

Institution: University of Sheffield
Unit of Assessment: 12B - Aeronautical, Mechanical, Chemical and Manufacturing Engineering: Chemical and Biological engineering
<p>a. Context</p> <p>Chemical and Biological Engineering (CBE) is a unique melding of traditional chemical and process engineers, engineering scientists, and biological/life sciences academics, strategically placed in the same environment to grow expertise at the life sciences interface, while nurturing the engineering and biological sciences expertise simultaneously. Because engineering operationally is about the solution of problems of interest to humanity using applied science, impact is embedded in most of our activities by the aims and objectives. More than 90% of staff have collaborative R&D programmes with large industry (e.g. biopharma, food and consumer products), government at all levels, and small to medium enterprises. The main types of impact are economic and technological -- improvements to processes, products, and services, as well as spinouts.</p>
<p>b. Approach to impact</p> <p>We provide state of the art research information, access to facilities, IP protection, expertise and trained personnel to facilitate knowledge exchange, for instance with three "top down" impact generation mechanisms:</p> <p>1. Smart Materials: Granulation course: A vehicle for knowledge exchange with end-users.</p> <p>The sole International Granulation conference is Sheffield-led (Hounslow and Salman), with the most recent in June 2013. It is the centrepiece for the community gathering, but also for networking between industry and academe, with ~200 attendees. The associated training course draws >50 participants from several continents, with the lecturers drawn from industry, yet laboratory based "hands on" training in the key instrumentation and processes for granulation studies are offered. By showcasing the R&D as well as specialist facilities, the course and conference result in a steady stream of industrial research contracts and sponsorships, which have crystallised into one of our case studies, as well as enduring relationships with Nestlé, Lausanne Switzerland; BASF Germany; ARAMCO Saudi Arabia; AstraZeneca Sweden; Procter & Gamble. S. Palzer of Nestlé was appointed to a visiting professorship to enable the granulation work and liaised on the donation of the funds and equipment for the Nestlé lab for food processing research in CBE.</p> <p>2. Environment & Energy: SUWIC: An organisation for energy and waste management R&D</p> <p>The Sheffield University Waste and Incineration Centre (SUWIC) engages with government, the UK Environment Agency, DECC, DEFRA, the Energy Institute and the Waste Management Institute, on policy as well as projects. Regulations for gas residence time by the UKEA are based on our experimental technique (pseudo random binary tracer technique) and applied in Sheffield, Ely, and Kent. Sheffield City Council is leading internationally in the adoption of District Heating based on our research which is being rolled out nationally now with planned take up by local governments, including London. Many municipal incinerators (e.g. Veolia, Yorkshire Water, Toyota) in England have been designed by SUWIC using FLUENT (CBE spinout) in-house software (FLIC) for fluidised beds.</p> <p>3. Chemical engineering at the life sciences interface: A forum for KE in biological engineering.</p> <p>The current impact profile comes largely from DC James in the area of bio-manufacturing. Biotech or biopharma companies (Lonza, Pfizer, MedImmune, Pall, Cobra Bio, Biogen Idec) sponsor every PhD student in the group, resulting in 3 patent filings by the sponsors for therapeutic proteins derived from mammalian cell processing. Zimmerman has several engagements with companies for algal biomass utilisation (TataSteel, Aragreen, Syntaptic Research, and Carbon Sequestration) using microbubble processes, leading to 2 patent filings. Biggs engages with knowledge transfer, as part of the Pennine Water Group (PWG), which has five UK water company R&D Innovation Managers (Yorkshire Water, United Utilities, Northumbrian, Severn Trent, and Anglian Water) on the industrial steering group. Many of Perlemax's (spinout) biotech microbubble processes have grown in collaboration with our life sciences interface, and water applications, through PWG company partnerships.</p> <p>We provide three examples of "bottom up" impact generation and use of University support mechanisms:</p> <p>1. Grass roots "clusters" to target strategic opportunities and maximise the value of R&D.</p> <p>In 2009-10, CBE undertook an internal analysis of the research interests of the academics and</p>

held a series of cluster meetings on common thematic areas. From these, the CO₂, Water and Smart Materials clusters self-organised and sought significant funding, including from non-academic sources, such as the Grantham Foundation, DECC, and TSB, as well as several industrial contacts. The CO₂ Cluster initiated an industrial advisory panel, with members such as EDF, AECOM, TataSteel, and Carbon Sequestration (Sheffield-based SME) for steering on industrial relevance, which became part of the successful £5.7m 4CU EPSRC Programme Grant.

2. Commercialisation of research outputs.

The Departmental Director of Research (DoR) also manages Innovation and Impact. The DoR meets all newly appointed academic staff as part of their induction and discusses with them support available for commercialisation, contractual arrangements for IP protection and internal procedures for IP registration (the Commercial Assessment System). Regular external lectures on IP protection by the University's patent agents (HGF) aim to ensure academic staff are in a strong position to maximise opportunities. CBE hosts an Engineering Entrepreneurialism seminar series with guest speakers (6 in 2012) who are spinout or start-up company founders. Academic staff can be relieved of teaching and administrative duties to allow a period of contiguous quality time to work in a third party organisation. We have enabled secondments for Zimmerman (2010, Royal Academy of Engineering) and James (2011, EPSRC Knowledge Transfer Account, (KTA) resulting in a licensing agreement and a plan for industrial partnering in biologics.

3. Flexible, low level industrial rapid deployment partnerships.

Our three MSc programmes are multi-disciplinary and themed, with over 200 FTEs in 2012-13. An appreciable fraction of our MSc projects are industrially driven, with industrial partners encouraged to supply "what if" projects where field data or even industry-supervised projects are proposed. Several projects are community based, with paradigms such as assessing whether a rural community would benefit from an anaerobic digester, through energy audits of public buildings or biomass gasification or co-firing to carbon footprinting of industrial processes with non-academic partners. A co-author of the 2009 IChemE Moulton Medal winning journal article was an MSc student on a project proposed by a local company, Wastetoethanol Ltd., whose name describes the target of the novel microbubble mediated gaslift loop fermenter that was designed. By providing flexible access to the "seedcorn" activity, M-level projects can grow the interaction with industry or maximise already existing collaborations. For instance, a knowledge transfer partnership (KTP) with ACAL Energy has also attached two "blue skies" MSc projects. Industrial sponsorship of PhDs contributes to non-academic impact.

4. The Faculty of Engineering Gateway (EG) introduces potential corporate partners to academics through an enquiry based service. The EG introduced our cross-disciplinary microrheometry group to Kraft, which resulted in collaboration on a successful KTA partnership grant. It introduced Xeros, which is sponsoring a PhD student "top up", a KTP proposal, and a patent filing. EG provides institutional support for KTPs, which includes networking events for company supervisors, associates and academic supervisors. 3 impact case studies (LNG, Granulation, Microbubbles) have benefitted from KTPs.

5. University and Research and Innovation Services have several policies and support for external relationship building including: a generous consultancy policy to encourage new relationships; innovation vouchers; Business Innovation Network; our bioIncubator/KIC create forums for new partnerships; our EPSRC KTA for knowledge transfer and exchange (KE); HEIF Proof of Concept (PoC), collaborative R&D for partnership nurturing, and a commercial opportunity disclosure system that registers, protects, and develops strategy for IP. Granulation and Microbubbles case studies have been developed with support from KTA, PoC, and consultancy avenues.

Research that generates intellectual property with potential for commercialisation is handled at University level by a dedicated organisation, Fusion IP, and at Faculty level by a commercialisation manager. As with the consultancy arrangements, this approach frees academic staff to concentrate on the technical side of commercialisation and ensures the largest possible impact for the work. The microrheometry patent is being assigned to Perlemax for commercial development, following the route for microbubbles and plasma microreactor patents established in 2011.

The University has external links that promote industrial innovation, notably the N8 and METRC, but has cooperated with Sheffield City Council through University of Sheffield Enterprise and with Yorkshire Forward (YF) in incubating early stage commercial / enterprise projects. Microplasma reactors, microbubbles, and microrheometry (Perlemax case study) have had YF (concept fund)

and METRC (an N8 organisation for partnering University to Industry for R&D) support.

c. Strategy and plans

Our strategy is to have a “continuous conversation” with our end-users, R&D and commercialisation partners, to broaden the scope of our interactions to foster a permissive environment for associations with the users of our research. We already have a vital impact generation culture, but have recently added elements to our impact strategy that are expected to grow in importance:

1. Advisory panels and networks. We created administrator and project manager posts with narrow roles for coordinating dissemination, KE, and non-academic impact in the CO2Chem network and 4CU EPSRC Programme Grant. These two groups have advisory panels with representatives of the users of our research. Advisory panels feature in our current bids in water, energy, and biotech for large grants aimed at exploiting our research in synthetic biology, electrochemistry, and microsystems.

2. Smart entrepreneurialism. We have been pursuing a staffing strategy to promote individual academics as champions of innovation. The level of impact achieved by each academic is explicitly recorded on their submission to the promotion mechanism. Annual appraisal is a mechanism for planning applied research/consulting income, including impact activities. Filings with our commercial assessment system (CAS) are encouraged, planned and recorded.

3. New clusters. In 2012-13, we began new clusters in industrial biotech (IBT) and in energy, which promise not just new intradepartmental collaborations, but horizon scanning for industrially relevant collaborations. The ChELSI and the IBT will host the ChELSI conference as a regular event as an industry-academe forum. Energy is a Faculty research priority, with new initiatives for a multidisciplinary coordinated approach being led by Peter Hall.

4. Local management of impact plans. Our newly appointed business development manager (BDM) will support research grant proposals and create new non-academic partnerships, working with the new Faculty R&I support staff (10FTE). The new budget for impact activities and business development is held by the DoR with a pro-active plan in cluster development, relationship brokering, entrepreneurialism in engineering seminars and capturing of impacts for marketing purposes. Our near term plans for impact are to exploit recent patent filings and disclosures within the CAS process. The BBSRC has invited a pathfinder proposal, from a shortlisted follow-on-fund proposal on microbubble mediated fermentation. The 3 therapeutic protein bioprocessing patents are the basis of discussion for industrial uptake via their sponsors. METRC & Impact Acceleration funds for microbubble catalysis were just awarded.

d. Relationship to case studies

As the most recently nurtured impact case study, *Microbubbles/Perlemax* has the closest relationship to our current approach to impact. Shortly after the invention in 2005, CBE's BDM took over IP protection issues with the tech transfer office and liaised with eventual development partners Yorkshire Water and AECOM for the water sector. Internal PoC funds matched two Yorkshire Concept awards for pilot scale studies. Subsequently, AECOM and UU sponsored a PhD student to continue the technology transfer work. ACAL Energy co-sponsored a KTP once an MSc scoping study showed laboratory proof-of-concept for H₂ PEM fuel cell regeneration by microbubbles. fusionIP spun out Perlemax in 2010.

The *Wet Granulation (WG)* impact case study used a different subset of impact mechanisms. The granulation workshop and course helped to make the industrial liaisons, mediated by CBE's BDM for the potential of IP arising from GSK collaborations on particle characterisation and control systems. KTPs with P&G and Nestlé were essential in transferring the technologies that led to the impact. Salman and Hounslow held two PoC grants, demonstrating practical application/feasibility for WG.

The *LNG Monitoring* impact case study benefitted from two successive MSc projects on vapour-liquid equilibrium measurements, as well as small grants from the EPSRC locally managed Bridging the Gaps programme which nurtured the collaboration between Maths and CBE on inverse methods, leading to the speed up of the algorithms for coupling monitoring with modelling in the LNG software. However, the bulk of the impact came from a consultancy and two KTPs, one of which was KTA co-funded.

The *Fluidic Valve* impact case study is based on research that pre-dates the current impact environment and culture in CBE, but still demonstrates the legacy of close collaboration between industry and CBE – partially emerging from the DIPSS offshore engineering advisory panel.