Institution: University of Leicester		
Unit of Assessment: 9		
Title of case study: Enabling access to air quality data: influencing policy and behaviour change		
Period when the underpinning research was undertaken: 2000–2018		
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:**
Roland Leigh	Professor in Physics	2001–2019
Joshua Vande Hey	K.E. Fellow and Lecturer in Environment and Health	2013–Present
Period when the claimed impact occurred: 2016–2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Air pollution is a major challenge in the UK, causing approximately 40,000 premature deaths in the UK annually (2016), with associated health/social care costs in England estimated to reach GBP5,300,000,000 by 2035. Collaborative research at the University of Leicester (UoL) has resulted in new methods to map and measure spatial distributions of significant gases and particles at fine scale (postcode level). UoL research has also influenced government strategy on green infrastructure to mitigate air pollution. Techniques and capabilities have been spun-out in a company, Earthsense Systems Limited (instituted 2016). Based on UoL research and expert input, Earthsense has transformed public and local authority access to detailed air quality information through a mapping product servicing a British Broadcasting Corporation (BBC) pollution postcode checker and property risk reports for conveyancing; and novel, low-cost air pollution sensors, enabling local authorities to make interventions.

2. Underpinning research

Air Quality research has been undertaken at the University of Leicester (UoL) for over 20 years, under the leadership of Professor Monks with Professor Leigh and Dr Vande Hey. This team has worked intensively on problems of representation and modelling of urban air quality at fine spatial scales through fluid dynamical methods and physical sensors.

It was the development of remote sensing instrumentation that proved a particular spur to UoL research in this area. **[R1]** reports the first flight of a novel airborne nitrogen dioxide imager over Leicester and surrounding areas, providing spatial distributions of this pollutant at 2 m x 80 m resolution. The observations prompted the group to embark on investigations of the detailed heterogeneity of pollutants in the urban environment.

A series of studies followed, which focused on the application of computational fluid dynamics (CFD) calculations to urban pollution dispersion at a city-scale and led to the accrued impact. In particular, modelling work was reported in three papers that were significant investigations of green infrastructure at a local (street canyon) and city-scale, and its effect in suppressing air pollution **[R2–R4]**. Hallmarks of the UoL work were calculations for a “real-world” city with trees, initially over a 2 x 2 km area which was a major step forward at that time. The simulations utilised a 3D LiDAR topography dataset for buildings in the city of Leicester and the National Tree Map.

The studies showed that trees in deep urban street canyons could amplify pollutant concentrations **[R2, R4]** while in open spaces the dispersive capability of trees was significantly larger than the deposition (loss) for particles but air quality was improved. Crucially, detailed

calculations revealed that effects on PM2.5 (particles that have diameter of less than 2.5 micrometres) could be parameterised to estimate improvements; these were of the order of 10% city-wide in Leicester in the summertime **[R3]**, hence relatable to direct vehicle emission reductions. Related research during a productive five years of campaigns in Leicester, London, Beijing and Hong Kong (e.g. **[R1]**) demonstrated that fine-scale information on pollution could be also be produced from new sensors by applying parameterised fluid dynamical modelling to high quality in situ and satellite observations and incorporating information from lower spatial resolution, regional-scale, chemical-transport models.

The flexibility of the CFD approach was explored in two further innovative studies of human exposure, first by applying the same CFD techniques to car cabin ventilation systems **[R5]** and second to vehicular emissions in studies of urban mobility. Research in **[R5]** laid the foundations for a realistic system operating at pavement level through combination of an urban mobility simulator with the UoL CFD urban model and a human exposure model.

The second area of research was the development of small-form air quality sensors capable of measurement of nitrogen dioxide and ozone with acceptable accuracy **[R7]**, initially based on metal oxide sensors. The new sensors were designed with high performance electronics resulting in low power and low noise. These “Zephyr” sensors provided a thorough basis for reaching new low mass sensors that are more capable of low-cost deployment across urban landscapes. Sensor accuracy was significantly improved due to the aspiration of sensors via an active system in which a pulsed fan injects a parcel of air into the cartridge prior to it being stagnated around a sensing element. Research in **[R6]** investigated performance in low-cost, fine particulate (PM2.5) sensors in a similar way.

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

R1. Lawrence, J. P., Anand, J. S., **Vande Hey, J.** D., White, J., Leigh, R. R., Monks, P. S., and **Leigh, R. J.**: High-resolution measurements from the airborne Atmospheric Nitrogen Dioxide Imager (ANDI). Atmos. Meas. Tech., 8, 4735–4754, https://doi.org/10.5194/amt-8-4735-2015, 2015.

R2. Jeanjean, A. P. R., Hinchliffe, G., McMullan, W. A., Monks, P. S., and **Leigh, R. J**.: A CFD study on the effectiveness of trees to disperse road traffic emissions at a city scale. Atmos Environ, 120, 1-14, http://dx.doi.org/10.1016/j.atmosenv.2015.08.003, 2015.

R3. Jeanjean, A. P. R., Monks, P. S., and **Leigh, R. J.**: Modelling the effectiveness of urban trees and grass on PM2.5 reduction via dispersion and deposition at a city scale. Atmos Environ, 147, 1-10, http://dx.doi.org/10.1016/j.atmosenv.2016.09.033, 2016.

R4. Jeanjean, A., Buccolieri, R., Eddy, J., Monks, P., and **Leigh, R.**: Air quality affected by trees in real street canyons: The case of Marylebone neighbourhood in central London. Urban Forestry and Urban Greening, 22, 41-53, 10.1016/j.ufug.2017.01.009, 2017.

R5. Zavala-Reyes, J. C., Jeanjean, A. P. R., **Leigh, R. J.**, Hernández-Paniagua, I. Y., Rosas-Pérez, I., and Jazcilevich, A.: Studying human exposure to vehicular emissions using computational fluid dynamics and an urban mobility simulator: The effect of sidewalk residence time, vehicular technologies and a traffic-calming device. Science of the Total Environment, 687, 720-731, 10.1016/j.scitotenv.2019.05.422, 2019.

R6. Vande Hey, J. D., Sonderfeld, H., Jeanjean, A. P. R., Panchal, R., **Leigh, R. J.**, Allen, M. A., Dawson, M., and Monks, P. S.: Experimental and modeling assessment of a novel

automotive cabin PM2.5 removal system, Aerosol Science and Technology, 1-17, 10.1080/02786826.2018.1490694, 2018.

R7. Peterson, P. J. D., Aujla, A., Grant, K. H., Brundle, A. G., Thompson, M. R., **Hey, J. V.**, and **Leigh, R. J.**: Practical use of metal oxide semiconductor gas sensors for measuring nitrogen dioxide and ozone in urban environments, Sensors,17, 10.3390/s17071653, 2017.

4. Details of the impact

UoL research has developed air quality monitoring techniques and sensors, delivering highly detailed spatial information on pollutants to inform decisions at individual and policy levels. The chief mechanism has been a commercial, spin-out company but national impact has also been achieved through reports to Defra. Commercial activity has proved to be an effective route to make detailed, user-focused information at fine scale available to many more individuals and policy authorities than before.

Economic, public well-being and local intervention impact: EarthSense the company

The UoL's commercial spin-out from air quality research, EarthSense Systems Ltd., was incorporated in July 2016 as a private limited company in a joint venture between the University and Bluesky Ltd. The EarthSense mission is "*to seamlessly provide the most detailed global air quality information, showing real-time exposure and actionable future forecasting to optimise decision making and mitigation, for the betterment of human health*" **[E1].** The ambition for UoL was to utilise this commercial venture to change citizen access to air quality information, transforming personal and local decision making.

EarthSense is an SME growing at 60% year-on-year, achieving a turnover of GBP1,550,000 in 2020 with 24 employees **[E2]**. It has showcased delivery of UoL research expertise and techniques in its products for the environmental marketplace, selling more than 500 of its Zephyr® sensors, making its first sales in six continents and bringing fine scale map information (MappAir®) to the public. UoL achieved runner-up in the Guardian Education business collaboration award 2019 for its work with EarthSense as a company **[E3]**.

UoL staff have been integral to the success of EarthSense and to the translation of UoL research technologies into the products. Professor Leigh was the lead UoL staff member involved, with a founding position as part-time Technical Director of EarthSense in 2016; Professor Leigh moved fully to EarthSense in 2019. Four other PDRAs also moved from UoL research to EarthSense during the period providing a direct, seamless tie through staff expertise to the realised impact of the research **[E2].**

Changing public access to air quality information: the EarthSense MappAir® product

The MappAir® product is the first national (UK) high resolution map of air pollution that is both commercially and publicly available. Building on the UoL computational modelling, satellite expertise and in situ research, it is the product form of the city mapping prototype **[R2, R3]** with resolutions of 100m (national), 10m (city), and 1m (small areas). To fully develop MappAir® at EarthSense, the UoL PDRAs JeanJean, Grocutt and Brocksopp moved to the company over time with Leigh providing overall technical direction and the link to UoL. As noted in **[E3]** in 2019, "*Drawing on the expertise of Roland Leigh, (former) professor in climate change adaptation technologies at Leicester… MappAir launched in*

January 2018. It uses complex modelling to integrate data from emission estimates, satellites and air quality sensors, and then map the results".

The well-known publicly accessible form of MappAir® is the BBC pollution postcode checker **[E4]** showcased as part of a BBC series on air pollution and web-accessible to the public allowing people to see "How polluted is your street?". Led by Professor Leigh, the checker received over 3 million hits in the first 48 hours of release (January 2018) and 371 comments debating air pollution in 24 hours. As of December 2020, the postcode checker **[E4]** has reached 6.8 million views **[E2]** through the BBC and EarthSense sites.

A consequence of the UoL city-scale modelling research **[R2, R3]** was the realisation that the UoL system which enabled MAPPAir® could deliver detailed views of air quality risks for residential housing. EarthSense, through Leigh, provided the opportunity for this research to be turned into a commercial product for the public. In what has been described as a "first-of-a-kind" partnering and public product **[E5, E6]**, EarthSense have worked with Future Climate Information (FCI) since 2018 to include MappAir® information in FCI Premium Plus Planning Residential Reports **[E7, E8a]**; FCI is a risk reporting (conveyancing) vendor for the public. To date (December 2020), 285,296 reports have been sold by FCI **[E2]**, which is approximately 10% of the housing sales market for the same time period. Based on an average house property price of GBP231,829 (Land Registry Data; December 2019), this is estimated to equate to a value of GBP66,000,000,000 in property value conveyancing.

Thus, UoL research has created knowledge, methods and a pool of expertise in mapping air pollution that has enabled EarthSense, with ongoing support from UoL, to provide a completely new information source for the public at scales they care about.

Public well-being and interventions through local authorities: EarthSense Zephyr® product

The commercialised version of the Zephyr® sensor was developed at EarthSense by Leigh, Bailey and Brocksopp who led the original research at UoL. It represents a rugged, smart version of the research prototype, maintaining key principles and demonstrated technology features including: the stagnant air flow methods; the lower power, low noise, high performance electronics; and the form and aspiration of the sensor elements (now based on electrochemical sensors). Vande Hey contributed UoL expertise focusing on particulates. The devices provide detailed real-time air quality measurements of harmful gases and particulates to help identify pollution hotspots and can be used in conjunction with the MappAir® product.

The Zephyr® device has been sold to more than 60 local authorities—approximately 17% of all local authorities in England—raising understanding and awareness of the importance of measuring air quality. Examples include Leeds City Council, Harrogate Borough Council, Stockton Heath Council, Wolverhampton City Council and Norfolk District Council **[E8a]**. Leicester City Council are implementing the first fixed and mobile dense network of particulate sensors.

Practical interventions by authorities include behavioural systems advising alternative routes (Coventry) or activation of zero-emission modes in hybrid vehicles (Leeds) through real-time information on pollution levels along busy highways or roads. Monitoring of HGV emissions at polluted junctions has been conducted by Transport for Greater Manchester. North Norfolk District Council used a Zephyr® unit to show that pollution from heavily laden goods

trains affected local properties, and Dudley Borough Council used them to monitor air pollution levels around schools to inform future traffic policy **[E8b]**.

Impact on Policy and Decision Making: HMG Clear Air Strategy and Environment Bill

Primary UoL CFD research **[R2–R4]** has influenced UK government policy on air quality mitigation through urban green infrastructure. Referencing a Defra Air Quality Expert Group report **[E9]** citing UoL papers on the relatively small effects of trees in reducing city-scale air pollution, the HMG Clean Air Strategy 2019 states: "*Whilst urban vegetation can have significant other benefits such as for noise pollution, the government's independent scientific advisory body on air pollution, the Air Quality Expert Group (AQEG) have found that urban vegetation is not a solution to the air quality problems at a city scale*" **[E10]**; the Strategy underpins the Environment Bill (February 2020).

5. Sources to corroborate the impact

E1. EarthSense home page. https://www.earthsense.co.uk/
E2. Letter from Tom Hall, Managing Director of EarthSense.
E3. Guardian University Business Collaboration awards 2019 runner-up (UoL with EarthSense/BlueSky). https://www.theguardian.com/education/2019/apr/10/business-collaboration-award-winner-and-runners-up
E4. BBC pollution postcode checker (including EarthSense FAQs route):
(a) https://www.bbc.co.uk/news/science-environment-42566393;
(b) https://www.earthsense.co.uk/bbc-pollution-checker-faq
E5. Quotation from Geoff Offen, Managing Director of FCI:
https://www.earthsense.co.uk/post/earthsense-maps-gives-home-buyers-insight-into-air-pollution-levels
E6. Online, independent platform reporting, e.g. https://www.todaysconveyancer.co.uk/partner-news/future-climate-info-offer-first-kind-air-quality-risk-reporting/
E7. FCI Premium Residential Report: https://futureclimateinfo.com/wp-content/uploads/2021/01/FCI-Premium-Residential_Product-Card_240920.pdf (product card);
E8a. EarthSense use cases. https://www.earthsense.co.uk/use-cases
E8b. https://www.todaysconveyancer.co.uk/partner-news/air-pollution-young-lungs-risk-call-ban-idling-cars-outside-schools/
E9. Air Quality Expert Group (AQEG) report on "Impacts of Vegetation on Urban Air Pollution" to Defra, Scottish/Welsh govt; DoE, Northern Ireland.
https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1807251306_180509_Effects_of_vegetation_on_urban_air_pollution_v12_final.pdf
E10. HM Government Clean Air Strategy 2019 (Defra)
https://www.gov.uk/government/publications/clean-air-strategy-2019