Institution: Manchester Metropolitan University

Unit of Assessment: B7 Earth Systems and Environmental Science

a. Context

Our Earth Systems and Environmental Science (ESES) research is organised around three core groups: i) the Centre for Aviation, Transport and the Environment (CATE), ii) the Centre for Mathematical Modelling and Flow Analysis (CMMFA) and iii) the Centre for Earth and Ecosystem Responses to Environmental Change (CEEREC). Sustained funding and high quality output evidence the enduring nature and vitality of our research since 1993. ESES has been used consistently by UN Agencies, international, Governmental and Non-Governmental Organisations (NGOs), national and regional organisations, to formulate response to environmental change. Principal non-academic beneficiaries of the research of ESES are regulators and policy developers in environmental protection, aviation and renewable energy industries.

CATE's research centres upon the environmental impact of aviation and maritime transport. The impact of this work is highlighted in CATE's REF3b case study. Non-academic beneficiaries include aviation research regulators, e.g.: the UK Department for Transport (DfT); the European Aviation Safety Agency (EASA); the US Federal Aviation Agency (FAA); the International Civil Aviation Organization (ICAO); and the United Nations Environment Program (UNEP). Indicative industrial beneficiaries are the International Coordinating Council of Aerospace Industries Associations (ICCAIA), and Airports Councils International. Governmental based beneficiaries include the European Commission and UK Committee on Climate Change. Principal NGO beneficiaries are the International Coalition for Sustainable Aviation and the International Panel on Climate Change (IPCC). International regulators have benefitted from CATE's work on development of the ICAO CO_2 Emissions Standard, and UNEP's Bridging the Emissions Gap report, 2011. End-users benefit from CATE's research improving the scientific understanding of the impacts of aviation upon global climate. CATE co-leads ICAO's Impacts and Science Group, which communicates information of demonstrable importance to stakeholders (e.g. ICAO/ATAG Joint Statement) assisting agencies to judge the importance of aviation CO_2 and non-CO_2 impacts upon climate. Significant impact has also resulted from CATE's research on sleep pattern disturbance due to aircraft noise, which led directly to changes to UK night flying policy.

The offshore marine renewable technology industry is the principal non-academic beneficiary of CMMFA's research, the impact of which is summarised in their REF3b Case Study. CMMFA was integral to the development of the OYSTER wave energy converter, which gave rise to the formation of Aquamarine Power Plc., bringing the technology to market [CMMFA2]. Full-scale prototypes of OYSTER 800 have been built and tested. OYSTER was cited by RCUK as one of its Impact exemplars of energy research and capacity building [RCUK]. The UK renewable energy programme benefits through CMMFA's membership of the EPSRC's Supergen Wind and Supergen Marine consortia. Knowledge transfer to non-academic users occurs through formal Consortium Management Group Meetings and Annual Assemblies attended by industrial project partners. CMMFA was invited to participate in the recent scoping workshop (Jan 2013) attended by the major industrial players in the relevant energy fields (e.g. Garrad Hassan, EON). CMMFA's research has also informed the next phase of the UK's wind-energy research programme.

Non-academic end users and beneficiaries of CEEREC are primarily Governmental organisations and NGOs concerned with remediating and understanding anthropogenic impact on ecosystems. Beneficiaries include the UN convention on Biological Diversity, the UN Convention on Long-Range Transboundary Air Pollution and the IPCC. CEEREC is a key player in the European Peatbog Project, developing models and management tools, and informing policy across EU and UK peatlands. CEEREC has informed and advised Natural England and the Joint Nature Conservation Committee on the impact of air pollution upon ecosystem heath, and remediation policies. CEEREC has worked with DEFRA (UKREATE) to produce work packages on bio-indicators of change. More recently CEEREC advised upon strategies relating to tackling 'Ash die back' (March 2013). Moors for the Future, the Pennine Sphagnum Restoration Technical Advisory Group and the Natural England Upland Restoration Review Committee have all drawn upon CEEREC in relation to sphagnum moss re-establishment and the effect of anthropogenic N loads. This impact is central to CEEREC's REF3b Case Studies. CEEREC also advises and informs international conservation organisations such as the Kenya Wildlife Service, the Wildlife Conservation Society, Fauna and Flora International (Phillipines), the Convention on Biological

Diversity and governments in the tropics (e.g. Ethiopia, Ghana, Peru), and has provided legislative advice for the US Fish and Wildlife Service. This has resulted in significant impact on global conservation organisations responsible for the protection of tropical biodiversity.

b. Approach to impact

The impact agenda informs our research and the quality of its output. We judge the long-term success of our research by the impact it has upon beneficiaries, as exemplified in the REF3b case studies. In order to ensure that our research impacts upon non-academic users, our approach has been to establish and maintain lasting relationships with organisations that are strategically aligned with our expertise. This has been done by developing suitable engagement activities and communication channels such as becoming members of advisory bodies, industrial and government-academic partnerships, building trust by demonstrating relevance.

Since 1993 we have developed and maintained enduring relationships with key end users (e.g. the Manchester Airport Group, DfT, Moors For the Future) and industrial end users in the renewable energy sector (e.g. via Supergen). By reviewing the potential impacts of climate and environmental change, we have been able to identify the research needs of external stakeholders most likely to benefit from our research. This has ensured that our research activities are positively aligned to end users and that we are able to respond quickly to their needs. For example, in 2007, CATE recognised the wider potential of its expertise of CO_2 emission mitigation by carbon reduction in the airline sector leading directly to approaches from the maritime industry to undertake similar analyses. A proactive approach to Moors for the Future, resulted in our research informing and responding to the challenges of moorland restoration (2009 on). Likewise, key to obtaining a research licence (2007) from the Botswana Ministry of Environment to study soil CO_2 fluxes in the Kalahari was recognition of their need for baseline data in the context of the Kyoto agreement.

In order to optimise our reach, ESES disseminates its research widely in both academic and industrial publications. This has ensured that potential end users are aware of our research and its outcomes and actively seek our participation in activities relevant to their needs, such as, for example, the approach from the marine transportation sector (noted above). CATE's approach to achieve impact is to operate in the 'grey' area where science meets policy and stakeholder engagement whilst maintaining its international reputation in science. Hence, CATE staff are known and 'trusted' and have held international (e.g. World Meteorological Organisation, Int. Civil Aviation Organisation (ICAO), Airports Council International) and national positions (e.g. UK Committee on Climate Change, CCC). An example of widespread usage of CATE's science in the aviation sector is the 'radiative forcing bar chart' used in CCC and ICAO documentation. Similarly, CMMFA were invited in 2012 by Queen's University, Belfast, and Imperial College with industrial partners Aquamarine PLC, to submit a joint proposal to investigate the survivability of wave energy converters. This was an agile response to a Supergen Marine Grand Challenge Call. CMMFA ensured the impact of their work by disseminating research findings to industrial partners at Supergen Wind Consortium management meetings and to the wider wind energy community at Consortium general assemblies (noted in Sec.3a).

Senior research staff from overseas government organisations have been embedded within ESES enabling two-way exchange of knowledge and research needs. Conversely, at national Governmental level, staff have represented the Department for Transport on the International Civil Aviation Organisation. An important element of our approach has been to facilitate the mobility of staff between academia, business, government and industry. For example, there have been frequent two-way exchanges of staff between Manchester Airport and ESES.

c. Strategy and plans

To enable ESES staff to fully identify and undertake high impact, fully funded research and ensure that our research is agile and aligned to the needs of end users we will:

- Ensure that staff are supported by excellent facilities in an interdisciplinary academic environment
- Maintain a strong presence in international science (e.g. via the IPCC Fifth Assessment Report Working Group 1&3) and by publishing high quality peer-reviewed publications
- Disseminate our research widely to optimise its reach ensuring that potential end users are aware of our research outcomes such that they will actively seek our participation in

activities relevant to their needs

- Review potential impacts of climatic and environmental change in order to identify the research needs of stakeholders most likely to benefit from our research
- Establish and maintain lasting relationships with organisations that are strategically aligned with our expertise to ensure strong interaction with stakeholders and users of our research
- Develop engagement activities and communication channels by becoming members of advisory bodies, industrial and government academic partnerships to develop collaborative partners and facilitate access to end users
- Fully utilise MMU's support structures, (e.g. the Research and Knowledge Exchange, Knowledge Transfer, Key account and Business Support Managers, and research development teams) to ensure maximum leverage from research outcomes
- Support strategic activities with appropriate funding, administrative support, and staff release from other academic duties
- Support staff in the development of impact plans at the beginning of the research cycle and doctoral programmes to ensure that the outcomes are of maximum impact
- Incentivise impact activities through Knowledge Enterprise funding and rewarding staff via promotion into contribution zones and appointment to professorships and readerships
- Increase staff mobility of between academia, business, government and industry actively encouraging and funding 'sand pit' events between academics and end users to identify and foster new collaborate opportunities

Underpinning this strategy is a strong institutional commitment to recognising and rewarding staff that engage with the public and end-users. Since 2008 MMU has been a partner in the Manchester Beacon for Public Engagement project (funded by RCUK, HEFCE and the Wellcome Trust). Our approach complies with RCUK's Concordat for Engaging the Public in Research. MMU is a signatory to the Manifesto for Public Engagement

d. Relationship to case studies

The three case studies in REF3b, are drawn from a wider body of impact arising from ESES research between 1993 and 2013. They are evidence of the success of our approach to impact.

Since inception in 2002, CATE has continuously developed its range of expertise and sphere of influence, actively recruiting internationally known scientists and expanding its range of expertise from aviation to climate. CATE utilises sophisticated instrumentation (e.g. LIDAR, ALFA-rig) for emission measurements. CATE's expertise has extended proactively to include alternative fuels (e.g. it is now leading the EC Initiative *T*owards sust*A*inable *K*erosene in *A*viation, ITAKA project) and also from aviation to shipping impacts on climate. CATE has influenced the international agenda (e.g. UNEP Bridging the Emissions Gap report, IMO Greenhouse Gas Study, 2009), demonstrating its agility in embracing new topics and expertise as evidenced in REF3b, i.e. *The Impact of MMU Research on Technical Climate Policy in the Aviation and Maritime Sectors*. Further evidence of the global reach and impact of our approach are the four ESES staff who were lead authors in the *Fifth 2013 Assessment Report* of the IPCC, previously receiving Nobel commendations for their lead authorship in the *Fourth 2007* IPCC report.

Since 1993, CMMFA has successfully developed its expertise in applied computational hydrodynamics research. This has enabled CMMA to contribute to areas such as violent wave overtopping at sea walls, open channel flow, tsunamis, wave breaking and wave/structure interaction and more recently offshore renewable energy. The core impact of the latter is described in the CMMFA REF3b case study *Offshore Renewable Energy Deployment*.

CEEREC by focusing upon environmental response to climate change has ensured wide reach and impact. CEEREC is characterised by a team of highly interdisciplinary staff with expertise in a wide range of environments and ecosystems. This has brought strength and reach to its research enabling collaboration with a diverse range of international, EU and UK NGOs and governmental end users. The REF3b case study, *The influence of MMU research on protecting and restoring ecosystems affected by air pollution*, focuses on the impact of CEEREC's research upon moorland ecosystems.