Institution: University of Bristol

Unit of Assessment: UoA 8

a. Context

Relationship of impact to SoC Research Themes. The School of Chemistry (SoC, synonymous with UoA 8) has a broad spectrum of research across 9 Themes: (**a**) **Soft Matter, Colloids and Materials;** (**b**) **Energy;** (**c**) **Supramolecular and Mechanistic Chemistry;** (**d**) **Catalysis;** (**e**) **Synthesis;** (**f**) **Biological and Archaeological Chemistry;** (**g**) **Spectroscopy and Dynamics;** (**h**) **Atmospheric and Global Change Chemistry;** (**i**) **Computational and Theoretical Chemistry**. Accordingly, the impact generated affects a wide range of diverse end-users including more traditional chemistry beneficiaries such as pharmaceuticals, fine- and petro-chemicals (Themes **a**,**d,e**) through to spin-outs (**a**,**d,c**), instrument manufacturers (**a,g**), software developers (**g,i**), global and national policy makers (**f,h**), governmental offices (**f,h**), non-governmental organisations (**f,h**), arts-based audiences (**i**) and schoolchildren and educators (**f,h**). Indeed, except for Theme **b**, all have delivered mature impacts as exemplified by the Case Studies (CSs) submitted: CH1 and CH2, Theme **h**; CH3, **g**; CH4, **a** and **e**; CH5, **i**; CH6, **f**; CH7, **d**, **c** and **i**. Meanwhile impacts associated with **Energy** are emerging and these are outlined in **Sections b** and **c**.

Range of impact types. SoC research has led to a wide range of mature impacts across culture, the economy, the environment, public policy and services, and the quality of life and society. Indeed, *all* of the HEFCE-defined catagories of impact, except 'Health', are covered in the CSs. Four early-stage impacts (see **Section b**) are clearly aligned with 'Health' and this area will play an increasingly significant role in the SoC's portfolio of impact activity in the short-to-medium term.

b. Approach to impact

Interaction with key beneficiaries, users and audiences. A useful indicator of the SoC's extensive interactions with a wide variety of end-users is that since June 2009, the UoB's Research and Enterprise Development office (RED) has handled 50 contracts for PhD studentships partly or fully funded by end-users, 57 new non-disclosure agreements with potential end-users, and 24 research contracts with end-user collaborators. Researchers in the SoC filed 64 patents during the REF period, and 15 licences were granted. The SoC's extensive and diverse non-industrial beneficiaries base, as detailed in the Case Studies, includes: Department of Energy and Climate Change; the World Meteorological Organisation; the Intergovernmental Panel on Climate Change; the Home Office; Transport for London; WHO; the UN Food and Agriculture Organisation; secondary-level chemistry education in the UK and >20 other nations; educators; post-16 level students; educational publishers; ~75% of all candidates taking OCR GCSE Science A chemistry; the general public, artists, and festival and event organisers.

Selected highlights of emergent impacts: on-going engagement with end-users. In addition to the impacts outlined in the Case Studies, the SoC has numerous emergent impacts. In particular we are currently focussing efforts on targeting the development of new impacts in 'Health', typically from Themes **c**, **e** and **f**, and the delivery of impacts from our new **Energy** Theme (**b**). Future impacts aligned with 'Health' that we are currently targeting for development include: (1) a synthetic lectin (**Davis**) for use in blood glucose monitors (pat. app. filed); (2) a prostaglandin synthesis (**Aggarwal**) that will reduce costs in the manufacture of pharmaceuticals, (pat. app. filed, licensed to Bridge Organics and Topokine); (3) the development of an IGF2 receptor (**Crump**); (4) a new approach to the bio-functionalisation of Ti alloys for bone implants (**Faul**, pat. app. filed; in negotiations with Corin). The **Energy** Theme is on the cusp of yielding exciting impacts, *eg* the delivery of novel catalyst systems for 'upgrading' bioethanol to the far more attractive petroleum replacement, butanol (**Wass**). Initially supported by EPSRC sandpit funding (2006, £143,650), it is currently supported by BP Biofuels (£610,155). Also in **Energy**, new diamond-based materials for Concentrated Solar Thermal Power Generation are being developed (**Fox**). Initially supported by funding from RED (2007, £50k), in 2008 EON AG granted €986k allowing prototype thermionic emitters and energy converters to be constructed, (pat: US 20120244281 A1). Collaborations with Magnox, AWE, Nuclear Decommissioning Agency and SEA Limited are on-going and EPSRC have granted funding (EP/K030302/1, £951,947) to study solar energy converters and nuclear batteries. The project will recycle C-14 waste from Magnox reactors to make β-emitting diamond. The potential applications range from power sources for spacecraft to heart pacemakers.

Expert advisers, committee members and consultants. The SoC has had wide-ranging and extensive interactions during the REF period with key end-user groups. This is a key mechanism

for the flow of knowledge from the SoC to end-users, but also provides a clear picture of end-user requirements. Selected activities, all of which provide channels for communicating and maximising the potential impact from UoB research, include: *Consultancy and expert advisory roles* **Cox** (Mars, KWS Biotest), **Eastoe** (European Medicines Agency), **Gallagher** (GSK), **May** (Cherwell Ltd), **Mulholland** (Shire Pharmaceuticals, GSK), **Shallcross** (HEA NTF), **Pancost** (Shell); *Board and Committee Membership* **Aggarwal** (Scientific Advisory Boards, Celtic Catalysts and Shasun), **Eastoe** (Science Board, STFC, expert witness), **Gallagher** (GSK International Chemistry Advisory Group and International Advisory Board, Chulabhorn Research Institute), **Orpen** (Chair, Board of Governors of CCDC), **Shallcross** (director of AZ Science Teaching Trust, council of the Royal Meteorological Society, convenor Science Education Forum, invited member All Party Parliamentary Committee for Education, adviser Home Office, Porton Down and the Met. Office).

Use of Knowledge Transfer Partnerships. The SoC has exploited KTPs as a key mechanism for realising impact by working directly with end-users on targeted projects. These include **Ashfold** with Photek Ltd (2011-13, £165k) designing novel ion optics, **Lloyd-Jones** with AZ (2010-11, £113k) improving automated screening of catalysts using predictive modelling techniques and a long-term collaboration between AZ, CatSci and the SoC (**Harvey**, **Orpen**, **Fey**) facilitated a TSB Collaborative R&D award in Sustainable Manufacturing (**Lloyd-Jones**, PI) with CatSci, PhosphonicS, AZ, Syngenta and AMRI (2013-15, £257k).

Use of institutional awards to facilitate end-user engagement and impact delivery. The SoC makes full use of institutional funding for Impact-based activities, led and targeted by the School Impact Director (**Bedford**) in order to maximise end-user engagement. We routinely exploit these funds to leverage larger, longer-term funding streams. Specific examples of the institutional awards targeted include the following: *(a) EPSRC-funded Knowledge Transfer Secondments.* The SoC has secured £119k across four projects: (1) Huwe (**Bedford** group) seconded to GSK for 12 months (09-10) on 'transfer of novel iron catalysis to pharmaceutical chemical development', (2) **Walsh** (former EPSRC ARF in the SoC) seconded from Orthox to work with **Mann** for 7 months (from 1/12/10) on 'development of bone-like resorbable hydroxyapatite-silk scaffolds for load bearing osteochondral applications', (3) Shao (**Faul** group) spent 6 months in HP Labs (2011) 'assessing the performance of hybrid dichroic/electrochromic materials for display applications' and (4) Miles (**Reid** group) spent four months (2012) in Biral working 'towards a commercial optical tweezers instrument'. *(b) EPSRC Pathways to Impacts Awards.* **Butts** & **Harvey** seconded a programmer from MestreLabs (2011, 6 months, £23k) to develop an α-version of NMR-derived 3D-molecular structure elucidation software. A further £15k was awarded (2012) to integrate chemical-shift driven structure refinement into the software. *(c) EPSRC Institutional awards.* **Wass** was awarded £75k for UoB's component of 'A Strategic Alliance in Catalysis' (with Cardiff and Bath); 50% of the funding was aligned with impact-specific activities, including networking activities with industry partners. This helped facilitate the successful £12.9m EPSRC bid for a UK Catalysis Hub (**Wass** as Co-I) which has deep industrial involvement from BP, Sasol, TMO renewables, Johnson-Matthey, Amerys, Shell, GSK, Dow, Investa, Syngenta, Jaguar, CatSci, Solvay, EADS, Eastman, Robinson Brothers, Unilever and Petronas. The Universities have committed a further £150k to enable the Alliance to progress key industry-facing activities in developing the Bath-Bristol-Cardiff axis as a UK Centre that will link the knowledge base of the academic community with the national industrial capability. **Davis (A)** received a £45.5k proof-of-concept award with Glysure to assess whether new glucose receptors attached to hydrophilic gels can be used in bedside glucose monitoring systems. *(d) Enterprise and Impact Development Fund.* Successful applications from the SoC include: (1) £15k to **Cosgrove** (Revolymer, see CH4), to bridge the gap to securing seed investment and funding travel to develop commercial interest in the technology from global companies, (2) £15k to **Woolfson** (self-assembling peptides), for industrial expert evaluation of the technology, market and pathways to commercialisation and (3) £15k to **Aggarwal** (synthesis of prostaglandins), to engage industry experts to lead the marketing of the technology and accelerate its impact. Subsequently the technology has been licensed to two companies (see above).

The role of Centres for Doctoral Training (CDTs) in end-user engagement. The two main EPSRC-funded CDTs with SoC involvement are the *Bristol Chemical Synthesis* (BCS) and the *Bristol Centre for Functional Nanomaterials* (BCFN, joint with Physics). Both have extensive industrial involvement that provides clear pathways to impact through specific on-going collaborations, the development of long-term research interactions and industrial involvement with both CDT management and delivery of postgraduate training. The BCFN employs an Industrial

Research Fellow (**Collins**) who facilitates the interaction between industry and the BCFN nanoscience and nanomaterials network which involves delivering Industrial Training Modules (Unilever, BASF, Merck) and think-tank exercises (Syngenta), negotiating and supervising industrial project sponsorship (Nanosight, AkzoNobel, Sasol, Syngenta, Heinz) and performing direct consultancy services (Heinz, LMAT). **Collins** is also the point of contact for external interest in the Bristol nanoscience community. The BCS CDT is in the process of appointing a part-time Industrial Research Fellow. The BCFN Strategic Advisory Board has industrial members from Unilever and HP Labs as well as international representation from key strategic bodies in nanotechnology, including: Weiss (Director, California NanoSystems Institute) Aono (Director, MANA Japan National Institute for Materials Science), Besenbacher (Director, iNANO Interdisciplinary Nanoscience Centre, Denmark) and Dobson (Strategic Adviser on Nanotechnology, RCUK). The BCS CDT Steering Committee also has significant industrial membership including: Leonard (AZ), Middleton (Vertex), Hayler (Novartis), Kelly (GSK), Blakemore (Pfizer), Tooze (Sasol), Fox (Vulpine Learning) and Hachisu (Syngenta); Fox has proved instrumental in helping the BCS CDT form relationships with SMEs. The BCS CDT has also received £1.3m in industrial funding that has led to an extra 18 industry-funded students (full or partial, cash and iCASE: AZ x 4; GSK x 3; Novartis x 3; Pfizer x 3; Syngenta x 3; Vertex and AWE).

Bristol ChemLabS, Public Engagement and Outreach. The Bristol ChemLabS CETL has had a deep impact on the culture of the SoC. Initially focussed on enhancement of UG practical chemistry teaching and learning, it has dramatically changed the way that we undertake outreach and public engagement. The appointment of a School Teacher Fellow **(Harrison)** to work with staff and students across the SoC means that a culture of dissemination has now become embedded in our day-to-day activity and the SoC engages with >30,000 students a year and their teachers in the UK and beyond. Indeed ChemLabS Outreach has reached every continent except Antarctica! Typically PGs and PDRAs promote their own research, focussing on the fundamental science behind their discoveries and possible future applications. ChemLabS has provided a direct mechanism for delivering the impact described in two of our public-engagment CSs: CH2 and CH6.

Supporting staff to achieve impact from their research. In addition to the secondment of staff to industries *via* the KTS scheme (see above), academic staff from the SoC also spend time on secondments with end-user groups. For instance **Lloyd-Jones** spent a week in Pfizer exploring future research collaborations directed towards Pfizer's on-going projects, while **Shallcross** is currently seconded (20% FTE) to the post of Director of the AstraZeneca Science Teaching Trust, which provides financial assistance to help improve the learning and teaching of science in the UK.

Impact and the School of Chemistry's internal structure. The SoC's impact agenda and activity is led by **Bedford** whose primary responsibilities are to: (i) provide leadership in the wider understanding of impact both in the context of REF and in terms of the requirements of Research Councils, and in the wider demonstration and dissemination of the impact of research, and (ii) to develop a School-level view of existing areas of research impact and future opportunities. In order to achieve this second goal, **Bedford** works closely with the Chair of the SoC's Research Opportunities Group (**Wass**), the three Heads of Sections and the Head of School in the identification, development and delivery of impacts as well as in the formulation of policy and strategy related to impact delivery. This is illustrated by the SoC's contribution to the UoB's recent (May 2013) 'Excellence with Impact' Vision plan for BBSRC. **Bedford** is aided by **Pancost** (Director of Cabot Institute: see below) who focusses on engagement and global change-based impacts. Impact also plays a significant role in the activities of the SoC's Industrial Advisory Board, chaired by **Wass**, which meets annually to advise on and scrutinise the activities of the SoC from an industrial perspective. Current membership includes representatives from Sasol, Vertex Pharma, Syngenta, Butt Park Chemicals, AZ, Albany Molecular, Cambridge Displays Technology, GSK and the AWE.

The role of RED in facilitating impact-related activities. In addition to administering specific impact-related funding streams (see above), the UoB's Research and Enterprise Development office (RED) plays a crucial role in supporting the development of impact. The SoC utilises RED's expertise in the preparation of grant proposals (particularly pathways to impact), benefits from the support of RED's Research Commercialisation team to disseminate research through commercial channels for greater economic or social impact, receives support from the Enterprise Education team to develop professional skills and commercial awareness, and engages with the Research Development, Alliance Development and Project Management teams.

c. Strategy and plans

Bedford will continue to work with the SoC's Research Opportunities Group to foster a culture in which all researchers are able to plan for, identify and build upon potential research impact, from applications for funding, through to project development and beyond. In terms of specific future strategic development, the most extensive areas of impact that the SoC will be engaged in can be broadly divided into three categories: (1) industry-facing and commercialisation activity, (2) public engagement and outreach activity, (3) environmental and global change related activity. These areas are well represented in the SoC and we will not only continue our current level of activity, but will seek new ways to maximise engagement with end-users. Specific plans for enhancing the SoC's impact are given below with timescales where appropriate.

Industry-facing and commericialisation activities. The SoC has identified three actions to further boost its industry-facing activity in the short-to-medium term. *Action 1: More firmly embed impact into the role of the Industrial Advisory Board*. We are in the process of restructuring the Advisory Board and the delivery of impact will become a central tenet in the new Board's remit. In addition, based on our positive experiences with the BCFN CDT's Industrial Research Fellow (IRF) and the related role played by Fox for the BCS CDT (see Section **b**), we are in the process of identifying a part-time IRF (supported by the UoB's Impact Acceleration Account), in association with the BCS CDT, with a broad remit for facilitating industry-facing impact activity both within the CDT and in the SoC at large. The IRF will sit on and play a key, proactive role within the Industrial Advisory Board, helping to both identify and facilitate industry-facing activity. *Action 2: Greater use of KTPs*. KTPs represent an excellent means of furthering industrial impact generated from research. The SoC has been involved in successful KTPs over the REF period (see above), and we intend to make significantly greater use of this resource in the future. Accordingly, the SoC's Research Opportunities Group will take an increasingly proactive role in identifying potential KTP-based activity (1-2 years). *Action 3: Increased Spin-out and commercialisation activity*. The SoC has engaged in successful spin-out and commercialisation activity over the REF period, and we aim to significantly increase this in the future. This will rely on the resources, facilities and expertise of RED being utilised early in the course of project development, once opportunities have been identified by Research Theme leaders and mediated by the School Impact Director.

Public Engagement and Outreach. Bristol ChemLabS will continue to play a pivotal role in the SoC's public engagement and outreach activities (more than 120 national and international events planned over the next year alone, see: http://www.chemlabs.bris.ac.uk/outreach/latest.html) and is deeply involved in advising the RSC on its £5-6m spend on outreach ('Talent Pipeline' project). We will extend outreach impact across the SoC's portfolio of activity (*eg* an early realisation of this will focus on sustainable metals in catalysis), supported by requests for funding for engagement on a greater number and wider range of RC and other grant applications.

Environmental and Global Change activities. The impact of our environmental and global change research is extremely broad, ranging from world-leading engagement, through validation of international treaties to contributions to the UN IPCC reports. The UoB has launched the Cabot Institute (Director: **Pancost**), helping align SoC research with social scientists and engineers and directly engaging with industry, NGOs and government partners. Cabot will be central to transforming climate and biogeochemical research (*eg* **Evershed**, **O'Doherty**, **Pancost**, **Rigby**, **Shallcross**) into policy *via* our developing partnerships, especially with the MOD (security) and DEFRA and the Environmental Agency (food and water security). Our work in the Energy sector (**Fermin**, **Wass**) is benefiting from Cabot partnerships with, for example EDF and RegenSW, and, with guidance from our External Board (inc. Sir John Beddington) *via* Cabot's Energy Theme, will make major contributions to the transformation of the UK Energy economy over the next decade.

d. Relationship to case studies

The Case Studies presented pre-date, but play a crucial role in the development of the SoC's impact strategy. They have allowed us to clearly identify our core strengths, particularly in the three broad categories defined in **Section c**, and develop our impact strategy accordingly. In addition, emergent studies, such as those based on 'Health' impacts and impacts associated with our '**Energy**' Theme, have been identified as key areas for growth beyond the current REF period and are likely to tie in strongly with our industry-facing and spin-out activities.