BUS FLEET ELECTRIFICATION

ROUTE TO CLEAN AIR, QUIET TOWNS AND CITIES & NET ZERO

KLEANBUS
TRANSFORMING TRANSPORT

PURPOSE

This white paper presents the benefits for society and our environment of removing diesel engines from the UK bus fleet by repowering existing buses with zero-emission battery-electric powertrains. The purpose of the white paper is to enable decision makers from local authorities and bus operators to fully consider converting existing buses as a cost-effective means to accelerating their route to a fully electric fleet.

FOREWORD

The world has simultaneously woken up to both the threat of climate change to the planet, and the impact of diesel emissions on our health. As part of the solution we are seeing an unprecedented shift to electric vehicles. This is no longer a long term future vision, but our current reality. This shift will improve the air we breathe, make our towns and cities quieter, and put the transport sector on the path to achieving net zero greenhouse gas emissions.

Electrification of public transport is an essential part of this newly electric transport system, without which the inequalities associated with access to transport, pollution, health and congestion will only increase. Electrification of the public transport system has many challenges, but allowing the sector to be left behind is no longer an option for our planet or society.

New electric buses are coming into service around the world, bringing us one step closer to a fully electric efficient fleet. However, as buses are built to last, existing buses are expected to serve for up to 15 years in a typical fleet. Furthermore, electric buses still cost around 50% more than their diesel counterparts. The road to a fully electric fleet could be long and costly. In the UK, London has set out its ambition of achieving a fully zero emission bus fleet by 2034[1], but there are no specific commitments from central government on how all UK buses will meet the government target of decarbonising transport by 2050[2].

If existing buses are ‘re-powered’ through retrofitting, targets could be met much sooner, saving significant amounts of both money and emissions. Re-powering buses extends the life and value of the existing fleet, prevents the problem of old diesel buses being deployed to more socially-deprived areas, and removes the considerable environmental impact of manufacturing new buses

Lucy Parkin CEnv MSc
Director of Environmental, Social & Governance

DRIVERS

Diesel engines are a significant source of both greenhouse gases and air pollutants that are harmful to our health. There are a number of drivers for their removal, including:

CLIMATE CHANGE

Road transport emissions are rising faster than any other sector and account for over 10% of global greenhouse gas emissions[3]. Around the world, countries are committing to reaching 'Net Zero' greenhouse gas emissions by the middle of the century. In November 2021, COP26 in Glasgow saw countries pledge to take action to reduce greenhouse gas emissions to try and limit global temperature rise to 1.5 °C compared to pre-industrial levels.

Electrification of vehicles was one of four key mitigation goals on the COP26 agenda. Around 40 countries at the summit pledged to work towards all sales of new cars and vans being zero emission globally by 2040. But only 15 countries pledged to work together towards 100% zero- emission new truck and bus sales by 2040.

Transport is the largest emitting sector of greenhouse gas emissions in the UK, producing 27% of total emissions in 2019.

In 2018, 34% of Nitrogen Oxides (NOx) emissions and 13% of Particulate Matter ($PM^{2.5}$) emissions came from transport in the UK.[4]

AIR POLLUTION

Nitrogen dioxide (NO_2) aggravates respiratory diseases, particularly asthma, and stunts the development of children's lungs. Both short and long-term exposure to $PM_{2.5}$ increases the risk of mortality from lung and heart diseases, and increases hospital admissions.

According to the World Health Organization (WHO), ambient air pollution was estimated to cause 4.2 million premature deaths worldwide in 2016[5], and is one of the greatest environmental risks to health. The UK Governments Committee on the Medical Effects of Air Pollution (COMEAP) estimates exposure to $PM_{2.5}$ attributes to 29,000 premature deaths every year[6].

LEGAL REQUIREMENTS

The current legal air quality objectives in the UK are 40 µg/m3 for NO_2 and 25 µg/m³ for $PM_{2.5}$ [7]. The Environment Bill published in October 2021 mandated the UK government to set two new $PM^{2.5}$ targets within a year.

The WHO tightened its guidelines for NO_2 to 10 µg/m³ and for $PM_{2.5}$ to 5 µg/m³ in September 2021, and implored national and local governments to use the new guidelines to save lives - almost 80% of deaths related to $PM_{2.5}$ could be avoided if the guidelines were met worldwide[8].

In London, the Mayor set out what more needs to be done for $PM_{2.5}$ concentrations across London to meet 10 µg/m³ by 2030, but this is beyond the current funded trajectory and is still twice the level recommended by the WHO[9]. It is clear from the targets being set that more action is needed to reduce the burden of air pollution on public health, and that authorities face an enormous challenge to find, and fund, measures that will make an impact.

INEQUALITIES

Air pollution levels vary significantly according to the source of pollution and geographical differences such as meteorology and topography. The map of London's air pollution below illustrates this variance. The locations in red show where concentrations still exceeded the legal limits for nitrogen dioxide[10]; 70 % of roads in central London and 24 % of roads in inner London. For $PM_{2.5}$ the remaining challenge is even greater, with 99 % of Londoners still living in areas which exceed the WHO guideline limit.

Annual mean NO2 concentrations modelled using the London Atmospheric Emissions Inventory for 2016 (GLA & TfL[11])

There is no safe level of air pollution, but locations near busy roads in towns and cities are likely to be the most negatively impacted . Those who live, work or spend time in these locations are most likely to suffer from its adverse effects. This includes road users. Research undertaken for the Institution of Occupational Safety and Health found that professional drivers are disproportionately affected by exposure to diesel exhaust fumes and are put at greater risk of cancer[12]. Studies have also concluded that passengers are exposed to significant pollution during journeys[13], particularly onboard vehicles with the worst emissions.

ENVIRONMENTAL JUSTICE

The variance of air pollution levels is compounded by the difference in people's exposure to air pollution as they go about their daily lives, and their sensitivity to its effects. All of these factors contribute to the significant inequalities of air pollution.

Extensive research has demonstrated that children, the elderly, people with existing diseases, minority and low-income communities are particularly vulnerable to adverse impacts from exposure to air pollution.

Exposure to NO_2 has been linked to one in 12 new child asthma cases worldwide[14] . Significantly, in 2020 a UK coroner ruled that exposure to NO_2 contributed to the tragic death of 9-year-old Ella Kissi-Debrah. Children growing up exposed to $PM_{2.5}$ are more likely to have reduced lung function and develop asthma[15], and even short-term exposure to $PM_{2.5}$ is associated with reductions in school children's lung function[16]. This is even more significant, when you consider that recent research commissioned by Asthma UK and the British Lung Foundation found that more than 25 percent of UK schools are located in areas above the WHO's recommended air pollution levels[17] and children have the least control over their places of residence and school.

People living in deprived areas of London have been found be twice as likely to die of lung disease than in affluent areas [18]. Households living in poverty in the UK are exposed to the highest pollution levels - while being responsible for the least road transport emissions- compounding the inequalities of the impacts of road transport pollution[19]. Immediate action to improve air quality, and enhance access to zero emission public transport will help address this environmental injustice being suffered by many communities.

COST OF INACTION

Electrification of bus fleets can contribute significantly to reducing the economic costs of air pollution, noise and climate change.

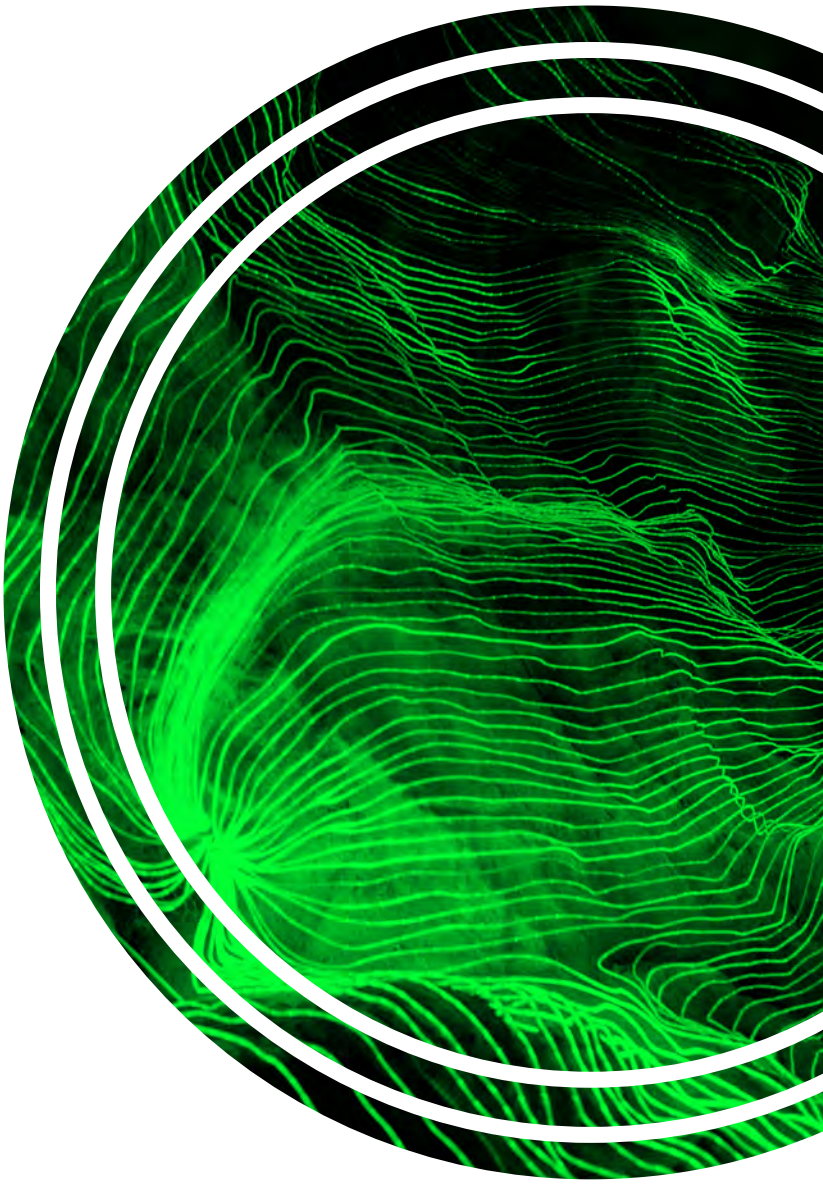
The public health impact of air pollution has an economic cost as a result of the life-years lost, hospital admissions and days spent unwell. The UK government's Interdepartmental Group on Costs and Benefits estimated that air pollution costs the UK up to £20bn every year. In addition, the annual social cost of urban road noise in England is £7 to 10 billion[21].

Climate change affects lives around the globe, including access to water, food production, health, and people's environment. The Stern Review[22] estimated that the cost of unmitigated climate change will be equivalent to losing 5% to 20% of global GDP each year, which equates to at least £5.3bn.

£20bn
in estimated air pollution costs

£7-10bn
in urban road noise costs

£5.3bn
in unmitigated climate change



CURRENT SITUATION

ACTION IN THE UK

The UK Government claims to have one of the most ambitious approaches in the world to achieving net zero by 2050. Its Transport Decarbonisation Plan published in July 2021 set out measures to help achieve this target and address the wider costs to society of the current transport system. As such, the plan acknowledges the need for measures to also improve air quality, noise, health, reduce congestion and deliver high-quality jobs and growth for everyone across the UK[23].

The Bus Decarbonisation Plan contains specific measures for buses and recognises the essential contribution buses make to the public transport system and how buses have been overlooked for many years by policy makers.[24] While recognising the potential cost savings offered by electric buses, the plan only supports the purchase of just over 10 percent of the UK's bus fleet (4,000 buses).

It is clear that there is ambition from the UK Government to overhaul the bus industry, from its vehicles, to the funding, and the operating structure. These plans are optimistic for the future of buses, and recognise their potential to decarbonise quickly, simply and cheaply.

WORLDWIDE COMMITMENTS

Around the world, countries and cities are pledging to no longer purchase diesel buses. Back in 2017, 36 cities pledged to end the purchase of diesel buses by 2025, through the C40 Cities Green and Healthy Streets Declaration[25]. In 2019, Denmark succeeded in making over three-quarters of new bus registrations for zero-emission vehicles. But outside of Denmark, Luxembourg and the Netherlands, no other country has achieved more than 30 percent of new bus registrations for zero emission vehicles that year[26]. There is a considerable way to go to meet some of the bold commitments that have been made.

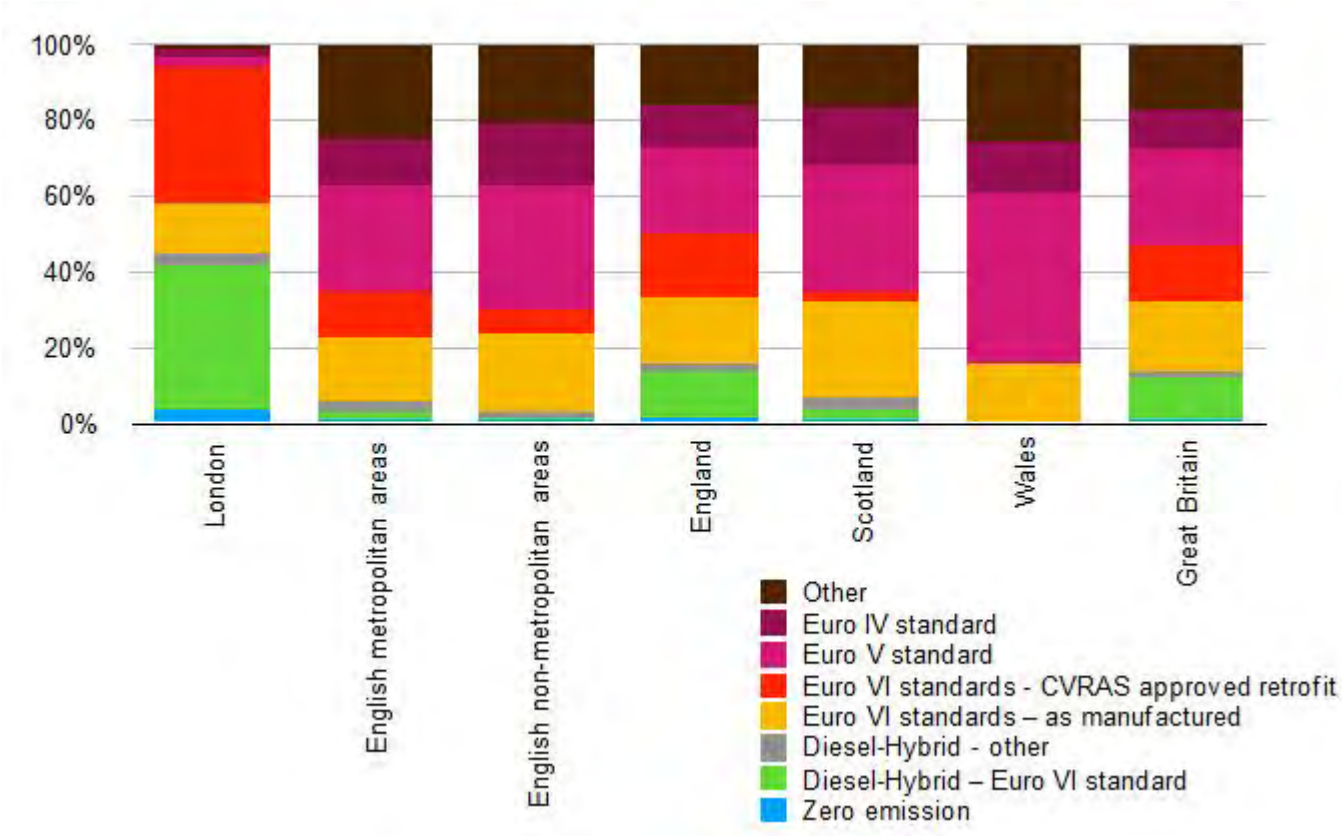
The UK Government has pledged to deliver 4,000 buses by the end of 2024, but to date there has only been enough funding to deliver 900, and currently only 50 are on the road. The Confederation of Passenger Transport believes that the current pace that buses are being rolled out is simply not fast enough and jeopardises the UK's legally-binding target of net zero emissions by 2050[27].

EXISTING DIESEL FLEETS

Government, local authorities, and bus operators must now find ways to honour their commitments to reaching net zero and achieving a fully electric fleet.

Diesel buses are classified according to their European Emission standard. This was intended to be the means by which emissions from newly manufactured buses decreased over time. The standards must be adhered to through type approval testing of new makes and models, over a specific drive cycle.

EMISSIONS STANDARDS AND FUEL TYPE OF BUSES OPERATING IN 2021, BY AREA [29]



Analysis of the current UK bus fleet shows that over half of the fleet does not meet Euro VI emission standard. From January 2021 all buses in London met Euro VI, in line with its Ultra Low Emission Zone standard[28]. However, if we look beyond London, barely a third of buses in the rest of the UK are Euro VI. Therefore, at the current rate of fleet turnover, highly polluting Euro V and Euro IV buses will be on the road for many years to come.

LIFE CYCLE IMPACTS

It is imperative that the environmental, social and economic impacts are considered across the entire life cycle of all solutions to this problem. For bus fleets this must incorporate the manufacture and operation of the vehicle in full, the full lifecycle, from well to wheel. This should also not overlook consideration of passenger capacity and range and its impact on fleets, or energy sourcing and consumption and the manufacturer of individual components. This a rapidly expanding area of research, and there are considerable variables according to the processes employed for an individual solution.

Recent evidence is that electric buses have shown up to 64-80% of savings in well-to-wheel carbon emissions when compared to their diesel equivalents[30]. Furthermore, repowering can offer clear benefits compared to purchasing a new vehicle, through the retention of the body of the vehicle itself. One study found the embedded emissions of electric buses to be as much as 40–80% of their total life cycle carbon footprint[31].

EVIDENCE

The following case studies clearly present the potential social, environmental and economic benefits of moving to fully electric bus fleets, using case studies from around the world.

CASE STUDY; YORK PARK & RIDE

Buses make a significant contribution to NOx emissions in York City Centre, where there is also high exposure to pollution, pedestrian activity, and building density. Experts from the University of Leeds undertook a detailed study to assess the economic and environmental case for investing in cleaner buses.

The study entailed detailed traffic and vehicle emissions modelling undertaken at a microscopic level. The model was combined with Cost-effectiveness of Air Pollution Reduction model (CAPTOR) toolkit to assess the impact of replacing York's 24 diesel 'Park & Ride' buses with electric buses. This measure was forecast to reduce NOx emissions by 7% resulting in health benefits of £5 million in the first year of operation and 27.6 million over a five year period.

CASE STUDY; LOW EMISSION BUS ZONES, LONDON

In 2016, buses contributed about 17% of London's NOx transport emissions. TfL had identified several areas where NO_2 concentrations were not meeting the EU limit values, and in some cases more than twice the legal limits. Analysis by TfL found that in a number of these areas, buses were contributing over 40% of transport emissions. These locations were also identified as having a high population and high number of pedestrians, further elevating the population exposure in these locations. This analysis clearly demonstrated the disproportionate benefits for public health that can be achieved by targeted improvements to buses.

TfL upgraded all the diesel buses passing through these areas to the highest available emission standard (Euro VI), reducing emissions between 87 and 92 per cent. Greater benefits could be achieved through electrification.

CASE STUDY; BENEFITS OF BUS ELECTRIFICATION IN QUITO, ECUADOR

Quito's air pollution is responsible for around 380 deaths per year, and $PM_{2.5}$ levels are 1.5 times greater than WHO guidelines.

The municipality are working with their 60 bus operators on an electrification programme to target bus emissions, which are responsible for 31% pf $PM_{2.5}$ emissions in the city. Every year until 2025 each bus operator will replace at least one bus per year with a zero emission model. From 2025 they hope this replacement should be accelerated to achieve a fully zero emission fleet by 2040.

As a member of C40, the city could access their air quality toolkit to assess the impacts of this programme of bus electrification and make the case for stronger action in the air quality action plan in 2020.

The programme was found to reduce $PM_{2.5}$ across the whole city by 1.2% and as high as 11.4% in intervention areas. Each year, 6.5 premature deaths would be avoided and the population would gain 121 life years, equivalent to 3 day in life expectancy for each citizen. The measures would also avert 7.3 hospital admissions per year. These impacts would save US$4.4m in averted deaths and US$6,456 in healthcare costs.

CASE STUDY; BENEFITS OF BUS ELECTRIFICATION IN CHENNAI, SOUTHERN INDIA

Chennai's air pollution is responsible for around 8,000 deaths per year, and $PM_{2.5}$ levels are 3 times greater than WHO guidelines.

Chennai is currently home to 7.5 million people, with a transport system serves around 5.5. million passengers every day. The city plan to purchase 2,000 electric buses and upgrade a further 4,000 to less polluting buses.

As a member of C40, the city could access their air quality toolkit to assess the impacts of this programme of bus electrification and make the case for stronger action in the air quality action plan in 2020.

The bus improvements were found to reduce $PM_{2.5}$ across the whole city by 3% and as high as 8% in intervention areas. Each year, 77 premature deaths would be avoided and the population would gain 860 life years, equivalent to 5 day in life expectancy for each citizen. The measures would also avert 82 hospital admissions per year. These impacts would save 401 million rupees in averted deaths and 7.2 million rupees in healthcare costs.

KEY ENVIRONMENTAL AND SOCIAL BENEFITS OF ACCELERATING TO A FULLY ELECTRIC BUS FLEET

This paper presents an unequivocal case for transitioning to zero emission bus fleets. There is strong evidence of a multitude of benefits for society, government and the environment. The question for authorities, operators, passengers and the public is no longer why, but how, and when.

Diesel vehicles are impacting our society and environment now; years of life are being lost, hospital admissions, climate change impacts and social inequalities continue to increase. The sooner operators can transition their fleets to zero-emission, the better for the planet and society.

For operators of existing diesel fleets who cannot afford to replace their entire fleet, or do not want to delay for natural fleet turnover, repowering can offer an achievable and efficient route to zero emissions. This would allow these operators to benefit from the lower running costs and significant environmental benefits of zero emission vehicles sooner. Repowering offers a relatively low cost solution for exceeding low emission zone targets, accessing current and future financial incentives for operating low carbon vehicles, and protecting investment in the current bus fleets.

Modernising and improving the efficiency of the bus fleet through repowering, will protect its future role in providing public transport and improve environmental and social justice for those who are impacted by emissions from buses, and the communities that rely on their services.

Repowering can significantly reduce the capital cost of reaching zero emission fleets, and combined with and reduced operating costs, can facilitate greater investment in charging and decarbonised grid infrastructure which is essential to the transition to electric fleets. Furthermore repowering can save significant embedded carbon emissions when compared to new electric fleets.

The environmental, social and cost benefits of transitioning to zero emission bus fleets are irrefutable. Repowering can sit alongside to new zero emission bus manufacture to further capitalise on these benefits, and accelerate world-wide transition to achieving clean air, quiet towns and cities, and net zero.

> "Fossil fuel use, especially diesel, must be removed from the transport system as quickly as possible. With public transport budgets tightening it makes sense to retrofit existing diesel bus fleets to electric and improve air quality in our towns and cities in the shortest time possible."
>
> Professor Frank Kelly
> Battcock Chair of Community Health and Policy, Imperial College London

> "Ditching diesel vehicles and speeding up the rollout of zero-emission bus fleets will prevent more lives from being lost or needlessly harmed."
>
> Oliver Lord
> Head of Policy and Campaigns for the Environmental Defence Fund Europe (2021)

> "Accelerating the shift to zero emission buses in London will encourage more people to use the bus and support the Mayor's mission to improve the capital's toxic air and tackle the climate emergency."
>
> Chris Remnant
> Engineering Director, Abellio London Bus

BIBLIOGRAPHY

[1] www.london.gov.uk/press-releases/mayoral/mayor-host-zero-emission-bus-summit-at-city-hall

[2] DfT National Bus Strategy: Bus Back Better, 2021
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/980227/DfT-Bus-Back-Better-national-bus-strategy-for-England.pdf

[3] Zero Emission Vehicles Transition Council: 2022 action plan Published 10 November 2021

[4] Department for Transport; Transport and Environment Statistics 2021 Annual report

[5] WHO Ambient (outdoor) air pollution factsheet, 22 September 2021

[6] COMEAP The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom. A report by the Committee on the Medical Effects of Air Pollutants. 2010

[7] 25 microgrammes of PM2.5 per cubic metre of air & 40 microgrammes of NO2 per cubic metre of air

[8] WHO Ambient (outdoor) air pollution factsheet, 22 September 2021

[9] PM2.5 in London: Roadmap to meeting World Health Organization guidelines by 2030, October 2019.
www.london.gov.uk/sites/default/files/pm2.5_in_london_october19.pdf

[10] Air Quality 2016 - 2020, released by GLA in October 2020, using modelling by Kings College London
https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/air-quality-london-2016-2020

[11] https://data.london.gov.uk/dataset/london-atmospheric-emissions-inventory--laei--2016

[12] https://iosh.com/diesel-exhaust-exposure

[13] Personal exposures to traffic-related air pollution in three Canadian bus transit systems: the Urban Transportation Exposure Study. Published: 16 July 2020. Keith Van Ryswyk, Greg J. Evans, Ryan Kulka, Liu Sun, Kelly Sabaliauskas, Mathieu Rouleau, Angelos T. Anastasopolos, Lance Wallace & Scott Weichenthal
Journal of Exposure Science & Environmental Epidemiology volume 31, pages 628–640

[14] Long-term trends in urban NO2 concentrations and associated paediatric asthma incidence: estimates from global datasets, Susan C Anenberg, PhD, Arash Mohegh PhD et al. The Lancet, Volume 6, Issue1, January 2022.

[15] Air pollution and family related determinants of asthma onset and persistent wheezing in children: nationwide case- control study. British Medical Journal BMJ 2020;370:m2791

[16] Xu, D., Chen, Y., Wu, L. et al. Acute effects of ambient PM2.5 on lung function among schoolchildren. Sci Rep 10, 4061 (2020). https://doi.org/10.1038/s41598-020-61003-4

[17] https://www.asthma.org.uk/about/media/news/schools-surrounded-by-pollution/

[18] https://statistics.blf.org.uk/lung-disease-uk-big-picture

[19] Emissions vs Exposure: Increasing injustice from road traffic-related air pollution in the UK. Jo Barnes & Jim Longhurst. Transport Research Part D: Transport and Environment Volume 73, August 2019

[20] Defra, The Air Quality Strategy for England, Scotland, Wales and Northern Ireland, July 2007

[21] https://www.gov.uk/guidance/noise-pollution-economic-analysis

[22] the Stern Review Report on the Economics of Climate Change https://webarchive.nationalarchives.gov.uk/ukgwa/20100407172811/https:/www.hm-treasury.gov.uk/stern_review_report.htm

BIBLIOGRAPHY

[23] www.gov.uk/government/publications/transport-decarbonisation-plan

[24] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/980227/DfT-Bus-Back-Better-national-bus-strategy-for-England.pdf

[25] https://www.c40.org/what-we-do/scaling-up-climate-action/transportation/green-and-healthy-streets/

[26] https://www.transportenvironment.org/discover/denmark-luxembourg-netherlands-lead-way-emissions-free-buses/

[27] https://www.cpt-uk.org/blogs/why-we-must-speed-up-the-zero-emission-bus-rollout/

[28] https://tfl.gov.uk/info-for/media/press-releases/2021/january/london-s-buses-now-meet-ulez-emissions-standards-across-the-entire-city

[29] BUS0609: Percentage of buses used as Public Service Vehicles by emissions standards and fuel type by metropolitan area, status and country: Great Britain (financial year ending 31 March 2021). https://www.gov.uk/ government/statistical-data-sets

[30] Transport Scotland. Zero Emission Bus Financing Ideas Pack March 2021

[31] The Carbon Footprint of Electrified City Buses: A Case Study in Trondheim, Norway. Kristoffer W. Lie, Trym A. Synnevåg, Jacob J. Lamb and Kristian M. Lien (published January 2021)