Institution: Durham University

Unit of Assessment: General Engineering

a. Context. The main groups to benefit from engineering research at Durham have been industry (e.g. economic impact of new businesses and products; reductions in energy consumption in the aero industry), the general public (e.g. healthcare impact of artificial joints, environmental impact of reduced CO_2 due to improved aero turbine design; renewable energy devices), practitioners and professional services (e.g. engineering analysis software) and public policy makers (e.g. electricity network management). Engineering research at Durham is managed through three research groups (RGs): Mechanics, Electronics and Energy.

b. Approach to impact. Our approach to impact in the REF period has been multilevel and varied, reflecting the General Engineering ethos of the School. We have chosen to consolidate a small number of major links to industry in key areas in the form of funded academic posts. Major partners join other representatives from industry (local, national and international) on our Industrial Partnership Committee (IPC). Our size and range of coverage in engineering means we are able to be agile in responding to opportunities for impact, through spinouts, workshops and CPD courses. Examples of interaction with research users to help drive impact generation during the REF period are given below:

(i) *Key industrial partners:* The School has developed special relationships with a number of major companies to promote appropriate research and knowledge transfer, and to aid passage of research findings into applications. Major examples are DONG Energy Ltd who have funded a research chair (£125k pa. Bialek) and Ikon Science, software developers for the oil and gas exploration industry, who have part-funded a lectureship in computational mechanics (£20k pa., Coombs). Other recent collaborators include major manufacturers (ABB, Siemens, Rolls-Royce, GE, Alstom and Jaguar Land Rover (JLR)), distribution network operators, energy supply companies (E.ON, British Gas), IBM, the regulator Ofgem and DECC. We also have relationships with consultants and engineering support concerns such as PB Power, Element Energy, SKM, PPA Narec and the biomedical engineering industry (e.g. Biomet, Stryker, Smith and Nephew, Invibio Ltd, Corin Ltd).

(ii) *Industrial Partnership Committee (IPC):* The School has an active IPC with over 20 industrial partners from local, national and international organisations (e.g. Gestamp Tallent Ltd, PDL Solutions Ltd, Yorkshire Water, Sage, BAE Systems, Contour Global, Enterprise plc, BA, Balfour Beatty, CE Electric UK, E.ON, Laing O'Rourke, Watersons Ltd & Renishaw). The IPC's objectives include ensuring that current industrial perspectives are reflected in our taught courses and students are given the best possible opportunities for industrial placements and graduate employment. IPC members work closely with students and staff in activities ranging from final year and design projects through to long term research partnerships which gives companies opportunities to select potential employees who best suit their needs. IPC members and other industry contacts also attend the School's annual Research Day at which current PGRs and PDRAs present their research.

(iii) *Training:* The School has run a number of significant training courses for outside organisations in the REF period: Since 2008 over 240 engineers from Alstom and GE have attended intensive training courses in steam turbine technology, including structural integrity, vibrations and aspects of fluid dynamics. In summer 2008 the School ran its second major 8-week summer school for 50 young engineers with very high potential from Nigerian Liquid Natural Gas. Training in the selection, function and use of artificial joints for orthopaedic surgeons has been delivered at Durham and elsewhere (Newcastle, Sheffield) by academic staff.

(iv) *Spinouts:* The School has supported the spinout of research ideas in the REF period including Durham Pipeline Technology's pipeline inspection robots, Evolving Generation's wind turbines and Concept Analyst's stress analysis software assisted by the University's Business and Innovation Services (DBIS).

(v) *Public Engagement & Outreach:* The School takes part in a large number of outreach activities. The Durham Solar Car project has grown out of research in vehicle aerodynamics and renewable energy and acts as a "shop window" for a multi-disciplinary approach to engineering, with the car having competed in races in the US and Australia. Durham energy research has featured in a number of public debates, e.g. 'Smarter Energy' with the New Statesman, 06/09/11 and a two-page interview with Bialek, "Perspectives on Energy" in the New Statesman 17/10/2011.

Impacts: Our areas of impact can be broadly classified into those given in Table B2 of REF 01.2012. Many of these are exemplified in the individual Case Studies submitted. Further examples include:

Economic: Savings in aircraft fuel over a number of years can be attributed to the research done in at Durham on secondary flows in turbines, culminating with the development of profiled endwalls (three dimensional shapes applied to turbomachinery blade rows to raise machine efficiency). Profiled endwalls are now used across the engine range at Rolls-Royce (for example, the Trent 900 engine). Vehicle aerodynamics is studied using computational and physical modelling in the School's own 2m wind tunnel. Industrial partners associated with this facility include JLR, Tata Motors (European Technical Centre), SAIC Motor Corporation (UK Technical Centre) and Ricardo. Improved methods for product development such as the introduction of a new metric for assessing wind noise on vehicles has been adopted by JLR. We have also worked with Red Bull Racing (Red Bull Technology) and Sahara Force India F1. In electronics we have collaborated with Senstronics to design and develop a fabrication process for a high performance pressure sensor for the off-highway vehicle market. Senstronics were able to specify their production facility as a result of the Durham-based work and moved out from our clean room with a demonstrator product and a substantial order book. They now employ over 60 people in Newton Aycliffe, manufacturing the sensors. AREVA have a range of Real Time Thermal Rating equipment arising from collaboration with the Energy RG. GE are also developing commercial products from this and Senergy Econnect have a range of DSR and grid connection solutions from research with Durham. Over the past 5 years collaborative research in new and renewable energy (NRE) has been undertaken with a number of industrial companies including Scottish Power, CE ElectricUK, Central Networks, AREVA, EdF Energy, ABB, PB Power, SenergyEconnect, Infoterra-Imass, Cummins Generator Technologies, Cummins Turbo Technologies, Whispertech, E.ON UK Ltd, Garrad Hassan, National Renewable Energy Centre (NAREC) and SEWind.

Public policy & services: NRE research at Durham has also had impact in industry and public policy. Since formation in 2003, the team has won 5 DTI awards, over 14 EPSRC research grants and an EU FP7 award, including participating in Supergen Wind, Supergen Flexnet, Supergen Marine, the RELIAWIND Consortium, the EPSRC Strategic alliance project AURA-NMS and the Sino-British Future Renewable Energy Network Systems (FRENS) Consortium. The team is also a member of the European Academy of Wind Energy and a Low Carbon Networks funded project investigating electrical energy storage systems. Durham hosted a workshop with DECC exploring Smart Grids and the Broken Value Chain in 2010 which resulted in recommendations to Charles Hendry at DECC. Bialek was seconded for 7 months to DECC in 2012 working on Electricity Market Reform. The 2011 IPCC report "Special Report on Renewable Energy Sources and Climate Change Mitigation" references Durham work when informing policy makers about RE and power systems. Elsewhere, parts of the International Telecommunications Union (of which Ofcom is a member) recommendations on radio propagation have been written by Salous and who has been part of the Ofcom delegation to meetings of this group. Contributions have been made to nuclear reactor safety and certification including projects on finite element modelling of reactors and work with EDF to simulate the multibody contact mechanics in the fuel rod and cooling rod systems.

Health: Tribological research at Durham since the late 1980s has led to improvements in the design and the longevity of artificial hip and knee joints in humans. Work within electronics has led to the development of sensors and actuators for medical usage (e.g. a micromanipulator for biological cells). Research in NRE within Durham Energy Institute (DEI) has led to improved understanding of how energy technologies can improve health in UK and developing countries.

Practitioners and professional services: We have developed a number of power systems tools and techniques in use by consultants and utilities in the NRE industry and software for stress analysis and contact dynamics. Sims-Williams chairs the SAE Road Vehicle Aerodynamics committee, the joint international industry/academic panel responsible for the development of formal standards.

Environmental: NRE research highlighted above clearly has major long term impact environmentally, through reductions in CO_2 generation and energy use. Johnson and Toll work in geo-environmental engineering with impact in techniques for remediation of contaminated land and the monitoring of the stability of slopes respectively. Toll has developed a device for monitoring suctions in slopes which has been commercialised by Controls Ltd during the REF period. Electronics research on chemical sensors also focuses on devices for environmental monitoring. Gallant (Electronics) and Johnson (Mechanics) have a joint project involving the use of THz

radiation for soil pollutant identification. This is also being investigated for novel harvesting of waste heat. The Electronics RG engages in research on devices for energy harvesting and Groves and Petty have significant outputs in organic photovoltaics, which is an emerging technology with the capability to produce renewable energy cheaply over a wide range of magnitudes. Our research is being used to connect RE, electric vehicles and heat pumps at a faster rate and lower cost which accelerates the UK's low carbon transition. A key aspect of our research is improving the efficiency of power plant, gas turbines and road vehicles.

Institutional support for Impact activities: The School works closely with Durham University's Business and Innovation Service (DBIS) which provides expertise in legal advice, management accounting, contacts with venture capitalists, business plan development, consultancy contracts, licensing and exploiting IPR, new business establishment and extensive business advice for all impact activities. PolyPhotonix and CPI at Sedgefield are examples of companies using our microelectronics fabrication facilities, the latter having seconded a Senior Scientist to work in the School providing a means for closer interaction, and we are currently working with CPI to examine how novel electronic noise measurements can be used to short-cut laborious lifetime testing of organic transistors. DEI has been fundamental to impact in energy research by providing resources, links and funding, including collaborative TSB and industrial research projects, interviews with energy customers, public debates (e.g. see above) and all day workshops with a wide range of energy practitioners through EPSRC InCluESEV project.

c. Strategy and plans. Our strategic approach to impact is consistent with the University's Impact Strategy 2010-2020 which embeds impact as a key component of academic activity across the institution. The University initiated the strategy through the creation of DBIS (mentioned above) which now has 17 staff members and won the Times Higher award for Outstanding Contribution to Innovation and Technology in 2012, whilst the Dean of Technology Transfer was awarded The Queen's Award for Enterprise Promotion (2012). The University also created a new role of Dean of Knowledge Exchange and Impact, (Prof. Richard Davies). Impact now forms a part of recruitment, probation, appraisal and promotion processes and also features in the academic staff training programme. The University provides dedicated support for impact activities through an Impact Coordinator, located in the Research Office, who assists in the development and recording of impact-generating activities and has made an annual sum of £250k available for an impact seedcorn fund, allowing individuals, project teams or departments to bid for sums of up to £20k to support new impact-generating activities. The Dean of Knowledge Exchange and Impact is supported by an Impact Advisory Committee, consisting of external representatives from a wide range of sectors, including local and national government, industry, commerce, NGOs and cultural organisations. The School has been recruiting heavily in strategic areas recently, particularly those related to computational methods (development and application) and this will continue, aligning with University goals being realised through initiatives such as the Institute of Advanced Research Computing (whose director is a member of the School). Our strategic aim is for our expertise in computational methods to have impact via collaborations with key industry players where we have jointly identified gaps in the capability of commercial software. The Electronics RG works in those areas in which we have a critical mass and are therefore more likely to make significant impact, i.e. organic electronics, microsystems, nanoelectronics, telecommunications & signal processing. Staff in the Energy RG play a leading role in the DEI which we see as crucial to developing and mainstreaming impact. Consolidation in these areas will lead to more focussed academic environments for staff, and prompt improvements to infrastructure. Impact generation in the School is also incentivised via Research Leave and support for placements for staff in industry. In summary we will continue to use our strength as a small but varied general engineering department to pursue a range of impact-achieving activities beyond 2013.

d. Relationship to case studies. The submitted case studies exemplify the range of research activity in engineering here and the different approaches to impact realisation. In Case 1 ("Artificial joints") research has been led by a senior academic for many years who has worked closely with selected industry partners. In Case 2 ("Endwall profiling") impact is also the result of a long period of research, through well-developed links with Rolls-Royce, who have recognised the world-class facilities at Durham. Case 3 ("Stress analysis") was also spun-out. Case 4 ("The GB Electricity Capacity Assessment") is different as the impact is to policy and it relates to a much more recent direction in School research motivated partly by climate change and energy usage.