Air Quality Impacts of Office and Home Working Under COVID-19

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Office and home working under covid-19

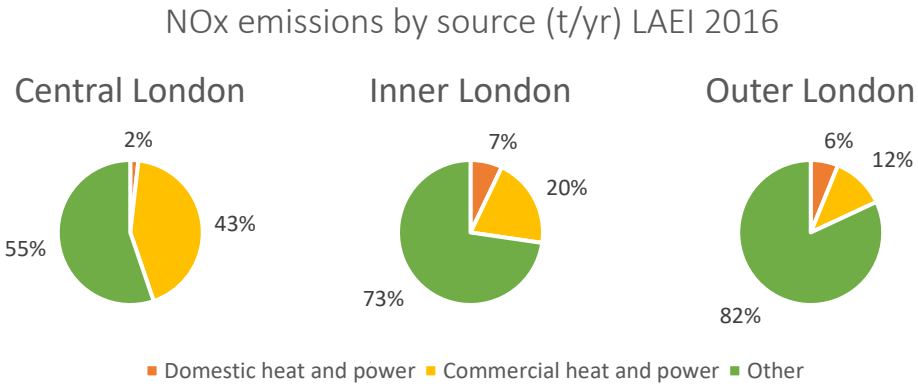
The Covid-19 pandemic has radically changed workplace operations across the economy. During the first lockdown the UK government insisted that the public work from home wherever possible, closed all non-essential shops and restricted non-essential travel. Air-pollution, particularly within urban areas significantly improved as a result of these measures.[1] This was largely due to a reduction in traffic, and reduction in energy use in commercial and office spaces for heating.

Whilst emissions from offices diminished thanks to lower demand for heating and hot water, some demand was shifted from the workplace to the homes of staff. In the intervening month between the end of the first lockdown and the beginning of the second lockdown offices re-opened, many with a fractional occupancy of their full capacity in order to follow social distances guidelines. Other health and safety guidelines, required changes to heating, ventilation and air-conditioning (HVAC) system's operation likely to cause significant increase in energy consumption. This will be impacting on emissions both in the residential and office sectors.

This paper examines how energy usage in homes and offices has changed as a result of measures against the pandemic and its impact on air quality. It looks at how these will change particularly during the heating season, and what action building facility managers, companies and householders can take in the short- and medium-term to tackle emissions.

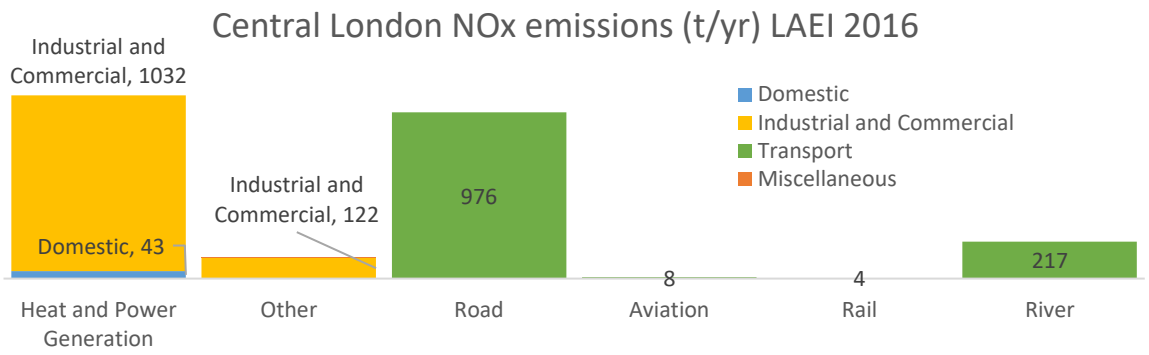
Air pollution from offices and homes

One fifth of London's annual NOx emissions are from combustion for commercial and residential heat and power. A great deal of focus has been put on reducing NOx emissions from road transport, which makes up just under half of greater London's emissions.



In central London emissions from heat and power generation are 10% higher than road transport. For inner London the commercial sector makes up almost two fifths of total NOx emissions. Valuation Office Agency data shows that offices make up 10% of London's non-residential premises[2].

[1] Mayor of London (April 2020) Estimation of changes in air pollution in London during the COVID-19 outbreak, Response to the UK Government's Air Quality Expert Group call for evidence https://tinyurl.com/y8um7jse
[2] Valuation Office Agency (2020) Non-domestic rating: stock of properties including business floorspace, 2020 https://tinyurl.com/yxshtwzs



The main sources of London NOx emissions are road transportation followed by heating and power. Most domestic and office NOx emissions are produced by gas boilers used for space and water heating. High temperature combustion encourages nitrogen and oxygen in the air to form NOx.

NOx levels have steadily decreased across the UK. In 2016, London monitoring sites recorded over 4,000-hour periods where concentrations breached the 200 μgm^{-3}legal limit for NO_2. But by 2019 this was reduced to just over 100-hour periods[3]. This has largely been thanks to efforts to tackle road transport including limits on diesel vehicles. Additionally, the phase out of non-condensing boilers, has helped to reduce NOx emissions from heating. The Energy-related Products Directive from September 2018 set NOx limits on all new and replacement boilers below 400kW which should also lower NOx emissions.

Nonetheless, further action is needed as 34 out of 86 London monitoring sites (40%) breached annual NO_2 limits in 2019. 22 exceeded hourly limits, altogether exceeding limits for 114 hours[4]. Furthermore, annual average NO_2 concentrations in central London are 38.2 $\mu gm^{-3,}$ only just within the legal limit of 40 μgm^{-3}, which points to a need to focus on emissions from heating which makes up 45% of emissions in this area. Beyond London, monitoring of NOx emissions across the UK showed that in 2018 only 7 out of 43 monitored zones complied with annual mean limit[5].

Diesel combustion is particularly bad for NOx emissions. Although it is mainly associated with passenger vehicles, it is used in oil-fired boilers, generally in rural areas and for electricity generation. Some businesses are reported to use standby diesel generators to provide electricity at peak times, incentivised by the National Grid's Short-Term Operating Reserve service, further adding to NOx pollution.

Some London local authorities are aware and highlighted this issue in their air quality action plans, but have limited powers to deal with the issue. The City of London has called for local authorities to be able to prohibit the use of generators sponsoring a private members bill in conjunction with London Councils[6]. It is unlikely the bill will become law. The City of London has also received funding from the London Mayor to research the impact of using generators during peak demand times and

[3] Mayor of London (October 2020) Air Quality in London 2016-2020, London Environment Strategy: Air Quality Impact Evaluation October2020 https://tinyurl.com/y6p9dj9n
[4] Mayor of London (February 2020) Air pollution monitoring data in London: 2016 to 2020 https://tinyurl.com/y57nucz9
[5] Defra (2019) Air pollution in the UK 2018 https://tinyurl.com/yae2p8t8
[6] House of Lords (2020) Emissions Reduction (Local Authorities in London) Bill [HL] 2019-21

have put forward recommendations, in conjunction with the city of Westminster to reduce emissions from generators being used[7].

Changes in office energy demand since Covid

From 16th March 2020, the start of the Covid-19 lockdown, NO_2 levels dropped significantly across London. Monitoring in central London saw mean hourly levels drop between 20-24% compared to the period from December 2019 onwards[8]. Further EDF machine learning analysis, correcting for meteorological impacts, suggests that lockdown measures may have been responsible for a 40% reduction in NO_2 levels across London[9]. Whilst reduction in transport was a major factor in this, the lockdown also affected emission sources including aviation, construction, commercial cooking, domestic and commercial heating.

The number of staff working exclusively from home shot up from 6% in January 2020 to 43% in April[10]. With the majority of staff working from home we should expect to see significant reductions in office energy use. However, monitoring by Carbon Intelligence of 300 buildings showed that on average office energy consumption shrank by only 16%. Some offices only reduced consumption by 3% whereas others managed a 54% reduction[11]. This indicates scope for significant reduction in energy consumption, but that building managers need to be proactive to maximise energy saving potential.

During the summer of 2020 workers were encouraged back to offices with social distancing arrangements in place[12]. However, office occupant density was less than pre-lockdown in order to maintain 2m distance indoors. In June the proportion of people reporting to work exclusively from home only fell marginally from 43% to 37% [13]. Thus, even though offices have been operating, a significant proportion of workers will be working from home for the majority of the week.

Along with social distancing, other measures were required to limit virus transmission in workplaces. Government guidance for offices also stated a need to maximise ventilation. Further guidance from the Federation of European Heating, Ventilation and Air Conditioning (REHVA) states the following requirements:

- Increase air flow
- Force dampers to introduce outdoor air only
- Deactivate heat recovery units
- Avoid energy-saving settings
- Run ventilation units 2 hours before and after office use.

[7] Mayor of London (November 2019) Mayor's Air Quality Fund Completion Report, Round 2 https://tinyurl.com/y6x7vjm3
[8] Environmental Defense Fund (April 2020) New Breathe London analysis sheds light on where, when and why pollution has dropped following Covid-19 measures https://tinyurl.com/y63ab34j
[9] Environmental Defense fund (October 2020) How we used machine learning to get a better estimate of London's NO2 pollution reduction during lockdown https://tinyurl.com/y4lqzzyw
[10] Felstead, A and Reuschke, D (2020) 'Homeworking in the UK: before and during the 2020 lockdown', WISERD Report, Cardiff: Wales Institute of Social and Economic Research https://tinyurl.com/yx8sszmw
[11] Carbon Intelligence (April 2020) Quick wins to manage facilities in the COVID-19 lockdown https://tinyurl.com/y3mmjj2y
[12] Department for Business, Energy & Industrial Strategy (12 August 2020) Working safely during coronavirus (COVID-19): Offices and contact centres https://tinyurl.com/y9ymvc2j
[13] ibid

Each of these measures increase energy consumption and, during the heating season, as outdoor air is significantly cooler, the requirement for added ventilation will put a substantial burden on heating systems. Carbon Intelligence estimate that these measures could increase energy demand in offices by 70-90%[14]. For areas such as Central London where 43% of NOx emissions come from commercial heat and power generation this could have a radical impact on air quality.

Added heat demand at home

There has been an increase in time spent at home with a corresponding decrease in time spent in the office. In April working from home increased to 43%. This excludes furloughed workers, which in May, made up 29% of the workforce[15]. There has also been a record additional 195,000 redundances in the 12 months before September 2020[16].

More employees than ever before are working on zero hours contracts. Latest figures showed that between April and June 2020, 1 million workers were on zero hours contracts a 19% increase compared to the same period in 2019[17]. These figures also show that the average time zero hours contractors worked dropped by 9.5 hours per week between 2019 and 2020. It dropped by 6.4 hours for the entire working population. With a greater proportion of the workforce at home not only could office energy demand increase, but also home energy use. This will be particularly marked during the heating season.

The Energy and Climate Intelligence Unit, put out a paper predicting that boiler use will rise by 56% this winter due to the coronavirus pandemic[18]. They extrapolate from the rise in domestic usage alone a 12% increase in NOx emissions across Greater London. This could offset the last two years progress on reducing emissions. However, this figure should be treated with caution.

Email discussion with ECIU reveals that the 56% figure is not a calculation of the *increase in energy usage*, but the increase in scheduled heating period during a weekday. They assume an increase in usage from 9 to 14 hours. As a boiler will only run for a fraction of a scheduled heating period, it cannot be assumed that there is a linear correlation between increase in heating period and NOx emissions.

Modelling three archetypal London properties suggests more modest increases in gas consumption are likely with householders working from home. Modelling was undertaken using BREDEM 8 methodology incorporated into the Department of Energy and Climate Change's Cambridge Housing Model[19]. If heating hours are increased by 7 hours during weekdays the modelled annual gas consumption would rise by 16% in a 78m^2 mid-century semi-detached house, 9% in a 48 m^2 mid-century terraced house and 12% in a 69m^2 mid-century top floor flat[20]. This would be alongside added gas consumption for cooking and electricity usage for lighting and appliances.

[14] Carbon Intelligence (2020) Reoccupy your buildings with confidence https://tinyurl.com/y6hjo28c
[15] Office of National Statistics (November 2020) Coronavirus (COVID-19) roundup, Labour Force Survey data October 2020 https://tinyurl.com/qtkpjcr
[16] Office of national statistics (September 2020) Comparison of furloughed jobs data: May to July 2020 https://tinyurl.com/y3r2jh9b
[17] Office of national statistics (December 2020) Labour market overview, UK EMP17: People in employment on zero hours contracts https://tinyurl.com/ybaj3rn4
[18] Energy and Climate Intelligence unit (October 2020) Gas boilers and NOx: the hidden emitter https://tinyurl.com/y2o46squ
[19] Department of Energy and Climate Change (2010) Cambridge Housing Model and user guide https://tinyurl.com/d6d5s68
[20] See Appendix D: Modelling changes in domestic heating

	Gas usage for heating kWh/yr		Increase in gas consumption	Increase in energy costs	g NOx / yr increase
	Standard heating pattern	with additional 7 hrs on weekdays			
Semi detached house	18,400	21,300	16%	£ 120	190
Mid terrace house	6,210	6,750	9%	£ 21	34
Purpose built flat	9,610	10,800	12%	£ 47	76

If 38% of the workforce have become newly established "home-centred" workers, and 87% of households are in work[21], then as a rough estimate a 9-16% increase in gas consumption would result in NOx emissions from the domestic sector rising by 3-5%. This figure may be around 4-7% for London where new home workers make up 49% of the workforce. This is still likely to be a marginal increase in London-wide NOx emissions where domestic heating accounts for 6% of total emissions.

Abating emissions from offices

Short term measures

Building facilities managers have the dual task of ensuring that office buildings are sufficiently ventilated to be safe to occupy whilst avoiding unnecessary energy wastage. As Carbon Intelligence data showed, many offices could do more to reduce demand by taking a pro-active approach to building energy management. The main energy saving advice they recommend is:

- Ensure that scheduling of heating and ventilation systems match the building's occupancy, e.g. reducing operation during out of office hours. If building is un-occupied schedule to maintain minimum internal temperatures to prevent damage to building fabric and services.
- Ensure that plant equipment is not running continuously in hand or being called on outside of scheduled times. Check that hold-off strategies are used for key plant equipment;
- Use a wider control deadband (the thermostat's setpoint temperature range) for heating & cooling systems to minimise energy demand and to avoid these systems competing against each other.
- Ensure that boiler combustion systems are calibrated to maximise efficiency at low firing rates during times of reduced demand.
- In less occupied areas consider providing comfort heating with standalone units (e.g. radiant heaters or fans) to avoid the need for central heating/cooling plant operation.

Each of these recommendations should minimise energy consumption reducing emissions and cutting operation costs. Facilities managers can also save costs by avoiding scheduling electricity intensive operations (e.g., running heat-pumps or air conditioning units) during peak rate hours (11am – 2pm and 4pm-7pm in London).

Local authorities, particularly in areas where commercial heating makes up a high proportion of NOx emissions like Central and Inner London, should engage with facilities managers to raise awareness that there are economic and environmental gains to be made by calibrating building energy management systems to match new ways of working.

Medium-term measures

Savvy offices managers can take the opportunity to exploit their premises' reduced occupancy to renovate buildings, retrofitting energy saving measures including low carbon and NOx free heating systems. Given that the pressure on businesses to decarbonise operations will inevitably increase as carbon budgets become tighter, adoption of low carbon technologies during this period could prove

[21] Office for National Statistics (2020) Working and workless households in the UK: October to December 2019 https://tinyurl.com/yxlaubnp

advantageous in the long run and help reduce health impacting pollution. Programmes such as London's RE:FIT programme (now part of the Retrofit Accelerator programme), provide support and guidance for businesses to implement such measures. Heat-pumps, geo-thermal energy and solar collectors are all low emissions technologies supported by the government's non-domestic renewable heat incentive and have zero local emissions.

Guidance for safely occupying workspaces maintains that heat-recovery units should not operate, to avoid re-circulation of potentially contaminated air. Turning heat recovery units off will increase heat demand in offices.

It is not clear that any air filtration systems capable of eliminating COVID are suitable for offices alongside heat recovery units. The UK Scientific Advisory Group for Emergencies (SAGE) says real-world research and development of guidance is urgently needed to determine which are safe and effective[22]. It is important that fresh air brought into the workplace should be free of contaminants such as engine exhaust emissions and particulates. As building regulations do not adequately account for ambient air quality, managers should be careful to check that air being drawn is does not come from heavily polluted areas, and that filtration is used to reduce exposure to harmful pollutants.

Offices and organisations with environmentally focussed corporate social responsibility agendas should be accounting for the shift in energy demand from the workplace to staff's homes. The publicly available Energy Performance Certificate (EPC) register, can help organisations estimate their staff's home energy requirements and what can be done to reduce energy use. The link between thermal comfort and productivity[23] may convince businesses to consider this as part of general assistance offered to adapt to home working. Businesses could provide energy saving advice to staff and even green home loans and grants for retrofit work. These measures are discussed below.

Abating emissions from homes

Our analysis (see *Added Heat Demand at Home* above) suggests that working from home may only have a marginal impact on total NOx emissions. Nonetheless working from home means additional domestic heating and cooking that could negatively impact indoor air quality. Additional lighting and appliance use will also increase carbon emissions and fuel costs. Heating costs will increase most for workers in large and poorly insulated homes. Helping workers to make their homes more energy efficient would:

- Make heating more affordable
- Limit households' impact on the climate
- Reduce harmful NOx emissions
- Improve worker's health
- Boost productivity when working from home

Low-cost measures and behavioural advice

[22]Scientific Advisory Group for Emergencies (September 2020) EMG: Role of ventilation in controlling SARS-CoV-2 transmission https://tinyurl.com/y2putpds

[23] Seppanen, O & Fisk, W, (2006) Some quantitative relations between indoor environmental quality and work performance or health. *HVAC&R Research*, 12(4), pp.957–973 https://tinyurl.com/y49xgwk7

Energy efficiency advice and low cost measures can help reduce boiler usage and cut NOx emissions. But this should not be in lieu of adopting more challenging medium-term measures that cut the dependence on fossil fuels for space heating. Relevant advice includes:

- Only heat the spaces being used. When working from home and space heating is needed, you can save money by turning down the radiators in rooms not being used and closing the door to these spaces. Some organisations advise using electric standalone heaters if using only one room. This will cut boiler use, however there is no definitive evidence that shows this will cut energy costs in the majority of cases, so should not be adopted as standard messaging.
- Lower the flow temperature of the boiler, particularly for modulating condensing boilers. Modulating boilers adjust the amount of fuel burned to provide the requisite heat. NOx production reduces with lower flame temperatures[24].
- Ensure that the home is well draught proofed. Good ventilation is important for indoor air quality, but it is important that this ventilation can be controlled. Removing draughts by putting draught strips around doors, windows and loft hatches can help to keep heat in. Also using sealant for gaps between floorboards, skirting boards and other cracks can help to improve the comfort of a home.
- Thick curtains that cover recesses for glass windows and doors all help to keep heat in after dark. It is important that these do not cover radiators, or encourage heat from radiators into recesses.
- If you have an old non-condensing boiler then a replacement condensing boiler will help to reduce NOx emissions. As of September 2018, all domestic boilers are subject to NOx emissions limits. You can check with manufacturers to compare emissions between models. If your home is suitable then an electrical ground- or air-source heat pump can provide heat without directly producing harmful emissions.

Insulation and heating system change

Radical action is needed to cut greenhouse gas emissions from homes, which will also reduce NOx emissions in the domestic sector. The first step towards this is making sure that homes are as thermally efficient as possible – installing high performance glazing, reducing uncontrolled ventilation and insulating walls, floors and roofs. This reduces the requirement for space heating, lowering fuel costs, emissions, the risk of fuel poverty. Once demand is reduced as far as possible, the remaining demand can be supplied with heating from a renewable source.

BEIS are due to release their Heat and Buildings Strategy outlining the trajectory for the nation's low carbon space heating. Heat-pumps, low-carbon district heating and hydrogen heating are proposed in the Mayor of London's 1.5°C compatible plan[25]. Air-source and ground-source heat-pumps will provide affordable low-carbon heat, but these can only operate efficiently in well insulated homes. As they are electrically powered, they do not add to local air-pollution. District heating similarly should not add to local air-pollution provided the heat source's emissions are regulated or run off a heat pump. However, hydrogen may prove problematic in terms of NOx emissions if a boiler is used

[24] Condensing boilers operate more efficiently when the return flow temperature (the temperature of water recirculated from radiators to the boiler) is below 55°C. This allows the capturing of latent heat from condensing burnt fuel. When a smaller portion of a home is heated, then the return flow temperature is likely to go up which is why lowering the boiler's flow temperature. Hot water tanks should be regularly heated above 60°C to prevent legionella bacteria forming.

[25] Mayor of London (2018) Zero carbon London: A 1.5ºC compatible plan. https://tinyurl.com/y29gw9tn

to provide heat[26]. There have been no widescale trials of domestic hydrogen boilers in the UK, however modelling of industrial boilers has shown a 650% increase in NOx emissions compared to natural gas[27]. The initial details of the Government's *Ten Point Plan for a Green Industrial Revolution*[28] proposes converting an entire UK town to hydrogen. It is therefore essential that any domestic hydrogen boilers at a minimum meet the current NOx standards as set out in the European Energy Related Products directive. With Brexit on the horizon, attention should be paid to ensure that the UK maintains tight standards on NOx emissions from boilers with a transition to hydrogen.

Accessing support

There are several support schemes for households looking to make thermal improvements to their homes. Some may be means tested, and some only available in certain areas. Advice services in Great Britain include the Simple Energy Advice service in England, Home Energy Scotland and Nest in Wales. It is recommended that households check their local authority first, for schemes that may be available locally. 80% of London local authorities mentioned domestic energy efficiency schemes within their air-quality action plans[29]. The majority referenced promoting the London wide RE:NEW scheme, which provides end-to-end support for home-owners as well as renters in private and social housing.

[26] Dorrington, M., Lewitt, M., Summerfield, I., Robson, P., & Howes, J. (2016). Desk study on the development of a hydrogen-fired appliance supply chain. *Kiwa & E4 Tech*. https://tinyurl.com/yyhrdwq4

[27] Cellek, M. S., & Pınarbaşı, A. (2018). Investigations on performance and emission characteristics of an industrial low swirl burner while burning natural gas, methane, hydrogen-enriched natural gas and hydrogen as fuels. *International Journal of Hydrogen Energy*, *43*(2), 1194-1207.

[28] Prime Minister's Office, 10 Downing Street (November 2018) *Press release,* PM outlines his Ten Point Plan for a Green Industrial Revolution for 250,000 jobs. https://tinyurl.com/yypvk6bq

[29] See appendix