Institution: University of Reading

Unit of Assessment: 7 Earth Systems & Environmental Sciences

Title of case study: Supporting climate policy through the assessment of the consequences of climate change

1. Summary of the impact:

Information on the potential impacts of climate change across the world, and on the effects of policies designed to reduce emissions, is fundamental to inform the development of climate mitigation and adaptation policy. Research conducted at the Unit has been critical to the establishment of a target 80% cut in UK carbon emissions by 2050, as enforced by the Climate Change Act (2008), and provided an affirmation of the relevance of the 2°C global mean temperature rise target central to national and international climate mitigation policy. Research into the global consequences of climate change, particularly for water resources and river flooding, has been used by the Department for Energy and Climate Change (DECC) to assess the impacts of un-mitigated climate change and the effects of different mitigation policy options.

2. Underpinning research:

Two complementary strands of the Unit's research have informed government policy in relation to climate change.

The first strand is led by Dr. Jason Lowe, a REF Category C researcher employed by The Met Office Hadley centre and on full-time secondment to the Unit (as part of the MetOffice@Reading group). He has been with the Unit between 2003 and the present day and the work cited here was with Unit PDRA and subsequently MetOffice@Reading researcher Dr L. Gohar. In that time, he has led research to set up and use numerical models specifically to evaluate the effect of different scenarios for the future emission of greenhouse gases on global and regional climate over the 21st century (Lowe et al. 2009)[8], (see also Allen et al., 2009[1]; Jones et al., 2010[2]; Huntingford et al., 2012[3]; and Parry et al., 2009[4]). These models have included both large global climate models and simpler energy balance models. The global climate models simulate the evolution of weather over space and time, and can represent non-linearities in the global and regional response to increasing forcing from greenhouse gases. However, they require considerable computational resources and so can be run only for a small number of potential future emissions scenarios. The simpler energy balance models can be run for many more emissions scenarios, but only simulate global mean surface temperature and global mean sea level rise due to the thermal expansion of sea water. A comprehensive assessment of the effects of different future emissions requires the co-ordinated use of both types of model. There are, of course, a large number of possible future scenarios for the future emission of greenhouse gases. Lowe developed a framework for characterising generic emissions scenarios (based on rate of rise, time of peak and lowest value to which emissions decline) and assessing systematically their implications for global temperature rise targets. The research has been undertaken with partners from CEH Wallingford and the University of Oxford, with funding from NERC, Defra (Department of the Environment, Food and Rural Affairs), the Committee on Climate Change, DECC and the Ministry of Defence as part of the Hadley Centre Integrated Climate Programme. Since 2009, the research has also been funded by DECC through the AVOID programme (http://www.metoffice.gov.uk/avoid/), which is designed to provide science-based policy-relevant evidence on climate change and its consequences to DECC. J. Lowe led the successful proposal to DECC, and was subsequently made the AVOID programme's Principal Scientist.

The second strand of research was led by the Unit's Prof Nigel Arnell (since 2007), with PDRAs Simon Gosling (2008-2011) and Ben Lloyd-Hughes (since 2008) and NERC Knowledge Exchange fellow Tom Osborne (with the Unit since 2003). Other inputs have been made by the Unit's Prof K. Haines with assistance from the Unit's IT staff. The work has involved the development and use of global-scale models to estimate the impacts of climate change, methods of constructing climate scenarios that can be used by these impact models, and the estimation of the impacts of climate change under a variety of assumptions about future emissions. The programme concentrated on hydrological impacts (water resources and floods)[6,7,9] and agricultural impacts (crop productivity[10]). This work was stimulated partly by the desire back in 1997 of the (then) Department of the Environment to understand the socio-economic impacts of change scenarios based on Met Office climate models. Since 2007 this research has been funded by a NERC consortium grant (QUEST-

GSI) led by Arnell and by the DECC AVOID programme. Both have involved partners (led by Arnell) from the universities of Southampton, Aberdeen and East Anglia, CEH Wallingford, and the Potsdam Institute for Climate Impacts Research in Germany. The work at UoR extended and exploited a hydrological model initially developed by Arnell at Southampton University (before he became director of the Unit's Walker Institute in August 2007) and developed the methodological framework in which the model was subsequently applied.[11] The research has demonstrated that the impacts of un-mitigated climate change can be very substantial. Projected impacts vary around the globe, and whilst there is broad agreement in the direction of change in many regions, the magnitude of change is often highly uncertain because of uncertainty in future rainfall patterns. For example, the paper by Gosling et al.[12] showed that in some regions (e.g. western Europe and the Mediterranean) river flows are projected decrease and water scarcity will therefore increase, but in other regions (e.g. south Asia and parts of China) there is more uncertainty over the direction of change. Arnell has also synthesised impacts of climate change across all the sectors (water, agriculture, coasts, soils and energy), under different scenarios for climate and socio-economic change[13].

Background information: related publications by Unit staff

1. M.R. Allen, et al. (incl. J.A Lowe) (2009). Warming caused by cumulative carbon emissions towards the trillionth tonne. *Nature*, *458*(7242), 1163-116. (195 cites)
2. C. Jones, J.A. Lowe, et al. (2009). Committed terrestrial ecosystem changes due to climate change. *Nature Geoscience*, *2*(7), 484-487. doi: 10.1038/NGEO555 (39 cites)
3. C. Huntingford, J.A. Lowe, L.K. Gohar et al. (2012). The link between a global 2° C warming threshold and emissions in years 2020, 2050 and beyond. *Env. Res. Lett.*, *7*(1), 014039. (4 cites)
4. M. Parry, J.A. Lowe, & C. Hanson (2009). Overshoot, adapt and recover. *Nature*, *458*(7242), 1102-1103 (46 cites)
5. R. Warren, (incl. J. Lowe, N. Arnell, S. Gosling, T. Osborne) (2013) The AVOID programme's new simulations of the global benefits of stringent climate change mitigation. *Climatic Change*, 120 (1-2). 55-70 (no cites yet)
6. Arnell, N.W. & Gosling, S.N. (2013) The impacts of climate change on river flow regimes at the global scale. *Journal of Hydrology* 486: 351-364. doi:10.1016/j.hydrol.2013.02.010 (no cites yet)
7. Arnell, N.W., et al. (2011) The implications of climate policy for the impacts of climate change on global water resources. *Global Environmental Change* 21(2), 592-603 (15 cites)

3. References to the research:

The 6 papers from the Unit's work listed below have been selected to demonstrate various aspects of the two strands of research discussed in section 2. Because the impact discussed in 4 is multi-faceted, there are many other papers that Unit staff contributed to that were also used. Some of these are listed under above.[2-6,8,9] The citations to papers are taken from a WoS search made in October 2013. Paper 12 listed below won Best Paper in the climate change category of the Lloyds 'Science of Risk' prize, 2010. The 3 papers marked with an asterisk can be used to assess research quality. The first strand of the research was supported by the Joint DECC, Defra and MoD Integrated Climate Programme—DECC/Defra (GA01101), MoD (CBC/2B/0417 Annex C5). The second strand of the work was funded by a NERC consortium grant NE/E001882/1 ("Global scale impacts of climate change: a multi-sectoral analysis": total value £1.1M).

8. *J.A. Lowe, et al. (2009). How difficult is it to recover from dangerous levels of global warming? *Env. Res. Lett.*, *4*(1), 014012. (42 cites)
9. Gosling, S.N. & Arnell, N.W. (2013) A global assessment of the impact of climate change on water scarcity. *Climatic Change* doi:10.1007/s10584-013-0853-x (not on WoS)
10. T. Osborne et al (2013) Variation in the global-scale impacts of climate change on crop productivity due to climate model uncertainty and adaptation. Agricultural and Forest Meteorology 170, 183-194 doi:10.1016/j.agformet.2012.07.006 (4 cites)
11. S.N. Gosling, N.W. Arnell (2010) Simulating current global river runoff with a global hydrological model: model revisions, validation and sensitivity analysis. *Hydrological Processes* 25 (7), 1129-1145. (19 cites)
12. *S.N. Gosling, D. Bretherton, J. Haines, & N.W. Arnell (2010) Global hydrology modelling and uncertainty: running multiple ensembles with a campus grid. *Phil. Trans. R. Soc. A-Mathematical, Physical and Engineering Sciences*. 368, 4005-4021 (11 cites)

13. *N.W. Arnell, J. Lowe, et al. (incl. B. Lloyd-Hughes, & T. Osborne) (2013) A global assessment of the effects of climate policy on the impacts of climate change. *Nature Climate Change*. 3 (2) 512-519 doi:10.1038/nclimate1793 (3 cites)

4. Details of the impact:

The United Kingdom is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), which commits countries to reduce greenhouse gas emissions in order to avoid dangerous human interference with the climate. As part of this commitment, the UK adopted the Climate Change Act in 2008 which requires the government to set and meet targets for the emissions of greenhouse gases. Research in the Unit has had a direct impact by: (i) providing the scientific basis for the reduction in emissions needed to meet the UK government's target temperature increase of 2°C above pre-industrial levels, and (ii) providing policy-relevant information to the UK's negotiators at international climate policy conferences. As detailed below, this has been based on underpinning scientific research conducted at the Unit, together with research specifically commissioned by DECC and the Committee on Climate Change (CCC).

The first task of the CCC, set up in the 2008 Climate Change Act[14], was to propose a target reduction in emissions for the UK. The CCC first selected a 'climate target': UK policy should seek to achieve a 50:50 chance of keeping the rise in global mean surface temperature below 2°C above pre-industrial levels, with only a small chance of an increase above 4°C. It commissioned the Unit (through Lowe) to identify and assess emissions trajectories which would meet this target. Lowe used an energy balance model with systematically-varying emissions scenarios to conclude that global emissions needed to be reduced by 50% by 2050 (relative to 1990) in order to achieve the specified climate target[15]. The CCC translated this to a UK target of an 80% reduction in emissions [16-17], taking into account historical responsibilities and equity considerations. This target is legally-binding, and informs the setting of successive 5-year carbon budgets. The Climate Change Act has become the focus of political debate about its relative costs and benefits over a range of timescales. It influences every inhabitant of the UK and, by leading by example, has the power to have great influence internationally. The CCC's advice on carbon budgets and targets is directly reflected in legislation and the Government's carbon strategy[18].

The UK government plays a key role in international negotiations over climate policy through the UNFCCC[19]. These negotiations consider both the targets for climate policy and mechanisms for achieving these targets. The focus of current negotiations is around a replacement for the Kyoto Protocol adopted in 1997, with a target agreed in the 2009 Copenhagen Accord[20] of keeping the increase in global mean surface temperature to 2°C above pre-industrial levels. The Unit has provided information and evidence to the UK government to support its international negotiations. This has largely been through the AVOID project, awarded by DECC in 2008 through open competition to a consortium led by the Met Office (Lowe was principal scientist) and including the Walker Institute at the University of Reading. The initial AVOID contract had a value of £800k, and additional funds were subsequently awarded to project partners for additional work requested by DECC and Defra. AVOID built explicitly on work in the Unit on the relationship between emissions and temperature changes (Lowe) and on the global-scale impacts of climate change (Arnell). The AVOID project actively sought engagement with stakeholders (largely in DECC and Defra), and presented results not only directly to DECC but also publicly through newsletters, factsheets and presentations at climate negotiation conferences. The research undertaken at the Unit[13,5] demonstrated the likelihoods of achieving climate targets with different emissions pathways, and showed the benefits of achieving these targets in terms of impacts avoided (with a particular focus on water availability, river flooding, crop productivity and the energy requirements for heating and cooling). The research demonstrated how reducing emissions will give extra time to install buildings, transport systems and agricultural practices that are more resilient to climate change.

Of the AVOID programme as a whole, the Minister for Energy and Climate Change said in 2013 [22] *"This has been a unique multi-disciplinary research programme ….. it has been an impressive demonstration of successful collaboration between academia and Government. And it has had concrete outcomes. For example, materially supporting the UK's international engagement and informing our negotiating position at Copenhagen and beyond; Contributing to the UN's Environmental Programme with robust, credible and timely research; and supporting the setting of our carbon budgets"*. A formal review of the AVOID programme in 2012 by Risk Solutions[23] concluded that *"The AVOID programme is delivering interesting and useful, policy relevant work. It helped frame the UK's position going into the Copenhagen COP and supported work*

internationally including work by the European Union and United Nations Environment Programme. It has helped inform policy making across government, for example the Committee on Climate Change has used outputs from AVOID to help inform its work on long term (2050) targets for the UK". With reference to the particular work of the Unit on estimating the impacts avoided by climate policy[13], the Secretary of State for Energy and Climate Change said[24] *"We can avoid many of the worst impacts of climate change if we work hard together to keep global emissions down. This research helps us quantify the benefits of limiting temperature rise to 2°C and underlines why it's vital we stick with the UN climate change negotiations and secure a global legally binding deal by 2015"*.

The research has not only been used by the UK government to inform target-setting, but is also contributing directly to international discussions.[27] For example, Lowe was an author of a report produced in 2010 by the EU Climate Change Expert Group *Science*, completed under the Belgian EU presidency and presented at the climate negotiation conference in Cancun in 2010[25]; the aim of the report was to inform delegates of the latest scientific evidence on the chances of achieving the 2°C target specified in the Copenhagen Accord. Lowe also made a presentation on the results of the Unit's research to the first meeting in 2013 of the "Structured Expert Dialogue" on the UNFCCC's 2013-2015 review of the 2°C target (the "Long Term Global Goal").[26]

Background information

14. Committee on Climate Change http://www.theccc.org.uk/about/
15. Smith,S et al. (2009) Chapter 1 Technical Appendix: Projecting Global Emissions, Concentrations and Temperatures. Committee on Climate Change. http://bit.ly/16DJSbP
19. United Nations Framework Convention on Climate Change: UNFCCC http://unfccc.int/2860.php
20. Copenhagen Accord: https://unfccc.int/meetings/copenhagen_dec_2009/items/5262.php
25. Scientific Reference Document produced by the EU for the Cancun climate negotiation conference. http://bit.ly/1gpIfDW
26. First Meeting of the Structured Expert Dialogue for the 2013-15 review (of the UNFCCC long-term climate goal): https://unfccc.int/science/workstreams/the_2013-2015_review/items/7803.php

5. Sources to corroborate the impact

Error! Hyperlink reference not valid.16. CCC (2008) Building a low-carbon economy – the UK's contribution to tackling climate change http://bit.ly/1dLuTyr
17. Statement of UK government policy on climate change: https://www.gov.uk/government/policies/reducing-the-uk-s-greenhouse-gas-emissions-by-80-by-2050
18. Committee on Climate Change: influence on policy http://www.theccc.org.uk/about/our-impacts/
22. Edward Davey MP (Secretary of State for Energy and Climate Change) speech to the AVOID symposium at the Royal Society, 12 February 2013, https://www.gov.uk/government/speeches/edward-davey-speech-to-the-avoid-symposium-at-the-royal-society
23. Independent evaluation of the AVOID programme. http://bit.ly/1a5rvgh
24. Edward Davey MP (Secretary of State for Energy and Climate Change) comment on publication of a paper[13] presenting AVOID project results: https://www.reading.ac.uk/news-and-events/releases/PR482917.aspx
27. Head of Climate Science and International Evidence, Department of Energy and Climate Change (DECC). Contact details provided.