Institution: Imperial College London

Unit of Assessment: 14 – Geography and Environmental Studies

Title of case study: C14-1 Air pollution research leads to local, national and international policies and actions that reduce air pollution impacts

Period when the underpinning research was undertaken: 2002 - 2018

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 Helen ApSimon	Professor of Air Pollution Studies	2002 – to present
Dr Audrey de Nazelle	Senior Lecturer of Environmental Policy	Sept 2012 – to present

Period when the claimed impact occurred: 1st August 2013 to the present.

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

1. Summary of the impact (indicative maximum 100 words)

Air pollution is Europe's largest public health risk, responsible for more than 500,000 deaths every year, and costing the UK alone some £20 billion annually. Pioneering research by Professor Helen ApSimon and Dr Audrey de Nazelle of Imperial College London is addressing this complex issue, informing international agreements and cost-effective national strategies to reduce emissions, while incorporating previously overlooked dimensions, including local processes and entrenched human behaviours.
Beneficiaries: National and international policymakers, wider society.
Significance & Reach: The research has directly supported new targets, policies and guidelines for reducing human exposure to air pollution in the UK, Europe and beyond, potentially benefiting billions of people worldwide.

2. Underpinning research (indicative maximum 500 words)

As part of the UN Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (the Air Convention) and the Task Force for Integrated Assessment Modelling (TFIAM) from 2000 until the present, alongside the International Institute for Applied Systems Analysis (IIASA), Professor ApSimon projected pollutant emissions across Europe and their atmospheric dispersion and deposition, critical loads as criteria for ecosystem damage, and potential cost-effective measures to reduce emissions and their costs **[1]**. The successful development of the Gothenburg protocols by the UNECE to reduce air pollutants depended critically on such integrated assessment modelling to assess cost-effective scenarios for reducing air pollution in Europe **[1, 2]**. Building on this work, ApSimon focused over the last 10 years on detailed modelling of national strategies to achieve compliance with targets set in the UNECE Gothenburg protocols and parallel national emission ceilings set by the EC **[3]**.

More recently, ApSimon has shown how to integrate urban and local dimensions, such as traffic and street-scale urban form, into overall air pollution control strategies. This work illustrated how real-world exposures may deviate from EU standards, leading to non-compliance with legislated NO2 concentrations **[4, 5]**. Her current work contributes to Defra's Clean Air Strategy, with a special focus on PM2.5 as the pollutant with the greatest health effects. She is also contributing to the development of targets for improvement in the new UK Environment Bill, working closely with government on post Brexit projections and synergies between air quality and climate measures. ApSimon now heads the National Integrated Assessment Modelling (NIAM) activities

within TFIAM, bringing together parallel work in other countries and providing knowledge transfer to eastern European countries outside the EU.

Her analyses of air pollution exposure pathways at local levels have shown that polices for protecting human health may be amplified or diminished by the mediating effects of individual behaviours. There is an urgent need for integrated health impact assessment and epidemiological models to link national and international policies to their effects on individual behaviours, exposures and health.

de Nazelle's emerging work is focused on understanding how the behaviours of individuals interact to determine personal exposures to air pollution **[6]**. She is accounting for individual activity patterns and evaluating trade-offs in risks and benefits of outdoor physical activity based on data from wearable sensors to underpin new models for individual activity patterns and associated exposure. Her work, for instance as Co-I on the EU-funded Physical Activity through Sustainable Transport Approaches (PASTA) project **[7]**, makes the case for systems thinking in urban policies that tackle air pollution, by considering multiple outcomes including effects of physical activity, traffic injuries, noise, or greenspace exposures and is already influencing national and international policy.

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

Research publications

[1] ApSimon HM Warren RF and Kayin S. 2002. Addressing uncertainty in environmental modelling: a case study of integrated assessment of strategies to combat long-range transboundary air pollution. *Atmospheric Environment* 36, 5417-5426. https://doi.org/10.1016/S1352-2310(02)00659-3

[2] Reis, S., Grennfelt, P., Klimont, Z., Amann, M., ApSimon, H., Hettelingh, J.P., Holland, M., Le Gall, A-C., Maas, R., Posch, M., Spranger, T., Sutton, M.A., & Williams, M. 2012. From acid rain to climate change, *Science*, 338, 1153-1154. https://doi.org/10.1126/science.1226514

[3] Oxley, T., Dore, A.J., ApSimon, H., Hall, J. and Kryza, M. 2013. Modelling future impacts of air pollution using the multi-scale UK integrated assessment model (UKIAM) *Environment International* 2013, 17-35. https://doi.org/10.1016/j.envint.2013.09.009

[4] O'Driscoll, R., ApSimon, H., Oxley, T., Molden, N., Stettler, M. & Thiyagarajah, A., 2016, A portable emissions measurement system (PEMS) study of NOx and primary NO_2 emissions from Euro 6 diesel passenger cars and comparison with COPERT emission factors, *Atmospheric Environment*, 145, 81-91. https://doi.org/10.1016/j.atmosenv.2016.09.021

[5] Smith AC, Holland M, Korkeala O, Warmington J, Forster D, ApSimon H, Dickens R, Smith SM. 2016. Health and environmental benefits and conflicts of actions to meet UK carbon budgets. *Climate Policy* 16, 253-283. https://doi.org/10.1080/14693062.2014.980212

[6] Tainio, M, De Nazelle, AJ, Gotschi, T, Kahlmeier, S, Rojas-Rueda, D, Nieuwenhuijsen, MJ, De Sa, TH, Kelly, P, and Woodcock, J. 2016. Can air pollution negate the health benefits of cycling and walking? *Preventive Medicine*, 87: 233-36. https://doi.org/10.1016/j.ypmed.2016.02.002

[7] Mueller, N, Rojas-Rueda, D, Salmon, M, Martinez, D, Ambros, A, Brand, C, De Nazelle, A, Dons, E, Gaupp-Berghausen, M, Gerike, R, Gotschi, T, Iacorossi, F, Int Panis, L, Kahlmeier, S, Raser, E, Nieuwenhuijsen, M, and Consortium, P. 2018. Health impact assessment of cycling network expansions in European cities, *Preventive Medicine*, 109: 62-70. https://doi.org/10.1016/j.ypmed.2017.12.011

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

Air pollution has long been a serious public health problem. Over 500,000 preventable deaths occur annually across Europe due to air pollution, making it the continent's largest environmental health risk **[A]**. In the UK alone, air pollution causes up to 40,000 deaths each year, costing the economy about £20 billion annually **[B]**.

Pioneering research by ApSimon and de Nazelle is transforming policy in the UK and internationally, paving the way for new, more effective solutions. Specifically, their work has impacted air pollution policy in two main ways:

a) by informing new, more effective, strategies for compliance with legally binding international emission ceilings;
b) by incorporating previously overlooked dimensions, including local factors and individual behaviour.

Strategies for Compliance

The UNECE Convention on Long-range Transboundary Air Pollution is the only legally-binding regional agreement of its kind in the world **[C] [2]**. ApSimon's pioneering approach to integrated assessment modelling **[1, 2]** supported governments in the UK and Europe to implement new strategies for cost effective compliance. These have been crucial in abating pollution levels, which have fallen by about 10% over the last 7 years **[1]**. The Deputy Director of Defra Air Quality & Industrial Emissions, states that: *"to design and evaluate effective policies, we need robust and agile evidence … [ApSimon's work] plays a highly significant contribution to our underpinning evidence base"* **[D]**. A key contribution was ApSimon's development of the UK Integrated Assessment Model, UKIAM **[3]**. The Deputy Director of Defra Air Quality & Industrial Emissions describes it "*as a unique capability for modelling future air pollution scenarios for the UK … [enabling] the assessment of the implications for health and natural ecosystems...*" **[D]**.

ApSimon's recent work for Defra focusses on reducing annual mean concentrations of fine particulate PM2.5 as part of the Government's Clean Air Strategy **[E].** Her extensive analysis of emissions of SO2, NOx, NH3, VOCs and PM2.5 summarised in the ground-breaking report on reduction of exposure to PM2.5 **[E]** provided the evidence to justify the UK Government's ambitious commitment to achieving the WHO guideline of 10 ug.m^{-3}. Defra confirms ApSimon's contribution, writing: *"the UKIAM model has been vital in enabling Defra to set out its ambitions to reduce exposure to fine particulate PM2.5 … The Imperial College Team and the model have a pivotal role to play in setting these targets and in ensuring that ambition is based on sound science."* **[D]**. They conclude that: **"***It is not overstating the fact that the team has a vital role to play in supporting development of policies … by providing the underpinning evidence to enable targeted reductions in exposure to fine particulate matter."* **[D]**

As the lead of the UK Focal Centre for Integrated Assessment, ApSimon's work underpinned development of the Gothenburg protocols to control transboundary air pollution in Europe and the National Emissions Ceilings Directive of the EC. The co-chair of the UNECE Task Force on Integrated Assessment Modelling, states that ApSimon is *"playing a leading role in strengthening the network of national integrated assessment modellers, which is aimed exchanging information … within the UNECE on understanding of emissions, measures to reduce them, and ways of evaluating the health benefits."* **[F]**

Local Factors and Individual Behaviour

A theme in the research at Imperial is that technological transformations alone are insufficient to address air pollution. In particular, as shown in **[4]** and **[5]**, because national- and continental-scale policies often fail to account for local factors and individual decision-making, real-world exposures may not comply with legislated NO2 concentrations **[4, 5]**. By integrating urban and local dimensions such as traffic and street-scale urban form, ApSimon's **[4, 5]** work showed that local processes can amplify or diminish the effectiveness of air pollution policies.

Her colleague, De Nazelle, has extended this work, investigating the trade-offs in individual decisions, particularly to walk and cycle instead of using polluting forms of transportation, showing they can reduce air pollution levels, improve health through increased physical activity, and reduce noise, traffic injuries and greenhouse gas emissions. De Nazelle influenced the transport appraisal by the UK Department for Transport through her report **[7, G]** that led Public Health England to conclude based on partly her work that, "*…that addressing air pollution can contribute to broader benefits, in particular through increasing physical activity levels in the population*" **[B]**. The Director for Health Protection for Public Health England, confirms De Nazelle's contribution: **"***We have*

specifically integrated Dr de Nazelle's findings – in particular those produced during the current REF period, i.e. since August 2013 - in our reports and guidance material such as: Review of Interventions to Improve Outdoor Air Quality and Public Health; Annual Report of the Chief Medical Officer 2017; NICE guideline Physical Activity: Walking and Cycling; Cycling and Walking for Individual and Population Health Benefits; Spatial Planning for Health [and] have also sought Dr de Nazelle's expertise directly as an advisor to our work reviewing interventions to improve air quality and public health." **[B]** Recently PHE has focused on walking and cycling strategies and that "*Dr de Nazelle's work has been a key contributor to this agenda, which has led to successful uptake by local and national governments of active travel policies*." **[B]**

de Nazelle's approach has resulted in new guidelines and policies internationally. She was Co-I on the EU PASTA project, which contributed to a sea-change in how active mobility is perceived and promoted in policy and public discourse. PASTA outputs were cited in global policy documents **[H].** The outputs of her PASTA project led to the creation of WHO's HEAT air pollution module, used by local policy makers internationally to decide on transport investments **[I]**. The WHO complied a set of 24 case studies across Europe which demonstrated the impact HEAT has had to promote healthy active travel policies **[I]**. One such example was Transport for London's use of HEAT to estimate that health made up two thirds of the benefits of their project which reduced space for cars **[I]**. Beyond HEAT, De Nazelle's work has been cited in WHO reports and guidance material including the *Global Report on Urban Health* (2016), *Environmental Risks of Cities in the European Region* (2017), *Preventing Disease through Healthy Environments* (2016), *Protecting Health in Europe from Climate Change* (2017), *Promoting Health, Preventing Disease* (2015), *Health as the Pulse of the New Urban Agenda* (2016) **[I]**. Cycling networks and active travel infrastructure have been expanded in all PASTA case study cities **[I]**. The WHO Head of Office reports that, "*expansion of the cycling network in European cities could achieve up to 25% of cycling mode share, which in turn could save more than 10,000 lives (based on estimates of 167 cities)*" **[I]**. Confirming de Nazelle's contribution, they add that "*ambitious strategies and major funding have been announced in the past years to promote cycling in particular, directly and importantly influenced by de Nazelle's work…*' **[I].**

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

[A] European Environment Agency. 2020. *Air quality in Europe, 2019 Report.No. 10/2019.* https://www.eea.europa.eu/publications/air-quality-in-europe-2019 (Archived here) and Evangelopoulos, D., Walton, R. P. H., Gumy, S., Williams, M., Kelly, F. J., Ku, N., Perez-velasco, R., Williams, M., & Kelly, F. J. (2020). *The role of burden of disease assessment in tracking progress towards achieving WHO global air quality guidelines*. *0123456789*, 1455–1465. https://doi.org/10.1007/s00038-020-01479-z (Archived here)

[B] Supporting Letter from Medical Director and Director for Health Protection, Public Health England. Dated 1 October 2020.

[C] UNECE (United Nations Economic Commission for Europe). 2019. *Protecting The Air We Breathe: 40 years of cooperation under the Convention on Long-Range Transboundary Air Pollution.* https://www.unece.org/fileadmin/DAM/env/lrtap/Publications/1914867_E_ECE_EB_AIR_NONE_2019_3_200dpi.pdf (Archived here)

[D] Supporting Letter from the Deputy Director of Air Quality & Industrial Emissions, Defra. Dated 29 September 2020.

[E] Defra. 2019. *Assessing progress towards WHO guideline levels of PM2.5 in the UK.* https://www.gov.uk/government/publications/air-quality-assessing-progress-towards-who-guideline-levels-of-pm25-in-the-uk (Archived here)
The Clean Air Strategy underlies the UK Government's policy and current actions to deal with air pollution in all its cities and reverse its detrimental impacts on human health.

ApSimon's work is Annex 1 of this report. See H ApSimon, T Oxley, H Woodward, D Mehlig. 2019. *PM2.5 exposure and reduction towards achievement of WHO standards.* Report for Defra published July 2019. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/930104/air-quality-who-pm25-report.pdf (Archived here)

[F] Supporting Letter from Co-Chair, UNECE Task Force on Integrated Assessment Modelling (TFIAM), National Institute for Health and Environment, Bilthoven, Netherlands, 2020.

[G] Tainio, M., Woodcock, J., Brage, S., Gotschi, T., Goodman, A., Kelly, P. and de Nazelle, A. 2017. SO17859 Research into valuing health impacts in Transport Appraisal. Final Report November 2016 (March 2017 update). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/639211/research-into-valuing-health-impacts-in-transport-appraisal.pdf (Archived here)

[H] PASTA outputs were cited in global policy documents including:

- the 3rd Global Ministerial Conference on Road Safety, an Academic Expert Group convened by the Swedish Transport Administration to recommend actions to reduce worldwide road deaths (see page 38: https://www.roadsafetysweden.com/contentassets/c65bb9192abb44d5b26b633e70e0be2c/200113_final-report-single.pdf), (Archived here)
- the Global Commission on the Economy and Climate's 2018 The New Climate Economy report (https://apo.org.au/sites/default/files/resource-files/2018-09/apo-nid190651.pdf, page 85 reference 617 (Mueller et al. 2017)). (Archived here)
- Castro et al. (2019) cited in the OECD's International Transport Forum's document: https://www.itf-oecd.org/transport-innovations-global-south. (Archived here)
- Mueller et al 2017 and 2015 (cited in Mueller et al. 2018, cited above) were cited in the Austrian Special Report 2018 Health, Demography and Climate Change. https://sr18.ccca.ac.at/downloads/. (In German) (Archived here)

[I] Supporting Letter from Head of Office, WHO European Centre for Environment and Health, Bonn. Dated 14 July 2020.