Institution: Royal Holloway, University of London

Unit of Assessment: 7 Earth Systems and Environmental Sciences

Title of case study: Measuring Greenhouse Gases: informing global and national policies and targeting reduction measures

Period when the underpinning research was undertaken: 2000-2020

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Prof. E.G. Nisbet	Prof. of Earth Science	1991-present
Dr. D. Lowry	Reader in Earth Science	1994- present
Dr. R.E. Fisher	Lecturer in Earth Science	2003 - present

Period when the claimed impact occurred: 2014-2020

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

The continuing rise of atmospheric methane and its unexpected increased growth rate since 2007 threaten to jeopardise global commitments to limit global warming to less than 2°C. Research by Royal Holloway's Greenhouse Gas Group has generated a body of evidence relating to methane measurements. The research has transformed understanding of the reasons for methane growth and led to refinement of mitigation targets. Impact has been generated through three main routes: 1) measurements of the current and likely future state of global methane; 2) shaping UK and global policy and helping the energy industry to mitigate against climate change and leakage at gas fields; and 3) shaping public debate through UK and international media. The Greenhouse Gas Group's research has been pivotal to enhanced understanding of methane's role in enabling UN Paris Agreement targets to be either reached or breached.

2. Underpinning research

Research by the Greenhouse Gas Group at Royal Holloway addressed three fundamental questions: First, what are the causes of methane growth? Second, which sources have changing emissions and why? Third, what are the opportunities for national and global mitigation? In addressing these questions, the Group used air sampling in the UK and around the world, to reveal that methane is often under-estimated in climate change modelling, where the focus is on carbon dioxide rather than other gases such as methane. Their research has demonstrated that not only that recent industrial activities such as fracking an important trigger of methane release but also that microbial emissions in the tropics from sources such as rice paddies and wetlands are a contributory source. Royal Holloway's air measurements highlighted 'plumes of methane' and warned that climate models would need to better account for this surge in methane because each molecule of methane has a greater warming effect than carbon dioxide. Failure to understand and respond to a spike in methane emissions, especially in natural ecosystems, will undermine the ambitious targets laid out in the UN Paris Agreement (**R1**).

Led by Professor Euan Nisbet and Royal Holloway colleagues, Dave Lowry and Rebecca Fisher, the focus of attention was ensuing that the group's research was underpinned by long-term measurement of methane and its isotopes at remote stations in the Atlantic, Arctic, Bolivia (Amazonia), Cape Town (Southern Ocean) and Hong Kong (tracking China's outflow). Royal Holloway Greenhouse Gas Group's first report of methane's renewed growth was in partnership with US federal agency, National Oceanic and Atmospheric Administration (NOAA, **R4**). RHUL/NOAA-led scientific papers are the key global reports on the ***State of Methane***, providing the primary scientific underpinning for tracking methane's input to global warming as nations seek

to meet the climate goals of the UN Paris Agreement (**R2 to R5**). It and showed that methane's $^{13}C/^{12}C$ isotopic ratio is trending negative (**R2** and **R3**), implying a significant global budget shift caused by changing proportions of biogenic and fossil fuel emissions, especially in the tropics, or declining sinks, or both. These findings reset the global methane debate and are key underpinnings to chapters in the IPCC assessment and to regional and global methane modelling and mitigation planning, both on national and global scales. Royal Holloway's research considered the potential impact of warming on Arctic methane release through destabilization of hydrate (**R6**) or warming permafrost and wetland.

A second strand of research addressed the role of methane emissions in urban areas. The Greenhouse Gas Group, using some of the world's longest peri-urban CH_4, CO_2, CO and H_2 records, led to the innovative development of new technologies for mobile measurement of methane around major sources, such as landfills, gas industry systems, cattle barns, and for determination of methane's C-isotopic ratios from natural and anthropogenic sources. This is important for developing methodologies for regulators and industry and illustrated how the research at Royal Holloway was very closely tied to national and international collaborative networks (**R1**). One example was the work that was undertaken with the UK government and European Union to identify and measure emissions from sources such as landfills, cattle feed lots, landfills and biodigesters.

Royal Holloway's research helped identify pathways and methane-reduction targets designed to encourage rapid emission reduction. Emission reduction is essential if the UN Paris Agreement and UK national 'Net Zero' goals for 2050 are to be met. If the methane rise documented by the Greenhouse Gas Group continues at the current pace in the coming decades, these commitments are likely to fail. Royal Holloway's research leadership has been recognised recently. In 2020, Royal Holloway researchers led a major invited publication on Methane Mitigation for the prestigious *Reviews of Geophysics*, published by the American Geophysical Union (**R1**). Professor Nisbet is lead editor for a special issue of *Philosophical Transactions*, a Royal Society volume on *Rising Methane* (originally set for publication in October 2020), and now rescheduled for publication at the time of the UK-hosted COP26 meeting in Glasgow.

The Greenhouse Gas Group is a leader in investigating ways that methane reduction might be accelerated via UV or catalytic destruction as well as biological oxidation, whereby gas emissions can be directly removed from the ambient atmosphere around intractable sources such as gas fields and land fill sites. As a consequence of this work, Royal Holloway's researchers continue to advise the United Nations Climate and Clean Air Coalition (UN CCAC) on methane reduction and in the recent past have led UN-sponsored aircraft campaigns in the North Sea for the purpose of reducing gas field emissions of methane.

The Greenhouse Gas Group's work has been underpinned by multiple grants and until recently was a member of the UK's NERC highlight consortium, *MOYA: The Global Methane Budget* (2016-2020 with an operational budget of £5,000,000).

3. References to the research

(**R1**) **Nisbet**, E.G. et al. (2020) Methane mitigation: methods to reduce emissions, on the path to the Paris Agreement. *Reviews of Geophysics* 58.1: e2019RG000675. *4 Scopus citations (31.12.2020)*

(**R2**) **Nisbet**, E.G. et al (2019) Very strong atmospheric methane growth in the four years 2014 - 2017: Implications for the Paris Agreement. *Global Biogeochem. Cycles.* **33**, 318-42 https://doi.org/10.1029/2018GB006009. *81 Scopus citations (31.12.2020)*

(**R3**) **Nisbet**, E. G., et al. (2016), Rising atmospheric methane: 2007–2014 growth and isotopic shift, *Global Biogeochem. Cycles*, **30**, 1356-1370 doi: 10.1002/ 2016GB005406. Web of Science 'Hot' paper through 2017 -top 0.1% for citation. *190 Scopus citations (31.12.2020)*

(**R4**) **Nisbet**, EG, Dlugokencky, EJ, Bousquet, P (2014) Methane on the rise – again *Science* **343**, 493-5 doi: 10.1126/science.1247828. *279 Scopus citations (31.12.2020)*

(**R5**) Dlugokencky, E.J., **Nisbet**, E.G., **Fisher**, R., and **Lowry**, D. (2011) Global atmospheric

methane in 2010: Budget, changes and dangers. *Phil. Trans Royal Soc Lond A* **369,** 2058–2072 doi: 10.1098/rsta.2010.0341.*376 Scopus citations (31.12.2020)*

(**R6**) Westbrook, G.K. et al. (including **Nisbet**, E.G and **Fisher**, R.E.) (2009) Escape of methane gas from the seabed along the West Spitsbergen continental margin. *Geophys Res. Lett*, 36, L15608 doi: 10.1029/2009GL039191. *341 citations* (*31.12.2020)*

Quality Indicators

Names in **bold** are staff at Royal Holloway University of London. All references are publications in internationally recognised peer-reviewed journals such as *Science* and *Geophysical Research Letters*. The work of Royal Holloway's Greenhouse Gas Group is heavily cited.

- Between 2013-2020, the Group's secured repeated competitive funding from multiple sources including NERC, EU, UN Clean Air Coalition and BEIS. This includes GBP 3,000,000 grant funding from NERC between 2013-2020.
- Royal Holloway leads and initiated the national GBP5,000,000 14-partner NERC Highlight consortium, Project MOYA, *The Global Methane Budget*, 2016-2020.

4. Details of the impact

A key challenge for this research is to ensure that policymakers and publics understand the current and future role of methane in climate change modelling and strategies of mitigation. The underpinning research been achieved through strong and long-lasting collaborations of over twenty years with other academics, funding bodies, and policy-making communities. Building on relationships, Royal Holloway's Greenhouse Gas Group encouraged knowledge transfer, policy impact and capacity building. The beneficiaries include academic and professional communities, policymakers and wider publics. Fundamentally, the need to understand the reasons for the continued growth in atmospheric methane and identify opportunities for mitigation are vital for achieving net-zero carbon ambitions.

There are three strands of impact: informing policymakers, thought leadership, and enriching public understanding.

Informing policymakers on UK and global greenhouse gas growth and sources

The Greenhouse Gas Group informs and influenced **global, regional and national policy-making** communities. First, the group contributes to reports that inform the United Nations and the World Meteorological Organization on greenhouse gas measurements and methodologies. Their scientific papers provide key information tracking the progress of the 2015 UN Paris Agreement. In the draft 6th Assessment Report of the Intergovernmental Panel on Climate Change, **R2**) is cited as a key report on the current state of methane. More widely, Royal Holloway's evidence on the global state of atmospheric methane is used by key **multi-national institutions, including the United Nations, the World Meteorological Organization and the International Atomic Energy Agency, and the Arctic Council,** to inform governments and businesses.

Second, the group's regional work on Arctic-based measurements informed policy community discussion about the potential impact of warming on Arctic methane release through destabilization of hydrate or warming permafrost and wetland (through multiple NERC projects since 2007). This research led to significant contributions by Royal Holloway researchers to the Arctic Monitoring and Assessment Programme Report (AMAP, 2015 and **S4**), which helped lead the Arctic Council to 'commit to **enhance actions to reduce black carbon and methane emissions** at the national level … through the development of national actions or action plans or mitigation' and creation of an Arctic Council Expert Group on Black Carbon and Methane. Arctic Council member states plan a minimum of 10 % reductions in methane by 2030.

Nationally, the group carried out mobile greenhouse gas measurement to inform the Department of Business, Energy and Industrial Strategy (BEIS) of local methane emissions, using isotopes to distinguish between gas and agricultural emissions, and have published recommendations for environmental baseline monitoring. In 2012-3, Royal Holloway's isotopic measurements from aircraft surveys identified the source of the Elgin gas field leak and in 2018 and 2019 Royal

Holloway led UN CCAC funded work to identify North Sea gas leakage, **improving governmental understanding of methane sources and helping industry mitigate against gas leakage**. The group developed mobile measurement techniques and has mapped fugitive methane emissions in street-by-street surveys across London, Birmingham and Bucharest for EU MEMO^2 and UN CCAC studies. The UN CCAC studies are carried out in co-operation with the Oil and Gas Methane Partnership (currently 62 partners) to inform industry of where oil and gas emissions can be reduced.

This collective work has been recognized as highly significant and cited as such by influential stakeholders. [text removed for publication], US National Oceanic and Atmospheric Administration (NOAA), states "[text removed for publication]" (**S1**). [text removed for publication] remarked that, "The work has been **widely influential on policy makers** … jurisdictions now have major programs and policy initiatives that stem directly from the careful monitoring carried out by NOAA and its key partners like Royal Holloway. Global and National Policy Agreements on methane are informed by this work… These initiatives are driven by the knowledge that comes in significant part from the work jointly carried out by NOAA and Royal Holloway". [text removed for publication] Atmospheric Environment Research at the World Meteorological Organization states [text removed for publication] (**S2**).

Royal Holloway is a key member of the Global Atmosphere Watch (GAW), the UN's long-term global programme providing the technical basis for the assessment of atmospheric chemical composition. Participation in such expert fora enabled as [text removed for publication] states, [text removed for publication] (**S2**). [text removed for publication] again noted [text removed for publication].

Thought Leadership in the Greenhouse Gas community. The Greenhouse Gas Group's academic reputation for innovation and outstanding science has enabled impact through expert participation and leadership. In terms of reputation for innovation, the use of drone measurement of methane above Ascension Island won *The Engineer's* prestigious '*Collaborate to Innovate'* award (**S7**). Since 2013, the group pioneered mobile measurement techniques and this work was presented at the biennial UN WMO/IAEA Greenhouse Gas and Measurement Techniques panel meetings. This panel was originally set up as the UN WMO/IAEA expert panel by C.D. Keeling and co-ordinates global greenhouse gas measurement. This innovative approach to methane measurement research led to role in EU consortia including Meth-MonitEUr, Geomon IP, which contributed to the 6th Environmental Action Programme of the EU, and currently MEMO^2. Professor Nisbet was asked to advise the International Methane Science Study within the United Nations Climate and Clean Air Consortium (**S6**; 2018 to 2020), where Nisbet shapes operational decisions. In a *Nature* news report of a RHUL led tropical methane emissions study in *MOYA* (2019), Jeff Tollefson said "**the key to solving the methane mystery might be in the air samples that Nisbet's team gathered**" (**S5**). Nisbet is an expert reviewer for the IPCC 6th Assessment Report and recently received American Geophysical Union Outstanding Reviewer Award 2016 and European Geoscience Union Bio-geosciences Outstanding Reviewer Awarded in 2020.

Enriched public understanding and media on methane. Nisbet and his research team are committed to sharing the benefits of research as far as possible. Between 2014 and 2020, the work of the Greenhouse Gas Group was cited and quoted in multiple media outlets and scientific publications. The *Economis*t (2018) and The *Financial Times* (2019) devoted lengthy articles to the Greenhouse gas group's findings, with long-read reports in other news outlets including the *Los Angeles Times* (2019), Bloomberg Markets (2020), NZZ Zurich (2019), *Daily Mail* (2016), *South China Morning Post* (2016). BBC Radio 4 (Inside Science, 2019) and the BBC's World Service (Discovery: Cheating the atmosphere, 2017) broadcast programmes on the work. Royal Holloway will lead the Royal Society's Discussion Meeting: *Rising methane: is the warming feeding the warming*? now scheduled for Autumn 2021 **(S9).** Royal Holloway researchers have also responded positively to requests for help from journalists writing about the impact of methane on world climate and environments. Examples of this collaborative approach included Yale Environment 360's blog essay 'What is Causing the Recent Rise in Methane Emissions?' by Fred Pearce (25th October 2016) and a Reuters's news agency 'Global methane emissions rising due

to oil and gas, agriculture – studies' (14th July 2020), Professor Nisbet continues to be in demand as an **expert commentator on the role of methane emissions on global climate**. Nisbet has been interviewed by journalists in Europe, North America, Africa and Asia, and featured on NASA's Earth Observatory (2016) and Radio Echo Shock (2019). [text removed for publication] of NOAA acknowledged that the [text removed for publication]" (**S1**).

5. Sources to corroborate the impact

(**S1**)**.** US NOAA Testimonial, [text removed for publication], US National Oceanic and Atmospheric Administration. 16th January 2020.
(**S2**). UN WMO Testimonial**:** global methane. *Evidence:* Letter from [text removed for publication] Atmospheric Environment Research Division, UN World Meteorological Organisation, and coordinator of the Global Atmosphere Watch. 10th January 2020.
(**S3**). Excerpts from WMO *Greenhouse Gas Bulletin No. 15*, 25th November 2019.
(**S4**). *Arctic Monitoring and Assessment Programme Report* (AMAP). 2015. Royal Holloway authors are highlighted on page iii in yellow.
(**S5**). *Nature* News Article, Jeff Tollefson, Nature. 14th February 2019.
(**S6**). UN Climate and Clean Air Coalition (CCAC) Oil and Gas Science Study Scientific Advisory Committee**.** *Evidence*: Contract letter "82346-X-A3-03 UN Environment Kigali Assessment-Methane Science Study". 25 June 2018.
(**S7**). The Engineer Collaborate to Innovate Award**.** 17th November 2016.
(**S8**). Bundled documentation of Media Reports, 2016-2020.
(**S9**) Royal Society Discussion Meeting on *Rising Methane*, led by Nisbet. Now rescheduled for Autumn 2021.
(S10) Altmetric data for Nisbet et al. 2019. Metrics for media reports and policy documents citing the paper.