UK ENERGY RESEARCH CENTRE

Renewable Energy-Generation Technologies

Response to the Science and Technology Committee Consultation

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This response is sent on behalf of the UK Energy Research Centre, a collaboration between eight universities and research institutes established through an award from the UK Research Councils.

Participants in the Centre have been consulted about this response but we do not assert that every individual would back every statement.

THE UK ENERGY RESEARCH CENTRE

The UK Energy Research Centre's (UKERC) mission is to be the UK's pre-eminent centre of research, and source of authoritative information and leadership, on sustainable energy systems.

UKERC undertakes world-class research addressing the whole-systems aspects of energy supply and use while developing and maintaining the means to enable cohesive research in energy.

To achieve this we are establishing a comprehensive database of energy research, development and demonstration competences in the UK. We will also act as the portal for the UK energy research community to and from both UK stakeholders and the international energy research community.

Executive Summary

- Funding of renewable energy is increasing, which is welcome
- Co-ordination of research has improved over recent years, but there is potential for further improvement
- The research landscape and funding structures continue to undergo disruptive change, which is counterproductive; a consistent approach should be pursued
- There is a need to improve funding in bioenergy systems, particularly biofuels
- The focus for large scale wind energy research should be on operational issues
- The challenge remains in producing viable cost effective PV systems
- Fuel cell research also faces considerable barriers, but the UK has a good position which should be maintained
- The UK has a leading position in marine renewables, but it is still far from commercial deployment
- In addition to research on the individual renewable energy technologies, integration issues are increasingly important and continuation of the existing strong research activity is encouraged

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The following submission is preceded by a tabled summary of the current state of energy research and development and deployment in the UK, technology by technology. This is used as the basis for commentary on the technology potential of:

- Wind
- Photovoltaics
- Hydrogen and fuel cells
- Marine renewables
- Bioenergy
- Groundsource heat pumps
- Microgeneration
- Intelligent grid management
- Energy storage

Finally, UKERC offers its views on the research funding landscape. Recommendations are highlighted in bold.

1 Summary of Current State of R&D and Deployment Technology by Technology[1]

Technology	R&D volume in last 4 calendar years (£million)	Current installed capacity
Wind - offshore	2.9 in 2007 4.4 in 2006 1.4 in 2005 0.7 in 2004	304 MW
Wind - onshore		1,872 MW
Photovoltaics	4.6 in 2007 3.9 in 2006 3.0 in 2005 1.9 in 2004	10.9 MW[2]
Hydrogen & fuel cells	7.5 in 2007 6.8 in 2006 5.4 in 2005 6.3 in 2004	
Wave	8.5 in 2007 11.2 in 2006 6.0 in 2005 2.6 in 2004	Shoreline wave - 0.5[3]
Tidal - barrage		The installed capacity of tidal power reached 3,836MW in 2005[4]
Tidal - current		
Bioenergy - biofuels[5]	0.9 in 2007 0.4 in 2006 0.4 in 2005 0.3 in 2004	0.5% of total transport fuel sales from UK-sourced biomass in 2007 (264 million litres)
Bioenergy - biomass[6]	2.9 in 2007 2.7 in 2006 2.1 in 2005 1.5 in 2004	4.1% of UK electricity and heat[7]. Total installed capacity in 2005 was 4850 MW.
Ground source heat pumps		3.2 MWth[8]
Microgeneration[9]	0.22 in 2007	Not available
Energy storage	1.6 in 2007 1.1 in 2006 0.5 in 2005 0.2 in 2004	Not significant

[1] Unless stated otherwise, data is from the UKERC Research Register
[2] 2005 data from IEA Photovoltaic Power Systems Programme
[3] DTI, DUKES 2006
[4] Variability of UK marine resources, 2005
[5] Biofuels designates liquid fuels derived from biomass including dedicated energy crops
[6] Biomass is biomaterial (eg from energy crops and forestry waste) burned to produce heat or electricity or both
[7] Figures taken from Biomass Strategy Document May 2007, published by DEFRA. DTI, DFT
[8] 2005 data from National Energy Foundation
[9] Microgeneration includes domestic scale generation from wind and CHP

2 Technology Potential

1. The potential of the different technologies is summarised below. Primarily this is in terms of the time to reach a level of development when significant contributions to energy generation can be expected. However, some indication of levelised costs for wind power will be presented, based on UKERC's recent report: Investment in electricity generation – the role of costs, incentives and risks (May 2007). Levelised costs provide an important indicator of the relative attractiveness of different technologies to investors but the complete picture includes market risks and volatility as well as the design and credibility of any support mechanisms.

2.1 Wind power

2. Although wind power is a relatively mature technology, **R&D is required to underpin the scaling up of the technology**. It is widely recognised that turbines larger than 2 to 3 MW rated require improved design codes to account for the intrinsically more flexible structures. Turbine manufacturers are under extreme pressures to deliver the increased volumes of machines and cannot undertake the basic research required. In setting up a technology platform for wind, the European Commission acknowledged that publicly funded research was required and that Universities and research institutes had an important role to play, both in delivering the research and in providing the highly trained engineers required by the fast growing industry.
3. There are engineering challenges in siting turbines offshore at increasing water depths. Condition monitoring for predictive maintenance is a key issue for operators if acceptable levels of reliability are to be achieved. Support for continued development of technology in these areas will help meet policy aims and potentially provide an exploitable knowledge base for the UK.
4. Wind energy is already making an important contribution to UK electricity supply. It is well known that the UK has a massive wind resource. Increasingly the barriers to exploitation will be the electricity distribution and transmission infrastructure (see section 2.8 below).
5. Current estimates of onshore generation costs according to UKERC[10] are in the range £39/MWh +- £17/MWh, with offshore in the range £48/MWh +- £20/MWh.
6. Energy payback period is a reasonable proxy for carbon footprint. Experts agree that the period is measured in months rather than years. For example, calculations by the Danish Wind Industry Association indicate the payback period for onshore wind turbines around three months (although clearly this figure is site dependent), with slightly lower figures for offshore wind.

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[10] UKERC report: Investment in electricity generation – the role of costs, incentives and risks (May 2007)

2.2 Photovoltaics

7. PV technology has been evolving steadily since its appearance in the 1960s. Initially the devices were based on crystalline silicon, drawing heavily on the knowledge of that material that developed out the fast growing electronics industry. The first thin film device was based on amorphous silicon soon after discovery of the material in the late 1960s. Thereafter a range of alternative thin film and wafer based cells were developed, some for space application where multiple-junction cells with over 40% efficiency have been demonstrated. Some were developed specifically for the terrestrial market, most notably Cadmium Telluride (CdTe) and Copper Indium di-Selenide (CIS) devices where monolithic manufacturing techniques have been applied to keep costs down. Efficiencies for commercial thin film modules can be up to 12% whilst experimental laboratory test cells have considerably higher efficiencies. This compares with the best commercial mono-crystalline silicon modules that have efficiencies approaching 20%. More recently research has opened up the possibility of low cost moderate efficiency organic cells, both dye based and polymer devices.

8. The primary challenge is the design and fabrication of low cost, stable, good efficiency cells that will eventually be able to compete with bulk generated conventional electricity. The expected timeline for technology development, and the point at which PV technology will be able to compete without explicit subsidy, is a matter of debate and of course depends of the levels of R&D expenditure that will be committed and the degree of commercial investment. The published Strategic Research Agenda of the EU PV Technology Platform presents an informed view on these key issues, and this has been adapted to provide UK specific targets in UKERC's UK PV Research Road Map.

9. The overall aim of research in PV has to be to reduce PV generated electricity costs. Some improvement in conversion efficiency is required, particularly for the thin films, but this must be coupled to dramatically reduce production costs; the goal is often considered to be the reduction in the cost per peak Watt, but should more accurately be the cost per kW hour generated considering all system and operational costs. There is no one approach or technology that stands out in terms of its potential to deliver but it is clear that **increased research emphasis on the manufacturing process is required**. Materials research aimed at improved PV devices must constantly bear in mind the manufacturability of provided device architectures. Although most of the research challenges lie with PV module design and manufacture, systems are presently let down by underperforming balance of system components and in particular the inverter. Moreover presently available performance prediction tools are inadequate and as a result, potential customers can be misled. **Research is needed to improve the available calculation tools**.

10. UKERC's Research Road Map for PV (January 2007) projects a target price for PV systems of 1 Euro/Watt by 2030, but of course this figure is critically dependent on R&D and market expansion. By this time it is estimated that PV in the UK could be contributing approximately 3% of national electricity.

11. Energy involved in the manufacture of a PV system is recouped in the case of the market dominant silicon wafer cells in between 3 and 4 years, with thin film cells, having less energy intensive manufacturing, at 3 years or less. Design and fabrication improvements are anticipated to reduce these figures substantially, perhaps to around 1 year for thin film devices.[11]

2.3 Hydrogen & fuel cells

12. Fuel cells, operating on hydrogen or hydrogen-rich fuels, have the potential to become major factors in catalysing the transition to a future sustainable energy system with low carbon dioxide emissions. The vision of such an integrated energy system of the future would combine large and small fuel cells for domestic and decentralised heat and electricity power generation with local (or more extended) hydrogen supply networks which would also be used to fuel conventional (internal combustion) or fuel cell vehicles.

13. As the table in Section 1 shows this field receives is the best-funded of the technologies discussed, although in comparison to other countries the absolute level is modest. The UK has established an internationally competitive position and can boast two world-class spin-out companies, which demonstrates a good return from the investment to date.

14. There remain three major technological barriers that must be overcome for a transition from a carbon-based (fossil fuel) energy system to a hydrogen-based economy. First, the cost of efficient and sustainable hydrogen production and delivery must be significantly reduced. Second, new generation of hydrogen storage systems for both vehicular and stationary applications must be developed. Finally, the cost of fuel cell and other hydrogen-based systems must be reduced.

15. Consequently we believe **there are strong grounds for the existing funding level to be at least maintained**.

2.4 Marine Renewables (Wave and Tidal Current Energy)

16. Marine renewables cover wave energy and tidal current energy. The potential for offshore wave energy in the UK has been estimated to be 50 TWh/year with nearshore and shoreline wave adding another 8 TWh. The UK tidal stream potential is 18 TWh. Taken together, approximately 15-20% of UK electricity demand could in principle be met by wave and tidal current. This growing sector believes that by 2020 there could be 1-2GW of installed capacity in the UK. To achieve this requires successful demonstration of the technology at full scale.

17. Since 2000, a number of large scale wave and tidal current prototypes have been demonstrated around the world, but marine renewable energy technology is still 10-15 years behind that of wind energy. UK based developers are leading the field with the majority being SMEs. The Carbon Trust estimates that there are 40-50 devices in various stages of development. In the UK only one wave energy device (Pelamis) and two tidal current devices (MCT & Open Hydro) have been demonstrated at near full scale in the open sea. The first commercial wave energy farms using the

[11] Figures from US Department of Energy.

Pelamis device are being planned in Portugal, Orkney and Cornwall. The largest tidal current turbine (Seagen, MCT) will be installed in August 2007 in Strangford Lough in N. Ireland. Although there are some companies installing large devices there is still no clear technology winner, with many companies still in the early development stage.

18. The UK leads the development in marine renewable energy and has the potential to benefit from any emerging global market. Areas where the UK can benefit from this global market include: wave & tidal current device development; Electrical system design; Scale model tank testing; Resource Assessment; Device Installation, Device Manufacture; Grid connection; System demonstration; Offshore test facilities at European Marine Energy Centre (EMEC) in Orkney and at the Wavehub off the Cornish coast.
19. Although progress is underway through deployment and test there are still key scientific challenges to be addressed in areas including, Resource Assessment and Predictability, Engineering Design and Manufacturability, Installation, Operation and Maintenance, Survivability, Reliability and Cost Reduction. The research priorities required to meet these challenges have been drawn from current roadmaps and vision documents including more recent consultations within the community by the UKERC Marine Research Network. Some of these priorities are being addressed by the EPSRC Supergen Marine Consortium. Development of a prototype is time consuming and very expensive, taking between 7 and 10 years. An overarching challenge is to reduce this development time, which will require developers and academic research teams to collaborate in research programmes such as Supergen Marine to develop reliable design codes and reduce the reliance on tank testing at different scales.

2.5 Bioenergy

20. The UK's biomass resource is significant and is estimated by some as generating up to 20 million tonnes per annum. Research and development needs within the bioenergy area have been identified in the UK horizon scanning activity in foresight, in the EU with the Biomass Action Plan and the ReFUEL project for liquid transportation and the development of the biorefinery concept. A clear distinction is necessary between first generation crops that have been developed for food (sugar beet, oil seed rape and wheat grain) that may be used for chemical conversions to biodiesel and bioethanol and second generation lignocellulosic (biomass) crops that can be used as feedstock for heat, power and liquid fuels. The UK biomass strategy report May 2007[12] makes it clear that biomass streams in the UK could be much better utilised.

21. First generation technologies have in general a poor carbon footprint and represent a 'intermediate step' towards second generation lignocellulosic feedstock. Research emphasis for these crops should be placed on landscape-scale impacts of moderate increases in OSR growth, on the knock-on effects on increased cereal growth and consequent loss of set-aside land and associated impacts on UK Biodiversity and altered carbon footprint and complete Life Cycle Analysis. At present there is limited understanding on

[12] UK Biomass Strategy, May 2007

how these bioenergy chains compare in environmental impact and a better evidence base is required.

22. **Future strategic research efforts should be focussed on second generation lignocellulosic feedstocks.** Current funding in place will address breeding and improvement for higher yield in these crops, but the UK should be prepared to **place additional resource to ensure adequate miscanthus, poplar and willow germplasm as the climate changes and this will require a strategic long-term investment in breeding and improvement.** Our 10 year aim should be to obtain reliable 20 tonnes ha^{-1} y^{-1-} yields, rather than the commercial-scale 10 t ha^{-1} y^{-1} currently reported, with limited inputs of water, fertilizer and chemicals. All evidence suggests that in comparison to arable crops, deployment of perennial second generation crops will give positive benefit to the environment, however landscape-scale issues of large commercial plantation still require further whole-system understanding, where spatial supply and demand are considered together in relation to the emerging technology deployment. It is well recognised that the 'bioeconomy' will be of increasing importance but in the UK limited research effort has been focussed on the biorefinery concept and this will require a cross research council initiative involving bioscientists, engineers, computer scientists and environmentalists working together to ensure the value chain is captured from these emerging concepts. The UK is some way behind the rest of Europe and the USA in this area.

23. The UK will continue to rely heavily on imported feedstock for liquid transportation biofuel and for co-firing. **The development of additional tools to assess sustainability in a global context should be given high priority.** Similarly, public awareness should be raised in this area, given current misconceptions and misinformation for example on food versus fuel, environmental impacts, and the biomass resource available to us in the UK and globally.

2.6 Ground source heat pumps

24. Ground source heat pumps make use of renewable (solar) energy stored in the ground and provide one of the most energy-efficient ways of heating buildings. They are suitable for a wide variety of building types and are particularly appropriate for low environmental impact projects. They do not require hot rocks (geothermal energy) and can be installed in most parts of the UK, using a borehole or shallow trenches or, less commonly, by extracting heat from a pond or lake. Heat collecting pipes in a closed loop are used to extract this ambient stored energy, which can then be used to provide space heating and domestic hot water. In some applications, the pump can be reversed in summer to provide an element of cooling.

25. The only energy used is electricity to power the pumps. Typically, a ground source heat pump will deliver three or four times as much thermal energy (heat) as is used in electrical energy to drive the system. And, in the longer term this electricity can be provided from renewable sources.

26.

Ground source heat pump systems are widely used in other parts of the world, including North America, China and Europe. Typically they cost more to install than conventional systems; however, they have very low maintenance costs and can be expected to provide reliable and environmentally friendly heating for in excess of 20 years. They require heating systems optimised to run at a lower water temperatures than conventional UK boiler and radiator systems. They are therefore well matched to underfloor heating systems.

27. No fundamental research is required and the basic technology is well developed. **Improved system designs for heating and cooling applications require research and development and improved design guidelines should be developed to increase the confidence in installation quality and performance**.

2.7 Microgeneration

28. Microgeneration covers the very smallest electricity generation plant. Most often these units are installed at consumers premises, and a large market is foreseen for domestic application. The key technologies are micro-wind, PV and micro-chp (usually gas powered). Common issues relate to grid interfacing through power electronics and the safe integration of numerous such sources into the electricity distribution system. Significant R&D is underway on these topics, much of it supported by EPSRC's Supergen Programme, but the challenges are considerable and continuity of research funding in this area is essential. Currently the technologies are far too expensive and research efforts should be directed at improved designs suited to high volume manufacture. For micro-wind there still exist challenging problems of yield estimation; the wind field in and around buildings is very complex and needs to be better understood through a combination of fluid flow modelling and field measurement.

29. **The roll-out of smart metering and the increasing use of IT in the home opens up the possibility of linking demand side management to micro-generation, house by house. Research is required to explore this new opportunity**.

2.8 Intelligent grid management

30. The UK's electricity system remains dominated by conventional generation that injects large amounts of power into the high voltage transmission network, where it is transported to passive distribution networks, and finally delivered to consumers. Future power systems based on renewable and low carbon distributed generation are likely to be rather different. Large numbers of generators varying in type and scale and with different operational characteristics will be connected across every level of the distribution system. Integration of these new resources is a central challenge and is key to ensuring the evolution of a viable and effective system based on sustainable generation sources.

31. There are numerous technical challenges to be addressed including the planning and operation of active distribution networks, the control and interfacing of renewable energy sources, and system protection. The UK is currently leading research in this area through the EPSRC Supergen consortia and the DTI Centre for Distributed Generation and Sustainable Electrical

Energy. Increasingly **there is a need to demonstrate the new technologies at a convincing scale**, and the concept of Registered Power Zones (RPZs) is useful in this regard. **Technical developments need to be supported by appropriate regulatory change and continuing cooperation between researchers, industry and the regulator (OFGEM) is important.**

2.9 Energy storage

32. Research undertaken by the DTI Centre for Distributed Generation and Sustainable Electrical Energy indicates that dedicated energy storage systems would need to be much cheaper than at present to play any useful role in electricity supply systems, even with an increased renewable energy penetration. Nevertheless there is always a hope that new and significantly improved energy storage systems will be developed and some level of background research is appropriate, as for example being currently undertaken by EPSPC's Supergen Energy Storage consortia.

33. In the longer term, say around 2050, when many observers expect the electricity system to be dominated by sustainable sources, energy storage could be essential to ensure stable and robust operation of the system.

34. However, **if there is parallel electrification of the energy system, which some believe is inevitable, then there would also be an increase in devices with in-built storage capacity, such as electric vehicles, heating systems, and other power devices with a large re-charging demand. Coupling this need with advanced Demand Side Management systems could give effectively the same flexibility as a dedicated network storage system. More open ended research should be funded to explore these longer term possibilities.**

3 Comments on Research Funding Landscape

35. Recent years have seen a welcome increase in R&D expenditure and activity for renewable energy technologies, applied at stages along their span of evolution from basic research to demonstration. The emergence of the Research Council's Energy Programme has increased collaboration and coherence across the UK research community. In addition significant R&D support is available from Carbon Trust and DTI, ostensibly to fund nearer to market research.

36. Nonetheless significant and strategically important areas of basic technology research remain under-funded[13]. Many researchers would accept that they often make use of available development funding to undertake work that is really of a more fundamental nature. That this can happen does reflect to an extent a lack of clarity in the provision of funding from the different agencies. UKERC welcomes the progress that is now being made in co-ordinating the

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[13] UKERC's PV Research Road Map for the UK (Jan. 2007) highlights significant under funding of PV and the lack of central research facilities as the key factors holding back the development of PV technology in the UK. The Carbon Trust's recent PV Accelerator Programme is welcome but not nearly enough to bring UK research funding into line with key competitor countries. And wind energy research has been under funded for many years in the UK following a mistaken belief that the technology is fully mature. Research into biofuel production is also currently low in relation to the challenges.

various energy RD&D initiatives that have developed in the last 3-4 years. However there is **further work to be done to ensure the effective, coherent RD&D effort along the innovation chain that is needed to realise the UK's long-term energy goals**. UKERC is already working with ERP, DTI and RCEP and is well positioned to contribute to the further development of energy research policy.

37. Much as the sector welcomes the proposed new Energy Technologies Institute (ETI) and significant associated increase in R&D expenditure, there are concerns that without appropriate high-level co-ordination, this additional source of funding could further complicate and obscure the research landscape. **UKERC sees itself having a useful role in supporting the Research Councils in their role in connection with the ETI.**

38. If Government wishes to create a smooth path for strategic research to move through to development to commercial deployment, then greater strategic persistence is required, outlasting individual Ministers or Governments. **The research funding landscape in the UK has seen a number of disruptive changes over recent years and we believe this should be avoided in future.** The support mechanisms, for technology transfer in particular, have lacked stability and this interrupts the process of technology development and discourages participation. Germany's Fraunhofer model in contrast has been developed consistently over decades and is widely regarded as exemplary. Japan and the USA have developed similar frameworks.

3.1 Training

39. R&D makes a valuable contribution to the training of skilled professionals. The measures in the UK Climate Bill, the intention to create 'zero carbon homes' by 2016, and EU intentions in the 2007 Energy Efficiency Action Plan for 20% of all energy to be renewable by 2020, imply an unprecedented expansion of renewables deployment. Although the energy sector does not see itself as held back yet by a lack of trained staff[14] this situation is likely to change quickly, and there are areas such as the wind sector that already have difficulty recruiting suitably trained engineers.

4 Postscript – Energy research data from UKERC

40. One of UKERC's key functions is to provide up to date and authoritative data on UK energy research. This is presented as an Energy Research Atlas comprising a Research Register (an online searchable database of energy related awards and projects), used in the production of the research spend figures of Section 1, a Landscape (including a comprehensive account of research groups by subject, and funding frameworks), and a collection of research Roadmaps covering the main energy fields. All of these can be accessed at www.ukerc.ac.uk. The Atlas is being used increasingly by Government departments to provide the evidence base to underpin R&D planning.

[14] ERP report: Investigation into high-level skills shortages in the energy sector.