Institution: University of Leeds

Unit of Assessment: 7, Earth Systems and Environmental Sciences

a. Context

The School of Earth & Environment (SEE) conducts world-leading, high-impact research in disciplines spanning the Earth's core to its upper atmosphere, and encompassing both physical and social sciences. SEE is structured into four institutes: *Climate and Atmospheric Sciences (ICAS)*, *Geophysics and Tectonics (IGT)*, *Earth Surface Science (ESSI)* and *Sustainability Research (SRI)*. These give us unique breadth and the capability to conduct multidisciplinary research in areas of global scientific and societal impact. Our impact is wide-reaching, including directing policy [C[†] 1-4], improving UK competitive advantage [C 5-8] and business performance [C 5,8], transforming UK public services [C 1,9] and training a skilled UK workforce [C 7]. Our research has particularly strong impact in the areas of climate change, where it has identified emerging issues and led to changes in policy, and in the hydrocarbon industry, where it has led to improved business practices and processes.

The co-location of centres of excellence in physical and social science research institutes within SEE, alongside cross-campus initiatives such as Water@Leeds, Africa College and the Centre for integrated Petroleum Geosciences (CiPEG), provides considerable advantages in delivering impact in complex and multidisciplinary issues such as climate change, water management and energy security. The hosting of national research centres in *Atmospheric Sciences* (NCAS) and *Climate Change Economics and Policy* (CCCEP) offer additional and significant opportunities for ensuring continued success in applied research. We use this branding of expertise within such centres and initiatives to increase the visibility and accessibility of our research to stakeholders.

SEE follows a strong research-led appointment process, and proactively supports the growth of cross-disciplinary thematic research teams in areas of research strength (REF 5a). As external funding regimes become more competitive, SEE is exceptionally well positioned to respond to Government funding priorities (e.g. climate change and energy security), and to grow and diversify industrial links (e.g. water and energy sectors).

b. Approach to impact

b1. Interactions with key users, beneficiaries or audiences to develop impact, and evidence for the nature of those interactions

The breadth of research excellence in SEE means that researchers interact with many different stakeholders at all levels, including national and international government and policy advisory bodies [C 1-4], industry partners [C 5-8], NGOs or community groups [C 3], and the general public. The School hosts two NERC Knowledge Exchange Fellows (McCaffrey, Quinn).

Since 1 January 2008, SEE staff have advised 3 UK Parliamentary Select Committees[‡], 4 UK DEFRA advisory groups[§], and numerous other branches of Government including the Strategic Advice to Government in Emergencies Group, the UK DECC, the Cabinet Office Effusive Volcanic Eruption Advisory Group, the UK Government Climate and Development Knowledge Network Roster of Experts, the UK Energy Research Council knowledge transfer network, the UK Committee for Climate Change and the ESRC-EPSRC Energy and Communities Programme. SEE staff have also advised the UK Met Office, the UK Aviation Commission, 3 overseas governments[**] and 10 international organisations including the European Environment Agency, the Council of Europe, the China Council for International Cooperation on Environment and Development, the International Energy Agency, the European Space Agency, the World Meteorological Organisation Commission for Climatology, the UN's Convention to Combat Desertification and Taskforce on Hemispheric Transport of Air Pollutants, and the Global Seismic Network. Impact case studies C 1-4 describe some of these activities. A key impact is through the Intergovernmental Panel for Climate Change (IPCC) reports. SEE has 5 lead authors of the IPCC 5th Assessment report,

[†] C refers to case study: ESSI (C 7,8); ICAS (C 3,4,9); IGT (C 5,6); SRI (C 1,2)
[‡] Energy and Climate Change (2), and Environmental Audit
[§] Carbon Accounting Standards, UK Climate Projections, Environmental Regulation, Social Sciences
[**] Greek Ministry of Education, Armenian Ministry of Energy, Quality Assurance Netherlands Universities

spanning all three working group reports on physical science, adaptation and mitigation, as well as a lead author of the synthesis report. SEE research features heavily in all these reports and our IPCC lead authors have briefed Secretaries of State, the Department of Energy and Climate Change, the UK Committee for Climate Change, and have also taken an official role at international UN climate negotiations.

SEE researchers have extensive links to industry, which are particularly strong in the hydrocarbon sector. During the REF period, we have strengthened the Centre for Integrated Petroleum Engineering and Geosciences (CiPEG), which is now established as the University bridge to the petroleum industry. With over 50 affiliated staff, the centre has specialist knowledge on hydrocarbon reservoirs that attracts considerable industrial funding (£9.9M to SEE during the REF period) and delivers high quality research impact (C 5,7,8). CiPEG engages directly with stakeholders in this sector through a variety of mechanisms, including the Industry Technology Facilitator (ITF) - staff in SEE (ANGUS, FISHER, MCCAFFREY) regularly participate in workshops with ITF's member companies to help co-develop the "ITF technology challenges". This interaction has resulted in projects with a total value of £1.5M, including SEE-led projects IPEGG, PETGAS-1/2 and SHAPE. CiPEG now employs a full-time business development officer to act as the first point of contact for all external enquiries.

SEE provides specialist industry-facing training at all levels. For example, our flagship MSc programme in Exploration Geophysics has been running for nearly 50 years and has trained ~30 students each year during the REF period. The course has an exceptionally good record of job placement for its graduates in the hydrocarbon industry, and most student projects are carried out as placements with industrial partners, who fund ~20 full scholarships each year. At PhD level, ~8% of our PhD students each year are funded directly from industry, with 26 of our current students funded through government scholarships or industry to work on research on hydrocarbons; 16% of our PhD studentships have CASE partners. We are part of EPSRC Doctoral Training Centres in Low Carbon Technology and the Nuclear Fuel Cycle and our recently-funded NERC DTP included 48 external partners. We also provide tailored courses to industry, such as the continuing professional development courses provided to the Sudanese Petroleum Corporation in 2011.

Researchers in SEE also have strong links with NGOs and Community Groups. For example, our research on the protection and management of forests led to the establishment of the United Bank of Carbon, a charity that aims to reduce climate change by protecting the world's rainforests and their peoples [C 3]. Leeds is responsible for rigorously checking rainforest projects across the globe and has established a comprehensive database of projects, run by various NGOs in several countries. By selecting from this bank, businesses can be sure that they are supporting a project that will deliver on its goals.

b2. Follow-through from these activities to identify resulting impacts

We have followed through on our interactions with industry, policy makers and other end users to maximise the impact. Examples of best practice include the establishment of several collaborative centres. For example, the *Centre for Climate Change Economics and Policy* (CCCEP), chaired by Lord Stern, is jointly hosted by SEE and the London School of Economics. It was established in 2008 and received renewed funding in 2013. CCCEP activity at Leeds capitalises on our interdisciplinary research strength in climate research, and aims to increase the capacity of public and private sector organisations to respond to climate change, to support climate change action by improving the evidence base and to develop policy options and implementation strategies for decision makers. Internationally, the centre has had a significant policy impact through input to the UN Secretary General's Advisory Group on Climate Change Finance, work with Globe, the international legislators' forum on various climate related issues, and the European Bank for Reconstruction and Development on Climate Change. Nationally, policy influence and impact is realised through CCCEP's close links with the Department for Energy and Climate Change, including work with the Climate Change Committee and Adaptation Sub-Committee, and discussions on the creation of a Green Investment Bank.

The *Centre for Low Carbon Futures* (CLCF) is a collaboration between the Universities of Hull, Leeds, Sheffield, Birmingham and York, established in 2008 to capitalise on our research on

sustainability for competitive advantage. CLCF activity at Leeds focuses on evidence-based research regarding carbon emissions and energy use, informs both policy makers and industry, and plays a key role in development and delivery of opportunities for UKPLC in emerging markets through collaborations on the new energy industries. UK INDEMAND is a new £11M national centre for reducing the use of both energy and energy-intensive materials in industry. Partners include the Universities of Cambridge, Leeds, Bath and Nottingham Trent, as well as key industrial partners and Government. Activity at SEE focuses on developing modelling capabilities to understand energy demand reduction though the whole supply chain as well as delivering practical scenarios to build the evidence into policy decision making processes.

We have also followed through on our research and impact links with the Met Office by establishing a formal academic partnership with them, along with the Universities of Reading, Exeter, and Oxford. The aim of the Met Office Partnership is to bring together leading researchers in a formal collaboration to advance the science and skill of weather and climate prediction, and to maximise the impact of the UK's investment in research and development to provide society with the best possible advice. The Met Office jointly funds two Chairs at Leeds (FIELD, PARKER) as part of the partnership. A particularly successful example of follow-through from this partnership has arisen from the Leeds-led *African Monsoon Multidisciplinary Analysis* project (2002-2010). This project identified major deficiencies in both the local observing systems, and in the skills of local meteorologists. Leeds, with support from the World Meteorological Organisation, the African Centre of Meteorological Applications for Development, the UK Met Office, and a NERC KE grant continues to train local scientists in state-of-the-art weather forecasting techniques. The research has been fast-tracked into operational weather forecasting in the region and influenced the international strategy for climate monitoring in Africa and the developing world.

b3. Evidence of an agile approach to opportunities

In a large School like SEE, we are well placed to respond rapidly to opportunities as they arise. Our response might be to a particular call put out by industry or other funding bodies. For example, the ITF calls from the hydrocarbon industry (see b1) have supported FISHER and others to work on research aimed at improving industry's ability to exploit tight gas reservoirs. This is an area where we have focused research efforts as the field becomes increasingly important for future energy security. Another good example is the successful bid for the NERC M&S Knowledge Exchange Fellowship by QUINN. We also are able to respond to time-limited opportunities for consultancy. For example, the Sorby environmental fluid dynamics laboratory, a NERC recognised facility, was used in a consultancy project with Speedo to accurately measure the speed of fabric through water as part of the development of the new FASTSKIN3 Racing System™ fabric.

Often, the Earth itself demands an agile response from researchers at SEE. A good example of our ability to engage in a multidisciplinary response effort was our reaction to the 2010 Eyjafjallajökull eruption. The School responded to this on many levels. MOBBS and WILSON (now Emeritus) advised the Government chief scientist as part of the Scientific Advice to Government During Emergencies Group, SAGE. MOBBS worked with the Met Office and Civil Aviation Authority, leading field experiments to obtain data on the ash plume over the UK. The measurements and samples collected during the first days of the ash emergency helped to set limits for ash concentrations to ensure safe flying and contributed greatly to the agreement with the aviation industry that allowed UK airspace to reopen. This work raised awareness in the general public of the importance of scientific research into volcanic hazards, for example featuring prominently in a BBC "Bang Goes the Theory" special on the eruption. In the longer term, SCHMIDT, WILSON and CARSLAW exploited the heightened awareness of the threat of volcanic hazards to the UK by working with SAGE to ensure that future fissural eruptions from Iceland, potentially far more devastating than the explosive eruption seen in 2010, are included on the UK national risk register [C 4].

b4. How SEE supports and enables staff to achieve impact from their research

An important mechanism for supporting and enabling staff to achieve impact is the recruitment of targeted academic staff in areas of potential impact. During the REF period, strategic appointments in applied geosciences research have included GLOVER (Chair in Petrophysics), HODGSON (Reader in Applied Sedimentology), and TORVELA (Lecturer in Applied Structural Geology). A joint chair

appointment with the Met Office, FIELD, is targeted at strengthening our impact by working with this key strategic partner. The appointment of DESSAI is targeted at creating impact in climate change adaptation, and UPHAM at impact in low carbon technologies.

Our research and innovation team in the School now includes a staff member with dedicated ongoing responsibility for impact. At the same time, existing staff are encouraged, where appropriate, to pursue activities that lead to increased impact, including the establishment of spin-out companies; SEE spin-outs RDR [C 5] and Getech [C 6] provide services primarily to the hydrocarbon industry that have had significant impact. SEE has also invested in infrastructure that is used by industry-facing projects, allowing both strategic research aims and industrial collaborations to be pursued. For example, SEE invested £600k in the towable Doppler radar system used by ICAS, and £300k in the Wolfson Laboratory used by CiPEG in its industry collaborations, with matched funding provided by the centre.

b5. Support from the Faculty and University

The University has a research and innovations team that invests in cross-campus initiatives to deliver impact. For example *Africa College* is an international research partnership, employing two members of SEE, working to improve food security and economic growth in sub-Saharan Africa via science entrepreneurship and the development of small-medium sized enterprises (SMEs). The college emphasises knowledge exchange and capacity building, such as through supporting visiting researchers, developing policy briefings, conducting training in Africa, hosting workshops and courses, and collaborative research and mentoring.

Another cross-campus initiative is the *Centre for Integrated Energy Research* (CIER) established in 2010 through the University Transformation Fund. CIER is a joint venture between the Faculties of Engineering and Environment and employs two members of SEE. CIER aims to support research that addresses major global challenges and provides the key tools needed to enable, enhance and accelerate the transition to low carbon energy systems at national, European and global levels, through integrating technological, economic, policy, and socio-technical dimensions of energy.

b6. Other mechanisms deployed by the unit to support and enable impact.

SEE places a high priority on public engagement in science through regular research updates and press releases. The Faculty of Environment employs a member of the central press office full time to work with its researchers on high-impact news stories. Additional resources within SEE are dedicated to regular news updates on the School website, and, more recently, research outcomes are also being made accessible through blogs, twitter feeds and other social media. The volume of our engagement with the media is extremely large. For example, a 15 November 2013 Nexis media search returns 586 unique news stories for our academic staff during the REF period, where their full name and the University had been explicitly identified. These included 242 newspaper articles in 9 languages, with an additional 267 Newswire articles. Notable TV interviews were of Andrew Gouldson talking about his low-carbon cities research on the BBC Politics Show, Andrew Shepherd describing his ice sheet research on several terrestrial news shows, Dominick Spracklen discussing his cookstove research on breakfast TV and Anja Schmidt talking about her volcanic research for a Nova/Channel 5 documentary.

c. Strategy and plans

Our strategy is explicitly to facilitate a culture of innovation and support for building partnerships with stakeholders in industry and the public sector. This is reflected in the continuing identification of opportunities to apply, exploit and build on research. For example, SEE held an Impact Workshop in September 2012 to help researchers formulate their research in developing impact strategies and discuss actions and support for individuals, SEE and the Faculty. SEE focus on the key global challenges of energy security and climate change, in line with RCUK priorities, is reflected in the SEE staffing strategy with recent appointments aligning with these research themes (b4). Some of our research themes have clear impact pathways, critically linked to our research excellence (REF5a). Plans to deliver impact in the future include increasing research funds from non-Research Council sources, such as the Industry Technology Facilitator (ITF) and Production Engineering Association for petroleum research, as well as further expanding our role in ESRC and EPSRC centres (UK Energy Research Centre - £18m; CCCEP - £5m; UK INDEMAND - £11m).

Our impact will also increase through deeper integration with Engineering to tackle key energy/climate change challenges (shale gas; carbon sequestration). We will target significant impact in food security and climate adaptation by bringing scientific rigour to work on climate change adaptation, building on links already made between physical climate science, biological sciences and social sciences.

SEE is playing a key role in several of the University's Higher Education Innovation Fund (HEIF) sector hubs. The hubs are designed to provide a focused and strategic approach to working with industry and other external partners, developing meaningful relationships, attracting further investment, maximising the impact of our research and fostering research excellence. They link external market demand with our recognised research and innovation strengths, and make our research more relevant to industry and external partners. Specifically, the *Climate & Geohazard Services* hub aims to provide solutions relating to natural hazards and climate, working closely with the public and private sectors to maximise translation of research. Work with the public sector will largely involve strengthening the existing formal academic partnership with the Met Office, and work with the private sector will focus on developing impact and knowledge exchange between, for example, natural hazard researchers and the financial services sector. Impact will derive from informing the debate on adaption to climate change and the associated increasing complexity and severity of contingent hazards. The *Energy Leeds* hub has 3 key themes: research, education and outreach. Within the hub, and as part of the newly formed UK Carbon Capture and Storage Research Centre, researchers within SEE are contributing to a multidisciplinary focus on carbon storage through expertise in the atmospheric sciences, geo-engineering, geosciences, environmental sciences, economics, energy policy and environmental governance.

In addition, we plan to build on our work with *Water@Leeds,* which conducts interdisciplinary water research through collaboration with industry and Government, and has strong links with the water industry and government bodies (e.g. DEFRA and the Environment Agency). The hub is extending and diversifying its impact outside academia by: (i) enhancing existing and developing industrial and commercial links with the water sector via data analysis, expert witness services, technical advice and hydrological survey, (ii) developing innovative approaches, tools and techniques for water-related applications with opportunities for commercialisation, (iii) knowledge transfer and training for industry, and (iv) creating a recognised Centre for Water Footprint Assessment & Policy Research. Water@Leeds also employs two full-time academic staff in SEE.

d. Relationship to case studies

The case studies clearly demonstrate SEE approach to impact through various mechanisms. The formation of spin-out companies RDR [C 5] and Getech [C 6] have led to direct positive economic impacts in the hydrocarbon sector via consultancy, software and data set development. Joint Industry Projects have led to improved value and efficiency in the petroleum industry, with research and software being taken up by a number of petroleum companies to achieve maximum value from reservoirs [C 8]. Applied research and focused consultancy are a key delivery mechanism for SEE. For example, the Turbidites Research Group (research group within ESSI) has improved the geological models used by the oil industry in decision-making, leading to economic advantage as a result of enhanced operations [C 7]. SEE has undertaken considerable research to inform national and international public policy**.** Research within Africa College has informed policy on dryland management in the developing world, including direct input into the future structure and operation of the UN Convention to Combat Desertification [C 2]. Research into the protection and management of forests has informed the UK Government's biofuel policy and has also led to the establishment of the United Bank of Carbon, a charity undertaking activity on climate change mitigation and providing impact through environmental management and the conservation of natural resources [C 3]. Research carried out in SEE has led to the development of a model for predicting severe turbulence at airports, implemented by the Met Office to avoid unnecessary diversionary flights away from the Falkland Islands [C 9]. SEE researchers produced the first quantitative assessment of the impact of an Icelandic Laki-type eruption on human health, providing the evidence for policy changes and incorporation into the national risk register [C 4]. Finally, research into energy efficient and low carbon options for the domestic, commercial, industrial and transport sectors is being used to underpin the new carbon reduction strategy on local, national and international level [C 1].