Energy&Climate
INTELLIGENCE UNIT

Gas boilers and NO_x: the hidden emitter

Air quality impacts of gas combustion in homes is put into focus this winter

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EXECUTIVE SUMMARY

Air pollution targets are being exceeded across the UK, and in some areas emissions are well above the World Health Organization's (WHO) guidelines. This is true for emissions of nitrogen oxides (NO_x): in many areas of the UK, concentrations are exceeding both the UK's own targets and WHO guidelines. Gas combustion, in both domestic and commercial boilers, is responsible for approximately a fifth of NO_x emissions London-wide. It is assumed that this is similar in other major cities studied in this report.

During the Covid-19 pandemic, large proportions of the population have been working from home and spending more time indoors. If this trend continues throughout the winter, as recent Government guidelines suggest it might, modelling shows that gas boiler use is set to rise by 56%. This increase in gas burning has implications for urban air quality, driving up NO_x concentrations by approximately 12% in towns and cities.

To date, NO_x emissions from boilers have not been addressed in Government policies in the same way as emissions from traffic. Measures to reduce traffic pollution are having an effect, bringing down concentrations of NO_x in our cities by about 5% per year. So the 12% spike in NO_x emissions from increased gas combustion expected this winter would more than offset the last two years' worth of progress on traffic emissions.

Of course, traffic may continue to be lighter than usual during lockdown, and this may mean that Britain's cities will bear a smaller overall NO_x burden than usual over winter – we do not attempt in this report to model traffic emissions. Nevertheless, the increase in pollution from gas boilers expected this winter provides a graphic illustration of their forgotten role in air pollution. And it is a role set to continue without practical policies to decarbonise home heating. Furthermore, future years could see elevated pollution from both homes and traffic, if more people work from home and those going into their workplace do so by car rather than public transport.

NO_x pollution carries significant health implications, with every 1µg/m^3 rise in NO_x concentrations increasing the number of respiratory hospital admissions by 0.5%, the chronic mortality odds ratio by 2.3% and diabetes by 5%. Asthma is raised by a factor of about 1% for every 1µg/m^3 increase in NO_2 and lung cancer by 2%.

Conversely, the benefits of meeting the WHO guidelines have been highlighted in recent research; in some of the cities considered in this report (namely London, Manchester, Birmingham and Bristol), meeting the guidelines for all air pollutants[1] could prevent 17,000 deaths, 3 million working days could be gained per year and benefits to the economy could be as high as £1.6 billion per annum. Additionally, over £190 million in damage costs is estimated from the additional NO_x specifically from increased use of gas boilers[2]. This is a result of loss of lives, productivity and economic damage.

This November, the Government is set to publish its Heat and Buildings Decarbonisation Strategy, which is expected to give details on plans to switch British homes to clean sources of heat. The findings in this report add to the urgency for the Government to lay out a clear path to staying warm at home without burning fossil fuels.

[1] This includes PM_{10}, $PM_{2.5}$, NO_2, O_3, and SO_2, and is not limited to NO_x which is the focus of this report.
[2] This is across the 21 million gas boilers in England across the whole of 2020.

INTRODUCTION

Air pollution in the UK is a major issue. It contributes to about 40,000 early deaths and costs the economy more than £20bn per year. This is rising – respiratory disease now affects one in five people and is the third largest cause of death in England. Hospital admissions are on the increase too, as admissions for lung disease have risen at three times the rate of all admissions generally over the last seven years.

The link between air pollution and respiratory issues is well documented. Nitrogen oxides (NO_x) including nitrogen dioxide (NO_2) react with oxygen to form smog and acid rain whilst also contributing to a variety of health problems; lung tissue damage, respiratory and cardiovascular issues have been linked with acute and long-term exposure to NO_x.

The main areas of damage surrounding NO_x are higher risk of chronic mortality (the relationship between chronic exposure to air pollutants and premature deaths, regardless of pre-existing conditions) and asthma in small children. In most cases, the impacts of NO_x are inflamed airways, and long exposure can decrease lung function as well as increase response to allergens.

In urban areas in particular, including cities outside of London such as Manchester and Bristol, concentrations of NO_x routinely exceed the WHO's recommended level of 40µg/m^3. In 2018, the UK did not meet its own targets, set at less ambitious levels than the WHO guidelines.

Pollutant	Measure	Performance against current UK target	Performance against WHO guidelines
PM_{10}	24 hour mean	Met in all zones	Exceeding target in 29 zones
	Annual mean	Met in all zones	Exceeding target in 24 zones
$PM_{2.5}$	24 hour mean	No current target	Exceeding target in 40 zones
	Annual mean	Met in all zones	Exceeding target in 38 zones
O_3	Annual mean of daily max 8 hour	Met in all zones	Met in all zones
NO_2	1 hour mean	Exceeding target in two zones (London and South Wales)	Exceeding target in 11 zones
	Annual mean	Exceeding target in 36 zones	Exceeding target in 36 zones
SO_2	24 hour mean	Met in all zones	Exceeding target in 4 zones
	10 min mean	Not measured in UK	Not measured in UK

Table 1 – The UK's performance against current targets and WHO guidelines in 2018 shows that some pollutants, like NO_x, are off-track against all measures. Others like O_3 are below both the UK's target and WHO guidelines. Source: Compliance Assessment Summary and CBI Economics.

The Government's Clean Air Strategy, published in 2019, begins to address the contributions made to air pollution from domestic fuel burning and commits the Government to meeting legally-binding targets in 2020 and 2030. Whilst reductions in emissions of NO_x so far have been aligned with the 2020 target, the UK is currently off track to meet the ceiling for 2030. In fact, it's currently not on track to meet any of the five pollutant ceilings for 2030.

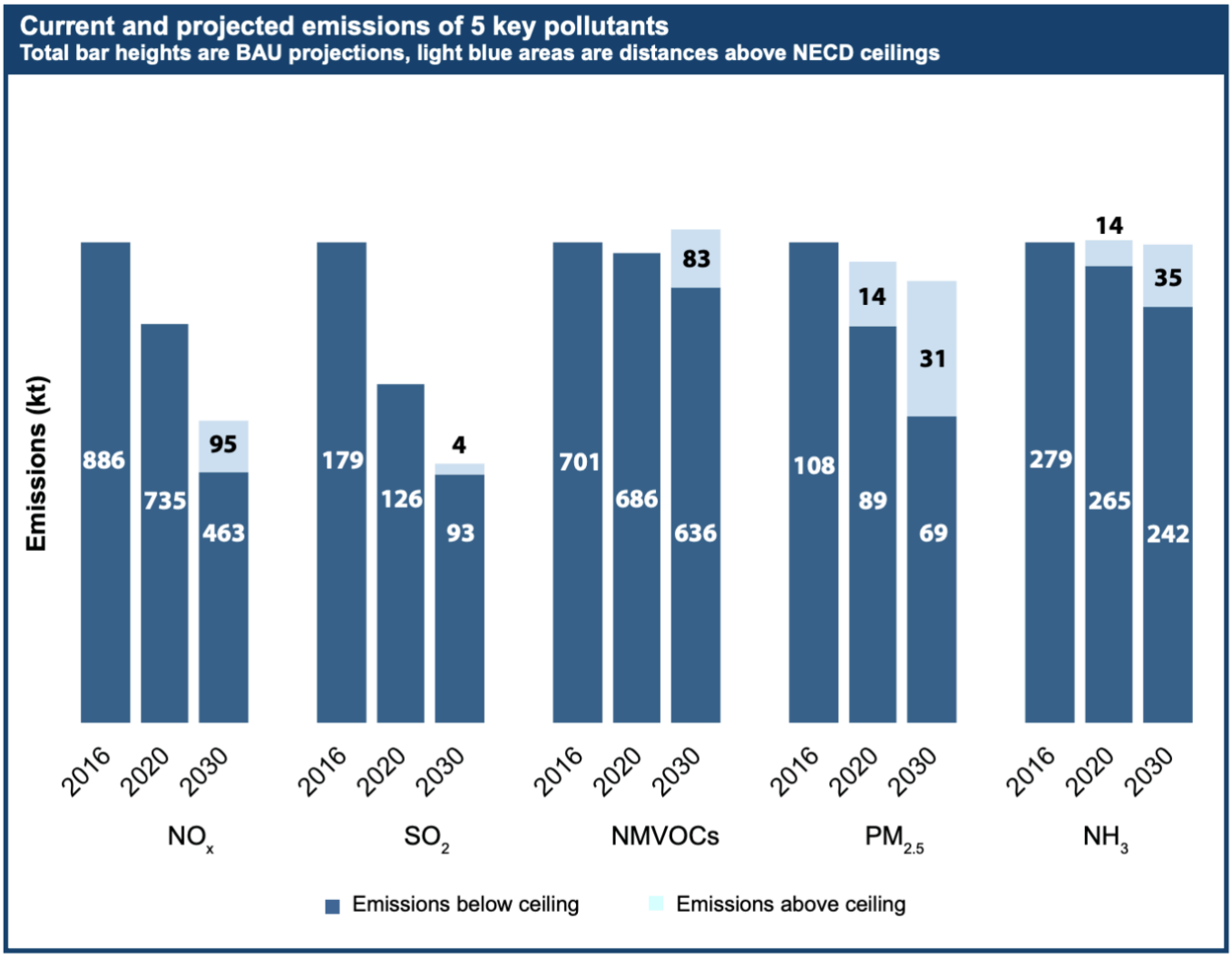

Figure 1 – Current and projected emissions of five key pollutants showing the UK is currently not on track to meet the ceilings for 2030. Source: Defra.

Not meeting air pollution targets for NO_x could have serious health impacts for people already vulnerable to respiratory problems – like the 5.4 million people with asthma, 1.1 million of whom are children. The coronavirus may also have long term effects on the respiratory and cardiovascular systems. In light of this, cleaner air may grow to be more important.

Recent research modelling the effects of poor air quality in London, Manchester, Bristol and Birmingham shows that the UK would not be compliant with WHO air quality guidelines for NO_x in 11 of 43 zones. However, if the levels of all air pollutants were under the guidelines[3] 17,000 deaths could be prevented each year, 3 million working days could be gained per year and £1.6 billion in benefits to the UK economy per annum could be generated.

Gas boilers are a persistent source of air pollution, especially in urban areas. The ongoing public health crisis has changed working patterns, with swathes of the public working mainly from home, especially in cities.

This report examines the effects of increased gas boiler use on air pollutant emissions in the event of a winter spent increasingly at home. It looks at the possible effects in six of Britain's major cities, in terms of increasing levels of dirty air and of the health effects this brings.

GAS BOILERS EMIT AROUND A FIFTH OF NO_x EMISSIONS

Houses across England are predominantly heated by burning natural gas, which releases NO_x alongside CO_2. There are 21 million gas boilers across the country, and currently less than 5% of homes are heated by low carbon sources. This means that homes across the country are having their air quality worsened by the use of gas for heating and cooking.

London-wide, around a fifth of NO_x emissions are related to burning fossil gas in domestic and commercial boilers, with 12% from domestic boilers specifically.[4] This is rising in highly urbanised areas such as Central London, where almost half of NO_x in 2025 is expected to be due to gas combustion. Despite this, Figures 2 and 3 below show that the public do not perceive gas combustion as a major source of NO_x.

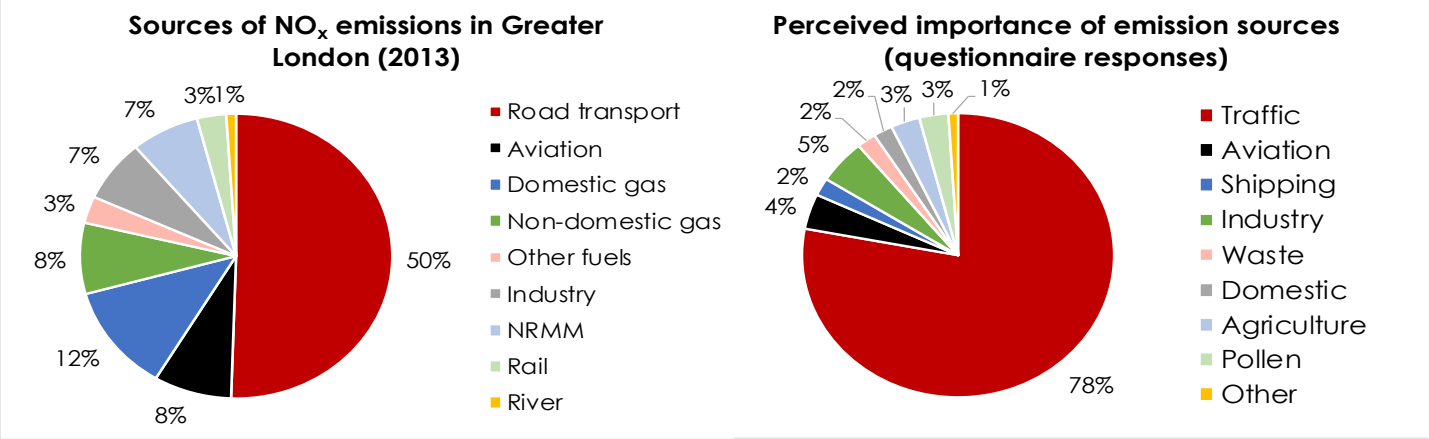

Figure 2 (top) – sources of NO_x emissions in Greater London 2010. Source: Policy Exchange. Figure 3 (bottom) – perceived importance of emission sources (questionnaire respondents), evidencing a significant underestimation of air pollution from fossil fuel combustion. Source: Defra.

[3] This includes PM_{10}, $PM_{2.5}$, NO_2, O_3, and SO_2, and is not limited to NO_x which is the focus of this report.
[4] In this report, we assume that the major cities analysed have the same sources and proportions as London.

Similarly, gas combustion's role in increasing NO_x concentrations has been largely absent from policy to date. This is the opposite to the transport sector; the Transport Decarbonisation consultation indicates car greenhouse gas emissions are projected to fall by 52% from 2018 to 2050, despite a projected increase in car distance (km) of more than 35%.[5]

This means that the proportion of pollution attributed to boilers will grow, becoming more of an issue, particularly in cities where air quality is already bad. For example, in London, measures to limit air pollution from road traffic have been successful, as exhaust NO_x emissions have been reduced by up to 45%. By contrast, gas combustion has remained untouched for many years, despite the fact that boilers in homes are a major source.

Other cities, like Manchester and Birmingham, do not have the same level of road easing or air pollution measures as London, yet suffer from the same significant pollution levels from gas combustion.

In more residential areas, or where there are 'low emissions zones' for transport and so less road traffic, the proportion of air pollution from gas combustion can rise to over a third, showing the large scale impacts gas boilers have. This poses a risk to inhabitants through increased risk of respiratory issues, especially if spending an increased amount of time indoors due to coronavirus measures.

The importance of clean air and nature for many people during the lockdown has been made clear. One poll commissioned by the National Trust revealed that more than two-thirds of adults agreed that nature made them happy during lockdown. However, respiratory system impacts of coronavirus have also put the damage, sometimes life-threatening, that pollution can cause under the microscope.

Over the last decade, the Committee on Climate Change state that buildings have had 'limited progress' and 'the bulk of the challenge to decarbonise buildings remains, with the greatest challenge on decarbonising heating and hot water barely yet addressed.' The Government is expected to publish the Heat and Buildings Strategy in November which is anticipated to give a sense of direction on how homes will be decarbonised in line with the net zero emissions target set for 2050. Decarbonising heating and moving away from fossil fuel use within the home will also decrease air pollution (particularly NO_x) as the pollutant sources will be removed.

[5] Government bases this figure on existing policies which do not yet include the planned phase-out of sales of new fossil fuel (petrol and diesel predominately) fuelled cars

ANALYSIS

INCREASED BOILER USE WILL OFFSET PROGRESS MADE IN REDUCING TRANSPORT EMISSIONS

In March, the UK went into lockdown, and many thought that air quality, as a result, would benefit. Indeed, air quality monitors identified that there was an average of a 30-40% reduction in NOx during the lockdown, highlighting the benefits of a reduction in road travel.

This temporary drop came on top of the average 5% annual reduction in NO_x emissions seen since 1990, with the last decade alone seeing total NO_x emissions falling from 1.45 million tonnes in 2008 to 0.8 million tonnes in 2018.

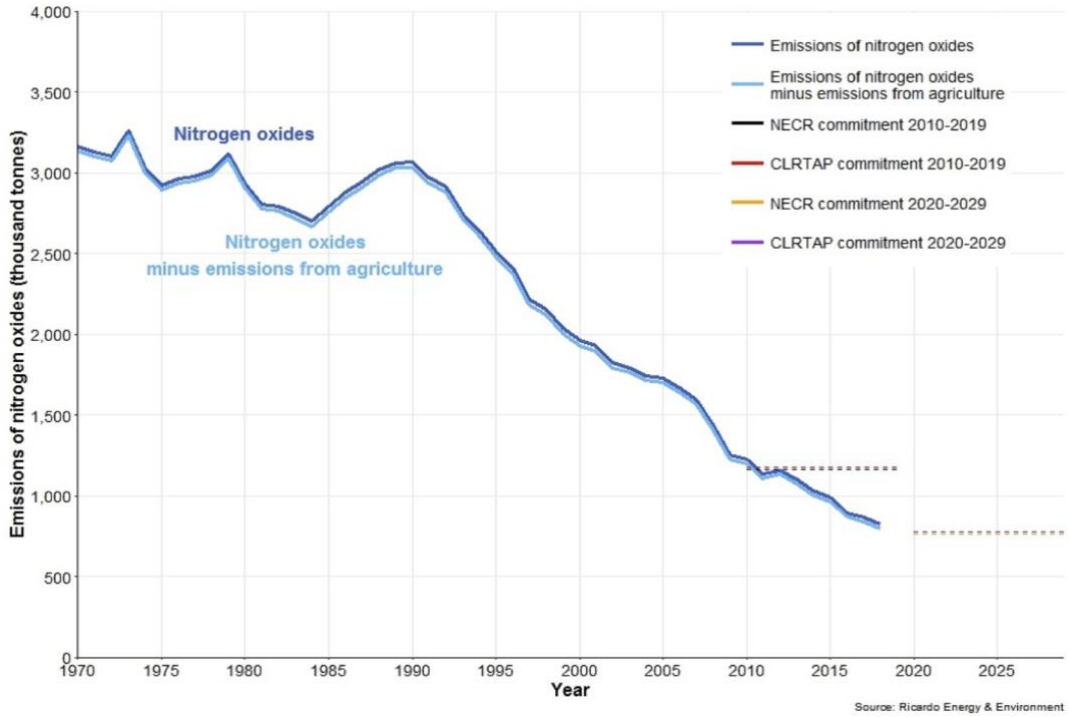

Figure 4. Trends in total annual emissions of nitrogen oxides in the UK. 1970 to 2018 show significant progress, with steep falls between 2005 and 2010. In the figure, NECR means National Emissions Ceilings Directive, CLRTAP means Convention on Long-range Transboundary Air Pollution.

The latest guidance from the Government regarding coronavirus is that people should work from home if they can. During the peak of the lockdown in March and April, up to a third of people were working from home, with London having the second-highest proportion of people working from home behind the South East (32% and 35% approximately). Also, a recent survey of 1,000 firms shows that three-quarters intend on maintaining increases in home working in the longer term.

Although transport may remain curtailed this winter, resulting in lower overall NO_x emissions than in a non-Covid year, a locked-down winter will significantly increase emissions from domestic gas boilers, illustrating their significance as a source of air pollution. Increased use of fossil fuel gas boilers during a winter working from home would more than offset two years' worth of progress on traffic emissions, in London specifically, and raise the amount of NO_x pollution emitted by 12%. Across England, it could create 14,515 extra tonnes of NO_x – which is 2% of the 2018 total. This would have considerable health impacts.

Figure 5 shows that in London, an increase from working from home in the winter can cause the proportion of NO_x emissions from boilers to rise by 56%. In turn, if traffic and other sources of NO_x are assumed to stay the same (as the rebound effect after lockdown remains unknown), this will cause an increase in total NO_x emissions of 12%. In London alone, this will cause an extra 4,000 tonnes of NO_x to be released.

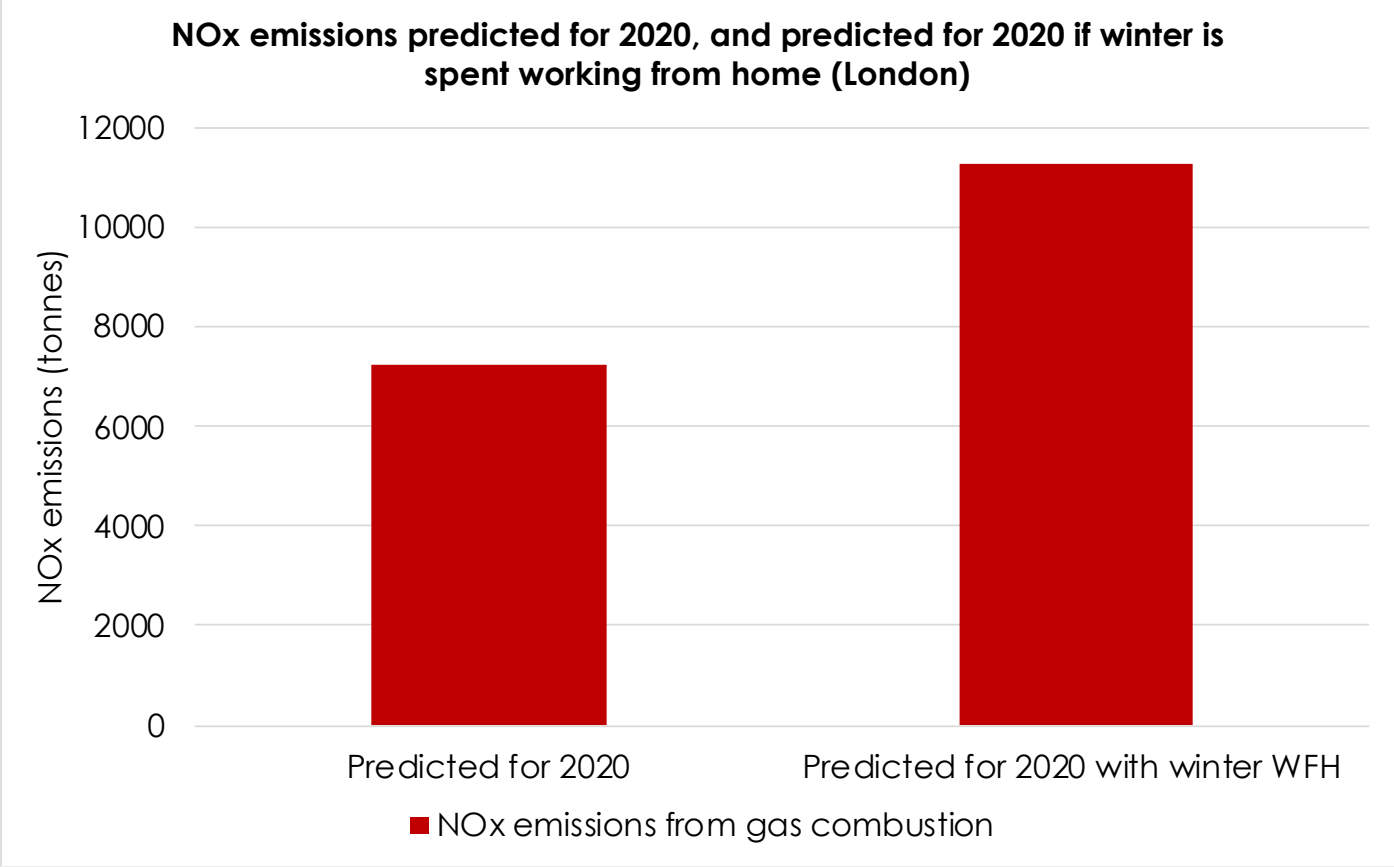

Figure 5 – NO_x emissions may be 56% higher from boilers in 2020. Overall, this will cause a 12% rise in the event of a winter working from home, purely due to the increase in the use of gas boilers for heating and hot water whilst more people stay at home, assuming no other changes. Source: London Environment Strategy and ECIU analysis.

Fossil fuel gas burned by domestic boilers over a winter spent indoors could see NO_x emissions rise closer to the World Health Organization's recommended limit of 40µg/m^3. In the absence of other changes, for example continued suppression of traffic emissions, some areas like Manchester could see NO_x levels just 1µg/m^3 away from the upper limit and posing a risk to Mancunians' health. In Birmingham too, the concentrations of NO_x are just 3µg/m^3 away from the upper recommended limit.

Although traffic emissions may well remain lower than usual this winter, at some point Britain's urban dwellers could find themselves facing a situation of high NO_x emissions from both homes and transport. Surveys show that Britons plan to work from home more in future (in many cases with their employers' blessing) but are also wary of travelling by public transport when they do return to their workplace. This shows that damaging NO_x emissions can only be alleviated by tackling air pollution from both cars and home heating.

Additionally, the monetary costs of a rise in NO_x emissions due to increased domestic burning are estimated to be £12,448 per tonne (DEFRA central case).[6] The UK currently has over 21 million boilers. Over the course of 2020, damage costs of air pollution from gas boilers equates to a cost of £191 million.

	Damage cost sensitivity range: low	Central damage cost	Damage cost sensitivity range: high
NO_x domestic damage cost (2017) in £/tonne	1,077	**12,448**	48,078
Extra NO_x emissions (tonnes) from WFH	14,515	**14,515**	14,515
Total damage costs 2017	£15,632,655	**£180,682,720**	£697,852,170
Total damage costs 2020 (inc. inflation)	£16,553,880	**£191,330,269**	£738,976,276

Table 2 – damage costs (low, central and high estimates) of the NO_x generated by all boilers in England over the course of 2020. This is mainly a result of loss of lives, lost productivity and wider economy damage. Sources: Defra and ECIU analysis.

Mainly, this is a result of the health cost and lost productivity that comes with the most prevalent respiratory issues linked to NO_x – asthma in small children and chronic mortality. This is likely as a result of a study by Defra earlier this year – which stated that for every 10µg/m³ rise in NO_2 levels, respiratory hospital admissions rise by 0.5%. For the same 10µg/m³ rise in NO_2, they estimate that the chronic mortality odds ratio is 2.3% and diabetes rises by 5%. Asthma is raised by a factor of about 1% for a 10µg/m³ increase in NO_2 and lung cancer by 2%. This therefore has major implications for the NHS and its capacity during a pandemic such as the present.

There is evidence of longer-term respiratory problems resulting from coronavirus. Poor indoor air quality, including NO_x from gas boilers, can cause the concentrations of NO_x to almost double during the heating season (26 parts per billion (ppb) to 43 ppb). This may be heightened if use of the fossil fuel rises during a winter working from home, creating difficulties as existing respiratory problems are heightened in a vicious circle of health concerns.

This proves that a high level of NO_x is not only an issue faced on the nation's streets. A recent report found that indoor air quality is a major risk factor in many cardiovascular diseases, lung and other cancers, and even ultimately 9,000 deaths per year across the EU. Poor indoor air quality as a result of pollutants including NO_x from boilers will do nothing to help those now suffering from breathing issues as a result of the current pandemic.

[6] ECIU analysis using the Defra Damage Costs Appraisal Toolkit – and values of £1,077 (low estimate), £12,448 (central estimate) and £48,078 (high estimate) per tonne for domestic NO_x as well as an estimated increase in NO_x emissions of 14,515 tonnes / year.

CONCLUSION

This report finds that the air pollution, specifically NO_x, emitted from gas boilers could spike over the course of a winter spent working from home. The additional NO_x emitted is roughly equivalent to cancelling out two years' worth of gains from traffic pollution measures, and would in the absence of any other changes raise NO_x concentrations in major UK cities by as much as 12%, compromising the UK's ability to meet legally binding air pollutant targets.

Increases in NO_x, particularly NO_2, due to intensified gas combustion could also push cities, including Manchester and Birmingham, dangerously close to the World Health Organization's 40µg/m^3 limit. This would also contribute to the number of air pollution related hospital admissions, which in the case of NO_x are mainly due to asthma in small children and chronic mortality.

Additionally, it is estimated that over the course of 2020, £191 million in damage costs is generated by extra NO_x emissions from domestic gas use for heating and hot water.

Moreover, in four of the cities modelled in this report, if the WHO guidelines were met, it is thought that[7] 17,000 deaths could be prevented, 3 million working days could be gained per year and benefits to the economy could be as high as £1.6 billion per annum.

The Government's upcoming Heat and Buildings Strategy brings the opportunity to address both the carbon emissions associated with fossil gas heating and the associated air quality impacts. Opting for an electrified alternative to fossil gas will help to curb CO_2 generated by keeping warm at home, and also the dangerous levels of NO_x that this report has highlighted.

[7] This includes PM_{10}, $PM_{2.5}$, NO_2, O_3, and SO_2, and is not limited to NO_x which is the focus of this report.