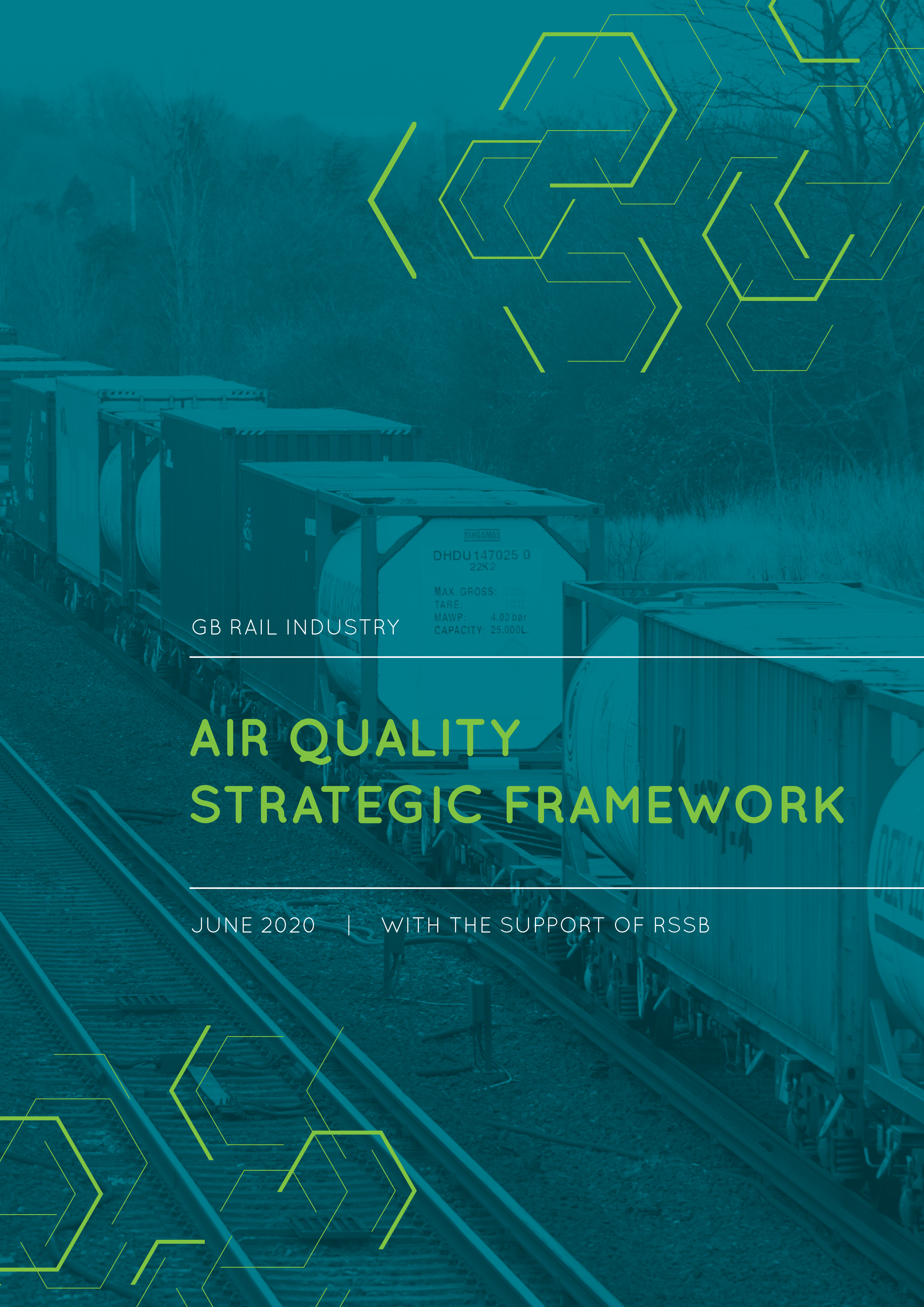

GB RAIL INDUSTRY

AIR QUALITY STRATEGIC FRAMEWORK

JUNE 2020 | WITH THE SUPPORT OF RSSB

Purpose and Vision

This document sets out the initial stage of an industry-wide strategic framework coordinated through RSSB. It is backed by all participating companies and rail bodies including:

- Abellio UK
- Angel Trains
- Arriva Trains UK
- Beacon Rail
- Eversholt
- First Group
- HS2
- Network Rail
- Porterbrook
- Rail Delivery Group
- Rail Freight Group
- Freight operating companies
- Rail Safety and Standards Board
- Railway Industry Association
- Transport Scotland

Through the strategic framework provided in this document, the GB rail industry will strive to achieve its vision of:

'A rail network with a minimal impact on local air quality.'

Air pollution is a major public health risk ranking alongside cancer, heart disease and obesity. It poses the single greatest environmental risk to human health. This document brings together current industry led initiatives to improve air quality and reduce emissions which impact human health. It provides recommendations on how to improve air quality, prioritises initiatives and sets the basis for an ongoing commitment to make rail the cleanest form of transport in the UK. As well as reducing overall emissions, the GB rail industry is committed to identifying and reducing problematic concentrations in certain locations where they may significantly impact health.

An initial research programme will significantly improve the understanding of rail's overall impact on air quality. Future updates to the Air Quality Strategic Framework will log progress of this work and highlight new initiatives and targets as the knowledge base grows and the GB rail industry moves forward.

Scope

The Air Quality Strategic Framework covers all pollutant emissions from the GB rail industry which have proven to impact human health. The document covers the entire rail network of England, Wales and Scotland and includes station platforms, concourses, depots, offices and line side locations. Sub-contractors to major rail organisations are also included. Underground rail, light rapid transit systems and trams are outside the scope of this document along with heritage railways and heritage locomotives.

All sources of these emissions have been considered and prioritised, including but not limited to:

- exhaust emissions from traction
- stationary emissions from rail infrastructure—such as power generators
- non-exhaust emissions from traction—such as brakes, wheel abrasion, pantograph or wire abrasion, interaction between trains and the third rail
- on road vehicle fleets directly owned or leased by the rail industry
- on road vehicles whose operation can be influenced by the rail industry—such as taxi and bus routing, parking, and so on
- mobile emissions from infrastructure maintenance and construction operations, road rail vehicles and 'yellow machines'.

The initial version of the strategy focuses on exhaust sources from traction as these are the biggest contributors to nitrogen oxides (NOx) and particulate matter (PM) emissions. Significant evidence links exposure to these pollutants to negative impacts on health, especially in busy locations such as stations. Future iterations of the strategic framework will cover the areas listed above in more detail, as well as the impact of certain pollutants that effect vegetation.

Distinction between air quality and decarbonisation

Decarbonisation is concerned with reducing the emissions of gaseous pollutants that contribute to climate change. These are commonly described as 'greenhouse gases' due to their ability to trap heat in the Earth's atmosphere. Climate change is linked to overall levels of greenhouse gases in the Earth's atmosphere and therefore where these emissions occur is less important. Two of the most common greenhouse gases are carbon dioxide (CO_2) and methane.

Although many mitigation measures are effective for reducing greenhouse gases and improving air quality, short-term and location specific air quality mitigation measures are also needed.

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Increasing our understanding 30

Background

Air Quality – An Introduction

Air pollution is a major public health risk, ranking alongside cancer, heart disease and obesity, and poses the single greatest environmental risk to human health (Defra, 2019). The Department of Health and Social Care's advisory Committee on the Medical Effects of Air Pollutants (COMEAP, 2018) estimated that long-term exposure to air pollution shortens lifespans and is equivalent to an additional 28,000 to 36,000 deaths a year.

Individuals such as the elderly, infants, pregnant women and their unborn children may be more vulnerable to the health impacts of air pollution. As a result, some locations such as schools and hospitals tend to be more sensitive to poor air quality.

Figure 1 – Illustration

The health effects of air pollution are locally concentrated and heavily depends on where the pollution is emitted, its residence time in the local atmosphere, and its proximity to the immediate population. For example, the impact of air pollution near a busy urban road may be increased by the density of buildings, which reduces the dispersion and increases residency time. Therefore, pollutants emitted in rural areas tend to have less impact on health than emissions in heavily populated urban areas.

Two widespread pollutants with evidence linking exposure to health effects are nitrogen oxides (NOx) and particulate matter (PM).

“DESPITE ITS OVERALL LOW CONTRIBUTION TO NATIONAL NOx AND PM EMISSIONS, IT IS IMPORTANT TO RECOGNISE THAT RAIL’S CONTRIBUTION WILL BE SIGNIFICANTLY HIGHER IN CERTAIN AREAS.”

Nitrogen Oxides

NOx gases are mostly emitted from the combustion of fossil fuels, with the biggest source in transport being diesel engines. The majority of NOx emitted from fossil fuel combustion is in the form of nitric oxide (NO). When NO reacts with other gases present in the air, it can form nitrogen dioxide (NO_2), which is more harmful to health. NO_2 can cause inflammation of the airways and exacerbate symptoms of those suffering from heart or lung conditions. NO_2 is also a precursor to ozone gas, which also causes inflammation of the airways.

In the UK, the National Atmospheric Emissions Inventory (NAEI) shows the transport sector as the single biggest contributor to NOx emissions, contributing to 47% of the total (NAEI, 2018). Other major UK sources of NOx include the energy industries which contribute 20% and the manufacturing and construction industries which contribute 17%. Road transport contributes to 33% of national NOx emissions, although in roadside locations this can be up to 80% illustrating the magnitude of local impacts. Within the transport sector itself, land-based NOx emissions are dominated by cars, LGVs and HGVs (Figure 2).

Particulate Matter

PM is a mixture of solid and liquid particles—derived from natural and man-made sources—suspended in the air. Natural sources include pollen, spray from the sea, and dust from deserts. Man-made sources of PM include smoke from domestic fires, cooking, soot from vehicle exhausts, and abrasive sources from tyres and brake wear.

PM is commonly classed as PM_{10} (particles smaller than 10μm in diameter) and $PM_{2.5}$ (particles smaller than 2.5 μm in diameter). PM_{10} particles are approximately 5 times smaller than the width of a human hair whereas $PM_{2.5}$ particles are roughly 20 times smaller. $PM_{2.5}$ particles can travel deep into human lungs and even enter the bloodstream, where they can be deposited in internal organs, increasing the risk of cancer and brain diseases. The majority of $PM_{2.5}$ in the UK (43%) originates from burning domestic wood and coal, with manufacturing industries and construction contributing 18%. Overall, transport contributes 15% to the amount of $PM_{2.5}$ in the UK, and road transport contributes 12% (NAEI, 2018).

The UK transport $PM_{2.5}$ emissions are presented in Figure 3, which illustrates the scale of abrasive or ‘non-exhaust’ emissions from road transport. These outweigh exhaust sources by approximately double and will become more significant as more zero emission vehicles are adopted.

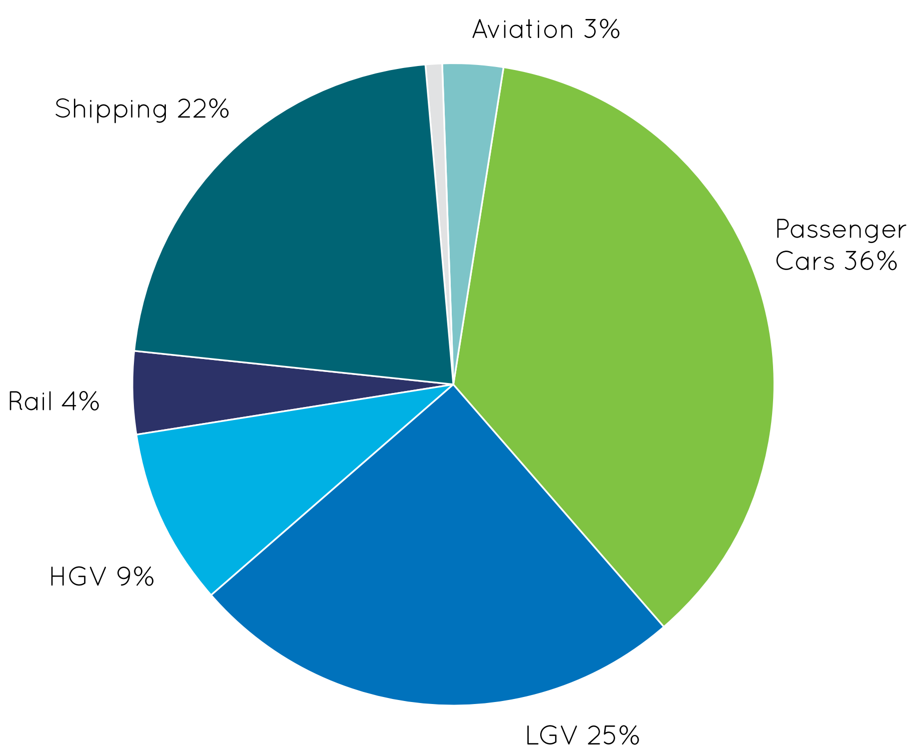

Figure 2 – UK transport NOx emissions split by source (NAEI, 2018)

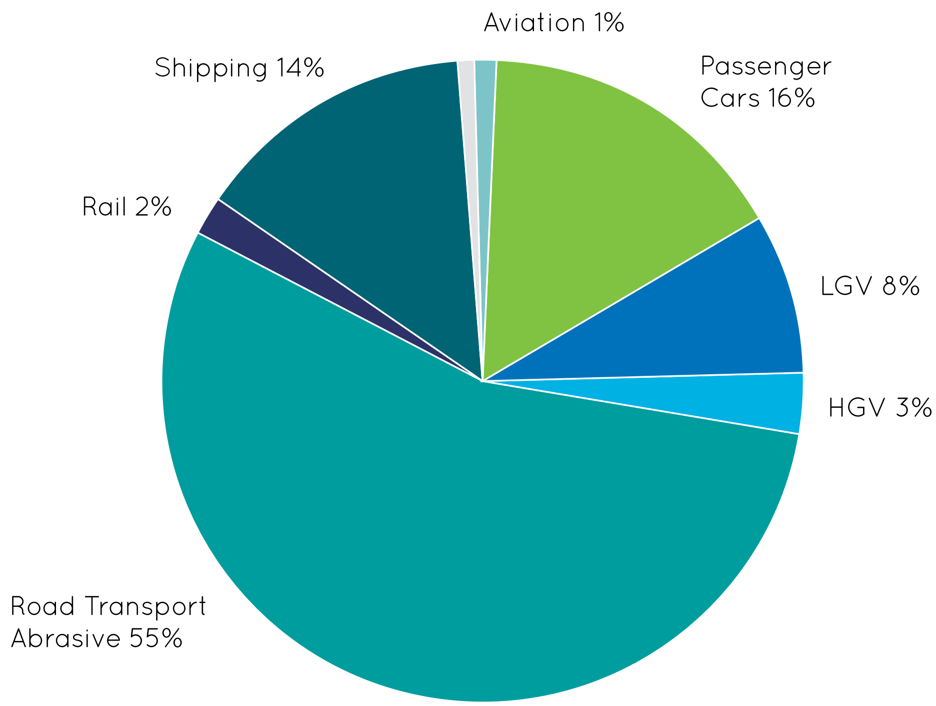

Figure 3 – UK transport $PM_{2.5}$ emissions split by source (NAEI, 2018)

- Aviation
- HGV
- Rail
- Passenger Cars
- Shipping
- LGV
- Road Transport Abrasive
- Other

Policy Response

UK Clean Air Strategy

In 2019, the Department for Environment, Food and Rural Affairs (Defra) produced the *Clean Air Strategy 2019*, which plays a key part in delivering the government's 25 Year Environment Plan. The aim of the strategy is to 'drive down the national emissions of pollutants, reducing background pollution, and minimising human exposure to harmful concentrations of pollution'. The strategy states that 'the government is committed to... reduce emissions from rail and reduce passenger and worker exposure to air pollution'. Scotland has an equivalent Cleaner Air for Scotland strategy and Wales launched the Clean Air Plan for Wales in 2019.

The UK has signed up to ambitious emissions reduction commitments as part of the revised National Emission Ceilings Directive (NECD). This directive sets national commitments for EU Member States that cover five important air pollutants: NOx, $PM_{2.5}$, non-methane volatile organic compounds (NMVOC), sulphur dioxide (SO_2) and ammonia (NH3). Defra's *Clean Air Strategy* describes how the UK plans to reduce emissions in line with these targets.

Air Quality Management Areas

Since December 1997, UK local authorities have been obliged to continually review and assess air quality as part of their ongoing responsibilities for health and the environment. This involves measuring air pollution and predicting future changes. The aim is to ensure that national air quality objectives—which are broadly in line with EU directive 2008/50/EC—will be achieved throughout the UK by the specified deadlines. The EU directive 2008/50/EC standards for PM and NOx are shown in the appendix.

If a local authority identifies areas where the objectives are not likely to be achieved, it must declare an Air Quality Management Area (AQMA). This area can be one or two streets or borough wide, Figure 4 provides an example of AQMAs for NO_2 in London and Edinburgh. See the appendix for further information on air quality legislation in the UK.

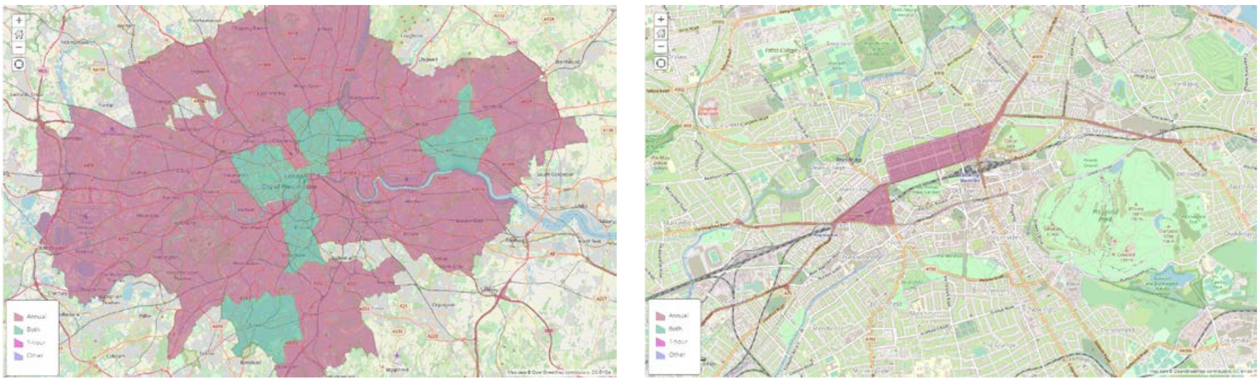

Figure 4 – AQMAs for NO_2 in London and Edinburgh (Defra, 2019)

Clean Air Zones

In the last 30 years, stricter European standards have delivered reductions in engine and exhaust emissions in the road sector. This has resulted in an approximate 80% reduction in NOx emissions. Further significant improvements are forecast for larger towns and cities—such as Birmingham, Leeds, Nottingham, Derby and Southampton—due to the introduction of Clean Air Zones (CAZs). A CAZ defines an area where targeted action is being taken to deliver immediate improvements to air quality. These can range from charging drivers of more polluting vehicles to enter the zone to banning diesel vehicles from city centres. Vehicle types covered by the zone can vary from city to city depending on their specific emissions problems and transport infrastructure which are categorised into four classes, A to D. Class A zones include buses, coaches, taxis and private hire vehicles (PHVs) whereas a Class D zone includes buses, coaches, taxis, PHVs, HGVs, LGVs and cars.

Likewise, the Scottish Government has committed to introducing low emission zones (LEZ) into Scotland's four biggest cities: Glasgow, Edinburgh, Aberdeen and Dundee. LEZs operate a similar charging mechanism to CAZs and may be introduced into other AQMAs in Scotland by 2023 where evidence shows they are the appropriate option to improve air quality.

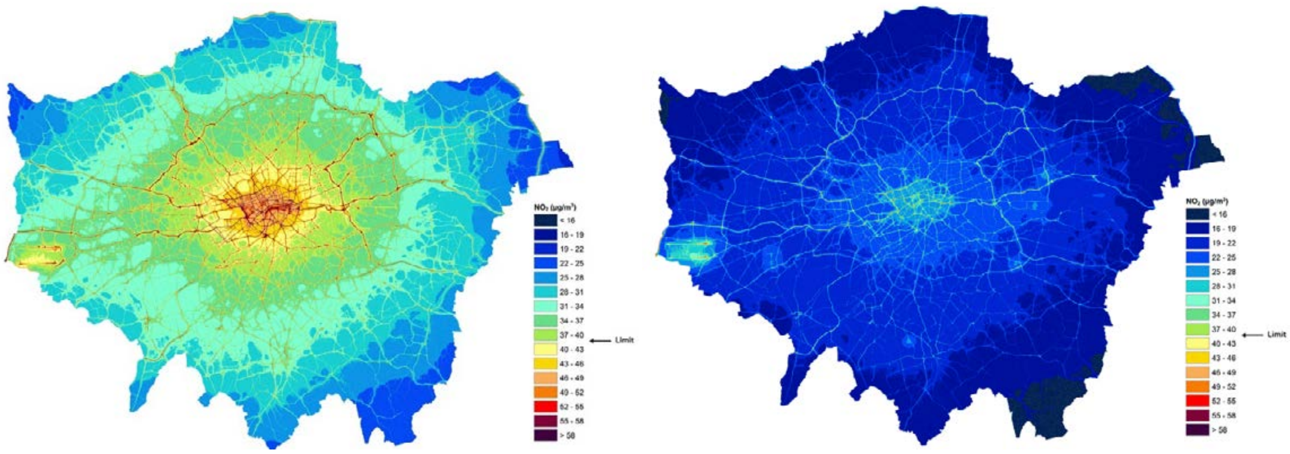

Figure 5 – Projected NOx emissions from 2016 to 2025 across London

In April 2019, the Ultra Low Emissions Zone (ULEZ) was introduced in London. The ULEZ operates 24 hours per day and 365 days per year and charges drivers of older, more polluting vehicles that enter the Central London zone. Figure 5 shows a forecast of NOx emissions across London before and after the introduction of the ULEZ. From 2021 the ULEZ will expand to the North and South Circular roads. Other CAZs are planned or are underway in various UK cities in which similar air quality improvements are expected to be seen. Rail is currently excluded from AQMAs and CAZs but recognises the need to understand its impacts and how it can contribute to improve air quality.

“RAIL RECOGNISES THE NEED TO UNDERSTAND ITS IMPACTS AND HOW IT CAN CONTRIBUTE TO IMPROVE AIR QUALITY.”

Road Vehicle Technology Improvements

In addition to the improvements brought about by CAZs, further reductions in road sector emissions are likely as the number of electric vehicles with zero tailpipe emissions increases. In the future autonomous vehicles could bring about additional improvements through smoother driving patterns, more efficient (shorter) journeys and potentially lower overall vehicle numbers on the road. Some experts have, however, suggested that the introduction of such vehicles could increase demand and therefore usage, negating any such improvements.

Public Awareness

In recent years, media coverage and public awareness of air pollution has increased significantly.

Higher customer expectations, increased awareness of air quality, and wider environmental issues are influencing vehicle purchasing decisions, particularly around diesel vehicles. The independent global testing and data specialist, Emissions Analytics, has produced the EQUA index which provides an independent, third-party rating of a vehicle’s emissions. This has been adopted by the Greater London Authority (GLA) in its Cleaner Vehicle Checker to provide guidance on real world emissions as well as ULEZ compliance (GLA, 2019). Defra also uses the EQUA Index to set minimum standards for fleet vehicle purchases (Harris, 2018).

Research suggests that greater awareness of air quality and climate change issues, particularly among young people, has reduced the demand for private car journeys. In 2019, new car registrations in the UK fell for the third year running, according to the Society of Motor Manufacturers and Traders (SMMT). In February 2020, sales of new diesel vehicles were 27% lower than the same month in 2019 whereas sales of electric vehicles increased by 243% (SMMT, 2020).

“IN RECENT YEARS, MEDIA COVERAGE AND PUBLIC AWARENESS OF AIR POLLUTION HAS INCREASED SIGNIFICANTLY.”

Where are we now?

The GB Rail Industry

The rail network is a vital asset for Great Britain providing a safe, efficient and sustainable transport option which supports commuters, industries and communities. Furthermore, the rail sector is a major employer in the UK, currently employing about 240,000 people (ORR, 2019).

Passenger Rail

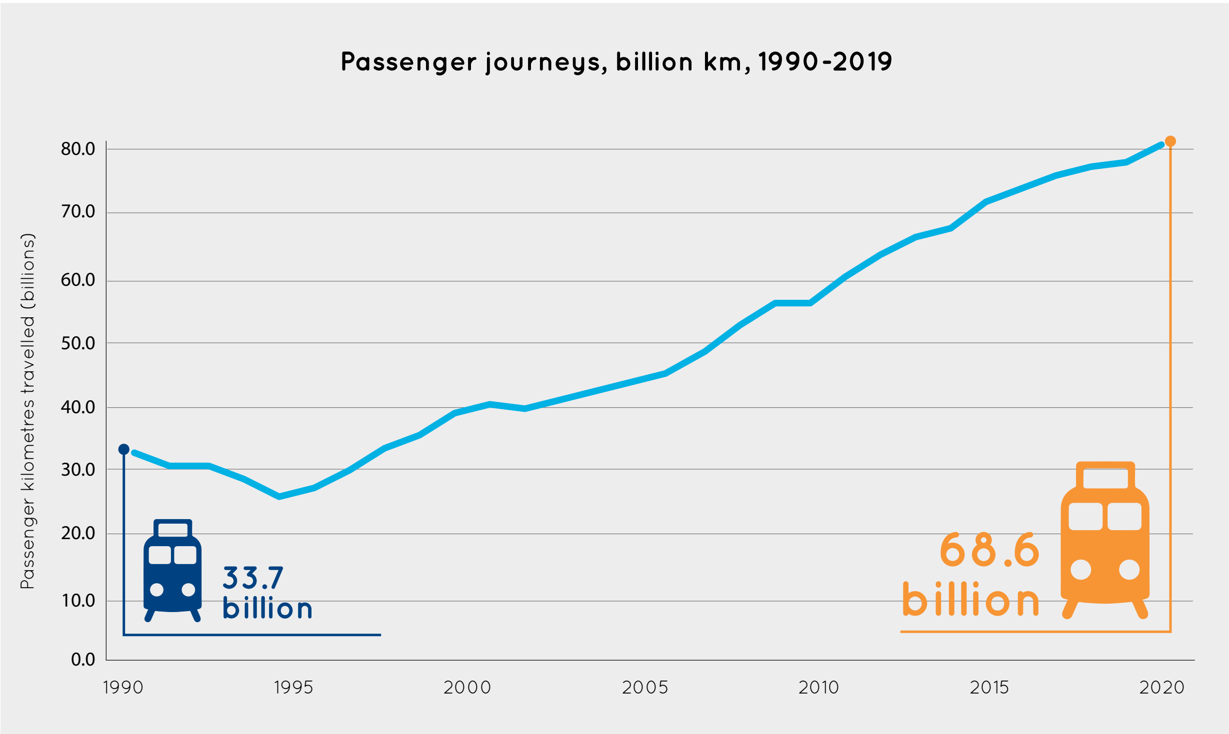

Figure 6 – Rail passenger kilometres by year (ORR, 2020)

Since 1990, passenger journeys have doubled from 33.7 billion passenger km per year to 68.6 billion passenger km per year in 2017 (Figure 6). Moreover, since 1997, rail has increased its modal share of travel by 4%, whereas domestic air travel has remained broadly flat and road travel has fallen by 4% as shown in Figure 7. Great Britain's shift to rail is one of the biggest seen across Europe during this time.

“ALTHOUGH RAIL’S OVERALL CONTRIBUTION IS SMALL ON A NATIONAL SCALE, IT IS UNCLEAR HOW THIS VARIES LOCALLY.”

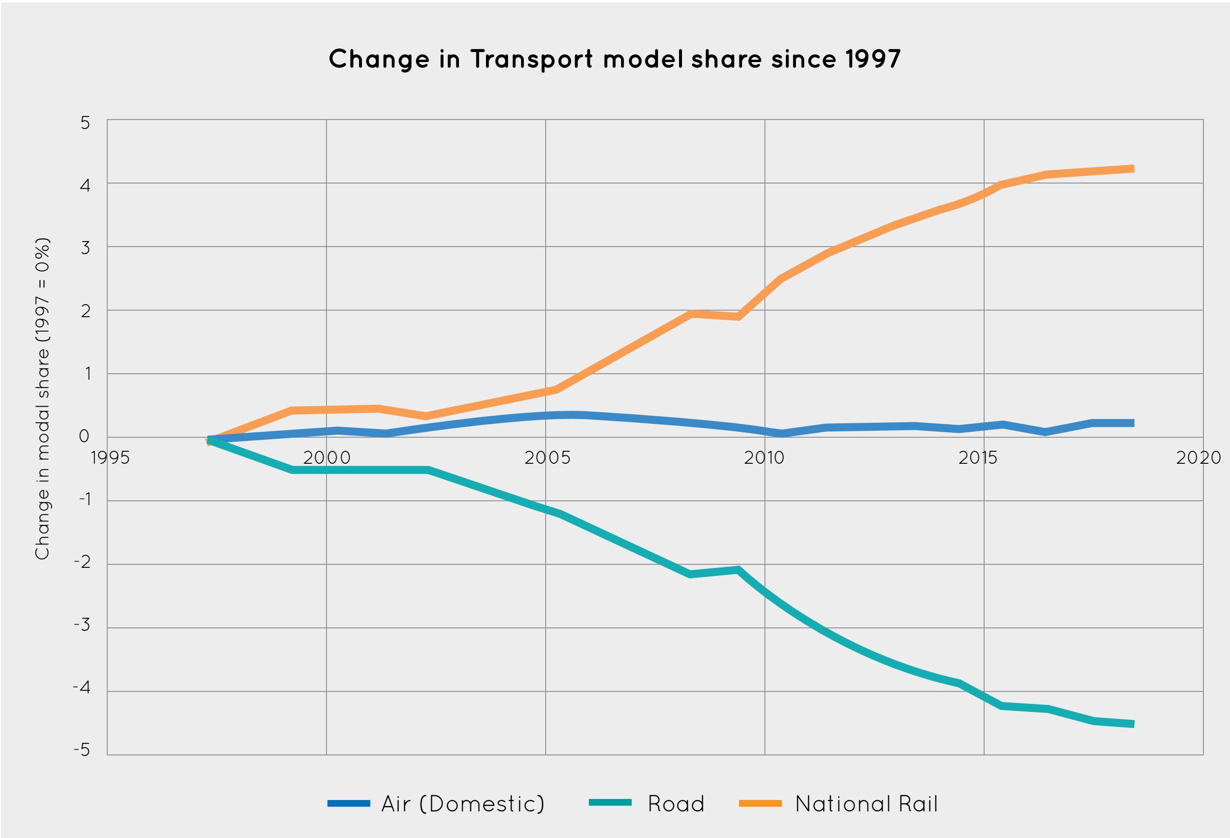

Figure 7 – Change in passenger modal share in UK (DfT, 2019)

Rail Freight

As well as providing an important service for passengers, the GB rail network also plays a vital role in transporting goods between ports, industrial locations, towns and cities. Traditionally, coal was the predominant commodity transported by rail, but this has declined since the introduction of a policy to phase out coal-based energy production in the UK by 2025.

However, over the last decade construction and domestic intermodal (container) freight have seen increases of 50% and 37% respectively (ORR, 2019).
Major construction and infrastructure projects, for example, would struggle to be completed on time without the ability to move large quantities of materials into urban centres reliably while also limiting road congestion.

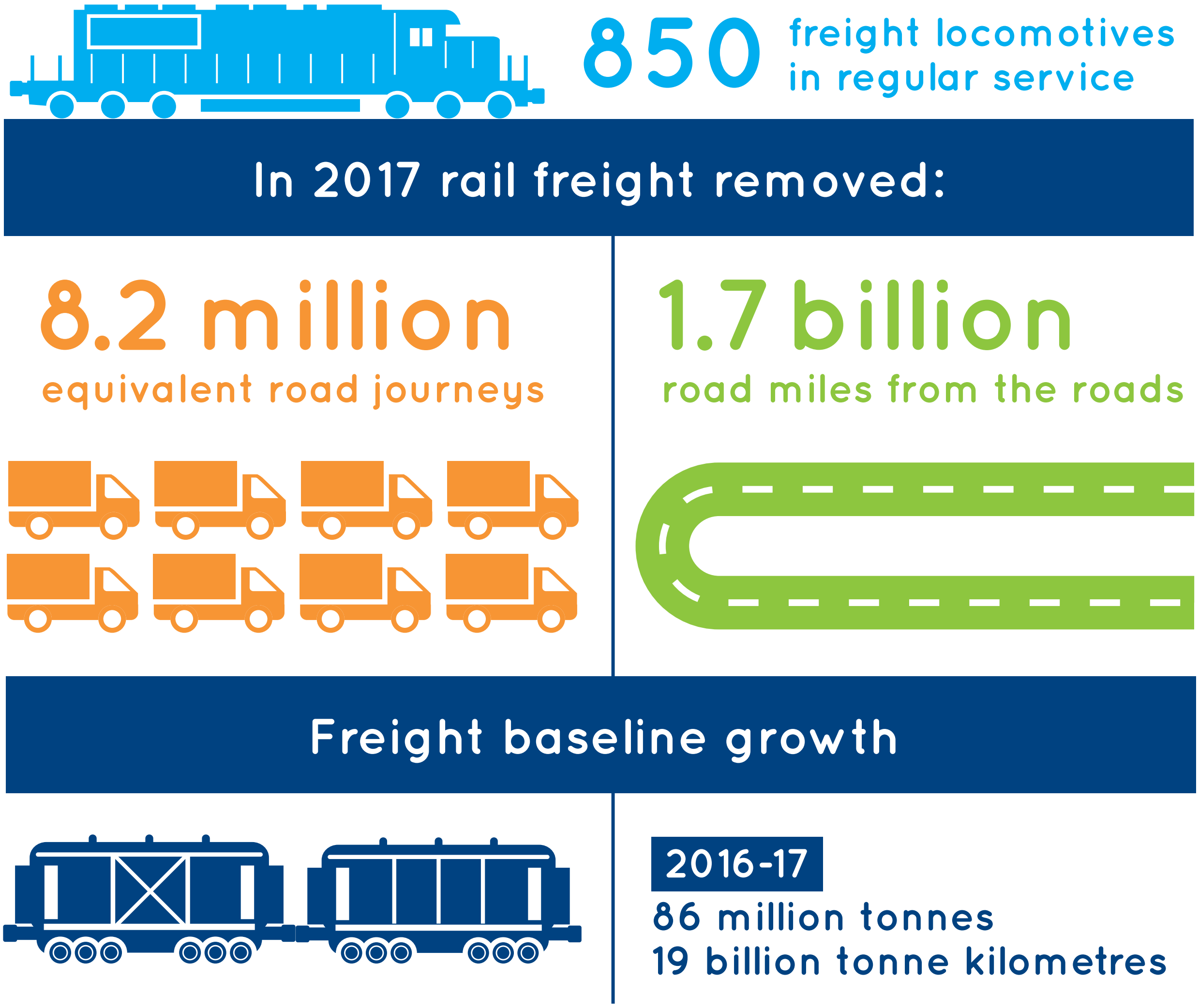

Figure 8 – Freight industry statistics (Rail Industry Decarbonisation Taskforce, 2019)

The Williams Review

Established in September 2018, the Williams Rail Review examined the structure of the rail industry and the way passenger rail services are delivered. The review's findings and recommendations are expected to be published in a government white paper in 2020. The development of any new industry structure will be taken into consideration to ensure the recommendations of the review and the end vision of the strategic framework can be realised. On the publication of the review findings, the process will start to set air quality targets and establish clearer roles and responsibilities.

Air Quality Impacts from Rail – Emissions Sources

Exhaust Emissions from Traction

Traction emissions occur across a wide range of locations from rural areas to heavily populated urban areas and stations where they can affect staff, passengers, and the public. As previously explained, the majority of transport-derived NOx emissions result from diesel engines which are in widespread use in the GB rail industry. Currently, 28% of rolling stock is diesel powered (DfT, 2018) and 622 million litres of diesel was used to run the rail network in 2018-19 (ORR, 2019).
Diesel passenger trains can be split into two main categories; diesel locomotive trains such as the Class 43 (HST) and Class 68 and diesel multiple units (DMUs) such as Sprinters and Turbostars which, in most cases, have a smaller diesel engine under each carriage.

In the rail freight sector, about 90% of traction is diesel powered. One reason for this is that freight trains need to run across the entire rail network—only 38% of which is electrified (ORR, 2019). Electric locomotives can only operate on routes which are electrified from beginning to end, including the depots. Other than electric traction, diesel is currently the only fuel which has the energy density needed to pull loaded freight trains, which can weigh up to 4,000 tonnes.

A factor specific to GB rail is the narrower GB rail gauge. This means the packaging of alternative traction options such as batteries or alternative fuels within the allowable space on a GB freight locomotive is more challenging than in other countries.

It is estimated that approximately 40% of all diesel engines used for traction on the GB railway are not certified to any emissions standard.

Exhaust Emissions from Other Sources

Other than trains, there are various other sources of diesel exhaust emissions on the GB rail network. For example, emergency generators are used to provide backup power for signalling and other equipment.

Diesel engines are also used widely in infrastructure maintenance operations to power machinery needed to maintain rail infrastructure and keep the network running. Some examples of such machinery usage includes:

- maintaining and renewing the tracks
- transporting materials for maintenance work
- maintaining and installing overhead line equipment
- inspecting and clearing drainage
- maintenance support.

Maintenance machinery tends to be used in specific locations for short periods of time. Vehicles can either be built specifically for use on the rail network, or they may be road derived—such as cranes and excavators—adapted by fitting retractable rail wheels so the machinery can alternate between road and rail use.

The GB rail industry operates many road vehicles to support rail operations, and their emissions need to be considered, as do emissions from road vehicles operated by non-rail organisations working in rail locations such as taxis, buses and delivery vehicles .

Non-Exhaust or Abrasive Emissions

As previously described, abrasive emissions from tyre and brake wear on road vehicles are estimated to be a significant source of PM emissions and are forecast to grow in significance as tailpipe exhaust emissions reduce. Similarly, PM emissions from trains are not limited to exhaust emissions from the engine, but also result from abrasion or mechanical wear sources. These include the interaction between wheels and rails, wheels and brakes, pantographs and overhead lines, and train shoes and conductor rails. These emissions are produced by both diesel and electric trains, but little information currently exists about the relative contribution of abrasive emissions from the rail sector.

Electrically regenerative braking is becoming more widespread in rail. In the years to come, this technology may significantly reduce or eliminate abrasive emissions associated with mechanical braking systems and provide significant energy efficiency improvements.

Although total PM emissions from rail may be significant in terms of total mass of PM, the relative size of these particles and how far they are dispersed away from the source is unknown, therefore the health effects are unclear. As will be described later, RSSB is carrying out research to characterise and understand these emissions.

Air Quality Impacts from Rail

The National Picture

According to the NAEI 2018, GB rail is responsible for approximately 2% of national NOx emissions and around 4% of transport NOx emissions. Rail contributes less than 0.5% of national PM_{10} and $PM_{2.5}$ emissions and around 2% of transport PM_{10} and $PM_{2.5}$ emissions. Although rail's overall contribution is small on a national scale, it is unclear how this varies locally.

Combining NAEI emissions data with passenger rail usage data indicates that NOx emissions per passenger, for example, have approximately halved since 1990.
As will be detailed later in this document, the figures used to derive the NAEI emissions estimates need to be updated, so it is expected that these figures will drop further.

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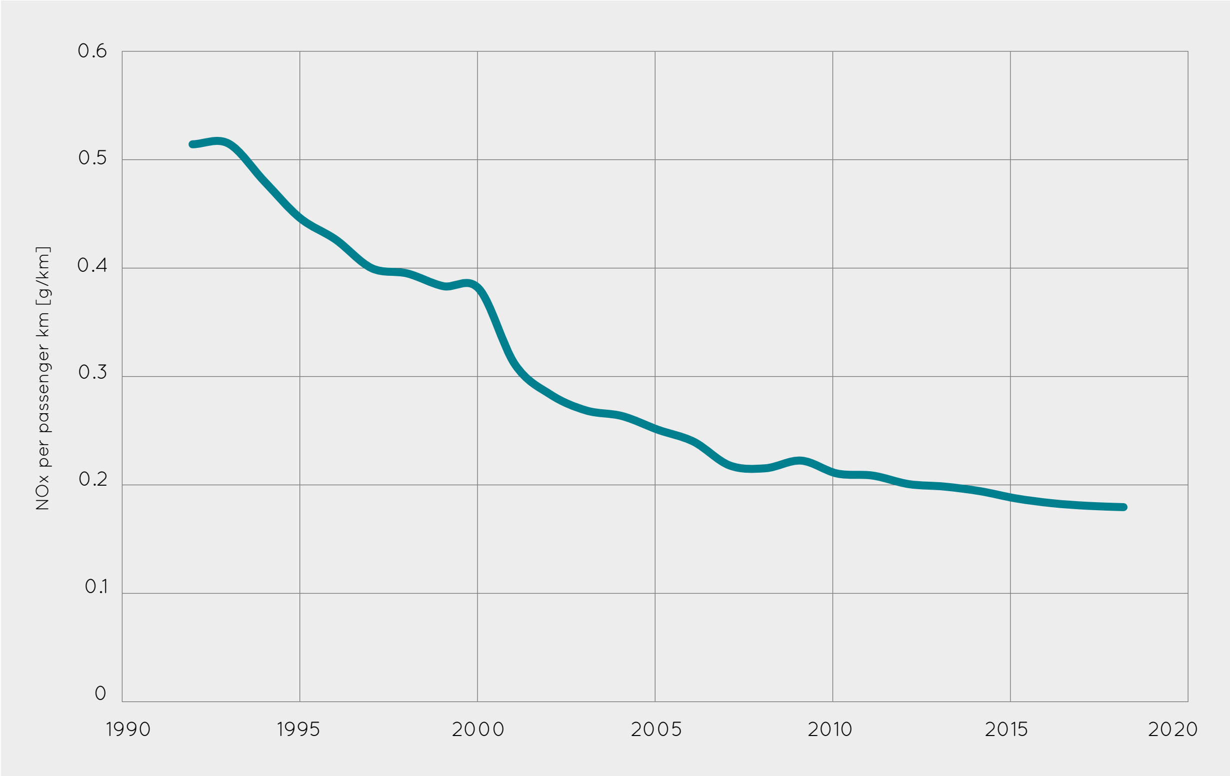

Figure 9 – NOx emissions per passenger kilometre (NAEI, 2018) (ORR, Passenger rail usage, 2019)

Air Quality in Stations

RSSB has recently funded research to improve the understanding on air quality in stations (Research into Air Quality in Enclosed Stations (T1122) (RSSB, 2019)). This study, carried out by King's College London, performed detailed measurements of PM and NOx concentrations over several months using state-of-the-art equipment within Edinburgh Waverley and London King's Cross stations. The project included air flow and ventilation assessments to explain the variations in measured pollutants at different locations within each station.

Figure 10 – King's College specialist measurement trailer in Edinburgh Waverley Station

At Edinburgh Waverley, the concentrations of PM and NOx were, on average, greater inside the station compared to measurements directly outside in the street and in the surrounding urban areas. These elevated concentrations were due to internal pollution sources—principally the emissions from diesel trains but also from other sources like food outlets. The levels of recorded NO_2 inside the station were 57% higher than directly outside the station. At London King's Cross, the levels of recorded NO_2 inside the station were only marginally higher than the outside environment whereas $PM_{2.5}$ concentrations were about 12% higher.

The EU sets a 200ug/m^3 hourly ambient mean limit which should only be exceeded 18 times per year. This limit is likened to being close to a very busy road in a city centre, but both stations breached this target after two weeks,

A previous study conducted at Birmingham New Street (Hickman, 2018) found NO_2 concentrations to be 332ug/m^3 on average during the study period. This was significantly higher than outside levels which were approximately 62 ug/m^3.

Current Mitigation

Various air quality improvement measures are already in place across the GB rail network.

Station Improvements

Following the investigation into air quality at Birmingham New Street station, Network Rail started to investigate improvement measures. In 2019, a new ventilation system was commissioned in which the existing 98 fans linked to the building management system are triggered according to NOx levels measured by real time sensors. In addition, reductions in train idling and emissions have been achieved through train operator focus group meetings. All participating operators have confirmed that auto shutdown system software upgrades are being implemented. These upgrades will mean that after 4-5 mins of idling engines are shut down. Ongoing station and occupational health monitoring will assess the effect of these improvements.

There are also various other passive measures being trialled in other stations such as air filters which clean the air and remove pollutants. However, it is generally accepted that it is better to reduce or eliminate the emissions at source rather than dealing with them once they are diluted in local air.

New Rolling Stock

GB rail has recently made significant investment in new rolling stock. Therefore, in the near future, newer, cleaner trains will enter into service and replace older more polluting trains. For example, Class 800 bi-mode trains are in operation on Great Western and Trans Pennine routes and will be introduced to Avanti West Coast. The Stadler Class 755 bi-mode is being introduced on Greater Anglia routes.

Franchise awards in 2019 included commitments for Avanti West Coast and East Midlands Railway to replace their long-distance diesel trains with bi-modes, which will help improve air quality in Birmingham New Street and other locations. In Wales, the new franchise includes electrification of local services around Cardiff.

On publication of the Williams review and as the government decides on the way forward with franchising or another model, it is likely that other fleet replacements will be initiated. A summary of known fleet replacements is given in Figure 12.

TOC	OLD	NEW	TIMESCALES
GREAT WESTERN	HSTs	93 X CLASS 800/1 BIMODES	2018-19
SCOTRAIL	VARIOUS DMUs, EMUs	70 X CLASS 385 EMUs	2018-19
LONDON AND NORTH EASTERN	HSTs (+ ELECTRA TRAINS)	65 X CLASS 800/1 BI-MODES	2019
GREATER ANGLIA	VARIOUS DMUs	10 X CLASS 755 BI-MODES	2019-20
HULL TRAINS	CLASS 180 DMUs + HSTs	5 X CLASS 802 BI-MODES	2019-20
NORTHERN	VARIOUS DMUs	31 X CLASS 331 EMUs	2019-20
TRANSPENNINE	CLASS 185 DMUs	12 X CLASS 397 EMUs	2019-20
TRANSPENNINE	CLASS 185 DMUs	19 X CLASS 802 BI-MODES	2019-20
AVANTI WEST COAST	CLASS 220/1 DMUs	23 X EMUs and BI-MODES	2022
EAST MIDLANDS	HSTs / CLASS 222 DMUs	33 X CLASS 810 BI-MODES	2022
TRANSPORT FOR WALES	VARIOUS DMUs	24 X CLASS 756 TRI-MODES	2022
TRANSPORT FOR WALES	VARIOUS DMUs	36 X CLASS 398 TRAM-TRAINS	2022-23

Figure 12 – New rolling stock introductions at the time of publication

Stop-Start Systems

Stop-start technology automatically turns an engine off to minimise emissions from engine idling at stations or other stops. In the automotive sector, stop-start is commonly used to reduce emissions, with many cars being fitted with stop-start. In the rail sector, stop-start can be incorporated into new designs or retrofitted to existing engines. However, rail engines often need to idle while stationary to provide power for internal electrical systems such as doors, lighting and air conditioning, and to maintain system pressure for the braking system pneumatics. This means the complexity of retrofitting stop-start systems varies according to on-board power needs and is therefore more easily applied to freight trains.

Many existing Class 66 freight locomotives are retrofitted with stop-start technology. In service, stop-start is estimated to reduce idling time and associated emissions by up to 50%.

Engine Replacement

The average age of rolling stock is 20 years with a typical asset life of around 35 years. Therefore, a significant number of engines are in operation that do not need to meet Non-Road Mobile Machinery Regulations (NRMM) requirements, which only came into effect in 2006. However engines can be modified or replaced in that time. By 2010 approximately 200 Class 43 HST locomotives were upgraded with newer, lower emission engines which met the International Union of Railways (UIC)—UIC II—emissions standard applicable at the time. Recent RSSB research on rail emissions (T1187) estimates that PM and NOx emissions were improved by 90% and 20% respectively with the deployment of these new engines.

Low Sulphur Fuel

Sulphur is a compound present in crude oil which needs to be removed during the refining process when fuel is produced. When fuel burns in an engine the sulphur does not contribute to the combustion process. It leaves through the engine exhaust and results in the formation of PM and sulphur dioxide, which leads to acid rain (Fuller, 2018). In 2009, GB rail adopted the use of diesel fuel with low sulphur content (10ppm) for traction energy across the industry. Previously, sulphur content in rail diesel fuel was 2,000ppm.

The adoption of 10ppm low sulphur fuel brings rail in line with the road sector where 10ppm fuel is also mandated. The 10ppm sulphur content fuel is an important requirement which will facilitate the introduction of NOx aftertreatment, since these systems can be inhibited by sulphur compounds in exhausts. An RSSB study, T536 *Investigation into the use of sulphur-free diesel fuel on Britain's railways* demonstrated small reductions in NOx and PM, in the region of 3-9% and 10-25% respectively.

As a comparison, the marine sector currently has a maximum allowable fuel sulphur content of 1,000 ppm in sulphur oxides (SOx) control areas (SECA). More recently limits of 5,000 ppm (previously 35,000ppm) were introduced in other areas (IMO, 2020).

Aviation	3,000*
Marine non-SECA	5,000**
Marine SECA	1,000**
Rail	10***
Road	10

Figure 13 – Max Allowable Fuel Sulphur Content * (JIG, 2018) ** (IMO, 2020) *** (RSSB, 2006)

Bi-Mode Trains

Bi-mode trains are designed to run predominantly on electrified routes but are also fitted with diesel engines that conform to the latest emission standards. The addition of a diesel engine allows trains to run on non-electrified routes and provides a useful interim step on routes where electrification gaps still exist. The advantage is that the use of electricity as a traction power source can be maximised on electrified sections where previously, a diesel train would have run. These trains are also 'future proof' for extensions of electrification.

A disadvantage of bi-modes is that in either traction mode, the train will be carrying redundant traction energy equipment which contributes to a fuel consumption penalty and increased wear. Therefore, bi-modes should be seen as an interim solution towards further electrification.

The two main types of bi-modes introduced in the UK include the Hitachi Class 80x and the Stadler Class 755. Both are fitted with exhaust aftertreatment technology to reduce exhaust gas emissions when in diesel mode.

Figure 14 – Class 800 Bi-Mode Train

In the freight sector, a small number of Class 88 bi-mode locomotives have been introduced by Direct Rail Services.

Figure 15 – Class 88 Bi-Mode Locomotive

Electrification

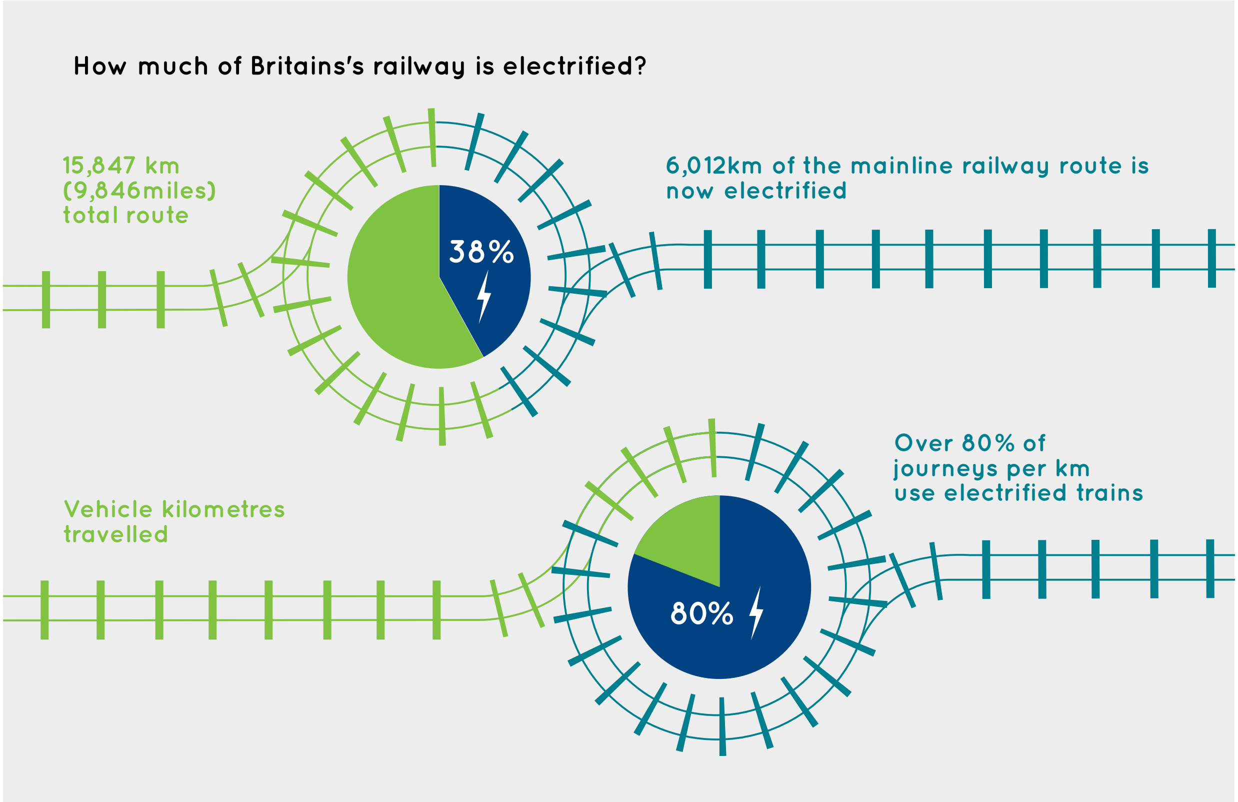

Figure 16 – GB rail electrification statistics

Currently, on a route km basis, 38 % of the GB rail network is electrified. Recent programmes of electrification include the Great Western Route from London to Cardiff, London's Gospel Oak to Barking Line, The Midland Main Line between Bedford and Market Harborough / Corby; routes in north west England and two routes between Glasgow and Edinburgh. Plans to create an electrically powered metro-type service in the Cardiff Valleys are also being progressed.

Electrification is a good option to reduce or eliminate diesel emissions and currently it is the only viable option for freight operations and high-speed passenger trains. However, electrification is expensive and lead times are significant meaning that short-term measures are still needed to improve air quality across the network.

In recent years some electrification schemes have been cancelled, but the Traction Decarbonisation Network Strategy, being delivered by Network Rail's System Operator is currently reviewing the extent of new electrification that may be needed to achieve carbon targets. While The RIA electrification cost challenge (RIA, 2019) concluded that an ongoing electrification programme could considerably smooth costs and retain skills. It is therefore possible that some schemes will restart in the medium- to long-term.

Potential Mitigation Options

Introduction

To date some improvements have been made through the examples provided in the sections above. However, there are other options that can be deployed to reduce emissions, some of which the GB rail industry is already trialling.

Idling Reduction

Some trains need to idle to keep on-board electrical and pneumatic systems running for heating, lighting and braking systems. Some initial efforts have been made to reduce unnecessary idling, including the implementation of maximum idling times. However, the correct balance between idling and passenger and staff comfort should be achieved. Efforts to reduce idling have so far been operator or route specific. Significant air quality improvements could be achieved by a network wide coordinated effort to eliminate unnecessary idling through behavioural change, operational measures, technical measures, or a combination of these.

Aftertreatment Retrofit

Diesel particulate filters (DPFs) have been in widespread use on diesel vehicles in the road sector for over 10 years. These provide a significant reduction (>99%) in PM mass emissions through filtration of the exhaust stream.

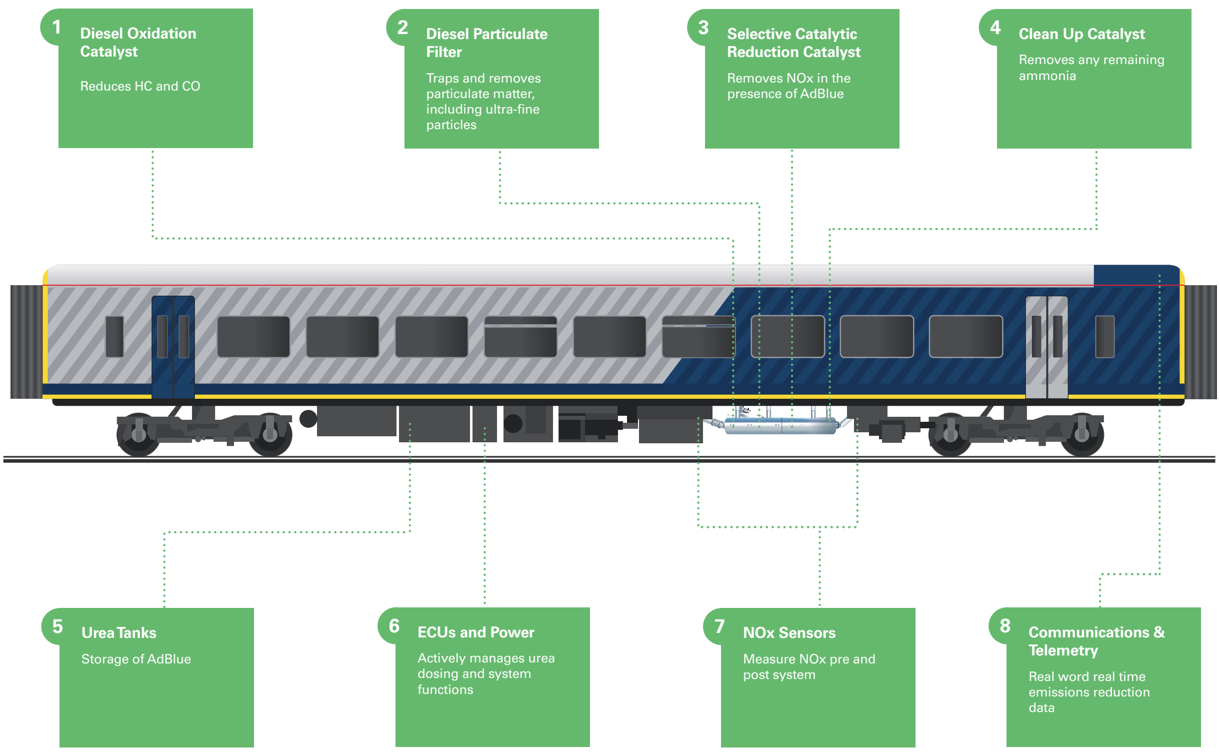

Figure 17 – Eminox EMxS5 Installation on SWR Class 159

In addition to DPFs, the use of selective catalytic reduction (SCR) has grown rapidly over the last five years. SCR is used to reduce NOx emissions from diesel exhausts by injecting a reducing agent (urea) into the exhaust. When the correct exhaust temperatures are reached in the exhaust stream SCR can reduce NOx emissions by over 95%.

In the UK, the bus sector has recently received government funding for SCR retrofit systems to be installed on older buses. The aim of this is to bring bus tailpipe NOx emissions in line with the latest Euro VI standards (Barrett, 2019). To be eligible to receive this funding, exhaust retrofit devices need to meet the requirements set out by the Clean Vehicle Retrofit Accreditation Scheme (CVRAS).

In the rail industry, Porterbrook is collaborating with Eminox, a UK based leader in aftertreatment technology, to deliver the Green Rail—Exhaust After Treatment System (GR-EATS) project. This project seeks to transfer proven on-road aftertreatment technology to a railway operating environment, with the first being installed on a South Western Railway Class 159. The project will:

- ensure the system conforms with applicable rail standards
- ascertain ongoing maintenance requirements
- establish emissions performance and durability.

Hybrid Retrofit Systems

Chiltern Railways is due to trial two different diesel and battery powered hybrid train retrofit systems. These will replace existing diesel engines with newer hybrid retrofit powetrains that combine a battery and a diesel engine that complies with the latest NRMM standards. As the train brakes, the battery is charged, ready to power the train in 'zero emissions' mode in locations such as stations. The control system automatically switches between diesel and battery power based on location information, ensuring that battery mode is always used at the right time. These systems may significantly reduce or eliminate emissions associated with engine idling and emissions from entering and exiting stations, depots and sidings as well as other sensitive locations. The approximate reductions forecast are (Porterbrook, 2019):

- noise emissions are cut by around 75% (20 dB(A)) in stations
- fuel consumption and CO_2 emissions can be reduced by up to 25%
- NOx emissions can be reduced by up to 70%
- particulate emissions can be reduced by around 90%.

Stop-Start and Selective Engine Shutdown

As previously described, usage of stop-start technology in rail is made more complex by the need to keep auxiliary systems running. However, DMU trains which have more than one diesel engine can shut down all but one or two engines in stations and at other critical locations.

As part of the improvements at Birmingham New Street, it may be possible to shut down all but one engine on Class 220 and 221 stock when entering stations, based on GPS location information. This approach has already been in place on the Class 185 fleet for over 10 years.

Class 220 and 221 operators have implemented a software upgrade by Bombardier which makes train engines change to a minimal power level within 4 to 5 mins of the key being removed.

Increasing our understanding

Introduction

Compared to other transport sectors there is relatively little data available in the rail sector on emissions rates, air quality levels, likely exposure and health risk. This section outlines data gaps that need to be filled to improve understanding and provide a sound basis for the prioritisation of future improvements.

To enable the development of this strategy, the GB rail industry recognised the need to quickly increase its understanding and improve the evidence base on air quality across the network. Published air quality or emissions studies on GB rail are limited to a small handful of studies including the previously mentioned RSSB project T1122, *Research into Air Quality in Enclosed Railway Stations*.

The Clean Air Research Programme (CLEAR)

RSSB A Better, Safer Railway | CLEAR

Following some initial discovery projects, the Air Quality Steering Group recognised the need to improve knowledge of rail emissions and air quality and implement a wider research programme. The Clean Air Research Programme (CLEAR) was developed by RSSB, in liaison with the Air Quality Steering Group. The programme directly supports the development, delivery and implementation of the industry's Air Quality Strategic Framework; and supports wider government initiatives such as the Clean Air Strategy 2019.

CLEAR incorporates three main workstreams: Modelling, Mitigation and Monitoring. These workstreams support the Air Quality Strategic Framework and establish a baseline from which improvement measures can be implemented and evaluated against.

> “NEW EMISSIONS FACTORS WERE DEVELOPED FOR CLASS 66, 68, 70 15X, 16X AND 170/171. ON AVERAGE THESE RESULTED IN REDUCTIONS IN ESTIMATED PM AND NOx EMISSIONS OF AROUND 70% ACROSS THE TRAIN CLASSES”

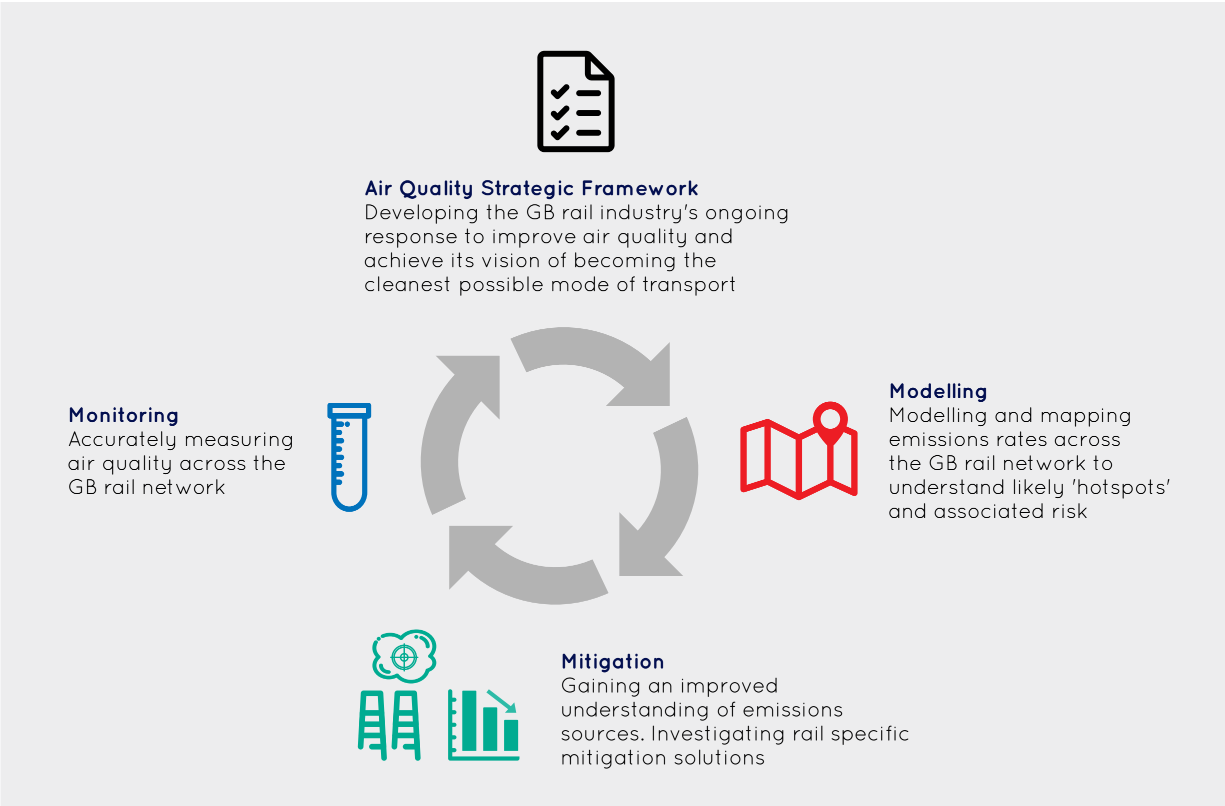

Figure 18– CLEAR Programme Overview

The individual projects within each workstream will be described in the following section.

Modelling – Traction Emissions Rates

What we Know

Estimates in emissions inventories such as the National Atmospheric Emissions Inventory, London Atmospheric Emissions Inventory and equivalents from other countries are based on factors for a particular sector as a function of activity.

In the transport sector, for example, emissions factors are commonly expressed as a function of the 'activity' of distance travelled for a particular vehicle.

Emissions [grams] = Emissions Factor [g/km] x Activity [km]

Remaining Gaps

Until 2019, GB rail emissions factors were based on work that had been conducted around the year 2000 and had not been updated. Since that time, certain locomotives have been re-engined such as Class 43 (HST), Class 57 and 73. Importantly, various new passenger trains were introduced (such as Class 172, 195, 755, 800 and 802) as well as new locomotives (such as Class 68 and 70) which did not have specific emissions factors developed for them at the time of their introduction.

After-treatment technologies (such as diesel particulate filters to reduce PM and SCR to reduce NOx) have been deployed to focus on addressing newer emission standards. It was also discovered that the Class 66 emissions factor was approximately three times higher than actual due to a unit conversion error.

What we are Doing

RSSB's Air Quality Steering Group was keen to conduct research to establish priority areas for new rail emissions factors. For more accuracy, this included testing a new method to express emissions as a function of engine operating condition.
The objectives of the project were:

- review current rail emissions factors for the UK against the current and projected UK passenger and freight diesel rolling stock fleets
- identify and prioritise areas to update and improve these emissions factors
- provide technical justification for the suitability of the new emission factor method
- compile relevant industry data and develop new emissions factors
- identify how new emissions factors can be used and make recommendations for future work.

The method used to develop these new factors took existing engine test data from certification tests or in-service tests. The data was used to develop new emissions factors as a function of engine power setting or engine 'notch'. These factors were combined with real time recordings of train journeys to understand the variation of engine notch setting over a range of typical journeys. In doing so an aggregated single number emission factor for a particular train type was produced.

The project managed to develop new and improved factors for rolling stock types which accounted for approximately half of all GB rail activity. One train type was the Class 43 HST, where the previous emissions factor had not been updated to account for the upgrade of engines from pre-emissions standard Paxman Valenta engines to newer MTU UIC 2 compliant engines. The new factor was approximately 20% lower for NOx emissions and over 90% lower for PM emissions.

As well as the Class 43, new emissions factors were developed for Class 66, 68, 70 15x, 16x and 170/171. On average these resulted in reductions in estimated PM and NOx emissions of around 70% across the train classes.

Nationally, the new emissions factors reduced the total estimate of rail NOx emissions from 2.75% to 2%.

The success of this project led RSSB to commission further research to continue updating emissions factors, *Fleet-Wide Assessment of Rail Emissions Factors* (T1187). In addition, the new engine notch-based factors will be used to model the potential real-world emissions improvements that can be made by implementing new operational measures.

Despite rail's overall low contribution to national NOx and PM emissions, it is important to recognise that rail's contribution will be significantly higher in certain areas.

Modelling – Local Variations

What we Know

Current rail emissions estimates come from the National Atmospheric Emissions Inventory (NAEI). The NAEI is primarily concerned with providing national totals for the UK's emissions reporting obligations. The NAEI maps emissions in 1km^2 grid increments (Defra, 2019) which are suitable for deriving national totals but do not provide enough detail on local variations. Local rail emissions can be extracted from the NAEI and compared to emissions from other sources. As well as emissions factors being out of date, the calculated PM and NOx emissions are averaged along the length of a rail line and therefore do not reflect local variations (figure 19) due to changes in traffic volume and operating condition.

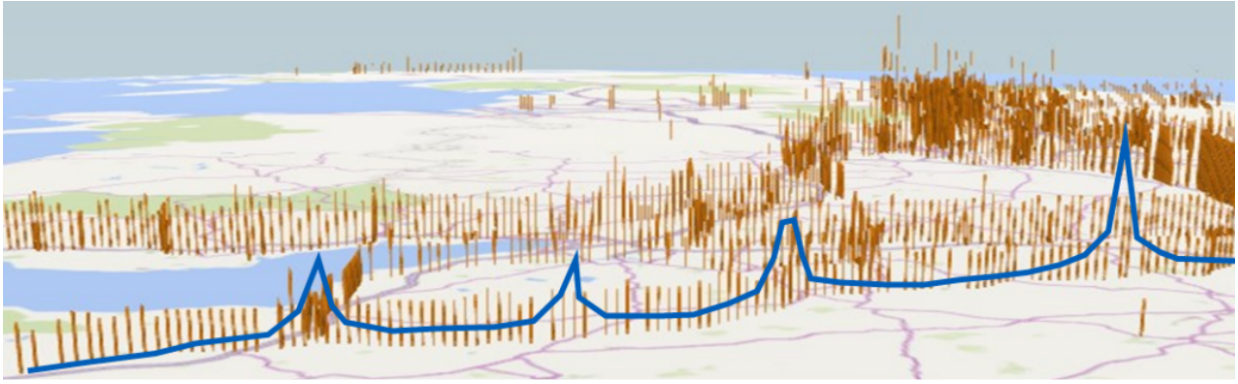

Figure 19 – The orange bars show aggregated NAEI derived emissions. The blue lines show how emissions are more likely to vary along a rail line.

Remaining Gaps

The rail industry needs an up to date and more detailed inventory of its emissions to identify hotspots and improve air quality at these locations. In addition, an improved understanding of the interactions between the rail network, AQMAs and CAZs is also needed. With this better understanding of rail's contribution to local air quality, mitigation and monitoring activities can be prioritised for locations with the highest exposure levels.

What we are Doing

Current estimates of emissions across the rail network are focused on providing a national total and do not provide reliable information on local rail emission variations.

RSSB has commissioned the project Rail Emissions and Air Quality Mapping (T1186) to significantly improve understanding of emissions variations across the network and to identify locations where rail may significantly impact local air quality.

Through this project an online mapping tool will be developed to provide better data on the location of emission hotspots and associated risks. With this tool the industry will better understand why such hotspots exist and how air quality can be improved at these locations. The online mapping tool will allow the findings to be communicated easily and interactively to industry stakeholders.

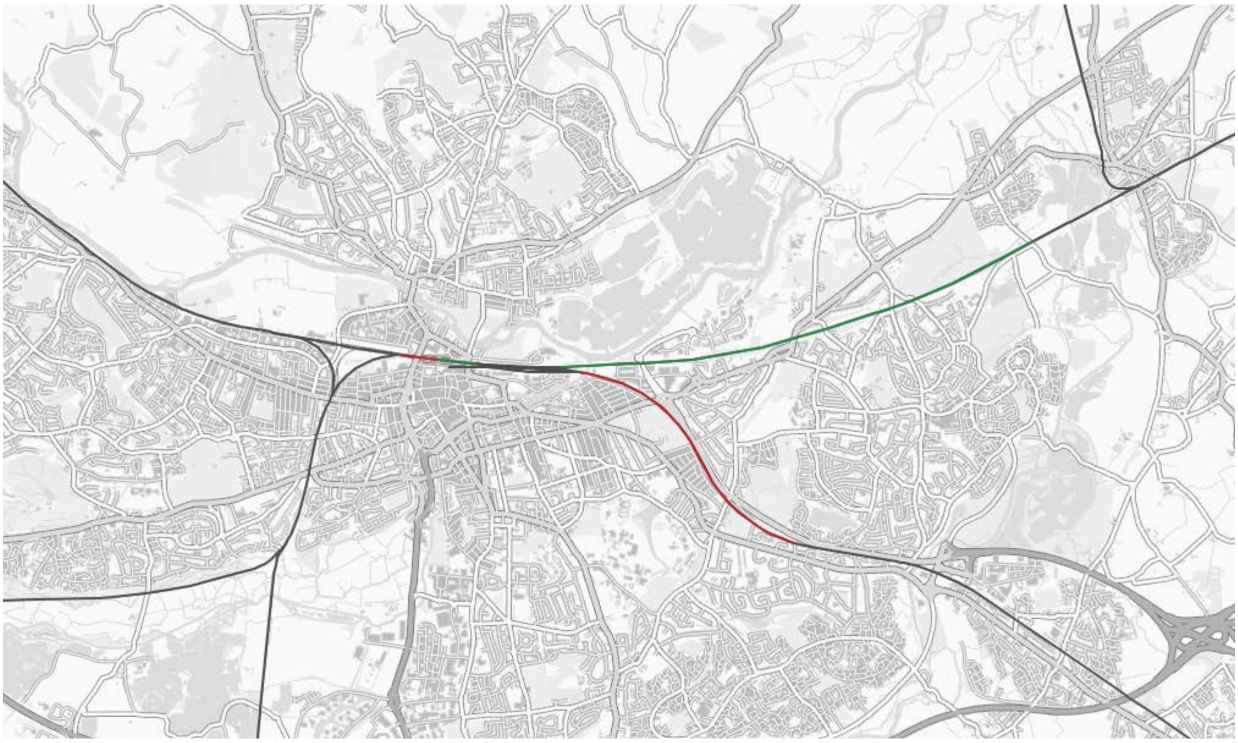

Figure 20 – Illustration of emissions mapping

Furthermore, the tool will allow ongoing improvements to be tracked and visualised geographically. For example, as electrification programmes or new rolling stock types are introduced. The tool will also provide the basis for forecasting future emissions.

"CURRENT ESTIMATES OF EMISSIONS ACROSS THE RAIL NETWORK ARE FOCUSED ON PROVIDING A NATIONAL TOTAL AND DO NOT PROVIDE RELIABLE INFORMATION ON LOCAL RAIL EMISSION VARIATIONS."

Monitoring - Stations

What we Know

Great Britain has approximately 2,500 train stations, these are located in urban, semi-urban, and rural locations with varying levels of 'background' air pollution from non-rail sources. Size and design of stations can vary significantly, ranging from enclosed types such as terminal stations to those that are completely open with minimal buildings or infrastructure. In addition, train traffic volumes (and passenger numbers) vary from station to station, including different proportions of diesel and electric trains. Therefore, emissions rates vary from station to station. All of these factors combined mean some stations are more likely to suffer from poor air quality than others.

There are also numerous air quality monitoring technologies available. These include diffusion tubes which give an average NO_2 measurement, low cost sensors which give real time NOx and PM measurements and higher-quality EU-standard air pollution monitors which may be prohibitively expensive for widespread deployment.

Remaining Gaps

Data is currently publicly available for only three train stations—Birmingham New Street, Edinburgh Waverley and London King's Cross. Other monitoring campaigns are known to have taken place across the network, but the data is not yet freely available, either publicly or within the rail industry itself.

It is also unclear whether low-cost, real time air quality sensors provide the necessary accuracy and robustness for ongoing monitoring of the rail network. In future more location specific air quality information is needed to prioritise improvement measures in the highest risk locations.

What we are Doing

The GB rail industry will develop a network-wide plan to measure air quality in a range of key locations such as stations and depots. This plan will ensure a consistent measuring method is applied and that data is centrally collated. *Rail Emissions and Air Quality Mapping* (T1186) will provide useful data to prioritise key locations on the basis of highest modelled emissions and highest number of diesel services. The monitoring network will provide a baseline against which ongoing air quality improvement measures can be then assessed.

Monitoring – Traction Emissions Rates

What we Know

There are approximately 60 different diesel train types in operation on the network. These comprise of various diesel engine types, makes, models and emissions standards. The previously described emissions factor work provides up to date estimates of rail emissions based on data provided by industry. However, there is little available information on real world emissions rates of diesel trains in service.

Remaining Gaps

It is important to establish a method to measure emissions rates to compare against emissions factors and understand how emissions vary with engine age and operation cycle. More information is needed to improve understanding of actual emission rates from trains so that effective mitigation measures can be developed. Furthermore, the importance of non-exhaust or abrasive emissions must also be fully understood.

What we are Doing

In the automotive sector, on road emissions measurements are now routinely taken using portable emissions measurement systems (PEMS). This equipment commonly sits in the luggage compartment of a passenger car and provides real time measurements of exhaust emissions to certification standards.

Figure 21 – Example of automotive PEMS equipment

In 2018, RSSB launched a feasibility study to determine the suitability of this equipment for the rail sector. A Class 66 freight locomotive was chosen for this trial which was undertaken by Emissions Analytics, who are recognised for carrying out independent emissions tests on passenger cars in the UK.

The locomotive ran through its standard load bank test with the PEMS equipment installed in the exhaust and mounted on scaffolding as shown in Figure 22. The main challenges were how to measure the exhaust flow and how to ensure the PEMS equipment did not overheat due to the higher exhaust temperatures that were expected compared to passenger cars.

Figure 22 – PEMS setup on Class 66

One of the original aims of the project was to run PEMS on a moving locomotive but this was found to be impractical due to space, power requirements and lack of set up and dismantling time when a train needs to keep to the timetable. PEMS is probably restricted to use on a stationary locomotive or DMU where the electrical power generated by the engine is absorbed by a load bank rather than used to power the wheels. This also means that PEMS use is restricted to testing engines with electrical transmission because hydraulic and mechanically coupled trains cannot be tested on an electrical load bank. Therefore, another method is needed to measure emissions from a moving train.

Another emissions measurement technique used in the road sector is 'remote sensing' in which a laser scans tailpipe exhaust plumes of passing vehicles to measure emissions. The Real Urban Emissions (TRUE) Initiative provides third-party ratings of real-world vehicle emissions for a range of vehicle makes and models, using a pool of remote sensing data captured in various locations around Europe (TRUE, 2020).

Figure 23 – Example of remote sensing trials in rail

The project, *Rolling Stock Emissions Testing* (T1189), will determine the suitability of remote emissions sensing to measure the concentrations of pollutants emitted by in-service passenger and freight trains.

Monitoring – Depots

What we Know

In the passenger sector, many rail depots are located in large cities. These are in relative proximity to the start or end of journeys and are located where trains can be cleaned and maintained overnight and at weekends. The freight sector also has depots in urban locations where freight cargo can be loaded and unloaded. Freight depots are needed in urban locations so that goods can be delivered close to the final destination. This maximises the proportion of the journey on the rail network, thereby reducing the number of local lorry journeys.

Remaining Gaps

Little data exists on air quality in and around train depots and how pollutants disperse from the boundary of the depot. A detailed study is needed to quantify the emission sources within a range of rail depots, and to understand how these disperse beyond the boundary of the depot into surrounding areas.

What we are Doing

Assessment of Air Quality at Depots

In the project, *CLEAR Assessment of Air Quality at Depots* (T1190) air quality measurements will be recorded at depots to identify major sources of emissions and carry out pollutant dispersion modelling. This will determine whether, and at what distance, depot derived pollution is contributing to concentrations of pollutants in addition to other sources. The study will cover a wide range of depot types in a variety of locations.

The project will also develop good practice guidance on improving emissions and air quality at train depots, and the recommended measures to reduce emissions. An accompanying document will provide guidance for depot operators or owning companies on how to replicate the study and carry out ongoing independent monitoring.

Monitoring – Internal

What we Know

On the GB rail network, some passengers have taken air quality measurements using low cost air quality sensors with results published on social media. In other countries (such as Denmark, Israel and Canada), more detailed studies have been conducted with results published in academic journals; these studies show elevated levels of pollution inside diesel trains.

Remaining Gaps

There is little evidence available on the levels of harmful pollutants inside trains. There is also little information on air quality in workplace locations close to rail assets such as stations and depots. Therefore, a monitoring programme that accurately and reliably assesses air quality in internal locations on the network is needed to understand health risk to passengers and staff.

What we are Doing

Due to increasing evidence and emerging standards relating to vehicle internal air quality in other transport modes, RSSB has commissioned a study to measure pollution concentrations within passenger train compartments. This study, *Analysis of Air Quality Onboard Trains* (T1188), will cover a range of train types.

The study will determine the variation of recorded pollutants according to train type, direction of travel, location on train and train operating condition among other factors. The study will also compare internal air quality in rail to other transport modes such as buses, private cars and taxis.

Figure 24 – Air quality monitoring equipment

Monitoring – Staff

What we Know

Fixed location air quality monitoring can provide an accurate assessment of how air quality in a particular location varies with time. Many jobs require staff members to move between locations, fixed monitors will not provide the full picture.
Therefore, assessments of pollutant exposure for occupational health purposes are carried out using wearable pollution monitors. Such assessments provide a more accurate picture of what individuals breathe in during a normal working day.

Remaining Gaps

Currently, little publicly available data exists on the exposure of rail staff to air pollution.

What we are Doing

RSSB's project *Air Quality Personal Monitoring* (T1191) will assess employee exposure against current and emerging legislation at a range of rail locations to improve the understanding of occupational exposure to air pollutants. Personal monitoring for air quality exposure is usually conducted using compact, wearable air quality monitoring devices such as that shown in Figure 25. These can be fitted to a worker for the duration of their shift. Such devices aim to capture the air quality a worker is exposed to during a typical day's work. The advantage of personal monitoring—compared to fixed monitoring—is that the device captures air quality as breathed by the worker when they move around to carry out their duties.

Figure 25 – Typical personal sample pump

To monitor PM volumes, the devices draw air through a filter that collects and weighs the PM present. An employee's exposure to PM is calculated using the weighed PM collected in the filter and the volume of air that the pump has drawn in. Sample filters can also be chemically analysed to determine the constituents of the PM. The study, *Air Quality Personal Monitoring* (T1191) will look at four large enclosed stations and one maintenance depot.

The project will also develop a good practice guide to help rail organisations carry out similar occupational health monitoring studies. More specifically, this will include:

- an outline of suitable equipment
- currently applicable and emerging regulation
- guidance on experimental design
- overview of processing and presenting air quality exposure data
- advice on further exposure management.

How Air Pollution from Rail Leads to Health Risk for Staff, Passengers and the General Public

What we Know

Evidence linking air pollution exposure to adverse health effects is rapidly evolving. For example, a recent report by the Centre for Cities outlines that overall $PM_{2.5}$ emissions contribute to around 1 in 16 early deaths in the worst affected UK locations (Centre for Cities, 2020). A recent study suggested that air pollution might potentially affect every organ in the body (Schraufnagel, 2019).

Remaining Gaps

It is unclear how rail-specific air quality impacts on the health of passengers, staff and the general public.

What we are Doing

Revised Guidance on Air Quality and Health Effects in Rail (T1192) will summarise findings from the various CLEAR projects. It will produce general recommendations on how to reduce exposure and implement 'best practice' to reduce emissions and exposure.


5b

Mitigation

What we Know

In early 2019, RSSB commissioned *Air Quality Improvement Measures* (RSSB, 2019) a high-level technology feasibility and cost study exploring potential air quality improvement measures for GB rail. The study included technological measures as well as operational and infrastructure measures, both on and off the train.

Measures were assessed according to these criteria:

- operational practicability
- technical feasibility
- commercial viability
- applicability
- long-term sustainability
- other benefits that the measure brings.

Measures were split into those which reduce emissions at source and measures which reduce exposure. The potential air quality improvement of each measure was difficult to quantify in precise terms and varied depending on location and rail asset. Therefore, the potential air quality improvements were rated as:

- low – little or no measurable change in sources or exposure
- medium – a small measurable change in air quality
- high – a large measurable improvement in air quality.

The conclusions of this study are worth reading in some detail (RSSB/Ricardo, 2019). In summary the study found the most effective ways of reducing emissions throughout the rail network include:

- retrofit exhaust after-treatment systems
- reducing the diesel on-time or on-power-time through:
  - selective Engine Shutdown
  - powertrain hybridisation
  - stop-start technology.

Remaining Gaps

The previous RSSB study *Air Quality Improvement Measures* ranked each potential measure as either low, medium, or high against the chosen assessment criteria. A more detailed appraisal of the most viable air quality improvement measures is needed to ensure the most effective measures are targeted in the appropriate locations.

What we are Doing

Rail Emissions and Air Quality Mapping (T1186) will provide improved data on the routes, stations and other sensitive locations with the highest local concentrations of rail derived air pollutants. This will allow improvement measures to be targeted to priority locations on the network. The mapping tool will also show which rolling stock types have the biggest impact in each location.

Fleet-Wide Assessment of Rail Emissions Factors (T1187) will provide new and updated emissions factors for the mapping tool and a much-improved understanding of the emissions rates of different rolling stock types.

Once priority locations and rolling stock have been identified from these projects, a detailed study is needed to understand which emissions reduction measures will have the biggest impact. The emissions benefit should be quantified at a range of operating conditions, including idle, so that emissions reduction in sensitive locations such as stations is fully understood. Any study will need to provide more detailed cost estimates, as well as associated fuel savings or penalties.

Air Quality Standards Across the Network

What we Know

Ambient air quality regulations in the UK are derived from EU directive 2008/50/EC which sets limits for a range of pollutants over short- and long-term averaging periods. Indicative occupational exposure limit values (IOELV) are health-based limits set under the Chemical Agents Directive (98/24/EC) to protect workers' health through exposure to natural or man-made substances at the workplace. EU member states are obliged to implement IOELVS by introducing national limits. The World Health Organisation Air Quality Guidelines offers threshold limits for air pollutants that pose health risks, and provide a reference for setting air pollution targets at regional and national levels to improve air quality.

Remaining Gaps

It is currently unclear which air quality standards apply at various locations on the network. To establish industry targets, it is vital to fully understand the standards applicable to the full range of locations such as indoor stations, outdoor stations, office buildings, and inside vehicles.

What we are Doing

A full review of current and emerging air quality legislation will be conducted to provide clarity to the industry.

Emissions Rates from Generators and Maintenance Equipment

What we Know

A wide range of diesel-powered plant and machinery is used across the GB rail network for emergency power generation and maintenance.

Remaining Gaps

Currently the usage patterns and emissions rates from non-traction exhaust sources such as generators and the wide range of maintenance machinery is unknown.

What we are Doing

A survey of all non-traction emission sources is needed to understand usage patterns and likely emissions rates.

Recommendations

The following table presents initial recommendations for the GB rail industry to reduce harmful emissions and improve air quality across the network, specifically in the highest risk locations.

	Recommendation	Lead	Support	Timeline
	Modelling			
1	Continually improve the emissions mapping model to ensure risk to passengers, staff and the general public is fully understood.	RSSB	Network Rail	Annual reporting
2	Prioritise, develop and implement any interventions needed at any 'hotspots' identified by the emissions modelling projects.	NR for managed stations TOCs for operator stations	-	Annual reporting
3	Annually review and update emissions factors to consider new rolling stock, infrastructure, and retrofit technologies to ensure rail emissions estimates are as accurate as possible. Feed new factors into NAEI.	RSSB	Network Rail, ROSCOs, train and engine supplier	Annual updates
	Mitigation—Retrofits			
4	Develop a hierarchy of mitigation options based on cost, benefit and risk so that the emissions value of each mitigation option is fully understood.	RSSB	ROSCOs	12 months
5	Ensure an emissions reduction pathway exists for higher-risk or unmitigated rolling stock by reviewing mitigation options and reporting annually on options and planned improvements.	ROSCOs	TOCs	Annual

	Recommendation	Lead	Support	Timeline
6	Conduct a review of rail industry standards to assess applicability in achieving emissions reductions and improvements in air quality. Identify gaps where new and/or modified standards are needed.	RSSB	All	12 months
7	Continue to investigate options for reducing traction emissions at source, and annually report on progress as an input to the Strategic Framework.	ROSCOs TOCs Network Rail	RSSB	Annual reporting
	Mitigation—Idling			
8	Establish an industry-wide working group to tackle idling emissions. This should focus on operational measures and behavioural changes to achieve benefits without needing investment or significant train upgrades.	RDG Network Rail	RSSB	3 months
9	Agree industry-wide targets for maximum idling times in stations and other sensitive areas.	RDG	RSSB	6 months
10	Develop an effective communication strategy to share new idling policy with relevant staff such as train drivers and dispatchers.	RDG	RSSB	9 months
11	Update engine management systems for all modern DMUs to reduce engine operation in sensitive locations.	ROSCOs TOCs	RSSB	18 months

	Recommendation	Lead	Support	Timeline
	Mitigation—Other Sources			
12	Continue to investigate other innovative measures to reduce emissions at source. Monitor other transport sectors for technologies which could be carried over and trialled in rail.	All	-	Yearly report
13	Carry out work to improve the evidence base on other emission sources within rail. This should cover both exhaust emissions and non-exhaust or abrasive emissions.	RSSB	AQSG	12 months
14	Conduct a survey of all non-traction emissions sources to understand usage patterns and likely emissions rates.	Network Rail + maintenance contractors	RSSB	12 months
	Monitoring			
15	Develop a long-term, network-wide air quality monitoring programme for stations and other priority locations such as depots. This should include an agreement for data/knowledge sharing and a database to centrally store monitoring data.	RSSB and Network Rail	TOCs	6 months
16	Use T1186 modelling outputs to establish priority locations for air quality monitoring.	RSSB	Network Rail, TOCs	6 months
17	Implement an initial monitoring network across 100 priority locations using NO_2 diffusion tubes to increase understanding of air quality with a proven monitoring technology.	Network Rail + maintenance contractors	ROCs	9 months
18	Establish the most accurate and cost-effective real time air quality monitoring solution for GB rail.	RSSB and Network Rail	TOCs	12 months
19	Enhance monitoring with real time air quality monitoring technology in a subset of locations, if suitable technology exists.	RSSB and Network Rail	TOCs	18 months

	Recommendation	Lead	Support	Timeline
20	Expand the monitoring network to further priority locations, ensuring air quality risk to rail users is fully understood.	RSSB and Network Rail	TOCs	24 months
21	Conduct a full review of current and emerging air quality legislation to provide clarity to the industry on which standards apply in which locations.	RSSB	Network Rail ORR	12 months
22	Establish appropriate air quality improvement and emissions reduction targets, including supporting targets such as idling reduction and other best practice targets to reduce emissions.	RSSB	All	18 months
	General Recommendations			
23	Update the strategic framework annually and pursue further research projects to improve the knowledge base. Engage with the rail industry to ensure new priorities are covered.	RSSB	All	Next version 12 months.
24	Establish responsibilities and ownership for air quality within all rail organisations to ensure the recommendations and vision of the strategic framework can be achieved.	TOCs ROSCOs IMs	All	6 months
25	Establish an air quality data sharing agreement to ensure learnings can be maximised between train operating companies, routes and any other relevant organisations.	RSSB	Network Rail, TOCs	12 months
26	Continue engagement with other transport sectors, academia, local and national government to maximise learnings, continually innovate and enhance the air quality knowledge base in rail.	RSSB		Report yearly

Aligning with the Decarbonisation Programme

The Rail Industry Decarbonisation Taskforce's Final Report to The Minister for Rail was published by RSSB in July 2019. The report recommends that by 2040 the removal of diesel only passenger trains from the national rail network can be achieved and that the whole rail industry can contribute to the government's net zero carbon target by 2050. The reduction of diesel usage across the network will deliver significant air quality improvements; and increased electrification has been identified as a key measure to achieve this. Use of batteries and hydrogen fuel cells will also deliver benefits on specific routes where diesel traction is replaced.

Many of the decarbonisation measures are unlikely to be in widespread use in the short term, meaning specific air quality measures will be needed in the interim period.

Both the air quality and decarbonisation programmes are being run by the Sustainable Development Team at RSSB. Close coordination of these will ensure that air quality measures do not adversely impact decarbonisation efforts and vice versa. Data sharing and opportunities for learning will be maximised between the two programmes. For example, two CLEAR projects *Fleet-Wide Assessment of Rail Emissions Factors* (T1187) and *Assessment of Air Quality at Depots* (T1190) include assessments of fuel consumption and CO_2 emissions which will help inform GB rail's decarbonisation efforts.

RSSB leads the industry approach to sustainable development, including the Sustainable Development Principles. This includes the strategic approach to both carbon and air quality.

"RSSB LEADS THE INDUSTRY APPROACH TO SUSTAINABLE DEVELOPMENT, INCLUDING THE SUSTAINABLE DEVELOPMENT PRINCIPLES. THIS INCLUDES THE STRATEGIC APPROACH TO BOTH CARBON AND AIR QUALITY"

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Appendix

Emissions Regulations Applicable to Diesel Engines

Emissions from rail diesel traction engines are regulated by European NRMM Regulations (Delphi, 2018). Regulations applicable to rail commenced with Tier IIIa from 2006-2009 which were superseded by Tier IIIb in 2012. The main improvement between Tier IIIa and IIIb was an 87.5% reduction in PM emissions. NRMM Stage IV legislation did not apply to rail but Stage V emissions standards for new rail vehicles are set to come into force in 2021. These will see further reductions in PM for diesel multiple units and the introduction of a particulate number limit.

Despite the reductions in permitted PM emissions in NRMM regulations, permitted NOx emissions have remained relatively constant and appear to lag behind other sectors. For example, Stage V 2021 limits for NOx emissions from DMUs are 2.00 g/kWh whereas the latest applicable emissions regulations for heavy duty trucks and buses mandate NOx emissions of 0.4 g/kWh from 2013 onwards.

Ambient Air Quality Limits

Ambient air quality regulations in the UK are derived from EU directive 2008/50/EC which sets limits for a range of pollutants over short- and long-term averaging periods. The shorter 1 hour and 1 day limits also have a number of permitted annual exceedances.

Pollutant	Limit Value [ug/m^3]	Averaging Period	Averaging Period
$PM_{2.5}$*	25	1 year	-
PM_{10}**	50	1 day	35
	40	1 year	-
NO_2	200	1 hour	18
NO	40	1 year	-

Figure 26 – EU ambient air quality regulations (European Parliament, 2015)

* Scotland has a lower annual PM_{10} limit of 18 ug/m^3
** Scotland has a lower annual $PM_{2.5}$ limit of 10 ug/m^3 in line with WHO guidelines.

In 2005, the World Health Organisation (WHO) published guidance levels which it recommends be achieved everywhere to significantly reduce the adverse health effects of pollution.

Pollutant	Limit Value [ug/m^3]	Averaging Period
$PM_{2.5}$*	10	1 year
	25	1 day
PM_{10}**	20	1 year
	50	1 day
NO_2	40	1 year
	200	1 hour

Figure 27 – WHO Air Quality Guidance Level (WHO, 2005)

Workplace Exposure Limits

It is important to consider the fact that many locations on the rail network are workplaces as well as being occupied by passengers and the public. Indicative occupational exposure limit values (IOELV) are health-based limits set under the Chemical Agents Directive (98/24/EC) to protect workers' health through exposure to natural or man-made substances at the workplace. EU member states are obliged to implement IOELVS by introducing national limits.

In Britain, the Health and Safety Executive (HSE) sets workplace exposure limits (WEL) to protect the health of workers. These are summarized in its EH40 document (HSE, 2020). WELs are set for time-weighted averages (TWA), usually for an 8-hour day during a 40-hour week. Also, for some substances, short-term exposure limits (STEL) are defined and refer to 15-min exposures.

The WELs for the substances emitted by rail traffic are summarized in Figure 27. Particles in the railway environment are classified as 'dust' by HSE and two size fractions are distinguished: 'inhalable' and 'respirable'. Inhalable dust approximates to the fraction of airborne material that enters the nose and mouth during breathing and is therefore available for deposition in the respiratory tract. Respirable dust approximates to the fraction that penetrates to the gas exchange region of the lung.

	Long-Term Exposure Limit (8hr TWA)		Short Term Exposure Limit (15 mins)	
Substance	**ppm**	**ug/m3**	**ppm**	**ug/m3**
Inhalable dust	-	10,000	-	-
Respirable dust	-	4,000	-	-
NO_2	0.5	960	1	1
NO	2	2500	--	--

Figure 28 – WELs set by HSE in the UK relevant to railway workers (HSE, 2020)

Forthcoming European Legislation

On 16 January 2019, Directive (EU) 2019/130 came into effect amending Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work. This includes a limit of 50µg/m3 for diesel engine exhaust emissions measured as elemental carbon, which will apply from 21 February 2023. For underground mining and tunnel construction the limit value shall apply from 21 February 2026.

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