Institution: Manchester Metropolitan University

Unit of Assessment: B7 Earth Systems and Environmental Sciences

Title of case study: The Impact of MMU Research on Technical Climate Policy in the Aviation and Maritime Sectors.

1. Summary of the impact

This case study describes the impacts of the work undertaken at Manchester Metropolitan University's (MMU) Centre for Aviation, Transport, and the Environment (CATE), on international and national policy and legislation for reducing CO_2 emissions from aviation and shipping. The research has provided a robust technical basis for emissions reductions of CO_2 from aviation and the maritime sectors. It has influenced international and national policy development of the International Civil Aviation Organization through their Committee on Aviation Environmental Protection (ICAO-CAEP), the International Maritime Organization (IMO), the European Commission (EC), and the UK Committee on Climate Change (UKCCC). Greenhouse gas emission reductions have been pledged under the United Nations Framework Convention on Climate Change's (UNFCCC) Conference of Parties (COP) as a result of the United Nations Environment Program's (UNEP) influential report "Bridging the Emissions Gap", in which a chapter on aviation and shipping was led by CATE staff (**[1],** sec.3, numerical references to the research).

2. Underpinning research

The context: Reductions of greenhouse gas emissions, and principally those of CO_2, represent one of the greatest environmental challenges to society today because of the nature, scale and longevity of impacts. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change's (IPCC), transport emissions of CO_2 were 23% of energy-related CO_2 emissions in 2004 (**[A],** sec.5, alphabetical sources to corroborate the impact). However, the aviation and maritime sub-sectors of transport (~21% of transport CO_2 emissions) have less potential for dramatic reductions in CO_2 emission intensity. This is because of their dependence on liquid fossil fuels and slow fleet turnover. Moreover, both sectors are predicted to continue to grow at rates greater than that of the GDP. Thus, aviation and maritime sectors are likely to represent increasing proportions of both total transport and global fossil fuel related CO_2 emissions.
CATE, at MMU, has been researching the environmental impacts of aviation (noise, air quality and climate) since 1993. Since 2003, CATE has focussed upon the impact of the aviation and maritime sectors on climate. CATE's key REF staff, (Prof. David Lee and Dr Sarah Raper, supported at any one time by a team of ~10 RFs, RAs and PhDs), have developed research that has earned a global reputation for its policy-relevance on emissions, atmospheric impacts and the impact of future alternative fuel (biofuel). This is evidenced by continuous support by the Department for Transport (DFT) since 2003 (sec.3) and key widely cited research on the quantification of the impact of aviation on climate (**[1],** sec.3).
Research on international aviation emissions (2010–2013): This research has focused upon i) the design of a whole aircraft performance-based emission metric for international regulation, ii) the design of emission scenarios and assessment of future trends, and iii) developing summaries of the science of aviation and climate. This has led to three internationally authored ICAO 'White Papers' for policy makers. Key outputs at ICAO-CAEP 9th meeting, Feb. 2013 (**[B],** sec.5).
Research on international maritime emissions (2007–2010): Historical, current-day and potential future maritime emissions and climate impacts comprise the core of this research (**[2]**, **[3],** sec.3), which is of particular importance to the IMO. Key outputs of benchmark emissions and mitigation options were given in an IMO report (**[3],** sec.3), and development of understanding of trade-offs in CO_2 and non-CO_2 emissions in 2009, 2010 journal articles (**[2]**, **[4],** sec.3) supported by EC grants, Quantify, ATTICA, sec.3).
Designing aviation policy options in the European Union and the UK (2005–2012): This has involved i) design of the scope and coverage of the European Aviation Emissions Trading Scheme, resulting in key outputs published in 2005 (**[5],** sec.3), 2008, that led to legal implementation of the scheme in 2012, ii) assessment of the size and scope of UK international aviation emissions at baseline and future years for the Committee on Climate Change; key output a 2009 CCC report forming the basis of UK policy on international aviation emissions of CO_2 (**[C],** sec.5).

Informing climate negotiations for emissions reductions pledges (2010–2011): Primarily research into the mitigation potential from aviation and maritime CO_2 emissions by 2020. One key peer-reviewed output was the UNEP report (**[6],** sec.3), presented to the 2011 COP meeting in Durban.
Work for the Intergovernmental Panel on Climate Change (1997–2013): This has encompassed assessment of aviation emissions and impacts for the IPCC Special Report 1999, an emissions calculation methodology for IPCC Greenhouse Gas Guidebook in 2006 (both of which have enduring impacts and continued usage into the REF period); the assessment of transport-related mitigation potential in the IPCC Fourth Assessment report (2007) (**[A],** sec.5); and contribution to the IPCC Fifth Assessment Report between 2010 and 2013 (published, Sept. 2013).

3. References to the research

[1] Lee D. S., Fahey D., Forster, P., Newton P. J., Wit, R. C. N., Lim L. L., Owen B., and Sausen R. (2009) Aviation and global climate change in the 21st century. *Atmospheric Environment* 43, 3520–3537, **DOI:** 10.1016/j.atmosenv.2009.04.024, *(154 citations)*
[2] Fuglestvedt J. S., Berntsen T., Eyring V., Isaksen I., Lee D. S., Sausen R. (2009) Shipping emissions: from cooling to warming of climate – and reducing impacts on health. *Environmental Science and Technology* 43, 9057–9062. **DOI:** 10.1021/es901944r *(19 citations)*
[3] Buhaug O., Corbett J. J., Endresen O., Eyring V., Faber J., Hanayama S., Lee D. S., Lee D., Lindstad H., Markowska A. Z., Mjelde A., Nelissen D., Nilsen J., Palsson C., Winebrake J. J., Wu W., Yoshida K. (2009) Second IMO GHG Study, 2009. International Maritime Organization, London.
[4] Fuglestvedt J. S., Shine K. P., Cook J., Berntsen T., Lee D. S., Stenke A., Skeie R. B., Velders G. J. M. and Waitz I. A. (2010) Transport impacts on atmosphere and climate: Metrics. *Atmospheric Environment*, 44, 4648–4677. **DOI:** 10.1016/j.atmosenv.2009.04.044, *(92 citations)*
[5] Wit R. C. N., Boon B. H., van Velzen A., Cames M., Deuber O. and Lee D. S. (2005) Giving wings to emission trading. Inclusion of aviation under the European emission trading system (ETS): design and impacts. CE-Delft, No. ENC.C.2/ETU/2004/0074r, the Netherlands.
[6] Lee D. S., Hare, W., Endresen Ø., Eyring V., Faber J., Lockley P., Maurice L., Schaeffer M., Wilson C. (2011) International emissions. In '*Bridging the Emissions Gap. A UNEP Synthesis Report*'. United Nations Environment Programme (UNEP).

Research Grants
In the time covered by this impact case study MMU has attracted ~ £10 million of direct income from research grants and contracts related to this impact study. This includes funding from the EPSRC (£1.5M), UK Government (DFT, DEFRA, DECC; £4.5M), and the European Union (Quantify, ATTICA, ECATS, AERONET, AERO2K, REACT4C, ITAKA; £2M). From 2007 – 2009 CATE led the £5M HEIF-funded OMEGA project (£1.5M direct funding). OMEGA is a network of UK based research centres (Cambridge, Cranfield, Leeds, Loughborough, MMU, Oxford, Reading, Sheffield and Southampton) focussed on providing scientific data for sustainable growth in the aviation industry.

4. Details of the impact

The principle impacts are those upon public policy and the environment through scientific work to support international/national policy and regulation. These have resulted in real-world impacts, which ultimately result in tangible reductions in global CO_2 and other atmospheric emissions.

Research on International Aviation Emissions: CATE, at MMU, has been working within a technical body of the UN ICAO Agency, to design the first CO_2 emissions standard for aircraft (see 'Research on international aviation emissions', sec.2). MMU input has been crucial for the relevant UK and European regulatory authorities (**[D],** sec.5). The ICAO formally adopted the metric in February 2013 (**[B],** sec.5), but the standard has not yet been set. MMU is active in both establishing the principles for standard-setting and quantifying the impact of standards on future CO_2 emission reduction. CATE leads one of the 6 technical ICAO Working Groups (Impacts and Science Group) and supports 3 others. According to the Executive Director of the Federal Aviation Administration of the US: *"CATE's efforts to quantify aviation's emissions inventories have informed critical decisions on new air quality and noise engine and aircraft standards in 2010 and 2013 at ICAO/CAEP. Such policy decisions have tremendous costs and offer substantial*

environmental benefits. They must be made carefully and be informed by the best available science. CATE has been at the forefront of informing policy makers and ensuring their decisions are science-based" (**[D],** sec.5).

Research on International Maritime Emissions: The IMO is the UN Agency responsible for international emissions of CO_2 from the maritime sector, under Article 2.2. of the Kyoto Protocol. The IMO commissioned a 'game changing' emissions and impacts assessment, published in 2009, to which David Lee contributed. This report has made a major impact on the maritime sector and has set benchmarks for historical, present, and future potential emissions through the development of scenarios. *"The involvement of Professor Lee, amongst other world-leading experts has reduced the uncertainty for governments in their decision making process and is one of the main reasons for IMO's successful adoption of the first binding and global CO_2 regime for an industry sector." (Technical Director, IMO,* **[E],** sec.5) In addition to the emissions assessment, the section on the climate impact of maritime emissions was co-led by David Lee. Through the IMO report (**[3],** sec.3) and follow-on publications (**[2]**, **[6],** sec.3), this shifted the perspective of the maritime and shipping industry to accept that the sector's emissions of CO_2 lead to global warming in the long-term, despite short-term cooling from sulphur emissions. Thus SO_2 emissions regulations proceeded (entered into force 1 July 2010), with the consequential protection of local and regional air quality, simultaneously combined with a separate focus on CO_2 emissions reductions. This resulted in adoption of a CO_2 emissions standard/energy efficiency design index in July 2011.

Designing aviation policy options in the European Union and the UK: In January 2012, the European Union introduced aviation into its Emissions Trading Scheme (ETS). The original scope of the scheme, in terms of pollutants and policy/geographical scope, was commissioned by the European Commission in 2005 (**[5],** sec.3). The 2005 report set out the basic design of the ETS. Crucially, the European Parliament wanted to include non-CO_2 emissions from aviation, and David Lee, concluded in this (**[5],** sec.3) and a later (2008) report to the Commission that they should not be included in the ETS as the science was not sufficiently developed. As a result of the EU-ETS, significant CO_2 emissions savings will result (currently under some negotiation at the international level, to which MMU is contributing data). *"From the early stages of policy formulation through to on-going international negotiations over the future global policy and rules on aviation emissions, timely MMU research and input have enabled EU policies and positions to be formulated and defended on the basis of solid and state-of-the art knowledge, the most prominent example hereof being aviation's inclusion in the EU's Emissions Trading System"* (*Personal assistant to Member of Cabinet of Connie Hedegaard, European Commissioner for Climate Action* **[F],** sec.5)
The UK Committee on Climate Change (CCC) was established by Parliamentary Act to examine UK CO_2 emissions each year and ensure that the UK is on course to meet targets. The CCC assessed whether aviation emissions should form part of these targets, and examined impacts and mitigation options. David Lee was appointed to the CCC as special advisor on aviation, and contributed towards the writing of the CCC's 2009 Aviation Report, as recorded in the report's acknowledgements. As a result, the CCC noted that CO_2 emissions from international aviation should be considered in the UK legal targets for CO_2. Moreover, the CCC adopted and re-published the main chart from **[1],** sec.3, and recommended that non-CO_2 impacts should be revisited in the future *"David Lee was an expert advisor for our review of aviation emissions (CCC, 2009), where he provided advice on non-CO_2 effects, aircraft and fleet technologies and future scenarios. This report was, and continues to be, very influential in debates around the future of UK aviation"* (*Climate Science Advisor, Committee on Climate Change Secretariat* **[G],** sec.5).

Informing Climate Negotiations for Emissions Reductions Pledges: As a result of extensive technical and scientific experience in the aviation and shipping sectors, David Lee was invited by UNEP to lead a chapter of a UNEP Synthesis Report (**[6],** sec.3) on whether pledges of emissions reductions will be sufficient to meet the '2 degree target' for global warming. The UNEP report 'Bridging the Emissions Gap' was launched at the Royal Society in 2011, and presented to the Conference of Parties to the Climate Convention at Durban in 2011. As a result, various 'Parties to the Convention' re-pledged emissions reductions and for the report to be taken into account in climate negotiations. *"The UNEP series reports on the 'emissions gap' of where we need to be on a 2 degree trajectory, and where we are according to current pledges and projections, has been of*

vital importance to policy makers in the UNFCCC negotiations. The analysis from the gap report has been extensively used by negotiators to support their work and is often quoted during the climate talks and negotiation sessions." (*Deputy Director, Division of Technology, Industry & Economics, United Nations Environment Program* **[H],** sec.5).

Work for the Intergovernmental Panel on Climate Change: The work of the IPCC was awarded the Nobel Peace Prize in 2007. Four of MMU's staff from CATE (Lee, Raper S, Raper D and Dimitriu) are Lead Authors. Lee as REF researcher has contributed to the 1999 Aviation Report (**[I],** sec.5), the 2006 Greenhouse Guidebook (**[J],** sec.5) and the 2007 Fourth Assessment WG3 Report (**[A],** sec.5), and the writing of the Fifth Assessment Report from 2011 to 2013. CATE has made significant contributions to IPCC reports that have been critical in informing international climate policy and have enduring impact in the current REF impact period. The IPCC Greenhouse Guidebook (2006) for example (**[J],** sec.5) is still the de facto standard for estimating and reporting aviation and shipping emissions internationally and still in use to 2013.

5. Sources to corroborate the impact

[A] Kahn-Ribeiro S., Kobayashi S, Beuthe M., Gasca J., Greene D., **Lee D. S**., Muromachi Y., Newton P. J., Plotkin S., Wit R. C. N. and Zhou P. J. (2007) *Transportation and its infrastructure*. Chapter 5, IPCC Fourth Assessment Report, Working Group 3.

[B] Report of the Ninth meeting of the International Civil Aviation Organization Committee on Aviation Environmental Protection, Montreal, February 4th to 15th, 2013.

[C] Meeting the UK aviation target – options for reducing emissions to 2050. Committee on Climate Change, London**.**

[D] Quote from Executive Director/Chief Scientist (Environment/Energy), US Federal Aviation Administration *corroborating impacts on establishing the principles for standard-setting on international aviation emissions and on quantifying the impact on future CO2 reduction.*

[E] Quote from: Technical Adviser to the Secretary-General, Office of the Secretary-General, International Maritime Organization *corroborating impacts on setting benchmarks for international CO2 emissions from the maritime sector.*

[F] Quote from: Personal assistant to Member of Cabinet of Connie Hedegaard, European Commissioner for Climate Action *corroborating impacts on EU policy and position in relation to CO2 emissions from aviation.*

[G] Quote from: Climate Science Advisor, Committee on Climate Change Secretariat *corroborating impacts on UK aviation and shipping emissions policy.*

[H] Quote from: Deputy Director, Division of Technology, Industry & Economics, United Nations Environment Program *corroborating impacts on international aviation / maritime policy and potential CO2 reductions.*

[I] Henderson S. C., Wickrama U. K., Baughcum S. L., Begin J. L., Franco F., Greene D. L., **Lee D. S.**, Mclaren M. L., Mortlock A. K., Newton P. J., Schmitt A., Sutkus D. J., Vedantham A. and Wuebbles D. J. (1999) Aircraft emissions: current inventories and future scenarios. Chapter 9 of '*Aviation and the Global Atmosphere'*. Special Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

[J] Maurice L. Q., Hockstad L., Hoehne N., Hupe J., **Lee D. S.** and Rypdal K. (2006) Mobile combustion: aviation. In '*2006 IPCC Guidelines for National Greenhouse Gas Inventories'* Chapter 3, Section 6, Intergovernmental Panel on Climate Change, Japan.