Institution: University of York		
Unit of Assessment: 8 - Chemistry		
Title of case study: Influencing UK air pollution policy and legislation.		
Period when the underpinning research was undertaken: 2010-2020		
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:**
Alastair Lewis	Professor	May 2003 to present
Sarah Moller	KE Fellow	Oct 2011 to present
David Carslaw	Reader	Apr 2015 to present
James Lee	Professor	Sep 2003 to present
Jacqui Hamilton	Professor	Aug 2003 to 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 (indicative maximum 100 words)

Research at the University of York has influenced policy and legislation to improve air quality in the UK for nitrogen oxides, volatile organic compounds and particulate matter. Insight into real-world vehicle emissions motivated national and local actions that reduced urban NO_2. Evidence on emerging sources of chemical pollution led to policies in the Defra *Clean Air Strategy* (2019) and informed government target-setting in the *Environment Bill* (2020). Research has been used extensively in plans published by government, cited in parliamentary committees and debates, provided at Ministerial level, to the Chief Medical Officer, and through outreach activities which raised public awareness of issues relating to use of chemicals in the home.

2. Underpinning research (indicative maximum 500 words)

The University of York has generated a substantial body of research (>400 publications 2005-2020) addressing contemporary issues associated with atmospheric chemistry and air pollution. Impact has arisen from primary research into the emissions and atmospheric behaviour of air pollutants, including nitrogen oxides (NO_x), volatile organic compounds (VOCs) and particulate matter (PM). Nitrogen dioxide, a component of NO_x, is a regulated pollutant that is directly harmful to health. VOCs are precursors of photochemical ozone and PM, both of which are regulated air pollutants.

A body of research by **David Carslaw** and **James Lee** identified that emissions of NO_x from road transport and diesel vehicles in the urban environment substantially exceeded the amounts in regulatory national emissions reporting and for air quality forecasting and policy-setting. Carslaw pioneered the use of remote sensing methods to evaluate the real-world emissions of NO_x from 100,000's of vehicles driving on public roads and published some of the earliest and most globally influential papers on the discrepancies between diesel vehicle test-cycle emissions standards and on-road emissions [3.1].

Lee complemented this by developing the first top-down estimates of city-scale NO_x emissions using eddy covariance measurements from tall towers (notably the BT Tower in London) and from low-and-slow flying aircraft, quantifying emissions across London. This later work identified that in central London private cars contributed relatively limited amounts of NO_x, relative to other diesel power users [3.2]. Using large decadal datasets drawn from across Europe in 2017 **Carslaw,** Moller and **Lewis** identified that policy projections of urban NO_2 had started deviating from observations around 2010 and that the policy models used across Europe for estimating direct tailpipe NO_2 required substantial revision. This research highlighted that the well-reported problems of excessive roadside NO_x reached their peak at that time and were declining faster than anticipated [3.3].

In 2012 **Lewis** and **Hamilton** completed a comprehensive evaluation of emissions of gas phase organic composition in UK air and identified that emissions of evaporative and unburnt diesel fuel were up to 70 times greater than assumed in national emissions inventories. They quantified

how VOC emissions from the diesel fleet would impact on secondary ozone and PM formation [3.4]. In separate research ethanol was then identified as the most abundant VOC found in UK urban air, a consequence of changes in gasoline composition, a reduction in hydrocarbon emissions from gasoline vehicles and an increase in domestic solvent consumption [3.5].

The implications of growth in VOC emissions from the domestic sector were reported as having wide impacts both outside and indoors, affecting the attainment of the UK's international obligations to reduce transboundary pollution, and directly impacting public health. **Lewis** identified the growing significance of the indoor emissions of VOCs from consumer products and specifically that substantial quantities of solvents and monoterpenes were ubiquitous inside homes, both having potential to form harmful secondary products [3.6] such as formaldehyde and fine particulate matter ($PM_{2.5}$).

3. References to the research (indicative maximum of six references)

3.1. **Carslaw**, **D.C.,** Murrells T.P., Andersson J., Keenan M. (2015) Have vehicle emissions of primary NO_2 peaked? Faraday Discussions, **189**, 439-454. DOI:10.1039/c5fd00162e

3.2. **Lee**, **J.D.,** Helfter, C., Purvis, R.P., Beevers, S., **Carslaw**, **D.C., Lewis**, **A.C., Moller**, **S.J.,** Tremper, A., Vaughan, A., and Nemitz. E.G. (2015) Measurement of NO_x fluxes from a tall tower in central London, UK and comparison with emissions inventories. Environmental Science and Technology, **49**, DOI:1025-1034. 10.1021/es5049072

3.3. Grange, S., **Moller**, **S.M., Lewis, A.C.,** and **Carslaw, D.C**. (2017) Lower vehicular primary emissions of NO_2 in Europe than assumed in policy projections. *Nature Geoscience, page 19*, **10**, 914-918. DOI:10.1038/s41561-017-0009-0

3.4. Dunmore, R.E., Hopkins, J.R., Lidster, R.T., **Lee**, **J.D.,** Evans, M.J., Rickard, A.R., **Lewis**, **A.C.,** and **Hamilton, J.F**. (2015) Diesel-related hydrocarbons dominate reactive carbon in megacities. Atmospheric Chemistry & Physics, **15**, 9983-9996. DOI:10.5194/acp-15-9983-2015

3.5. Dunmore, R.E., Whalley, L.K., Sherwen, T., Evans, M.J., Heard, D.E., Hopkins, J.R., **Lee**, **J.D., Lewis**, **A.C.,** Lidster, R.T., Rickard, A.R., and **Hamilton, J.F**. (2015) Atmospheric ethanol in London and the potential impacts of future fuel formulations. Faraday Discussions. **189**, 105-120. DOI:10.1039/C5FD00190K

3.6. Wang, C.M., Barratt, B., Carslaw, N., Doutsi, A., Dunmore, R.E., Ward, M.W., and **Lewis, A.C**. (2017) Unexpectedly high concentrations of monoterpenes in a study of UK homes. Environmental Sciences: Processes and Impacts, **19**, 528-537. DOI:10.1039/c6em00569a

All references have been peer reviewed. [3.3,3.4] are being returned to REF2021.

4. Details of the impact (indicative maximum 750 words)

Background summary

Air pollution generates substantial costs to the economy through health impacts, lost productivity (e.g. time off work, building damage) and damage to crops and ecosystems. Research at the University of York has influenced multiple areas of recent policy and legislation in the United Kingdom and led to improvements in air quality, particularly for NO_2, which is now declining in many cities. York research was central to the UK evidence base on which timely action was taken on NO_2 by vehicle manufacturers, central Government and at city level. This research shaped actions introduced by the UK Government in its 2019 *Clean Air Strategy*. The body of research led to York providing direct scientific advice on the setting of new legally binding targets for Particulate Matter in the *Environment Bill* (first introduced to Parliament in 2019, under the May Government, then re-introduced by the Johnson Government in 2020). There have been further impacts on several other areas of policy and planning, including strategies for monitoring emissions from shale gas, Cabinet Office planning for extreme pollution events, the reduction of health impacts from exposure to indoor pollution and quantification of air pollution effects on COVID-19 mortality rates and links to health inequalities.

Route to achieving impacts on policy and legislation

The route to impact has been through the use of science and data from individual research

publications, and through analysis and advice provided to, and used by, government departments, by virtue of acknowledged expertise from cumulative research. A key mechanism for the translation of science into impact has been through York's leadership of the Defra Air Quality Expert Group (AQEG), the independent science advisory committee that provides science to Government on matters relating to air pollution. **Lewis** is currently Chair of that group and Moller and **Carslaw** members by public appointment. Moller led the Scientific Secretariat of AQEG 2012-2018 and is now a Senior Defra Fellow advising the Chief Scientific Advisor. Carslaw is also a member of the Defra-Department for Transport Technical Independent Review Panel (2017-present) that provides the scientific assessment of Local Authority plans that introduce Low Emission and Clean Air Zones.

Defra began developing a new 10-year *Clean Air Strategy* for the UK in 2017, and in 2019 introduced new primary legislation including air quality in the *Environment Bill*. Critical scientific evidence informing the development of both was provided by York. Evidence on air pollution sources and processes was presented in eleven separate AQEG reports to Defra [5.1] with York research being cited more than 60 times. During the development of the *Clean Air Strategy*, Lewis and Moller provided input to a joint Environment / Health and Social Care / Transport select committee inquiry on "*Improving Air Quality*". Recommendations from York research were cited ten times in the parliamentary report, and also included in the official Government response [5.2]. Research and evidence from York was sought directly to inform the committee and parliamentary debate stages of the *Environment Bill* on issues related to the composition of PM, and new air quality targets to be enshrined in the Bill. Lewis gave evidence before the Scrutiny Committee [5.3]. He also presented new research evidence on the interactions between air pollution and COVID-19 at Ministerial meetings and to the Environment, Food and Rural Affairs select committee.

What has been the impact on NO_2 pollution?
The research of **Carslaw** on diesel vehicle NO_x emissions supported the Department for Transport in their planning around clean air zones, and was a key part of the scientific evidence base used to develop national plans to reduce urban NO_2 Those plans formed the central themes of a Judicial Review in 2017 (High Court, Case CO/4922/2017). These NO_2 reduction plans provided the technical basis for city-level initiatives on air quality including the introduction of the ULEZ in London, and other clean air zone plans such as in Leeds and Birmingham. The real-world outcome of this research is that NO_2 is now declining in many cities. Progress towards the UK complying with its legal obligations on roadside NO_2 concentrations have been brought forward by around five years as a result [5.4]. The research continues to be used as technical evidence in High Court litigation related to Volkswagen diesel engine emissions, where both Lewis and Carslaw have been engaged as expert advisors. The High Court action is the largest consumer class action in UK legal history.

What has been the impact on VOC pollution?
The research by Lewis and Hamilton highlighted discrepancies in emissions and impacts of VOCs from the diesel transport sector [3.5] and from domestic solvent emissions [3.6]. This has been incorporated by Defra and Ricardo plc in revisions of the UK National Atmospheric Emissions Inventory, the legal reporting mechanisms used each year to demonstrate UK regulatory compliance with the UNECE Gothenburg Protocol on transboundary pollution and the EC National Emissions Ceiling Directive. Lewis presented research on solvent contributions at an industry - Ministerial Roundtable on VOC emissions and air pollution, and contributed evidence to Defra in support of their policy proposals to address domestic sector VOC emissions in the *Clean Air Strategy* [5.4]. The Clean Air Strategy includes policy proposals to reduce domestic sector VOC emissions through interventions including improved consumer product labelling.

What has been the impact on legislation?
The *Environment Bill* (2019-21) is a major piece of post-Brexit primary legislation on environmental quality and includes the adoption of new comprehensive targets for the long-term reduction of human exposure to $PM_{2.5}$. It sets environmental targets for the UK for the next 20

years and is a landmark piece of environmental statute. Science from York has directly informed the air quality target setting in the Bill in areas associated with feasibility, timescales for implementation and measurement and model metrics for assessment. During 2019 and 2020 York research was summarised in written submissions and committee witness statements at the Bill scrutiny stage, to the Environment Food and Rural Affairs (EFRA) Select Committee, and at Defra's request the leadership of technical reports. This work was then cited in Defra public policy reports as the Bill progressed and the work of Lewis cited in the EFRA committee report "Air Quality and coronavirus: a glimpse of a different future or business as usual".

As an example of the influence of research at the highest levels of decision-making, an extract is taken from Committee Stage debate: Minister of State for the Environment (Rebecca Pow MP). *"I was going to mention Professor Alastair Lewis…. He gave stark evidence. He is obviously an expert in his field, and it was really interesting to hear what he said. He stressed the technical challenges involved in setting a target for a pollutant as complex as $PM_{2.5}$, which he explained is formed from diverse sources—the shadow Minister is right about that—and chemical reactions in the atmosphere. He was at pains to explain that a lot of $PM_{2.5}$ comes from the continent, and it depends on the direction of the wind, the weather and the atmospheric conditions. Professor Lewis explained the need to decide how we would measure progress towards the target, and that the process would be challenging and would take time. It is crucial to get it right.*" [5.5]. The impact of the research has been the development of a new, and lowered, concentration limit value for $PM_{2.5}$, alongside a long-term population exposure reduction target.

Wider impacts of the research

Further evidence of impact and the shaping of national policies and strategies on air quality can be found in i) York research included within the 2017 Chief Medical Officer's annual review [5.6] ii) a synthesis of air pollution impacts and chapter within the Cabinet Office National Risk Assessment by Lewis and Moller, including the national response plans for extreme pollution events; iii) leadership of a cross-government assessment of the air quality impacts of the Committee on Climate Change Net Zero 2050 Plan [available via 5.1]; iv) advice to the Environment Agency on strategies for air pollution assessment from shale gas sites; v) evidence within the Royal College of Physicians review of indoor air pollution impacts (2020) [5.7] and iv) leadership by Lewis of a rapid evidence review on air pollution – COVID-19 interactions for Defra/Public Health England and scientific contributions to reports to SAGE (Scientific Advisory Group on Emergencies) by the Office for National Statistics on the influence of air quality on COVID-19 mortality rates [5.8].

Through a range of outreach and media activities York has used its research to support broader public engagement with issues relating to air quality, taking a leadership role in bringing to public attention issues associated with indoor air quality and rising consumption of chemicals in the home. Lewis collaborated with broadcaster Marcus Brigstocke and Aardman Animations to produce a short film, *Clean Air Starts at Home*, first shown at the Hay Festival in 2018 [5.9]. Over the REF assessment period the team at York have given more than > 40 TV/Radio/Newspaper interviews) and syndicated multiple public interest articles through The Conversation, (e.g. *The Independent* [5.10], Lewis and Moller) reaching a verified unique readership in excess of 400,000 people.

5. Sources to corroborate the impact (indicative maximum of 10 references)

5.1. Multiple AQEG evidence reports to Defra: all reports available for download at: https://uk-air.defra.gov.uk/library/aqeg/publications.

5.2. The Environmental Audit, Environment Food and Rural Affairs, Health and Social Care, and Transport Committees' report to the House on *Improving air quality* https://publications.parliament.uk/pa/cm201719/cmselect/cmenvfru/433/433.pdf [see p.17, 19, 29, 30, 32, 34, 37,38, 40] (note the Lewis / Moller evidence submission is referenced by the committee as National Centre for Atmospheric Science (NCAS). NCAS, Lewis and Moller are part of the Department of Chemistry at University of York.).

Government Response:
https://publications.parliament.uk/pa/cm201719/cmselect/cmenvfru/1149/114902.htm

5.3. Scrutiny Committee, *Environment Bill* second reading (2020)
https://publications.parliament.uk/pa/cm5801/cmpublic/Environment/PBC009_Environment%20Bill_1st-4th_Combined_12_03_2020.pdf [pdf pages 49-55]

5.4. Clean Air Strategy (2019), Department of the Environment Food and Rural Affairs. AQEG report references P 25, 33, Clean-air-strategy-2019.pdf. Chapter 10, p 97 and references therein e.g. "UK Plan for tackling roadside nitrogen dioxide concentrations".

5.5. Hansard parliamentary and committee debate records
https://hansard.parliament.uk/commons/2020-03-17/debates/cd4ea283-1944-4921-b661-c9fa2eadee4a/EnvironmentBill(SixthSitting) [quotation from pdf page 10]

5.6. Chief Medical Officer's annual report (inc. York citations and text).
http://allcatsrgrey.org.uk/wp/download/public_health/CMO_Annual_Report_2017_Health_Impacts_of_All_Pollution_what_do_we_know.pdf

5.7. Royal College of Physicians report on indoor air quality (2020). Recommendations (see p. 14,20,35,36, citation 122, and pull out text box P40).
https://www.rcpch.ac.uk/sites/default/files/2020-01/the-inside-story-report_january-2020.pdf

5.8. Defra report: "Estimation of changes in air pollution emissions, concentrations, and exposure during the COVID-19 outbreak in the UK". See: https://uk-air.defra.gov.uk/library/reports.php?report_id=1005, and Link to ONS report
https://www.ons.gov.uk/economy/environmentalaccounts/articles/doesexposuretoairpollutionincreasetheriskofdyingfromthecoronaviruscovid19/2020-08-13

5.9. Hay Festival 2018: https://www.youtube.com/watch?v=ShLV86tWOtM

5.10. Example article "Clean air strategy: What you need to know about the UK's latest pollution policy". Alastair Lewis and Sarah Moller, *The Independent* 2018.
https://www.independent.co.uk/environment/clean-air-strategy-environment-air-pollution-co2-emissions-diesel-a8365511.html