0.37	0.32	0.35	0.34	0.36	**0.36**
Scotland	0.34	0.29	0.29	0.27	0.29	0.28	0.34	**0.30**
Wales	0.29	0.29	0.26	0.23	0.26	0.25	0.26	**0.26**
UK average	**0.31**	**0.31**	**0.29**	**0.26**	**0.28**	**0.26**	**0.29**	**0.29**
UK aggregate load factor	***0.31***	***0.28***	***0.28***	***0.26***	***0.30***	***0.24***	***0.27***	***0.28***

It is particularly important to note that even in regions such as Scotland, which undoubtedly possess a superior wind resource, the overall average computed for the period 1998-2004 is just 30% (the figure routinely used by the wind industry and by studies such as Graham Sinden's to represent the overall UK mean). The UK average

[68] 'Why wind power works for Denmark', 68.

[69] Mike Janes and Andrew Tipping, and Steven Dagnall, "UK onshore wind capacity factors 1998-2004", *Energy Trends and Quarterly Energy Prices* (DTI: Mar. 2006), 28-32. Available online from http://www.dti.gov.uk/energy/inform/energy_trends/index.shtml.

for that period, in spite of remarkable results in Northern Ireland, is still below 30%. If we remove the Northern Irish data, and this is entirely reasonable on the grounds that 1. it is in effect a separate system, linked principally with Eire, and 2. It may skew mean results giving a false indication for the rest of the UK, the result falls still further to 27%. It should be noted that the mean for England and Wales for the two years in which we have good data (2003 and 2004) is 24.5% and 25.5% respectively.

Four further points should be borne in mind:

1. The sites selected under the Non-Fossil Fuel Obligation programme and at other locations up to 2001 probably possess more favourable wind regimes than those currently being examined.
2. The data from the years 2003 and 2004 is largely based on data collected during the administration of the Renewables Obligation, and is therefore free from estimation errors thought to have troubled earlier data.[70]
3. The vast majority of the plant reported has yet to show signs of age, and it is reasonable to anticipate some decline in performance.
4. New plant, with much greater hub heights (approaching 80 to 90m) may improve results, but construction is uncertain since the visual impact of such structures will stimulate intense opposition at planning.

We therefore conclude that:

- The overall UK capacity factors predicted by the wind industry and presumed by studies such as Graham Sinden's are optimistic, and unlikely to be realised over the medium term.
- Regional variation within the UK is very considerable. The UK does not possess several uncorrelated areas of high wind, but a superior wind resource in one region only. Consequently, the smoothing effect would be moderate or weak, even if the UK succeeded in building a distributed wind carpet.
- A distributed wind carpet is unlikely to be built, since sites in Southern England are so wind poor that they will struggle to be economic, even with full RO support.[71] Investment is therefore likely to be concentrated in superior sites, such as Scotland, and may even be concentrated within the NW of that country, thus invalidating much of the analysis in both Mr Sinden's study and that of the United Kingdom Energy Research Centre.

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[70] Email: Gareth Evans (Technical advisor, Ofgem) to Mr Hugh Sharman 17.01.05: "We note that you are quoting DUKES data for UK wind generation. We would like to point out that until recently this was based on generators estimates rather than actual output. Since ROC data has been used the output statistics have indicated lower capacity factors than appear to have been used for the earlier estimates."

[71] Oxera Consulting Ltd, *What is the impact of limiting ROC eligibility for low-cost renewable generation technologies?* (August 2005), p. 10. Commissioned by and available from the DTI.

6. Realism with Regard to Renewable Energy Futures

There is a tendency amongst non-engineers and some environmental lobbyists to regard our current energy debate as confined to the provision of an interim or bridging solution to carry the UK over into a situation where energy, or at least electricity, is predominantly and perhaps wholly provided by renewable sources. The Foundation believes this is a deeply misleading and potentially disastrous view. **Exaggeration must be avoided if renewables are to realise their potential, and make a fruitful and worthwhile contribution to our energy needs.** Hyperbole in this sector, as in many others, will have the ultimate consequence of destroying value. Realism, then, is essential, and in support of such a re-orientation we using our submission to put before the Review the text of an article currently being prepared for publication by Michael Laughton. To avoid confusion with our own text this article is given here as Appendix 1, but we recommend the reader to consult it at the relevant point indicated below.

We draw the Review's attention to the fact that this article formed the working paper for a letter sent on the 27.03.06 to the Sustainable Development Commission, by Professor Laughton and a number of other leading experts in the electricity industry. With permission, we reproduce the text of this letter as an introduction to Professor Laughton's article:

> *The energy policy recommended in the recent Sustainable Development Commission Report to achieve an overall 60% reduction in the UK CO_2 emissions by 2050, as adopted by the Government in the 2003 White Paper, is based on accomplishing massive energy savings combined with the idea of supplying most if not all electricity from renewable resources. Neither proposition is supported by evidence and shows an inadequate understanding of technical and practical economic constraints.*
>
> *There will always be a major requirement to deliver a reliable and cost effective public supply of electricity to run public services, whatever the growth of micro-generation and renewables. This implies the continuance of a grid supplied system supported by sophisticated controls requiring central human supervision to ensure security and quality of power supply, especially when unforeseen contingencies arise.*
>
> *Renewable sources such as biomass, tidal, hydro, solar, and wind have much to offer and if correctly managed will make a useful contribution to our energy needs. The use of such resources would be constrained, however, by the requirements of balancing power demand and supply at all times, transmission network management involving the maintenance of voltage and frequency standards and, most importantly, the delivery of security of supply standards. Thus renewable energy can only be part of a larger framework of electricity supply in combination with other generation sources which can be scheduled and dispatched in a predictable way.*

If the purpose of the Report was to find an alternative future without nuclear power then this will have to involve more high efficiency gas-fired generation (but still with some CO_2 release) and "cleaner" coal-fired plant necessarily with carbon capture and sequestration. These have the attendant problems of new technology and storage development, increasing world prices and security of supply of fuel. Set against these factors nuclear is a carbon free proven technology; however all these sources - gas, cleaner coal and nuclear, along with some renewables - are likely to be needed.[72]

This is a sobering perspective, but entirely consistent with what is now known about renewable energy. The Foundation considers the issue of a nuclear rebuild to be outside its remit, but in the light of expert analysis such as this it would inexcusable to suggest that it is within the capability of renewable energy to render that rebuild needless. As Professor Laughton and his colleagues indicate, only fossil fuels can provide an alternative, with the scale of this fossil deployment being mitigated to some degree by renewables, preferably those capable of firm generation. The technical argument underlying this position is given in the full text of Professor Laughton's article, "Renewable Energy and the Power Market Bottleneck', which we provide in Appendix 1, and we refer the reader to it at this point.

We have examined Professor Laughton's analysis and find it raises various issues regarding the long term future of renewable electricity generation that have not been sufficiently appreciated by policy analysts or investors. It is clear that a simple transition from a statement of available practicable resource to an estimate of probable contribution to electrical energy is naïve. There are technical features inherent in the character of the electricity supply industry that make it highly unlikely that a portfolio wholly or predominantly composed of renewable technologies, many of which are stochastically variable or intermittent, could operate at the maximum capacity factor theoretically attainable from the available renewable energy resource. In other words, some degree of market constraint is likely to apply to renewable generators, making it very unlikely that they can supply all or even a major part of national electricity. This is of major significance for two reasons:

- The actual contribution of renewable sources to national electricity needs is unlikely to be as large as projected.
- Investors are being misled into making long term income stream projections on a false assumption with regard to achievable load factor.

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[72] Dr Robert Hawley, CBE, FREng, FRSE, (Past President IEE); Sir John Horlock, FREng, FRS, (Formerly Treasurer and Vice-President of the Royal Society) Dr Sue Ion, OBE, FREng, (Vice-President, Royal Academy of Engineering) Dr Malcolm Kennedy, CBE, FREng, FRSE, (Past President IEE) Professor Michael Laughton, FREng, (Emeritus Professor of Electrical Engineering, University of London) Dr Philip Ruffles CBE, FREng, FRS. (Formerly Vice President, Royal Academy of Engineering), to the Sustainable Development Commission, 27 March 2006.

We draw a number of conclusions from this, the first and foremost of which is that a lack of realism in regard to renewable energy futures will damage both the UK and the long term future of the renewable sector. It is vitally important that government and investors are aware of the high probability of inherent limitations to renewable contributions especially in the longer term. While advances in the engineering and economics of storage options may to some degree mitigate this it would be very unwise to bank on such improvements.

We therefore recommend that the government does not regard the current energy debate as concerned with the provision of an interim or bridging solution, which must only carry us over into and prepare for a renewable future. Instead, **the current solution must be a low risk strategy which is robust in the long term and can carry the UK and its people through even the more pessimistic conceivable scenarios**.

7. Conclusion

The government has preferred to leave the market much freedom in determining the future of energy provision for the United Kingdom, and has limited its involvement to the provision of guidance via policy instruments such as the Renewables Obligation. We share the government's desire to ensure that national energy supplies are secure, reliable, affordable, clean, and sustainable. However, in the light of the above analysis **we are deeply concerned that current policy is not correctly configured to deliver a diverse and balanced portfolio of renewable electricity generation**. We have concluded that the Renewables Obligation is in large part the cause of these deficiencies, with unsatisfactory consequences in the rest of the energy sector. In our view the single most important action that the government could take in relation to renewables is to revise the Obligation to reduce rewards for near-market technologies. **We emphasise that the benefits of a revision to the Obligation would be felt both within and without the renewable energy sector.** For a more detailed schedule of our conclusions we refer the reader the "Summary of Response" above (p 5ff).

Appendix 1: Michael Laughton, "Renewable Energy and the Power Market Bottleneck"[73]

INTRODUCTION

The Sustainable Development Commission (SDC) has recently published a position paper, *The role of nuclear power in a low carbon economy* (March 2006), intended to contribute to the current "Energy Review". The SDC concludes:

> *[…] the majority view of the Sustainable Development Commission is that […] there is no justification for bringing forward plans for a new nuclear power programme, at this time, and that any such proposal would be incompatible with the Government's own Sustainable Development Strategy. This is our advice to Ministers.*[74]

In support of this main conclusion the SDC has issued seven supporting studies, some authored by the Commission alone, and others in conjunction with external consultants. The second of these studies, Reducing CO_2 emissions – nuclear and the alternatives, is crucial to understanding the conclusion reached by the SDC in its final analysis. However, examination shows that one of the grounding principles of the study is dangerously flawed. In assessing the potential for renewable energy in the UK's future portfolio the SDC draws on two studies, one by the Tyndall Centre and another by the Interdepartmental Analysts Group (IAG), and draws the following very striking conclusions (all footnotes are those of the present author):

> *The data on UK renewable resources suggests that the total practicable resource is at least 334 TWh/year,*[75] *or 87% of current electricity production. Introducing price restrictions*[76] *reduces this somewhat, but at 258 TWh/year (67%),*[77] *it is still considerable. […] Significant technological progress in renewables and infrastructure could push the practicable resource further towards the theoretical resource estimates. It is, therefore, reasonable to state that it is theoretically possible to supply all of the UK's electricity from renewable sources in the long-term, especially when combined with energy efficiency. The main constraint is likely to be economic rather than technical.*[78]

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[73] Professor M.A. Laughton, FREng. FIEE, CEng, "Renewable Energy and the Power Market Bottleneck: An analysis of the policy advocated by the Sustainable Development Commission in *The role of nuclear power in a low carbon economy*", working paper circulated within the IEE.

[74] Sustainable Development Commission, *The role of nuclear power in a low carbon economy* (March 2006), 20.

[75] Tyndall Centre, *Renewable energy and combined heat and power resources in the UK* (2003).

[76] Up to 7p/kWh.

[77] Interdepartmental Analysts Group (IAG), *Options for reducing carbon emissions in the UK* (2002).

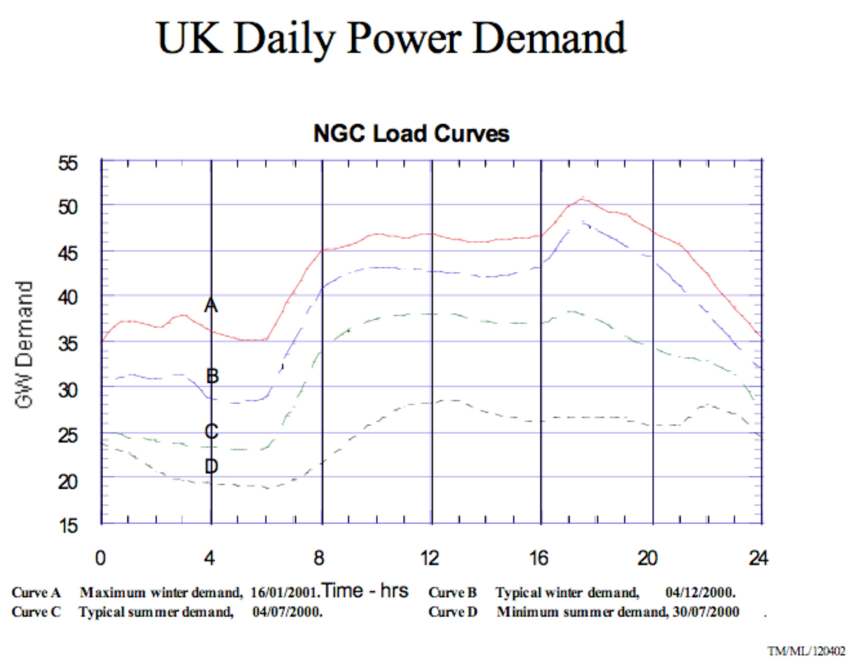
[78] Sustainable Development Commission, *The role of nuclear power in a low carbon economy Paper 2: Reducing CO_2 emissions – nuclear and the alternatives* (March 2006), 16.

In the run-up to the long-term future projected here, the SDC believes that unprecedented energy efficiency gains can be realised (which is a goal certainly worthy of support, though somewhat idealistic), that fossil fuels can be used more efficiently through more Combined Heat and Power schemes, and that carbon capture and storage can be employed as a bridge to the time when renewable sources can be used to the extent described in the paragraph quoted above.

This hypothetical solution to the problem of carbon free electricity production in 2050 persuades the Commission that nuclear is not a necessary option. However, the SDC has not attempted to test the strength of its reasoning by examining it from the viewpoint of the technical requirements of an electrical power system. For example, questions might be raised regarding crucial points such as the ability of the system envisaged by the SDC to meet the demand for instantaneous power (as opposed to gross energy requirement) in a way that is both stable and secure. For brevity though, it is perhaps most convenient to concentrate of one of the simplest and most obvious technical issues, namely that relating to the squaring of the relationships between energy, power and load factors.

SYSTEM LOAD FACTOR

The following figure[79] illustrates typical and extreme daily cycling of power demand on the UK electricity grid supply system for days in both winter and summer.



A clear understanding of this chart requires the understanding of the following points:

[79] The figure is simply to illustrate typical variations over 24 hours in the system power demand. The 2004 peak demand England, Wales ,Scotland and N Ireland was 61 GW (DUKES 2005) with an annual average demand of approximately 40.4 GW.

- The load, or power demand, is the height of the graph, and is measured in GW.
- The power supplied by generators must exactly match the load at all times, since electrical energy cannot be economically stored on the industrial scale.
- The energy supplied (GWh) is the area (power x time) under the demand curve.
- The system demand "load factor" is the ratio of the average to peak demand and gives system planners some understanding of the variability of the system. A load factor of 90% would indicate a system with little variation, while one of 40% would indicate a very variable system.
- For 2004 the "load factor" was 66.3% (i.e. average demand / peak demand = 0.663) indicating considerable but not extreme variation.

RENEWABLE ENERGY AND A VARIABLE SYSTEM POWER DEMAND

In grasping how renewable energy generators would access such a variable dynamic system demand, we must refer to load factor in another technical sense, sometimes called capacity factor.

- The input of a renewable generator, for example wind, wave or tide, usually fluctuates. Thus, the generator cannot operate at 100% capacity at all hours. The load factor of a renewable generator is understood as the energy output actually obtained over a year as a fraction of the theoretical output which would result if the plant were operated at 100% capacity.
- Load factor in this sense can be used to calculate the capacity necessary to generate a particular quantity of energy. (GW Capacity = GWh energy / {8760 hours per year x load factor})
- For onshore wind the load factor might be 30%, offshore wind 35%, etc.

Such "load factors" are used by investors to compute the likely income and hence the likely Internal Rate of Return arising from a particular generation project, for example a wind farm.

However, and this is crucial, such calculations assume that a renewable energy generator will be able to market all the power it produces, and will not be constrained by fluctuations in the demand curve and periods of low demand. As we will see, in the scenario outlined above by the SDC this is not a reasonable assumption.

The SDC bases its statement quoted above on claims made by The Tyndall Centre in a study which suggests that the practicable energy outputs to be expected from various renewable resources amount to some 334 TWh. We can calculate the installed plant capacities required to generate this energy by applying typical, perhaps somewhat optimistic, load factors:

Renewable Resource	**Expected Practicable Electrical Energy Generated TWh/year**	**Estimated or Typical Load Factors: %**	**Implied Generation Capacity: GW**
Municipal Solid Waste	13.5	0.66	2.3
Hydro	4.9	0.35	1.6
Wind onshore	58	0.3	22.1
Wind offshore	100	0.35	32.6

Energy Crops	17	0.66	2.9
Forestry & Agricultural Wastes	14	0.66	2.4
Wave - shoreline *- near shore* *- offshore*	0.4 2 50	0.35	17.1
Tidal-stream	36	0.35	11.6 (est. 8.2 peak)
Tidal-barrage	50	0.35	16.1 (est. 11.3 peak)
Photo-voltaic	7.2	0.35	2.3
Totals	**334**		**111**

Renewable Resource Energy Generation Potential and Generating Capacity Requirements

Thus we see that to generate 334 TWh of renewable electricity would require at least 111 GW of generating capacity. To put this in perspective, the current UK portfolio is approximately 78 GW.

Crucially, however, the SDC believes that this 334 TWh of practicable renewable resource generation would be 87% of the annual electrical energy needed. But with a system load factor of 66.3%, as it is at present, the system load demand cycle would have an annual peak demand of only 57.5 GW with an average demand of 38.1 GW.

The question which then arises is whether 111 GW of renewable plant can access the market without being constrained in its output by lack of demand.

As a matter of logic it is quite apparent that a bottleneck allowing only a maximum delivery of 57.5 GW and an average delivery of 38.1 GW will offer 111 GW of renewable power plant, much of it stochastically variable and non-dispatchable, only a **low probability of unconstrained access to the electricity market.**

If access to the market is constrained,[80] then the renewable generators will not be able to operate for all hours during which their input is available, and thus it must be concluded that the practicable renewable resource generation will be considerably smaller than the anticipated 334 TWh. The same conclusions also apply to the IAG's lower estimate of 258 TWh/year (67% of current demand), also referred to by the Commission.[81]

Exact calculation of what could be expected of renewables with such a system load factor depends on many other variables, not the least of which is cost. However, **it is clear that the SDC's assumption that <u>all</u> of the UK's electricity generation portfolio in the long-term future could in theory be supplied from renewable sources is not well grounded, and is almost certainly false.**

CONCLUSION

Contrary to the Commission's initial view, the main constraint on renewable energy is technical rather than economic. Power demand, not the quantity of the energy resource available, is the dominating scientific constraint.

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[80] As currently happens in Germany with excess wind generation. See E.ON Netz, Wind Report (2005), 18-19.

[81] Interdepartmental Analysts Group (IAG), *Options for reducing carbon emissions in the UK* (2002).

Biomass, tidal, hydro, solar, even wind, have much to offer, and if correctly managed will make a useful contribution to our energy needs, but as renewables can only supply an as yet undetermined fraction of the demand for electrical energy the need for other large, low carbon generation sources remains.

If the purpose of the SDC's report was to find an alternative solution to a future containing more nuclear power, then it has not succeeded. If the SDC still wishes to argue that nuclear power has no role, then it must endorse hydrocarbon sources with carbon capture and storage, and address the attendant price and security of supply questions.

Appendix 2: Michael Laughton, "Observations on the UKERC Report on 'The Costs and Impacts of Intermittency'"

Commenting on the UKERC Report,, Energy Minister Malcolm Wicks said:

> *Our target is to have 10% of the UK's electricity produced from renewable sources by 2010 and a significant proportion of that will come from wind power. Suggestions that it is excessively expensive, or that traditional power stations are needed to back-up the energy produced by all our wind farms, are just two of the myths that have been peddled by their opponents. The UK Energy Research Centre's study demonstrates that these claims have been exaggerated. I welcome the report's contribution to the debate."*

The problem is that according to studies by the National Grid and others traditional power stations <u>will</u> be needed for reliable electricity supply with sufficient capacity to meet peak power demand much as at present, so unfortunately the Minister's reference to the absence of need of conventional plant to back up wind energy has lead to some misunderstanding.

With or without wind generation in the electricity system, security of power supply is governed by the probability of the available plant being able to meet power demand at all times, especially at or near peak periods. Wind generation on its own cannot provide a reliable supply of power. When backed up if necessary by appropriate levels of reserve plant, however, it can provide an annual energy supply within desired levels of probability. The latter result is the essential conclusion of the UKERC Report and in previous studies listed. Unfortunately because the ensuring of the reliability of annual energy supplies and the reliability of daily power supplies are two very different problems, but perhaps confused as being the same by those not in the field, the Report is in danger of being misinterpreted and thus misreported.

By way of illustration, if 25,000 MW (25GW) of wind capacity were to be added to the electricity supply system only 5GW of conventional plant capacity could be retired. This result is contained in extensive studies made by the National Grid, ILEX Consultants and others. The relatively small capacity credit of wind generation in Britain is governed by existing security of supply standards (loss of load probability, or LOLP levels), where in general the capacity credit is of the of the order of the square root of the GW of wind installed.

With a 30% annual load factor this 25GW of wind capacity would generate annually the same energy on average as 7.5GW of conventional thermal plant capacity. If 7.5GW of conventional plant were to be closed as a result of this loss of market, however, then an additional 2.5GW of reserve capacity would have to be added to the system in order to maintain power supply security standards (LOLP) by ensuring that only a net amount of 5GW of dispatchable capacity were removed.

It is this cost of this extra reserve plant plus extra annual balancing costs that are quoted as the additional costs arising from the intermittency, or variability, of wind.

These are small relatively, or even zero, depending on the wind annual load factor and penetration of the market. Other additional costs from transmission reinforcement and additional distribution costs are omitted. From the ILEX Report to the DTI in 2002 on "Quantifying the System Costs of Additional Renewables in 2020" (the SCAR Report) these costs are seen to add a further 50% to the total. A further omission is the extra cost of the impact of the cycling wind power output on the operation and eventual replacement of the other retained conventional stations. If open cycle gas turbines were to replace combined cycle gas turbine plant up to the wind plant capacity the extra operating and reserve plant costs would then be pushed up towards levels quoted in the Royal Academy of Engineering report of 2004 on "The cost of generating electricity", which were based on such considerations. These considerations, however, were considered to be outside of the remit of the UKERC Report.