



ENVIRONMENT REPORT 2017



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Construction at Tottenham Court Road station

FOREWORD

The Crossrail project is nearing its final chapter as the programme to deliver the new railway for London and the South East is now more than 85 per cent complete. In just over a year, the Elizabeth line will begin its phased opening through the capital. When fully complete, it will increase central London's rail capacity by 10 per cent, reduce journey times and bring an additional 1.5 million people within 45 minutes of London.

The project has been as busy as ever. New tracks and railway systems installation has been turning 42 kilometres of large cavernous tunnels into an operational railway, 10 new stations in central London have taken shape as their presence has become visible above ground, the first of the new Elizabeth line trains has come off the production line and 19 kilometres of electrification work in the outer west has been completed. Throughout this process we have remained on track to meet the environmental targets we set ourselves.

A key commitment has been to minimise any negative environmental impacts while we build the railway. Since the start of construction, Crossrail tunnelling works have generated more than eight million tonnes of excavated material, 98 per cent of which has been beneficially reused for projects such as Jubilee Marsh on Wallasea Island in Essex, which was built in partnership with the Royal Society for the Protection of Birds. Two years on from completing the new wetland and breaching the sea

wall, during a survey over one day in December 2016, 29 species of bird in a total count of 7,839 individuals were counted at Jubilee Marsh alone. This out of a total count for Wallasea Island of 36 species and 12,096 individuals, demonstrating the significant contribution Jubilee Marsh is making to the Wallasea Wild Coast Project as a whole.

This past year we maintained our excellent performance in diverting construction and demolition waste from landfill with 97 per cent going for reuse and recycling. This means that overall Crossrail has now reused or recycled 98 per cent of the 428,000 tonnes of its construction and demolition waste.

The project is predicting 15 per cent energy reduction on construction works, exceeding the original target of eight per cent. Our commitment to minimising the negative impact on air quality has seen an increase in the proportion of construction machinery either fitted with diesel particulate filters or using cleaner engines on our sites. In the last year we have also undertaken a study to investigate the exposure of the workforce to diesel exhaust within the tunnelling and rail-head environment so that we can help identify intervention methods for health improvement. With the changing focus in the construction programme, we launched the Green Systems Recognition Scheme, which promotes positive environmental behaviour amongst our construction teams and we developed a new environmental performance

indicator to focus our attention on maintaining high performance across the programme.

Our environmental commitments also extend to the operational life of the railway. Production and testing of the new class 345 train has so far demonstrated the planned energy-efficiencies will be realised. Three railway structures were completed this year, each achieving an 'excellent' score under the Civil Engineering Environmental Quality assessment (CEEQUAL). Five landscape restoration schemes, designed to increase biodiversity, have also been installed, with two of these sites delivered during this financial year.

We will continue sharing insight from the projects through the Crossrail Learning Legacy online portal so that the industry and future projects can continue to learn from and build on our experience. While there is still an incredible amount of work to do, it won't be long before we hand the baton over to Transport for London, the future operators of the railway.

The Elizabeth line is on its way.



Andrew Wolstenholme
Chief Executive, Crossrail



REPORT STRUCTURE AND SCOPE

Crossrail's Sustainability Strategy established a number of key sustainability initiatives under the three pillars of sustainability (economy, society and environment) through which it has delivered its sustainability performance across the whole project. At this stage in the project's life cycle, the majority of the economic and social key sustainability initiatives have been substantively completed*. The key initiatives to measure, analyse and improve the project's environmental performance remain important in the latter phase of the project, as decisions can still be made which will reduce the project's impact to the environment and increase its positive contribution.

This environment report is a review of Crossrail's environmental performance in the year April 2016 to March 2017. The report includes the entire Crossrail delivery programme which covers the Network Rail works being delivered on the outer sections of the route.

The report sets out Crossrail's performance over the year against a number of key environmental performance indicators. As the Crossrail project is now nearing the end of the construction phase, it also presents an update on the cumulative performance over the entire construction period where this information is available.

This report has been designed to be comparable with the sustainability reports from previous years and covers the following sustainability themes:

- Sustainable consumption and production
- The physical environment and natural resource protection
- Address climate change and energy

Find out more at: learninglegacy.crossrail.co.uk



* Key initiatives on health, safety and wellbeing continue and are reported separately in the annual Health and Safety Report.

SUSTAINABLE CONSUMPTION AND PRODUCTION

Building large, long-life infrastructure such as a new railway requires the use of significant natural resources. Crossrail has tried to minimise the impact of this by designing the infrastructure to be sustainable long-term, specifying construction materials with increased recycled content and reducing the environmental impact of the excavated materials and waste.

Concreting train at Plumstead sidings, south east London

Indicator – Environmental assessment ratings

CEEQUAL

The tunnels, portals, shafts and other engineering structures being built are assessed for overall environmental quality using the Civil Engineering Environmental Quality (CEEQUAL) assessment scheme. All of these structures have either achieved an 'excellent' rating (the maximum possible score) in the design stage or are on course to do so.

Nine structures have been completed to date and each has achieved a post construction rating of 'excellent' under the scheme.

The Thames tunnel and western tunnels contracts that were completed last year performed particularly well in the categories of water resource management, and management of relations with local community and stakeholders respectively. Their performance was recognised at the 2016 CEEQUAL Outstanding Achievement Awards with a win and highly commended award respectively in each of these categories.

Nine projects are working towards achieving a CEEQUAL post construction rating of 'excellent'.

CEEQUAL	Target rating	Client and interim design rating	Construction rating
Western tunnels	Excellent	Excellent	Excellent achieved
Eastern tunnels	Excellent	Excellent	Excellent achieved
Thames tunnel	Excellent	Excellent	Excellent achieved
Sprayed Concrete lining structures	Excellent	Excellent	On target
Paddington Integrated Project	Excellent	Excellent	Excellent achieved
Eleanor Street / Mile End shafts and head houses	Excellent	Excellent	On target
Victoria Dock portal	Excellent	Excellent	Excellent achieved
Pudding Mill Lane	Excellent	Excellent	Excellent achieved
Royal Oak portal	Excellent	Excellent	Excellent achieved
Connaught tunnel	Excellent	Excellent	Excellent achieved
Stockley flyover	Excellent	Excellent	On target
Acton dive under	Excellent	Excellent	Excellent achieved
Western outer track infrastructure	Excellent	On target	On target
Western inner track infrastructure	Excellent	On target	On target
Old Oak Common Paddington approaches	Excellent	To be confirmed	On target
West stations	Excellent	On target	On target
Northeast section	Excellent	Excellent	On target
Southeast section	Excellent	Excellent	On target

BREEAM

Crossrail has adopted the Building Research Establishment Environmental Assessment Methodology (BREEAM) for all its central section stations and also for Abbey Wood station which is the only completely new-build station being delivered on the outer surface route.

Since the last report, all central section station design stage assessments have been completed and certified. Crossrail continues to work with contractors to identify where overall performance can be improved, subject to engineering feasibility, cost and programme constraints. Several opportunities are being investigated that will consolidate the 'very good' rating and contribute to an overall performance score towards the higher end of the rating band.

The majority of assets being certified under BREEAM are likely to be fully certified for their post-construction rating in the summer of 2018.

BREEAM	Target rating	Design stage rating	Post-construction rating
Tunnelling and Underground Construction Academy	Very Good	Achieved	Excellent achieved
Paddington station	Very Good	Achieved	On target
Bond Street station	Very Good	Achieved	On target
Tottenham Court Road station	Very Good	Achieved	On target
Farringdon station	Very Good	Achieved	On target
Liverpool Street station	Very Good	Achieved	On target
Whitechapel station	Very Good	Achieved	On target
Custom House station	Very Good	Achieved	On target
Abbey Wood station	Very Good	On target	On target
Woolwich station	Very Good	On target	On target
Iford logistics and stores	Very Good	Achieved	Achieved
Iford operations and welfare	Very Good	On target	On target
Plumstead depot	Very Good	On target	On target
Old Oak Common depot	Very Good	On target	On target



Whitechapel station
artists impression

Indicator – Recycled content by value

Recycled content by value is the standard industry metric developed by the Waste Resources Action Programme (WRAP) for the measurement of recycled content within construction products. Crossrail has set a target of 15 per cent recycled content by value across the programme, with a 'stretch' target of 20 per cent. The project has achieved 34 per cent, surpassing its target. This figure is consistent with previous years, attributed largely to the use of similar construction materials – predominantly steel and concrete.

During the year, Crossrail's contractors continued to assess the opportunities to procure products with higher recycled content where they exist and where there are no commercial constraints. Successes in this area have been delivered through an increase in cement replacement in concrete where it can be accommodated. This has the added benefit of reducing the embodied carbon in concrete.

The last year saw the cessation of major concrete pours, but opportunities to procure fit-out components such as blockwork with higher recycled content continued. Terrazzo flooring is another example of significant use of recycled content. It comprises stone chips from off-cuts generated in the cutting and processing of stone used in flooring, cladding and other architectural finishes.

Indicator – Recycling and reuse of waste material

A total of 146,000 tonnes of excavated material was produced over the year, of which 97 per cent was beneficially reused. The major excavation works on the project were completed in 2016-17 and delivered a much reduced volume compared to previous years. Over the life of the project, in excess of eight million tonnes of material has been excavated, of which 98 per cent was beneficially reused.

During 2016-17, 67,000 tonnes of construction and demolition waste was produced and 97 per cent of this was diverted from landfill. This brings the total produced to date to over 428,000 tonnes of which 98 per cent has been diverted from landfill. Crossrail has worked closely with its Tier 1 contractors to ensure the targets for this waste stream continue to be met.

Station contractors in particular have prepared strategies for the fit-out stage to identify opportunities for reduction, reuse and recycling. Crossrail has also been monitoring the volume of waste produced by all of its station contractors, with the aim of encouraging reduction in the waste produced. The station contracts have produced an average of 3.6 tonnes of waste for every £100,000 of spend on the contract. All of the stations meet the criteria for the maximum number of credits on waste production under the BREEAM rating.

Excavated material 2016-17



Construction & demolition material 2016-17



Opportunities for reusing waste materials continue to be sought. At Church Manor Way, on the south east surface section, the old Church Manor Way footbridge (a steel structure of approximately nine tonnes) was dismantled during a weekend of possession work and relocated to Brighton. In addition, the outer west surface stations' project team salvaged a large number of historic coping stones from West Ealing station and donated them to the Great Western Society (GWS) for reconstruction at Didcot Railway Centre. The stones were recovered from disused platforms that were dismantled to make space for a new platform at the station to accommodate the Elizabeth line trains. Didcot Railway Centre is a public museum and by donating the coping stones to GWS, these rare historic railway features will be saved and enjoyed by the public for years to come.

As the project nears completion, focus is moving towards finding new uses for assets that will no longer be needed. An example of this is at the Liverpool Street eastern ticket hall where the precast concrete slabs used to create a temporary deck were reused later at the contractor's yard in St Neots, Cambridgeshire.



Stones recovered from disused, dismantled platforms were donated to the Great Western Society for reconstruction at Didcot Railway Centre.

THE PHYSICAL ENVIRONMENT AND NATURAL RESOURCE PROTECTION

Crossrail's significant environmental impacts occur almost exclusively during construction. The aim on the project has been to protect the physical environment during construction, and where practicable to do so, to provide environmental mitigation.

The design of the operational railway has also sought to reduce impacts such as noise and vibration from the trains and equipment such as ventilation fans. Opportunities for providing green spaces have also been sought, particularly around portals and shafts and as part of site restoration across the outer surface sections of the route.

The opportunity to provide green spaces is more limited in the central section where oversite development is to be built above the stations as a vital part of the projects funding.

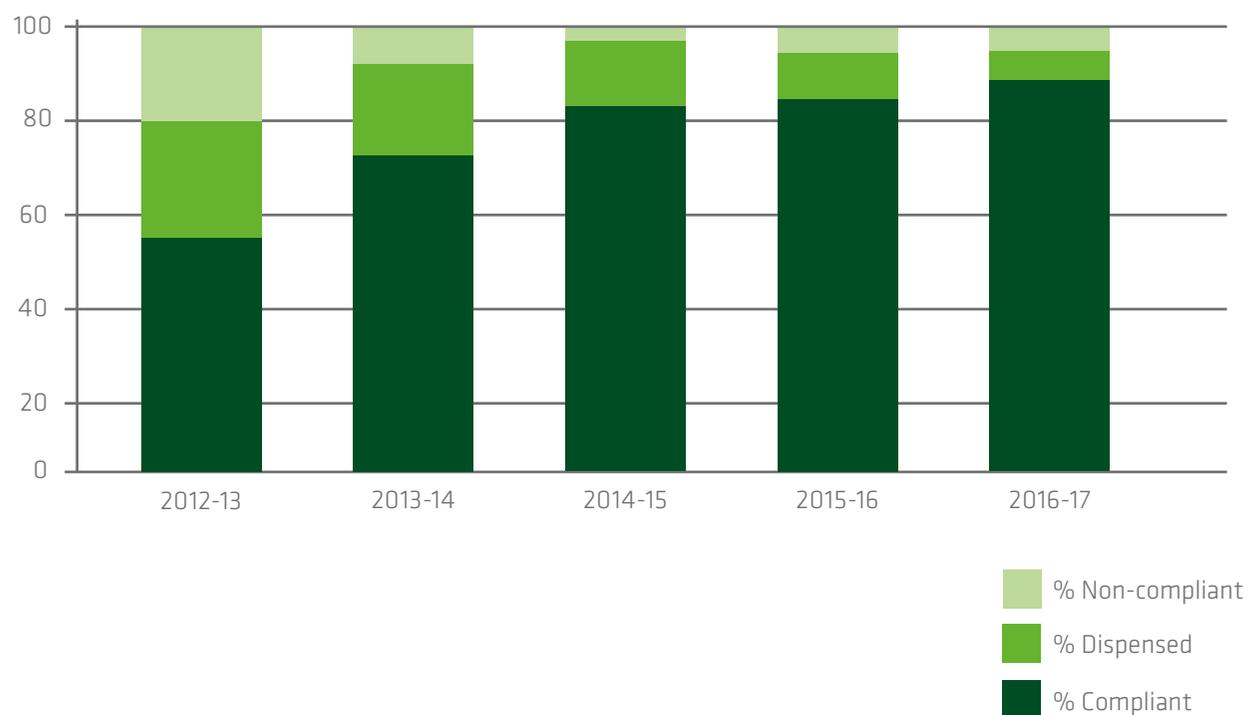
Air quality

Crossrail committed to reducing particulate emissions from construction machinery by using diesel particulate filters (DPF) or cleaner Euro Stage IIIB engines across the project. These engines comply with the requirements of the Central Activity Zone as specified in London's Ultra Low Emission Zone (ULEZ) for construction machinery.

The number of construction machinery working on the central section of the project has reduced from a peak of 334 (summer 2015) to 134 (spring 2017). Numbers will continue to decrease as the project nears completion. The proportion of machinery fitted with emissions controls being used on site has increased compared to the two previous years. In 2016-17, 88 per cent of equipment used in the central section of the route was fitted with emissions controls, an increase of three per cent.

Certain types of construction equipment, such as generators, are still not available with new cleaner engines and are therefore retrofitted. They are currently excluded from the requirements of London's ULEZ for this reason. Crossrail contractors, however, have continued to retrofit as many of these difficult pieces of equipment as possible. For example at Tottenham Court Road, Laing O'Rourke ensured that a 320KVA generator, which supplies energy to one of the sites, was fitted with a DPF prior to arriving on site. At Paddington, Costain Skanska joint venture retrofitted a 100KVA generator which is providing energy to the site offices and going further, they have been

Construction machinery emissions control performance



investigating retrofitting a 500KVA generator required for operation of the site's tower cranes. In another example, at Liverpool Street, Laing O'Rourke purchased new compressors, compliant with Euro Stage IIIB, as there was no availability in the rental market.

In all these circumstances the use of a generator is the last option where a mains electric supply is unavailable. DPF installation on generators does come with a cost, higher still for maintenance, however it is common that the generators are running 24 hours, seven days a week, so in these scenarios without a DPF they would be releasing particulate matter in highly populated central London locations.

Crossrail has also been working to raise awareness of the impacts of air quality on human health. A research study is being undertaken by King's College London, in collaboration with Crossrail and Alstom TSO Costain (ATC) joint venture, to investigate the exposure of the workforce to diesel exhaust within the tunnelling and rail-head environments. The study will measure exposure to diesel emissions and help identify and trial potential intervention methods for health improvement. The results of the study are expected in the summer of 2017.

As part of World Environment Day in June 2016, and with the help of Kings College London, Crossrail volunteers wore personal monitors to measure their exposure to harmful black carbon produced by diesel vehicles to see the affects of different modes of transport. The aim was to raise awareness of the impact of diesel emissions on health and ways in which to reduce their exposure. The findings will be made available through the Crossrail Learning Legacy website in 2018.



Moorgate ticket hall shaft

Water use

Nearly 300,000 cubic metres of water were used on the project during 2016-17, an increase of 13 per cent compared to the year prior. This brings total water use on the project to just over three million cubic metres. The most water intensive activity since tunnelling has been track installation and there has also been an increase in the volume of work undertaken on the surface section of the route.

Crossrail is providing water use information to HS2, which is developing a water calculator tool based on its own construction carbon calculation tool. It will enable HS2's contractors to predict water use, identify water saving measures and predict their likely outcome.

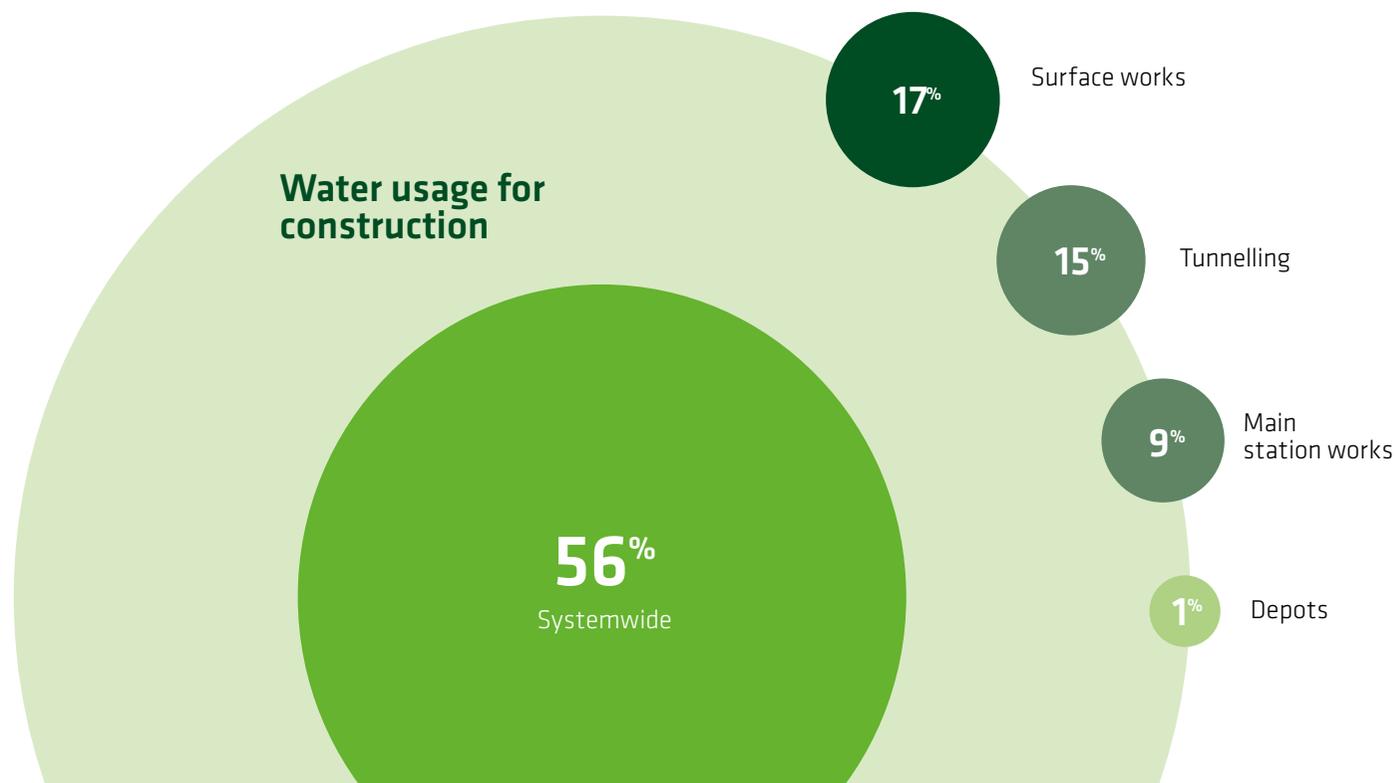
Crossrail contractors have continued to seek ways to reduce water use. At Abbey Wood, ingress water which was filling the excavations, was extracted using an electric pump and with the aid of an air compressor, used to damp down dust creation in the surrounding area. The site office at Abbey Wood was also fitted with two water butts, to harvest rainwater for the flower garden and to dampen the site compound. Systemwide contractor, ATC, has reused the water generated from wash out of the concrete train for batching new concrete.

At Pudding Mill Lane in Stratford, Crossrail completed groundwater remediation onsite using ozone sparging and vapour extraction to ensure suitability of the area for future use. The remediation aims to leave a positive legacy for the local area at a site that historically comprised various industrial uses which had left it with a source of groundwater contamination.

Biodiversity

Crossrail and Network Rail have undertaken work using the DEFRA biodiversity accounting methodology to determine the value (expressed as biodiversity units) of habitats lost, enhanced and created as a result of the project.

In the central section, the aim has been to incorporate biodiversity within site restoration schemes, wherever practicable and provide at least 80 per cent of the possible biodiversity units. Two sites were completed in 2016-17, bringing the total to five sites completed so far. At Pudding Mill Lane, restoration and urban realm works including a green wall, shrub, herb, grass seeding, woodland and street trees have been completed by Morgan Sindall.



At Royal Oak portal, Costain, as well as providing replacement ballast areas, planted shrub and grassland, wildflower meadow and trees. In addition, the Costain Skanska joint venture delivering the intermediate shafts contract commenced site restoration works at Eleanor Street by installing a sedum roof on the shaft structure, with the remainder of the planting to follow in 2017-18.

Together, these five sites have delivered 14 per cent of the potential biodiversity units which have been calculated to be achievable across the central section. Restoration schemes incorporating habitat enhancement and creation have been designed for a further six sites, which will contribute a further 70 per cent of the potential units available when complete.

On the surface section Network Rail has set a target to achieve no net loss of biodiversity. During the year, restoration work commenced at two sites; Acton dive under and Stockley Flyover. At Acton yard, tree species such as English Oak have been planted and a new species rich grassland has been created. At Stockley Flyover the restoration works include planting of broad-leaved woodland, scrub woodland, marginal vegetation and neutral grassland along with the installation of a pond area. When completed, restoration at these two sites will account for 11 per cent of the biodiversity units lost during the works. Restoration plans at other sites will account for 48 per cent of biodiversity units. Network Rail intends to continue working with the local wildlife trusts to identify areas of land they currently manage that would be suitable for biodiversity enhancements

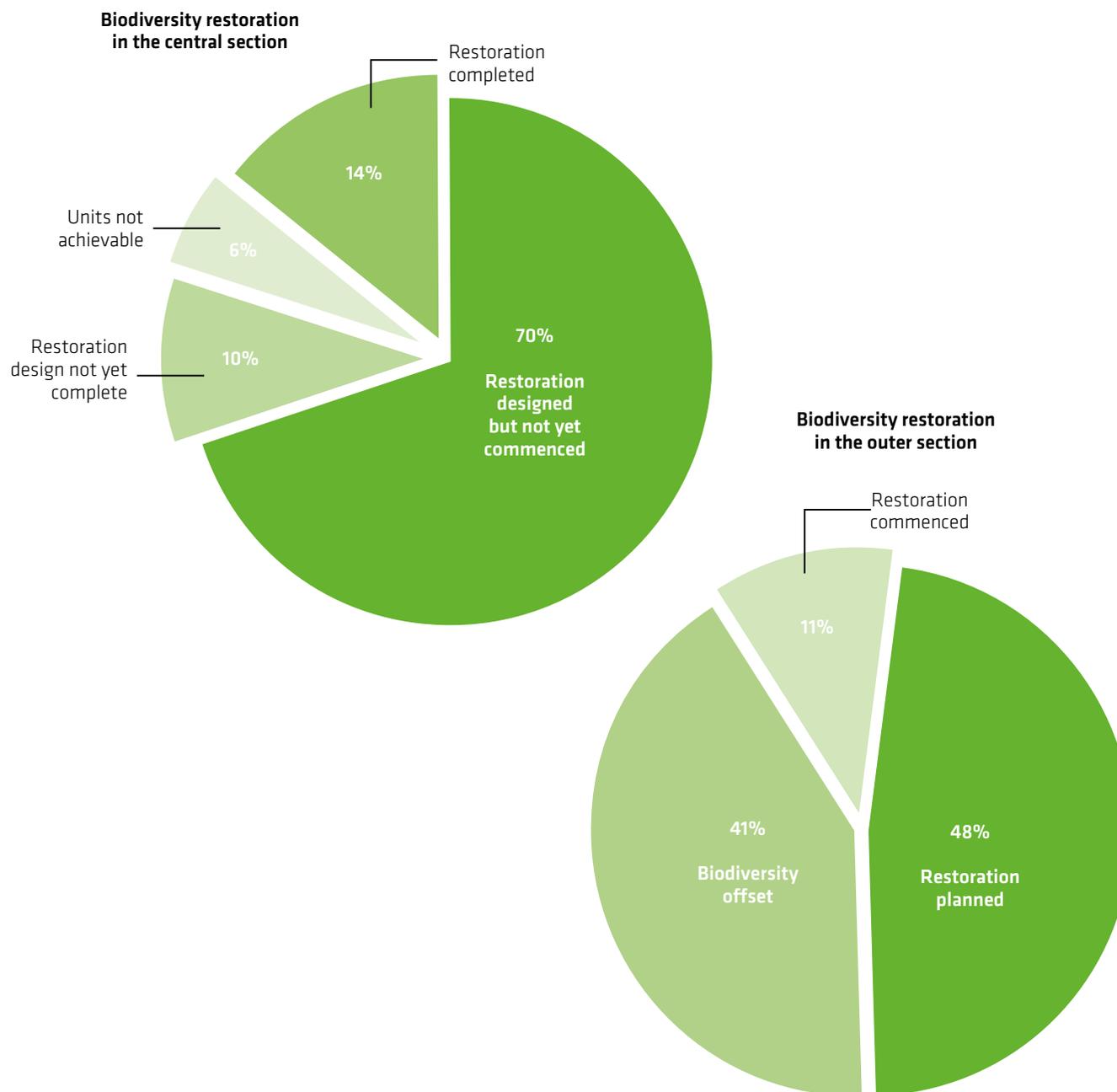




Mile End head house topped with a green roof

and thereby endeavour to offset the remaining 41 per cent of units that have been lost during the delivery of the works.

Together with the Royal Society for the Protection of Birds (RSPB), Crossrail help create a new wildlife reserve on Wallasea Island in Essex. Jubilee Marsh, as it is now known, is performing better than expected and has become a haven for wintering birds. Over one day in December 2016, the RSPB counted 29 species of bird in a total count of 7,839 individuals at Jubilee Marsh alone. Out of a total count of 36 species and 12,096 individuals across the entire wildlife reserve, this shows how big a contribution Jubilee Marsh is making to the Wallasea Wild Coast Project as a whole.



Archaeology

Museum of London Docklands partnership and exhibition

Museum of London Archaeological Archive received the final deposition of the Crossrail archaeological finds and archive materials at the end of 2016, and a digital copy of the archive is in the process of being uploaded to the Archaeology Data service (ADS) website for secure storage and public access (see: archaeologydataservice.ac.uk).

An agreement was reached with the Museum of London Docklands (MOLD) to work in partnership and deliver an exhibition to showcase the major finds of the project, give broad public access to the discoveries and relay the context of the engineering project in their presentation. 'Tunnel: the archaeology of Crossrail' opened at the MOLD (Elmers Gallery) on 10 February 2017. Over 500 objects from the tens of thousands discovered on the project were displayed, exploring 8,000 years of human history in the capital, ranging from Mesolithic tool makers and inhabitants of Roman Londinium to those affected by the Great Plague of 1665. Finds were discovered in locations as diverse as suburban Plumstead in the south east, through Canary Wharf, across to Liverpool Street, Tottenham Court Road and ending in Westbourne Park and Acton.

The free exhibition was launched by Andrew Wolstenholme of Crossrail and Sharon Ahment of the Museum of London, with an appearance by Crossrail-fan comedienne Mel Giedroyc. Media coverage of the exhibition included excellent reviews from print and



Tunnel: The archaeology of Crossrail exhibition at Museum of London Docklands



Tunnel: The archaeology of
Crossrail exhibition at Museum
of London Docklands

broadcast media. Between October 2016 until the end of March 2017 there were over 174 news articles with a estimated readership of over 51 million people.

The exhibition saw 30,500 visitors by the end of the reporting period. It remains open until 3 September 2017.

A book to accompany the exhibition was also produced in partnership with the museum. The book has been sold in a number of venues including Museum of London, London Transport Museum and online. It had sold 650 copies between February and the end of March 2017.

MOLD events

To accompany the exhibition the MOLD developed a series of public events. The 'Discover Crossrail' walking tours explore the archaeology, history, and construction of Crossrail in ten areas across the Crossrail route.

Twenty-three people attended a tour of Plumstead and Woolwich, and 25 people attended a tour of City Airport to Custom House. Further walks later in 2017 will focus on Paddington, Bond Street, Tottenham Court Road, Farringdon, Charterhouse Square, Liverpool Street, Stepney Green and Docklands.

MOLD will hold an additional three talks covering three themes on the project: Crossrail archaeology and engineering as well as London's railway history.

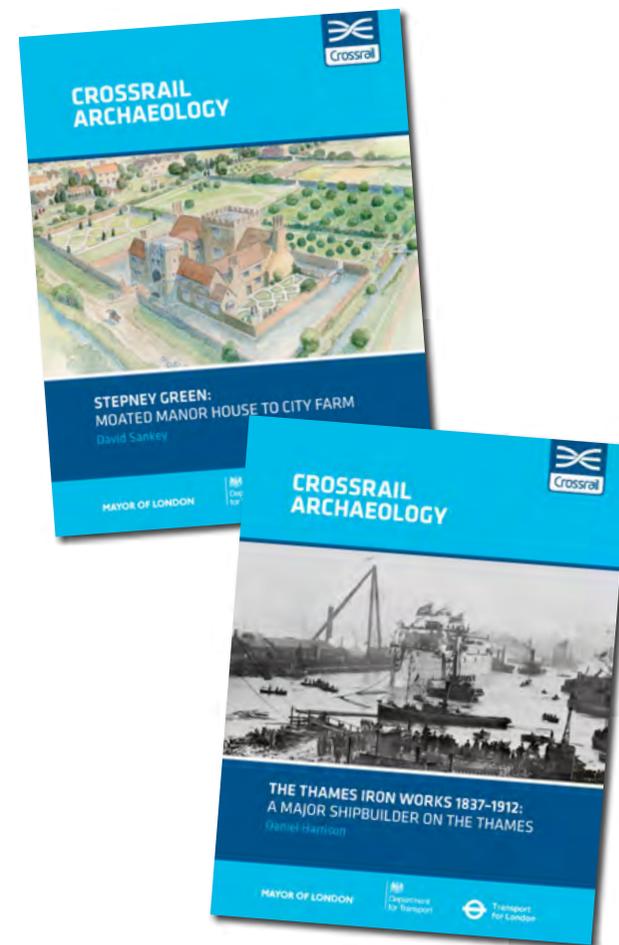
Post-excavation dissemination and publication

Following the publication of the first two volumes in the Crossrail archaeology series in 2016, Crossrail launched a further five volumes in early 2017:

- Volume 3 – The changing face of London: Historic Buildings and the Crossrail route
- Volume 4 – From Brunel to British Rail the Railway Heritage of the Crossrail Route
- Volume 5 – The new frontier: The origins and development of West London
- Volume 6 – Crosse and Blackwell 1830–1921: A British food manufacturer in London's West End
- Volume 7 – Charterhouse Square: Black Death Cemetery and Carthusian Monastery, Meat Market and suburb.

The final three volumes in the series will be published in the autumn of 2017.

Find out more at: learninglegacy.crossrail.co.uk

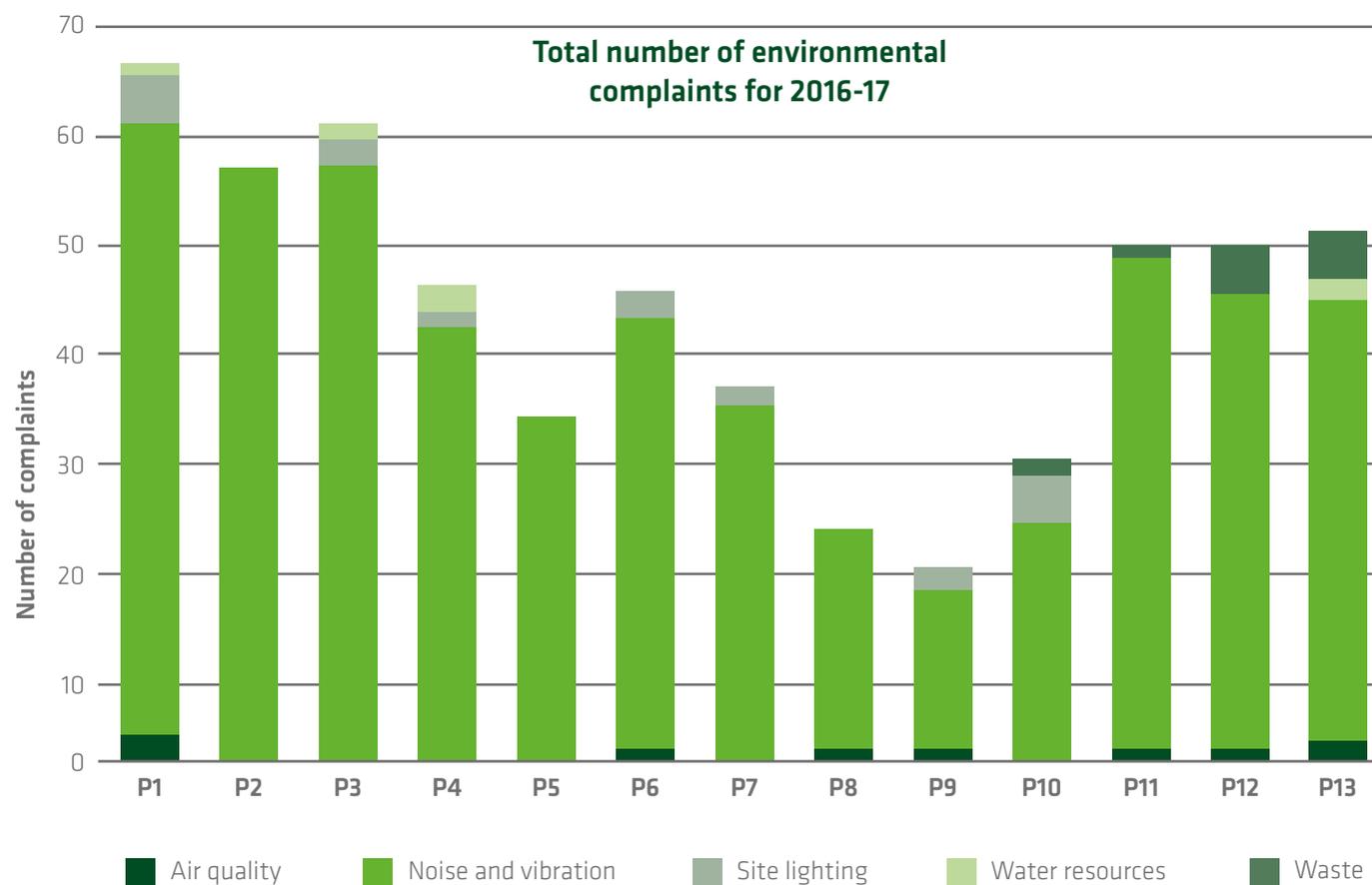


Indicator – Environmental complaints

Many of Crossrail's construction sites are located in urban and suburban areas in close proximity to local communities comprising residential and commercial properties. This means that the 24 hour, seven days a week construction works have the potential to disrupt the surrounding workforce and residents. Managing noise and vibration from construction has remained a key priority on the project during 2016-17.

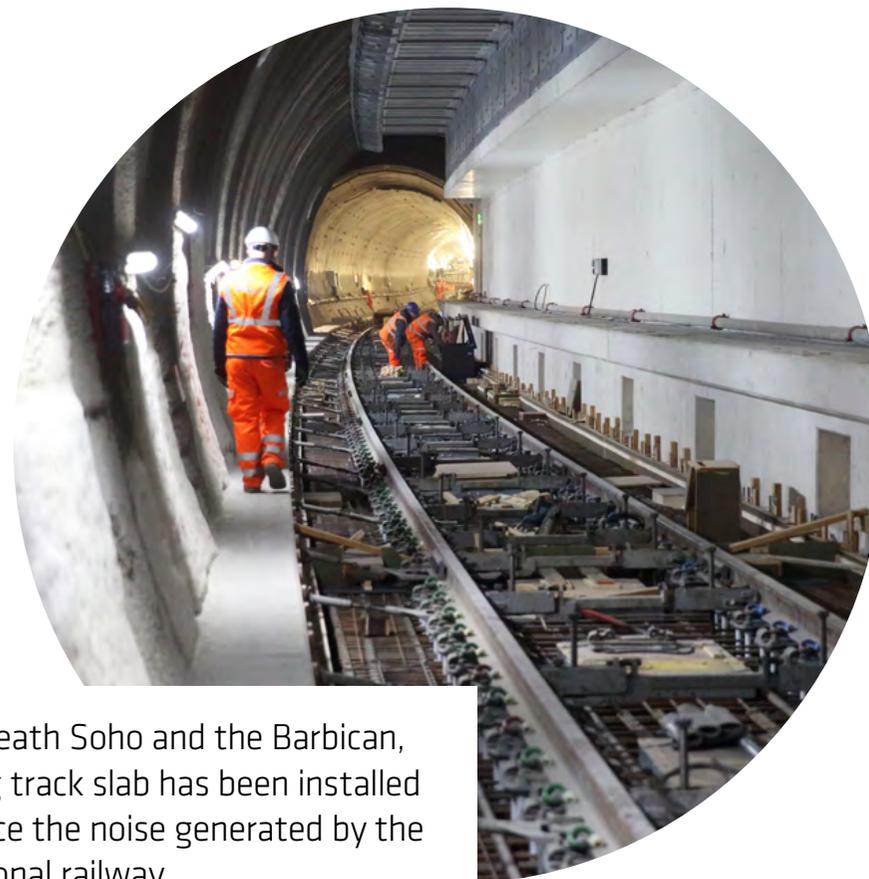
There were a total of 575 environmental complaints submitted to Crossrail during 2016-17 of which 94 per cent related to noise and vibration. This is a reduction compared to 2015-16. Just over half of the environmental complaints received were reported on the surface section, in particular at Maidenhead, Abbey Wood, Shenfield and Brentwood. In the central section, most complaints were at Whitechapel station, Liverpool Street station and Ilford stabling yard.

At many of the sites, including Whitechapel, Bond Street and Farringdon stations, there was a decrease in complaints which was due to the changing nature of construction works from heavy civil construction to mainly fit-out activities underground. At Whitechapel the most seriously affected residents were provided with temporary rehousing which also contributed to the reduction in complaints. Some sites such as Liverpool Street and Ilford yard had an increase in complaints. This was due to additional out of hours works taking place. At Liverpool Street there was also more work carried out above ground.



Crossrail continues to operate industry best practice mitigation methods to control noise from construction works. For example, during the autumn (2016), Alstom TSO Costain joint venture operated concrete pumping stations at Fisher Street, Bond Street and Farringdon work sites. Specialist concrete was pumped to cast a floating track slab system in sections of the eastbound and westbound running tunnels. The concrete pumping stations were operated after hours (between 18:00 and 8:00) to minimise the delay of the specialist concrete arriving by heavy goods vehicles. Purpose-built acoustic enclosures were employed to house the pumps and associated equipment, reducing the potential noise impact at surrounding receptor locations.

At Liverpool Street, a study was undertaken which utilised microphone technology developed by the National Physics Laboratory. A network of 16 microphones was used at the Moorgate site to collect and analyse noise data to help determine the impact of noise on the local community. The benefit of using the network was that it was possible to determine whether noise experienced by local residents was being caused by the Moorgate construction works (as opposed to surrounding sites) and from which specific site activities. The project successfully achieved its goal of demonstrating the concept of using an acoustic sensor network to study noise from a construction site.



Underneath Soho and the Barbican, floating track slab has been installed to reduce the noise generated by the operational railway.

ADDRESS CLIMATE CHANGE AND ENERGY

Crossrail is a major energy user, during construction (particularly through the operation of tunnel boring machines and associated material transportation) and operation over its lifetime.

Crossrail remains committed to reducing its carbon footprint, by reducing the energy consumption of the operational railway, the embodied energy in construction products and the energy used during construction.



GFRC cladding at
Tottenham Court Road station

Indicator – carbon footprint

In 2014 Crossrail signed up to the Green Infrastructure Board's (GIB) Infrastructure Carbon Review, making the following commitments:

- Commit to minimise the carbon footprint of the programme through the construction phase
- Commit to achieving energy saving efficiencies through design of station facilities and best practice in operation
- Commit to working with our supply chain to procure materials and products for Crossrail that take due account of their sustainability and impact on the project's carbon footprint

The commitment was signed by Andrew Wolstenholme, CEO Crossrail, and is supported by the senior leadership team. An annual report of Crossrail's performance is submitted to the GIB. Examples of key progress areas against these commitments are covered in the subsequent sections of this report.

Construction carbon emissions

Crossrail set a target of reducing its construction related carbon emissions by eight per cent which the project is on target to achieve. With over 80 per cent of construction completed at the end of the reporting period and many of the energy intensive activities reducing, the reduction was just under 15 per cent. This is higher than the figure reported last year, largely due to a revalidation exercise

undertaken for treatment of green tariff electricity and the continuation of many initiatives including LED lighting, hybrid and hydrogen technologies.

The project has used the Greenhouse Gas Protocol Scope 2 Guidance, an amendment to the greenhouse gas protocol corporate standard (published in 2015), to assure the use of green tariff electricity and that has only credited carbon reductions for tariffs that are calculated in accordance with that guidance. This has provided a more robust approach to the treatment of green tariff electricity used in the construction of the Elizabeth line.

Crossrail's construction carbon calculation tool and user guide was made available to the industry through Crossrail's Learning Legacy programme in 2016.

Embodied carbon

As reported previously, the project has been able to reduce its embodied carbon footprint primarily through the use of concrete with cement replacements. Cement production is carbon intensive as the conversion of calcium carbonate to calcium oxide, one of the key components of ordinary portland cement, releases carbon dioxide. Furthermore, the heat required for cement kilns is derived from hydrocarbon based fuels. Any reduction in cement therefore has a benefit in reducing the inherent carbon within the concrete.

Crossrail's concrete specification requires a minimum of 50 per cent cement replacement and in some cases the project has been able to increase this to as much as 72 per

cent with subsequent carbon reductions. However, it is not always possible to accommodate these changes due to the particular performance requirements of the concrete and the potential impact on the construction programme as a result of the extended curing time required for concretes with high cement replacement. The majority of Crossrail concrete pours have now been completed and the remaining data will be collated to provide a final project carbon footprint.



Find out more at: learninglegacy.crossrail.co.uk

Rolling stock and depot

Energy efficiency has been at the heart of design for the new class 345 rolling stock and with production and testing underway, the programme continues to give confidence that the planned efficiency will be realised. The project had initially set a target to achieve less than 350 tonnes of total train mass, which is a major determinant of how much energy the train will use on each journey. The total train mass achieved, however, was 319 tonnes, delivering a better outcome than was originally expected. The new Elizabeth line trains are 25 per cent lighter than existing trains on the network (for an equivalent length). They also feature:

- an aerodynamic front and body profile to help the train move more efficiently through the tunnels
- smart control software to maximise energy recovery during braking
- a traction drive designed to cut down mechanical and electrical system loss
- LED lighting with automatic dimming
- intelligent stabling to minimise energy use when parked
- driver advisory information to moderate power consumption if running ahead of schedule
- sensors to avoid waste in managing the fresh air flow, heating and cooling for the passengers.

At Old Oak Common the structure of the main depot building is now complete and solar photovoltaic and solar thermal roof panels, energy piles and rainwater harvesting systems have been installed. Overall, the combined technologies are predicted to reduce operational carbon emissions from the depot by 35 per cent, a considerable improvement on the overall target to reduce operational carbon dioxide from the depot by 20 per cent.



**New state-of-the-art class
345 Elizabeth line trains**



Inside the new Elizabeth line trains

Geothermal heat

Previous reports covered a future-proofing strategy for the oversite developments above stations, by incorporating technology to extract ground heat from around the station structure for their benefit. Crossrail has been working very closely with prospective developers of these sites to ensure that the capability to capture both heating and cooling from this provision is utilised when the first developments are built.

Ultimately the solution has had to prove financial viability for the developers which has varied from scheme to scheme based on building design, use, and so on. At the Fisher Street shaft and Liverpool Street station's eastern ticket hall, the developer is likely to utilise ground heat. At Farringdon station's eastern ticket hall the project is awaiting final tests on the geothermal piles to assess its viability. At Tottenham Court Road station's western ticket hall and Paddington station the scheme is being tested by the market and it is likely that ground heat will be utilised.

The significance of operational energy

The graphic (right) shows the importance of managing the operational energy over the lifetime of the project as it equates to 78 per cent of the overall carbon footprint.

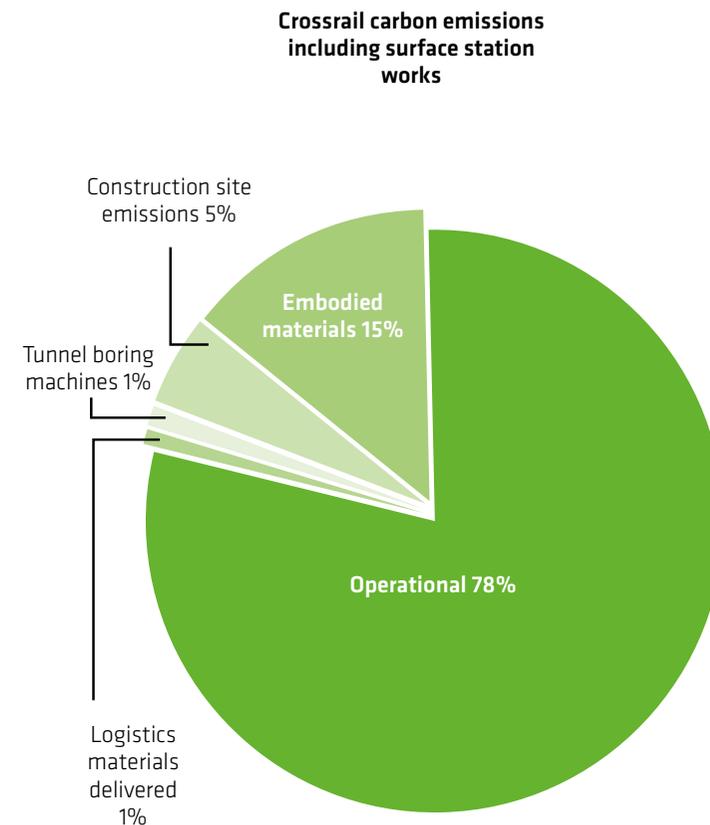
The focus on keeping train weights to a minimum and ensuring an uninterrupted service with minimal signal failures will help to minimise this aspect of the overall emissions. Furthermore, the design of the mechanical and electrical components within the stations has

progressed and a reiterative process is being undertaken to ensure that these are optimised and low no-load loss transformers have been procured for improved efficiency.

Green Systems Recognition Scheme

Crossrail recognises that improving environmental performance means helping everyone involved to understand what needs to be done and providing the motivation to do it. With the increasing involvement of contractors installing the railway systems, the Green Systems scheme was launched in 2016 to encourage Crossrail's systemwide contractors to engage with their workforce in environmental issues. It builds upon earlier work with civil contractors as part of Crossrail's Green Line Recognition Scheme.

The joint venture between Alstom Costain joint venture, who are working on one of Crossrail's systemwide contract, was the first contract to be recognised under the scheme. The contract demonstrated active engagement with their whole workforce and demonstrated some significant environmental improvements. For example, by carefully selecting more efficient auto transformers, ATC has enabled significant energy savings during the operation of the railway. They have also promoted energy savings during the construction phase through an initiative to switch from fuel to electric powered concrete pokers.



LEARNING LEGACY

In February 2016 Crossrail launched a new online resource to share insight from the project for the benefit of industry: The Crossrail Learning Legacy. There are nearly 500 documents available so far and new content will continue to be published every six months.

Since its launch, the project has published 94 environmental learning legacy documents. These include case studies, micro reports, good practice documents and further supporting documents such as toolkits, plans, procedures and policies.

The website has had 8,758 visitors over the year. Crossrail's environment team attended 18 dissemination events and six webinars were completed, jointly hosted by the Institute of Environmental and Assessment (IEMA) and Construction Industry Research and Information Association (CIRIA). There was an average of 150 – 200 attendees on each webinar and very positive feedback received including *"This has been a tremendous series of webinars"* and *"At a recent webinar on Crossrail's Green Line I saw that where there is a real determination at the top level, amazing achievements are possible..."*.



Find out more at: learninglegacy.crossrail.co.uk



" Passing on the lessons and good practice that we have learned at Crossrail is an absolutely essential part of raising the bar in the delivery of major projects".

Andrew Wolstenholme, Crossrail Chief Executive

Cladding the escalator barrel at Bond Street





www.crossrail.co.uk

MOVING LONDON FORWARD