THE UK'S NEW GREEN AGE

A step change in transport decarbonisation

January 2021

ALSTOM
• mobility by nature •

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ALSTOM IN THE UK

Mobility by nature

Alstom is a world leader in delivering sustainable and smart mobility systems, from high speed trains, regional and suburban trains, undergrounds (metros), trams and e-buses, to integrated systems, infrastructure, signalling and digital mobility. Alstom has been at the heart of the UK's rail industry for over a century, building many of the UK's rail vehicles, half of London's Tube trains and delivering tram systems. A third of all rail journeys take place on Alstom trains including the iconic Pendolino trains on the West Coast Mainline, which carry 34 million passengers a year.

Building on its history, Alstom continues to innovate. One of its most important projects is hydrogen trains—its Coradia iLint has been in service in Germany and Austria, and with Eversholt Rail, it has developed the 'Breeze' hydrogen train for the UK.

Alstom's state-of-the-art Transport Technology Centre in Widnes in the Liverpool City Region is its worldwide centre for train modernisation and is where the conversion of trains to hydrogen power will take place. It is among 12 other sites in the UK including Longsight in Manchester and Wembley in London.

Across the world Alstom has developed, built and maintained transport systems including high speed rail in every continent that has high speed rail, and mass transit metros and trams schemes including in Nottingham and Dublin. Alstom also has the largest framework contract for Network Rail's signalling programme and it is bidding to build the new HS2 trains, signalling and infrastructure.

As well as building trains, trams and rail systems, Alstom technologies enable networks to be the most effective and carbon efficient. Whether through energy efficiency and vehicle design, or integrating transport modes and optimising public transport networks to improve the user journey and allow stations to manage capacity, Alstom's technologies focus on sustainable and smart solutions.

In February 2020, Alstom announced it had come to an agreement to acquire Bombardier Transportation. Upon completion, Alstom will increase its scale in the UK and play an even more pivotal role in delivering sustainable transport systems designed and built in the UK.

With the adoption of its ‘Mobility by Nature’ branding in 2019, Alstom has made clear its objective to advance transport solutions that focus on sustainable performance, decarbonisation and digitally enabled efficiency to help the world meet its climate objectives. A snapshot of Alstom’s global presence in rail decarbonisation is outlined on the following page.

As the UK strives to achieve net zero and decarbonise the railway, Alstom can uniquely offer every traction solution identified by the rail industry taskforce in its response to the Government’s decarbonisation challenge—electrification, hydrogen and battery powered trains. Alstom’s technologies can help to lock in emission reductions and help set the UK on a green recovery path, as well as show leadership in this, the year of COP 26—the global climate talks being held in November.

Selected Alstom rail, light rail and metros global snapshot

Alstom plays a leading role in delivering transport decarbonisation through rail systems in countries and cities across the world. This includes the four areas examined in this report: electrified railways, high speed rail, hydrogen trains and mass transit and light rail systems, including metros, underground systems and trams.

High speed rail

UK (Pendolino/Eurostar)	Poland
France (TGV)	Portugal
Italy (AGV/Pendolino)	Spain
Germany	Finland
Luxembourg	Russia
Belgium	Morocco
Switzerland	USA
Czech Republic	China

Hydrogen trains

UK	Italy
Germany	Austria
Netherlands	

Electric regional and suburban

UK	Netherlands
France	Chile
Italy	Australia
Spain	South Africa
Germany	

Metros (Undergrounds)

UK: London	**Saudi Arabia**: Riyadh
France: Paris, Lyon, Marseille	**India**: Chennai, Kochi, Lucknow, Mumbai
Netherlands: Amsterdam	**USA**: New York
Spain: Barcelona	**Panama**: Panama City
Germany: Hamburg	**Mexico**: Guadalajara
Singapore	**Canada**: Montreal
China: Shanghai, Nanjing	**Australia**: Sydney

Trams

UK: Nottingham	**Algeria**: Algiers, Oran, Constantine, Setif
Ireland: Dublin	**Qatar**: Lusail
France: Paris, Bordeaux, Lyon, Tours, Nice, Caen, Angers, Avignon, Nantes	**Morocco**: Casablanca, Rabat
	Brazil: Rio de Janeiro
Netherlands: Rotterdam	**Canada**: Ottawa, Toronto
Greece: Athens	**Ecuador**: Cuenca
Germany: Frankfurt	**Australia**: Melbourne, Sydney
UAE: Dubai	**Taiwan**: Kaohsiung

THE UK'S NET ZERO IMPERATIVE

Context for change

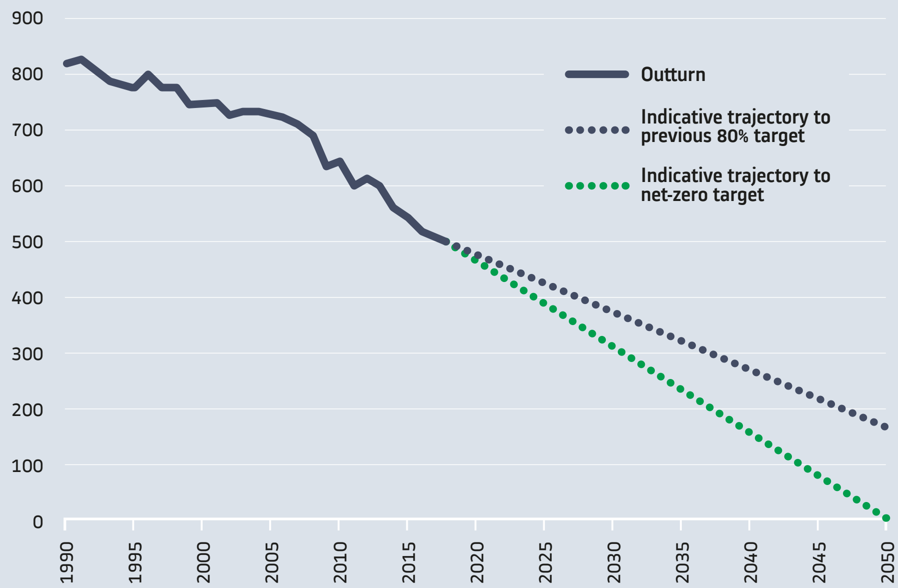
As we collectively experienced the life changing global COVID-19 crisis, we face another. Halting global temperature rises to avoid the catastrophic impacts of a hotter planet is going to be the greatest challenge facing countries across the world. There is now a crucial decade in which to take the actions needed to reduce carbon emissions to keep average temperatures from increasing by more than 1.5 degrees. Significant steps on this journey must be taken now. But, the actions and changes required also need to be taken at a time when countries are experiencing the severest public health crisis in a century, which has caused unprecedented social and economic impacts, many of which are still unfolding.

This landscape is challenging, and it requires every sector and company to play a role in the step change needed. As a leading global sustainable transport company, Alstom is stepping up as a driving force in the decarbonisation of transport in the UK. This report looks at a series of key challenges alongside the technologies and transformations that can help create a step change to enable the UK to meet its carbon targets and to secure many other benefits that stem from the creation of a decarbonised transport sector. Setting a clear pathway for transport decarbonisation and making much more rapid progress would be a clear demonstration of UK leadership in the year that the country hosts the critcal global climate talks, COP 26.

The role of transport in UK emissions

Since 1990, the UK has reduced its greenhouse gas (including carbon) emissions significantly. In 2018, UK emissions were 44% below the benchmark 1990 levels.[1] But, as the Government acknowledges, much greater reduction is required. In June 2019, the UK legislated for a net zero target by 2050, recognising the severity of the situation the country faces and, in the process, set a much more ambitious path for the nation (as the graph below outlines). Achieving net zero requires an annual rate of emissions reduction that is 50% higher than the UK's previous 2050 target would have required and nearly a third higher than achieved on average since 1990. In December 2020 the Prime Minister also laid out a new 68% target for overall emission reduction by 2030. In December 2020 the Prime Minister also laid out a new 68% target for overall emission reduction by 2030. As the UK's climate advisory body, the Committee on Climate Change (CCC) has outlined, achieving net zero requires a step change in action with rapid decarbonisation required across all sectors.

Graph 1: Drop in greenhouse gas emissions and need to fall further



Source: BEIS 2019 UK Provisional Greenhouse Gas Emissions[2]

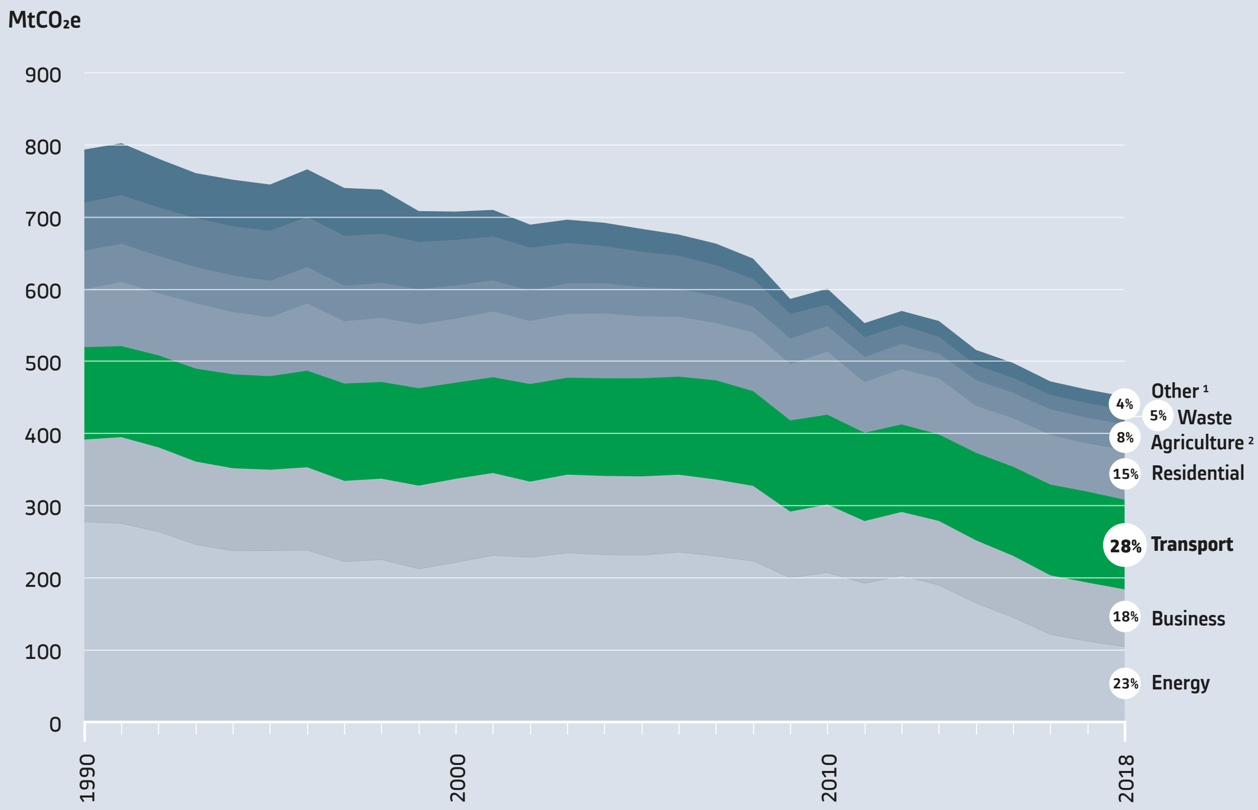
National emission reductions to date have largely been through progress made in the energy sector, particularly through the phasing out of coal. In a number of sectors much more improvement is needed and that is true of the transport sector.

As the CCC has highlighted, transport emissions (excluding aviation and shipping) are now the largest source of UK emissions and these actually increased between 2013 and 2018.[3] While a future downward trajectory is predicted by the Government, more progress is needed to achieve the step change that the CCC has called for. The Government's Transport Decarbonisation: Setting the Challenge consultation—henceforth known as the Government's shorthand reference the TDP (Transport Decarbonisation Plan) states:

> **'DfT projects transport emissions to fall steadily as a result of the existing firm and funded policies, but that the speed of reduction is much slower than what is likely to be needed'... 'the UK must go much further in reducing domestic transport emissions than currently projected if we are' ... 'to meet our legal obligation to reach net zero GHG emissions by 2050.'** [4]

The graph below shows the state of play.

Graph 2: UK Domestic GHG emissions 2018



Source: 2018 UK Greenhouse gas emissions and published in the TDP

[1] Includes Public and Industrial Processes emissions

[2] Includes Land Use, Land Use Change and Forestry (LULUCF)

The Government has set a target to decarbonise rail by 2040, including seeking to remove all of the circa 3,700 diesel rail vehicles used on the railway network.[5] The Scottish Government, which oversees most railway services in Scotland, has set an even more stringent target to remove all types of pure or partial diesel passenger trains by 2035.[6] Wales has set ambition for a net zero public sector by 2030 which includes transport.[7] An industry wide taskforce made a formal response to the Government confirming that the objective is achievable, and Network Rail has published a Traction Decarbonisation Network Strategy Interim Business Case.[8]

Regional and local leadership and major rail plans

In England, mayors, combined authorities and local authorities have set goals for achieving net zero emissions earlier than the Government's net zero 2050 target such as Greater Manchester, setting a 2038 net zero goal and the West Midlands, 2041.[9] Two thirds of authorities have declared climate emergencies and are drawing up local decarbonisation plans.[10] A number of areas are also bringing forward Clean Air Zones, which are coming into force much earlier than the net zero targets, and which will shape the local and regional transport landscape.

Major transport schemes are underway. HS2 creates a new rail network spine across the country whilst freeing up capacity on existing lines for passenger use and freight. Midlands Engine Rail (MER) and Northern Powerhouse Rail (NPR) are programmes which bring significant improved and new services and a new railway is being constructed between Oxford and Cambridge. Alongside, new sub-national bodies have been created to develop and take forward plans with devolved powers and budgets while cities have plans too including the extension of the Nottingham, Manchester and West Midlands trams.

The challenge

However, even with a national net zero target, local and regional ambitions and a range of transport plans, as the TDP states:

> **'Whilst we know the scale of the challenge, we do not currently know the optimal path for delivering a decarbonised transport network.'**

Critically, the TDP outlines the Government's goals of modal shift and to reduce car use:

> **'Public transport and active travel will be the natural first choice for our daily activities. We will use our cars less and be able to rely on a convenient, cost-effective and coherent public transport network.'**

The TDP's goal is echoed in the Government's Ten-Point Plan for a Green Industrial Revolution, which says that we must increase the share of journeys taken by public transport, cycling and walking.[11] This approach is a radical departure from previous policy approaches and reflects that a 'climate emergency' requires a different course of action to what has gone before. This in turn suggests there should be a reappraisal of how to assess and fund schemes given the required modal shift and carbon goals.

A third point is one of speed and scale. As Grant Shapps MP, the Secretary of State for Transport, says in the TDP:

> **'The scale of the challenge demands a step change in both the breadth and scale of ambition and we have a duty to act quickly and decisively to reduce emissions' … 'The faster we act, the greater the benefits.'**

The challenge therefore is creating:

1. A clear path to decarbonisation
2. Modal shift and reducing car usage in favour of public transport
3. A step change by acting swiftly

The goal is to make it a reality.

This report addresses these points and focuses on rail and mass transit systems, with technologies and solutions that can be deployed, harnessed and scaled. It is not simply about decarbonising each transport mode but modal shift to the greenest forms of transport; and reducing car use, moving to public transport including rail services, shifting freight from road to rail, and creating rail services that provide a viable alternative to flying.

It means developing and delivering transport plans at pace, bringing forward (new) funding and new funding models, embedding and accelerating green goals, and deploying technologies at scale and with a co-ordinated approach encompassing national, regional and local action. It also entails 'levelling up' green transport options to achieve a green transport transformation.

The report brings together industry perspectives, drawing on Alstom's global leadership and experience, with case studies from the UK and abroad and outlines agendas for national, regional and local decision makers in four key areas:

» **Electrification**—electrifying more of the existing rail network, which is among the least electrified in Europe, as well as expanding and improving rail services
» **Hydrogen**—the use of hydrogen as a traction power source for rail to replace the polluting diesels and as an option for future new and reopened lines
» **High speed rail**—bringing a step change in services, resilience and reliability with a new high speed network across much of the country
» **City and regional mass transit systems**—delivering new and expanded integrated city and regional mass transport systems with carbon designed out during construction and operation

COVID-19 implications and considerations

While the focus of the report is decarbonisation, COVID-19 sets a wider landscape. The pandemic has resulted in unprecedented economic and social impacts, including a reduction in use of transport and a financial hit for transport authorities. While the scale and scope of the longer-term implications are still emerging, there are factors to consider in relation to transport.

In the more immediate term COVID-19 will continue to affect transport including through curtailment of use and social distancing until the results of a full vaccine rollout are felt. However, the future cannot be a car-based approach. The impact of climate change is foreseeable with models showing the potential devastation at a scale in excess even of the pandemic. As such, the necessity to cut carbon emissions is still paramount. The increase in the use of cars seen as people returned to work post the first COVID-19 lockdown has seen correlating increases in congestion even without a full return to work. Greater car use also brings concomitant factors such as road deaths and the impact on air quality. Poor air quality is a cause of an estimated 28,000–36,000 deaths a year in the UK.[12] A Centre for Cities study suggests that the South East is particularly affected with one in 16 people dying from exposure to the PM2.5 pollutant in Slough, Luton and London every year.[13] Furthermore indications are that the effects of poor air quality can make COVID-19 symptoms more acute.[14]

The benefit of clearer roads and cleaner air during the first part of the pandemic has led to calls for the benefits to be retained. As part of this, car reduction schemes are being taken forward including cycling and walking programmes and closing some roads. This is happening outside of the UK too.

Looking ahead, historical trends on travel should be recognised. Passenger transport usage on rail has more or less increased continuously over the last two centuries. As a Rail Delivery Group (RDG)/High Speed Rail Group (HSRG) report has shown, rail travel demand has more than doubled since 1994. Demand bounced back following crises such as SARS in 2003 and the Spanish flu in the 1918-20s.[15] Passengers were told not to travel and when the outbreak eased passengers returned. Rising travel demand has been constant. Leisure travel is a growing part, and which makes up the majority of distance travelled across the transport sector. This proportion could increase if working from home becomes more permanent.

UBS research suggests that growth in air travel will fall leading to a model shift to high speed rail while high speed rail will expand faster than any other part of rail growth.[16] Rail is also not only a green way to travel, it has been a safe way to travel and will remain so. The task is to enable rail to be the mode of choice. Germany and France have both taken this approach for their COVID-19 recovery plans.'[17]

Alstom shares the view that a recovery must be a green one. The UK's comparator countries have embarked on a stimulus package to build back better, protect and support jobs and make good ambitious climate goals. France has agreed a €100bn (£89bn) economic stimulus package with elements including a stimulus equivalent of 4% of France's annual economic output, four times bigger than that implemented after the financial crisis of 2008.[18] It includes a £30bn investment in greener energy including £2bn for the hydrogen economy with a strong focus on greening transport including railways. Alstom has worked with the French Government on the programme. Germany has a similar package including support for public transport, rail electrification and €7bn for hydrogen including green hydrogen production.[19] Alongside there has been a campaign to encourage a return to rail. Belgium has initiated with a free ticket promotion.[20] A return to rail programme in the UK is supported by industry and passenger bodies and Alstom backs this too.

The Government is looking to bring forward infrastructure investment. This is a positive step and transport schemes should be an important part of this. They will help get the economy moving, provide skilled jobs, deliver some of the largest multiplier effects of spending, improve productivity and resilience long-term and critically help address the imperative of climate change. This report outlines measures that should be taken forward and accelerated.

ELECTRIFICATION

Upgrading and electrifying the existing railway network

Electrified rail is one of the greenest forms of transport. Rail enables significant numbers of people to travel long-distances, into, out of and across urban areas, and to carry freight. Rail represents 9% of the passenger journeys by distance travelled across transport modes and 9% of all freight carried.[21] In contrast, rail passengers and freight made up just 1.4% of the UK's domestic transport emissions.[22] Indeed, rail freight produces 76% fewer emissions than the equivalent HGV journey, with each freight train removing up to 76 HGVs from roads, resulting in 1.66 billion fewer HGV kilometres a year, and which emphasises the case for increasing rail freight.[23]

Trains in the UK are currently powered by either electricity or diesel. Diesel trains emit carbon which is why the Government has committed to their removal within the next two decades (in Scotland within 15 years). For electrified trains, if the electricity comes from fully renewable sources, then operationally it would be a net zero carbon railway. Renewable energy is an increasing proportion of energy generated for the grid, so the electrified railway is becoming greener all the time. In 2019 renewables accounted for nearly 40% of UK electricity power generation and low carbon sources increased to a record high of 54.2% in 2019.[24]

Within the rail industry there are initiatives to make further progress to reduce carbon through operations. Network Rail is purchasing its own low carbon electricity directly and HS2 is considering this too.[25] Network Rail, as a major landowner, is looking at the use of solar panels along the network.[26] New trains are coming into service that are more energy efficient while rail construction is reducing embedded carbon in construction (as outlined in the HS2 chapter).

Returning to electrification, it is the most efficient means of providing energy to trains and so uses less energy overall. Electric trains are also more reliable than diesels, while braking energy can be captured and fed back into the network. With diesels this is not possible.

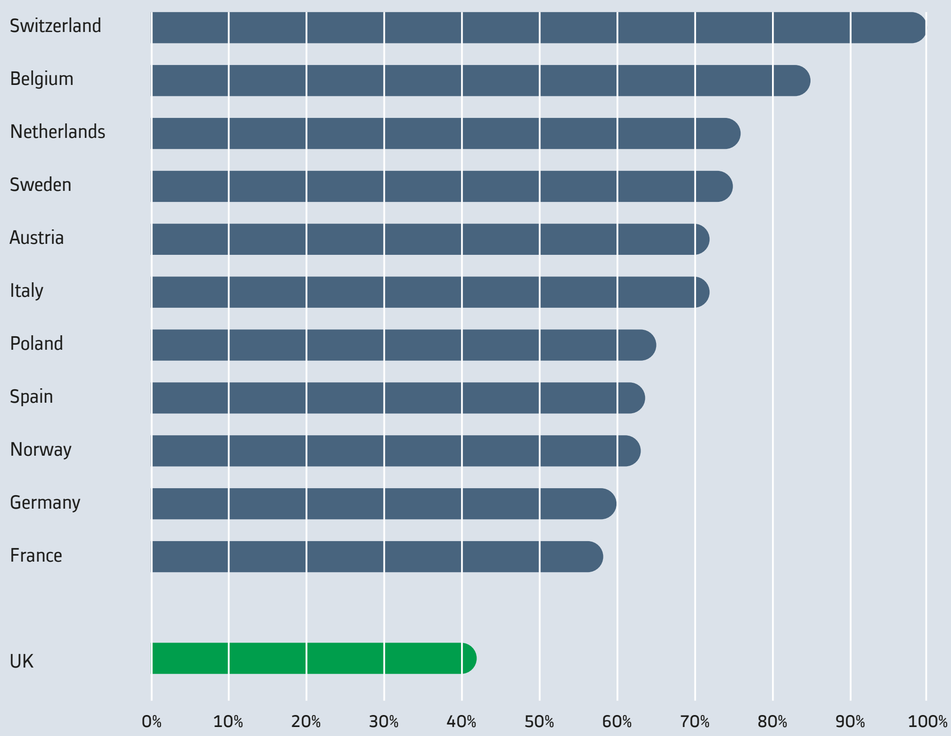
Electric trains do not emit toxic, particulate emissions. Diesels trains, in contrast, are not only a source of carbon emissions but particulates too. Stations have high concentrations of toxic particulate pollution. A study into Edinburgh Waverley and Kings Cross stations found rail stations in just two weeks exceeding annual limits for Nitrogen Dioxide (NO_2), and particulate matter of sizes less than 10 and less than 2.5 micrometres (PM_{10} and $PM_{2.5}$).[27] Previous studies have found similar levels at Birmingham New Street and London Paddington. Air quality is rightly being increasingly recognised as a major health issue, causing premature deaths, and worsening a range of health conditions from various breathing conditions through to Alzheimer's, heart attacks and stunting children's growth.[28]

However, while an electrified railway brings carbon and air quality benefits, and is much more efficient in running the railway, the majority of the network is not electrified. Just 42% of the UK network is electrified and looking at Scotland this percentage falls to 29%.[29] The UK compares unfavourably with other European countries. Switzerland has 100% of its railways electrified, Belgium 86%, the Netherlands 76% and larger countries like Spain, Italy and France have 57% to 71% of their network electrified.[30] However, while the UK's track electrification is 42% a much higher percentage of overall passenger journeys are made on electric trains. That said, there are still around 3,700 diesel rail vehicles used on the railway network.[31]

Case study—the UK electrification gap

The UK has a low rate of electrification compared to other European countries at just 42% (29% in Scotland) well below other countries such as Spain, Italy, Belgium and Sweden. The graph below shows the rate of electrification from sample European countries compared to the UK.

Graph 3: Electrification rates of selected countries



Source: Multiple sources for electrification figures.[32]

Reducing cost and a rolling electrification programme

How do you establish the rate and scale of further electrification for the 58% that is not electrified?

Further electrification makes sense for many lines suiting higher speed routes above 100 mph, high capacity commuter and suburban routes and where there could and should be an intensification of the route and/or there is a significant freight operating requirement. This is based on these types of train being the most energy intensive in operation, and the hardest to power using onboard, stored energy. Electrification also needs to be assessed against the speed of implementation, disruption caused through line closure and amount of embedded carbon used. There is a declining business case for electrification for routes that are longer, less trafficked and further away from existing, electrified lines. For these routes, hydrogen comes in as a green, versatile, cheaper, and easier to implement form of traction as outlined in the hydrogen chapter.

The green recovery programme and the goals laid out in the National Infrastructure Strategy provide an opportunity to bring forward a much more ambitious electrification programme in accordance with the recommendations of Network Rail's Traction Decarbonisation Network Strategy Interim Business Case.[33] A greater rate and scale of electrification can be delivered at lower cost than recent schemes have achieved. As the RIA Electrification Cost Challenge has highlighted, a continuous, rolling, long-term programme could reduce costs by 33% to 50%.[34] A continuous programme takes place in a number of countries across Europe. However, in the UK there has been a tradition of stop-start electrification schemes. In 2013/14 there were just three additional route kilometres operated electrically and four in 2014/15.[35] The lack of a continuous programme has made it difficult for suppliers to maintain resources and constrain costs through repeated cycles of mobilisation, training and demobilisation with each scheme. A rolling programme would address this, giving market certainty and driving down costs.

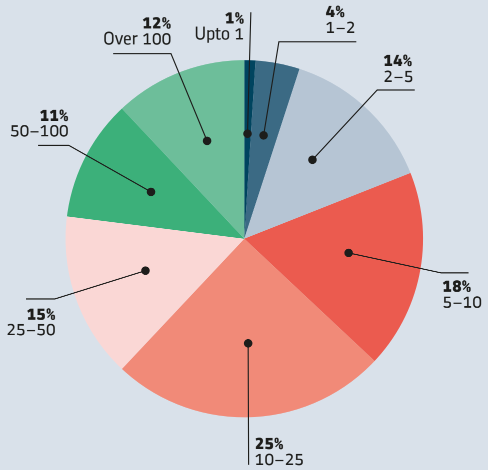
Alstom is a leading supplier of electrification which has decades of experience globally designing, supplying, installing, testing and commissioning electrification programmes, including in the UK. Alstom supports a rolling ten year programme of electrification and for such a programme to be at speed with the DfT's Acceleration Unit applied to this programme. The current electrification programme is due to complete in the 2050s, beyond the date set for net zero and beyond the 2040 decarbonisation challenge set for the rail industry. The programme should therefore be accelerated to the 2030s and 40s. Measures could help remove cost such as using an established design range with a supply chain and co-designing with the designer and delivery organisations; lightening NR's GRIP (Government for Rail Investment Projects) process to harness automation tools like BIM (Building Information Modelling); and avoiding duplication of survey information.

However, even if the political will and funding was in place and with the combined efforts of the entire UK supply chain, it would be virtually impossible to fully electrify the whole network by 2040 or even 2050. Instead, electrification should be targeted where it gives the best return, with alternative, complimentary technologies deployed elsewhere, primarily hydrogen.

Case study: the car challenge

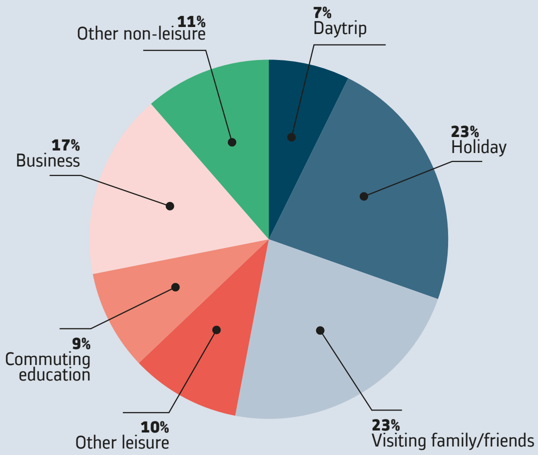
Rail can be the first choice for many journeys. Pie chart 1 shows the distance of journeys made and share of total mileage undertaken, indicating the high percentage of longer journeys. Emissions are harder to tackle for longer journeys. Rail is an answer to many of these. Pie chart 2 shows the purpose of trips above 50 miles and with leisure travel representing more than half. Rail has a greater portion of longer distance journeys but can have a higher share still, replacing cars and aviation. For commuting most people travel to work by car as map 1 shows. Modal shift means getting people out of cars but for many areas there are not the transport options. Improved rail services and mass transit systems (final chapter) can provide these alongside active travel—walking and cycling.

Chart 1: Mileage share by journey distance



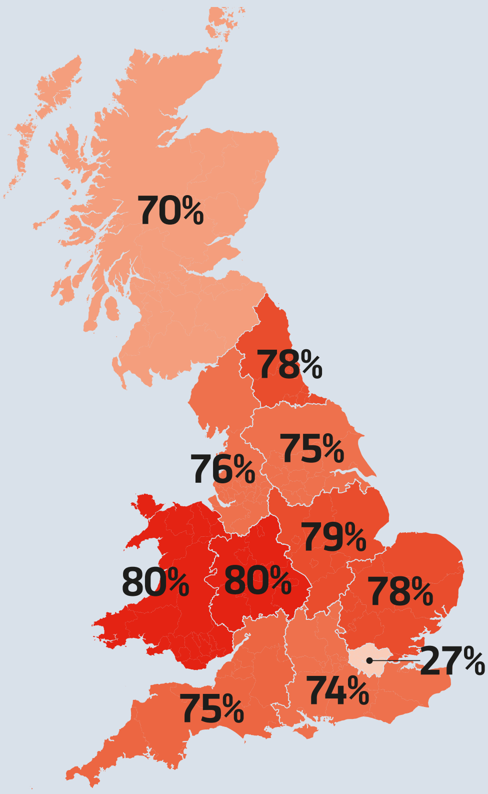
Source: Carbon Pathways Analysis. Informing Development of a Carbon Reduction Strategy for the Transport Sector (Department for Transport, 2008) in the report High Speed Rail Group's Response to Decarbonising Transport: Setting the Challenge

Chart 2: Mileage share by purpose of domestic journeys over 50 miles



Source: Analysis of National Travel Survey data (2015–2017) by ITS, University of Leeds in the report High Speed Rail Group's Response to Decarbonising Transport: Setting the Challenge

Map 1: Percentage of people normally travelling to work by car by region (Great Britain 2018)



Map source: Decarbonisation Transport: Setting the Challenge, March 2020

Case study—National electrification programme

Alstom, Babcock and Costain formed the ABC partnership to deliver electrification of routes between London and Crewe and the west of England and Wales as part of the National Electrification Programme. Over 6,000 overhead line structures had to be built over 350km of track, with 5,000 piles and 1,000 concrete foundations as well as modifications to 60 bridges and 20 substructures. Alstom developed a specialist state-of-the art wiring train for the programme that provided record breaking outputs of completed wire runs in a shift. This wiring train improves on traditional approaches as shown below. However, the train is currently parked in sidings and reflects the lack of a continuous at scale electrification programme.

Electrification underway

While enhancements will bring these benefits, they will be reduced given the Government's recent reduction of the CP6 enhancements budget by £1bn.[36] Alongside electrification, accelerating rail enhancements and bringing forward schemes will strengthen the network and deliver further decarbonisation benefits—making the railway more energy efficient, resilient and green as well as enabling improved services to support more passengers and modal shift. Alstom does welcome acceleration steps made already and supports the Government's bringing forward of six rail infrastructure projects including the Croydon Area Renewals, a £2.8bn remodeling scheme, which combines new infrastructure and the untangling of existing lines and brings forward the completion to 2027 instead of 2034. Alstom also backs RIA's call to bring forward the enhancements programme.[37] A number of schemes should be brought forward.

The Western Rail Approach to Heathrow would reduce car travel to Heathrow and obviate the need for rail passengers to travel from the Home Countries into London and back out to the airport. The £1bn scheme has been developed as a financed solution through a private investment model, which the Government should greenlight. East West Rail is a £5bn scheme already underway and should be accelerated including a flyover of the East Coast Mainline, as should the £15bn NPR and £3.5bn MER. These will improve regional rebalancing and modal shift, helping make rail the first choice.

With around 60% of signalling needing to be replaced and digitalisation of the railway network required, there is the opportunity for this to be advanced more quickly bringing reliability, capacity, and operational capability.[38]

A co-ordinated rail strategy would be a way to embed carbon goals, set a target for what portion of the rail will be electrified, the role of rail and targets for modal shift and an ongoing path to get there. This will enable industry to invest, reduce costs and create a pipeline, enabling rail to play a leading role in the UK's low carbon future. It also means a commitment to promoting rail as the travel mode of choice. Germany and France have taken this policy approach.[39]

While the Integrated Rail Plan for the North and Midlands seeks to integrate HS2, NPR and MER, and is a positive move, it is not an overarching rail plan for the entire UK network. Such a plan could come through the changes to the rail structure to be recommended by the Williams Review and the new 'guiding mind' body that is expected to be established. The TDP provides a path too. A process must begin on determining the future structure to bring certainty for transport authorities and transport planning and to enable private sector investment to continue in jobs and decarbonisation technologies. A rail strategy can anchor the role of rail in decarbonisation and its potential for changing the nature of travel with clear targets for passenger and freight modal shift and decarbonisation, including enabling more rail freight, which is at one of the lowest levels for rail freight for 20 years.[40] HGVs contribute 17% of greenhouse gas emissions from road transport (and 21% of road transport NOx emissions), despite making up only 5% of road vehicles.[41] A network with a higher level of electrification, digital signalling and the bringing forward of rail enhancement and expansion schemes will enable a step change—in moving freight and passengers to rail and bringing a zero carbon transport future.

Removing the barriers, accelerating transformation and creating a step change

- Establish a long-term comprehensive rail plan with the role of rail in modal shift for passengers and freight and defined plans for rail electrification
- Establish a rolling and more rapid programme of electrification to deliver the plan
- Bring forward enhancement and signalling schemes
- Harness and promote industry expertise to deliver cost-effective electrification and greening of the process of electrification through a rolling programme

HYDROGEN

Assessing the options

While significantly more electrification of the rail network is required as noted in the previous chapter, electrification does not suit all routes as it can be too costly, impractical or may not achieve sufficient carbon reduction due to embedded carbon in the construction. An alternative 'self-powered train' solution is needed. Battery trains can play a role, but mainly as a 'last mile' solution where a train runs on electricity for most of the route and a small portion on batteries where it is not electrified. The answer is hydrogen. It is a technology backed by the Prime Minister.[42] It can be deployed now, is emission free, cost effective over its life, flexible, can bring many wider benefits, and is perfectly suited for the regional services where the train refuels at the start of the day and runs continually and reliably all day.

There are a range of considerations which show why hydrogen is the answer.

Emissions

In operation neither battery nor hydrogen trains create emissions—hydrogen trains emit just pure water. Hydrogen trains carry compressed hydrogen gas as their energy store, using fuel cells to produce electricity in a chemical process that combines the hydrogen with oxygen from the atmosphere and which produces no harmful emissions. Zero emission at point of use does not tell the whole story. The lower the carbon mix in the electricity grid, the greener the charging for batteries (and for running electrified railways). Around 54% of the grid mix is generated from low or zero carbon sources.[43] For hydrogen traction, if the hydrogen is generated from renewable electricity the resultant 'green hydrogen' is a 'true zero emission' energy source, from what used to be referred to as 'well to wheel'. Green hydrogen can be produced using any form of renewable electricity (wind, solar, tidal, hydro, nuclear etc.) and can also be used as an effective store or buffer for excess generation. Hydrogen is also a by-product of many industrial processes. With CCUS (carbon capture, utilisation and storage), generation of hydrogen from fossil fuels (normally methane) also becomes very low in carbon emissions, if not fully zero.

Hydrogen can be produced in the UK using the country's considerable wind energy resources. The electrolysers used to split water molecules into hydrogen and oxygen have a minimal reliance on rare earth metals or precious resources in their manufacture. Indeed, the platinum that they do use in small quantities is infinitely recyclable. The UK is also a world leader in electrolysers with the world's largest electrolyser factory coming on stream in Sheffield. The UK's burgeoning wind energy sector has generated a domestic turbine production capability. The UK therefore has self-sufficiency in hydrogen technology and has huge raw resources to draw on.

Battery trains rely on very large batteries. The world's first production hydrogen train in service, Alstom's Coradia iLint, would have required a 33 tonne battery to achieve the same performance achieved with hydrogen. Battery production costs are driven by the required rare raw materials often from unstable countries. Much of the cost content of battery production consists of these imported elements, which also involves a carbon and environmental footprint associated with their mining. The battery sector is led by producers in China and the US, with the UK far from competitive. The disposal of batteries also needs to be considered. Hydrogen trains do have a battery in their hybrid drive used to reuse braking energy, but this is very small compared to a traction battery required to drive a train. Overall, these factors mean that these trains powered by green hydrogen would be the lowest emission form of powered land transport available today.

Energy storage

The ultimate goal for self-powered vehicles, be they trains, cars, HGVs or ships, is the ability to carry sufficient energy on board to give the best possible performance mix of range, speed and efficiency. Hydrogen has a very high energy density per kg but, as a gas, one kg is a very large volume and so, to use and carry hydrogen in vehicles, it is compressed. It still requires eight times the volume of a diesel train's fuel tank to store the equivalent amount of energy. Batteries have a lower density still—16 times that of diesel—and their weight for the amount of energy needed has a dramatic negative impact. A battery train demonstrated in the UK in 2015 showed that a 7.2-tonne battery pack could deliver electrified-comparable performance for 77km.[44] A battery to match the performance of Alstom's Coradia iLint hydrogen train (a range of 600+ miles, and maximum speed of 145kph or 90mph) would weigh 33 tonnes. Battery technology is developing rapidly but there are inherent issues with the amount of energy stored per unit volume or weight.

It is for these reasons that hydrogen offers the best compromise between space and weight of energy storage. A further attraction of hydrogen energy storage of particular attraction in the transport sector is the 'recharge' or refill times which are similar to the times required to refuel with petrol or diesel. This can have huge benefits with intensively used vehicles that cannot afford to be tethered to chargers for long period of time.

Performance and application

The technology for hydrogen is tested and ready to be applied for existing and new routes. Alstom's Coradia iLint trains have been operating in daily passenger service in Germany since 2018, offering reliable, smooth and quiet rides and have begun in 2020 in Austria too. They are being tested in the Netherlands and Alstom is also building hydrogen trains to run in Italy. In the UK, Alstom has worked with Eversholt Rail to develop a conversion and upgrade of an existing UK gauge train for hydrogen operation, called 'Breeze'. Hydrogen is also used elsewhere in the transport sector with bus fleets deployed in London and Aberdeen and to be introduced in other places such as Liverpool and Birmingham.

Through return-to-base fleets such as trains but also buses, taxis and HGVs, it is possible to deploy vehicles and fuel generation and storage facilities together, creating hubs and yielding immediate carbon and clean air benefits. This could be ahead of a national hydrogen distribution network being developed or the gas grid being repurposed, which is achievable, and needed for example to heat homes through hydrogen. With each fleet deployed, a fuelling facility is created, and as fleet numbers increase a larger network of fuel points will develop, in the same way that diesel did 70 years ago.

There is minimal service disruption involved with hydrogen's introduction. The electrification process, installing the overhead catenary and electrical supply, inevitably impacts service provision on the route being upgraded. This can be mitigated to an extent with limited night time working and only weekend shut downs of the line but is slower and more expensive. With hydrogen, the fuelling facility can be erected in a depot or suitable location without service impact and, once it is operational, a fleet can be introduced 'overnight' in relative terms—minimum disruption for passengers and operators alike.

The range of hydrogen trains reflects how much hydrogen they can carry. Current designs give a range of 600 miles before refuelling and speeds of up to 100mph. Trains are fuelled at the start of the route and then run reliably all day. Performance is similar to diesels, and offers a reliable, all-weather capability (batteries can be impaired in extreme weather). For a regional service operated by diesels, as opposed to higher speed or high-capacity urban services, then hydrogen is an obvious solution. The remainder would be replaced with electric trains and electrification where diesel high speed trains operate or battery-electric trains where electrification does not quite reach the end of the route (battery trains tend to have a maximum 60 miles range on the battery, 30 miles each way). The small battery in a hydrogen train captures energy from braking. Alstom's leading technology combines the battery with hydrogen traction to mean more power for peak loads, acceleration and is beneficial for train configuration and optimising the range of the train before refuelling.

There are still around 3,700 diesel rail vehicles used on the railway network.[45] Of these around 2,400 are regional diesel vehicles, and a conservative estimate is that half could be replaced with hydrogen equivalents. There is significant application for hydrogen in Scotland, and Wales and North, East and South West England where there is little or much less electrification and routes can have long, rural and less trafficked sections. The Government should initiate a ten-year hydrogen train programme to order 300 to 400 hydrogen trains for the network with more to follow. Hydrogen rail services could be operational in 2024 ready for the fourth carbon budget, where much more rapid progress is needed to meet the targets.

The deployment could include a first fleet procurement in Tees Valley. The Tees Valley programme is ready to go now, is supported by local stakeholders, is a centre of hydrogen production and is the site for the Government's UK Hydrogen Transport Hub announced by the Transport Secretary.[46] The Hub paves the way for exploring how green hydrogen production can be scaled to power trains and other transport modes. Hydrogen train deployment would provide much needed investment for the Tees Valley, a significant kick-starter for the regional hydrogen economy and be a demonstration of the UK's green commitments as it hosts the COP 26 later this year.

The 'shovel readiness' of this project means that it can be started swiftly, ahead of a full hydrogen strategy. To do so would add weight to the preparation of the strategy as an early indicator of Government intent. Network Rail in its Traction Decarbonisation Network Strategy Interim Business Case says that rail can 'be an early adopter of hydrogen technology in the UK and play a key part in supporting the establishment of the wider UK hydrogen economy'.[47]

There can be a step change deployment in Wales, giving a boost to the north and south. With Wales targeting net zero for the public sector by 2030, it will be essential in greening transport infrastructure and would work well with huge local renewable energy resources able to produce green hydrogen.

East West rail can move straight to hydrogen. The current plan is for an interim part diesel solution that would be obsolete almost as soon as it starts. Moving straight to hydrogen traction would create a compelling demonstration of a new era for the railways, signal the green recovery and reflects the strong environmental objectives of the local authorities, including Oxford and Cambridge, served by the new railway. It could also make the programme simpler and cheaper to deliver without the need to buy an interim diesel traction system then having to convert later to hydrogen or electrifying the route. Hydrogen is a reliable and simple to implement technology and a like-for-like replacement for diesels that could be used on East West rail from the start.

A map below shows the range of lines (not exhaustively) that could benefit from hydrogen in England, Wales and Scotland.

Cost appraisal

The natural inclination is to compare the cost of hydrogen trains to that of running existing diesel services, but this is flawed. As train operator franchise cost models have been based on the relatively low lease costs of (typically) old diesel units, running on duty rebated diesel dispensed via existing, depreciated fuelling assets, any change to a new traction technology will be more expensive. However, due to the fact that diesel must be removed across the UK by 2040 and in Scotland by 2035, the way costs and benefits should be assessed must be reset including looking at the whole life costs of the change, speed and efficiency of change, the potential accumulated environmental benefits of change as well as the jobs and skills that can be created.

With diesel dead, the comparisons are between the various decarbonised options—electrification, hydrogen or battery trains. To be clear, to deliver on decarbonisation should not mean a role for new hybrid diesel trains which would be a false economy, particularly given that they would need to be phased out well before the end of their operational life which should be reflected in any 'business case'; neither should there be a role for new diesels (which also would be more expensive than the older leased diesel model above). Electrification, as outlined, is a key part of the answer but given the extensive work and time required to install overhead catenary, grid connections and changes to structures along the line, and with the corollary impact of temporary line closures, there is a significant cost and disruption that may not be acceptable or effective on all routes.

There needs to be an at scale hydrogen deployment. Tens of trains do not realise the economies and create a market. The concern with NR's Traction Decarbonisation Network Strategy Interim Business Case, is that while it supports the introduction of hydrogen, the role for electrification is too pronounced. Alstom agrees on the need for more electrification, but the scale proposed by NR is more expensive than the deployment of hydrogen at scale for routes that are not cost effective for electrification. Hydrogen is faster, cheaper and less disruptive.

The 300–400 deployment outlined is around £1bn–£2bn. This is a financed solution with no initial government capital cost. Trains can be leased through the familiar system in place. The fuelling infrastructure can then be similarly financed, with hydrogen suppliers able and willing to finance their infrastructure over a period of time during which they can be certain of the hydrogen usage by train fleets—timetabled and predictable every day of the year. Whilst initial fleets would be more expensive to deploy, the cost will reduce as more fleets come on line. Hydrogen infrastructure is also potentially multi-modal, including for transport, buildings and industry allowing infrastructure costs to be shared with the right structures.

Map 2: Potential initial routes suitable for hydrogen (not exhaustive)

Charging batteries is more energy efficient than creating hydrogen, but batteries have a limited life and storage function whereas hydrogen can be stored indefinitely. Critically, batteries require the use of expensive rare earth metals mined in often unstable countries. Battery development is led by China. In contrast, a hydrogen economy can be developed in the UK. Rail redeployment will help kickstart this as an immediate at scale use of the fuel. Each fuel facility creates local jobs and skills to build and operate across the UK. As other uses for hydrogen grow, these transferable skills will form part of a growing hydrogen economy and support a green recovery. These benefits should be factored into costs. The hydrogen economy is explored more below.

The production of green hydrogen is currently the most expensive means of producing hydrogen, but in line with renewable energy costs, production costs are rapidly reducing, and excess renewable energy can be used to produce hydrogen.[48] Like the development of wind power before it, a policy structure is required to accelerate development of the supply chain to secure longer term cost savings. Wind is now the cheapest form of energy. Critically, hydrogen can be stored in tanks, in underground caverns or other existing facilities. In this way it can be used to buffer excess renewable energy and to meet seasonal demand variations. With the storage benefits and production in excess periods, green hydrogen production can be mutually beneficial.

'Blue hydrogen', reliant upon first deployment of CCUS at scale, requires early stage policy incentives and will take longer to deploy due to the scale of requirements and the wider consumer user base. For the decarbonisation of heat and the hydrogen conversion of the gas distribution grid, the production volumes of hydrogen required can only be met with widescale adoption of CCUS. Once a distribution network is established, the economics of green and blue hydrogen become very competitive, driving cost down further.

One of the major benefits of the gas grid itself, in comparison to the electricity network, is its ability to store huge amounts of energy due to the natural properties of gases. Hydrogen would offer all of the same benefits as are currently reaped from the natural gas network as a flexible energy store.

Overall

Hydrogen has high performance, wide application, and is a green and ready to go technology. When in operation, hydrogen produces no carbon or other toxic or harmful emissions and if the generation of the hydrogen is through renewables, it is truly zero emissions throughout the process. As a final solution, or as a transition technology to bridge operations until routes are electrified, hydrogen fits perfectly in the mix. It also has wider benefits of building UK industrial value. The table on the following page compares the benefits and challenges of different traction types.

Table 1: Summary of comparison of traction options to replace diesel trains

Factor	Traction mode for trains		
	Electric	**Hydrogen**	**Battery augmented electric**
Emissions	None operationally but overall depends on input energy mix from grid (electric trains currently emit 26% of the rail sector's emissions) Embedded carbon in wires and concrete for electrifying routes	None operationally and overall none if hydrogen is 'green' produced from renewables Very low with 'blue' hydrogen produced using CCUS Emits just water	None operationally but overall depends on input energy mix from grid Uses rare minerals with carbon impact for extraction and manufacture
Energy density	N/A	8× lower energy density than diesel	16× lower energy density than diesel
Refuelling	Needs electric lines for power transmission	Quick and same as diesel Refuelling facility needed but can be shared with other transport modes	Slower recharging Charging facility needed with capability to charge multiple trains simultaneously
Speed	Up to 250mph+	Up to 100mph most efficient	Up to 100mph but reduces range
Range	N/A	600+ miles	Current market offering typically up to 60 miles
Performance	N/A	Better than diesel and runs reliably all day All-weather capability	Similar to hydrogen but over short range only Batteries can be impaired in extreme weather
Suitability and wider benefits	Higher speed (100+mph, high capacity and metro services) Can meet power requirements for freight	Like-for-like replacement for diesels on regional, longer distance, less trafficked routes Fuel source multi-modal for buses, HGVs, ships	Very short distances and 'last mile' only
Service impact for introduction	Closures required over long periods Bridges and other structures likely to require modification	Can replace diesel like-for-like with refuelling facility needed—no service impact	Can replace diesel like-for-like with charging facility needed—no service impact
Tech readiness for application	Operational	Operational	Operational
True cost appraisal	Efficient power transmission but high initial cost to electrify routes and cost of disruption	All costs can be financed; no initial capital expenditure needed Hydrogen production costs falling and fuel source multi-modal so reduces costs Home grown UK industry opportunity reduces cost volatility	Needs increasingly expensive rare earth metals for batteries China and US dominating battery market

Case study – Hydrogen trains in operation

Germany has had Alstom Coradia iLint hydrogen trains running in passenger service since September 2018 in Lower Saxony. These are the first hydrogen trains in operation globally. The train offers reliability and passenger comfort with a smooth ride and quiet journeys. Emissions are just water. Since beginning service two fleets of Coradia iLint trains have been ordered for additional services.

Successful passenger trials have taken place in the Netherlands and have operated in service in Austria. The proven technology of the Coradia iLint will also be applied to Alstom's Coradia Stream-H trains—Italy's first order of a fleet of hydrogen trains.

In the UK, Alstom has worked with Eversholt Rail to develop a conversion and upgrade of an existing UK gauge train for hydrogen operation, called 'Breeze'. Alstom and Eversholt Rail have invested around £2.5m in the development of the train to date and with an order made soon Breeze trains could be operating as early as 2024.

Top: Coradia iLint running in Germany
Bottom: Breeze train designed for the UK network

Home grown hydrogen industry and building a hydrogen 'pipeline'

As a market leader in the development of hydrogen, Alstom recognises the opportunities and barriers. Alstom supports hydrogen's use in transport as part of a hydrogen economy and sees huge opportunities for the UK. As outlined, the UK does not have a competitive advantage in developing battery technology. The market has been captured predominantly by the US and China, with the latter being the world's largest producer, including in specialist corollary charging systems. In contrast, the UK can become a lead country in developing and deploying hydrogen technologies bringing environmental, industrial and economic benefits. Japan, Germany, China and Korea are making inroads into the hydrogen landscape, so the UK needs to move quickly.

The UK's industrial foundations and geography are two factors that make it well placed for hydrogen production and will bring advantages to regional economies. High energy use industries with concentrations in the North East, North West, Midlands and South Wales, can use hydrogen to decarbonise as well as generate new green products for export. The UK's is the world's largest offshore wind market and this industry and resource can power electrolysers to generate green hydrogen, with the UK already the home of the world's largest factory producing the electrolysers needed for the production of green hydrogen. The wind industry has a strong foundation along the eastern coast of the UK from Scotland to the south coast, with coastal communities in need of investment and regeneration and that are also served by regional railways suitable for hydrogen traction.

Hydrogen does not put significant extra pressure on the electricity grid nor does it require large quantities of rare precious metals that have a carbon and environmental impact. In addition, as Bloomberg New Energy Finance has outlined, clean hydrogen could be deployed to reduce 34% of global greenhouse gas emissions from fossil fuels to industry at an affordable cost.[49]

There are leading centres of hydrogen transport manufacturing in the UK. Alstom's worldwide centre for train modernisation and where the conversion of trains to hydrogen power will take place is at Widnes in the Liverpool City Region. Wrightbus, based in Northern Ireland, has recently built the world's first double decker hydrogen bus and is joined by Optare in Leeds and Alexander Dennis in Scotland all offering competitive products. Through supporting hydrogen demand today, the Government can support manufacturers and energy producers, help heavy industry decarbonise and transform transport. A demand-led industry will embed a world class supply chain in the UK that can serve both local and global demand moving forward.

The hydrogen rail deployment outlined provides skilled and resilient jobs, core to the green recovery. It supports around 500 manufacturing jobs in building and converting the trains, many hundreds more in construction roles for supporting fuel infrastructure, and 1,000s more in a new, innovative hydrogen technology supply chain supporting rail and other transport modes. The Hydrogen Taskforce suggests that the wider economic benefits of developing the hydrogen economy could lead to the creation of 28,000 jobs in hydrogen production, 15,000 in transmission, distribution and storage infrastructure and a further 31,000 jobs across different end uses, contributing £18bn to the UK economy.[50]

A skills partnership should be established across learning institutions and industry to rapidly upskill and create jobs pathways for the hydrogen economy, building on synergies across modes such as trains, buses and HGVs. At a time of impending unemployment at a scale not seen for decades, the hydrogen economy has the opportunity to provide a source of skilled, green jobs.

Currently, there is no co-ordinated approach to hydrogen across government and within regions covering production, refuelling facilities and application, and scaling and speeding this. In turn the potential for hydrogen is not reflected fully in government strategies, funding and programmes and the rail franchising system to date has not promoted hydrogen, even hindered it with the short-timescales of franchises. As the current franchising model is replaced, as the Government has indicated, the opportunity is for a new structure to support bringing forward hydrogen deployments, and other decarbonisation opportunities that could form part of a future rail plan and strategy.

We have seen the publication of recent plans and strategies related to net zero such as the Energy White Paper and the 10 point plan for a green industrial revolution. We are expected to see further plans such as the Transport Decarbonisation Plan, flowing from the consultation. All should promote hydrogen and hydrogen rail and outline a step change in its use in the path to net zero and to form a key part of the green recovery.

Removing the barriers, accelerating transformation and creating a step change

» Bring forward a long-term comprehensive rail plan with ambitions for hydrogen as both an end state and transition technology and set progressive targets for rail decarbonisation to 2040 (and 2035 in Scotland)
» Support hydrogen as part of the rail landscape with an initial ten year deployment for 300–400 trains
» Support the first hydrogen route in Tees Valley and roll out across Wales, Scotland and many parts of England
» Create a co-ordinated programme to support the wider hydrogen economy, including skills pipeline and connecting national, regional and local activity and support.

HIGH SPEED RAIL

HS2—a transformative railway

High speed rail has an essential part to play in the delivery of the UK's net zero carbon target, decarbonising the UK rail network and achieving modal shift. It is right that the Government took the decision to press ahead with the scheme in February 2020, with the Notice to Proceed taken in April 2020 and main works launched in September last year. HS2 brings a new dawn for UK railways.

HS2 should not be viewed as a single or stand-alone scheme but as the country's new railway spine, connecting many of Britain's major cities, underpinning other major schemes such as MER and NPR and releasing capacity on existing lines for new passenger services and for moving freight from road to rail.

Alstom is a leading member of the High Speed Rail Group and supports its report 'HS2—Towards A Zero Carbon Future'.[51] This gives a detailed account of the critical importance of high speed rail in achieving net zero. Alstom is supportive of HS2 and has seen the benefits from the experience of delivering high speed rail across several continents, including the comprehensive TGV service in France.

The HS2 Minister, Andrew Stephenson, has articulated HS2's clear role:

> **'HS2 is due to play a key part in the transition to a net zero carbon UK economy by 2050. HS2 will offer some of the lowest carbon emissions per passenger km—seven times less than passenger cars and 17 times less than domestic air travel in 2030. By providing a cleaner, greener way to travel, HS2 will help cut the number of cars and lorries on our roads, cut demand for domestic flights, and help the country's fight against climate change.'**[52]

HS2's Phase 1 revised business case, published alongside the Notice to Proceed in April 2020 outlines this argument in more detail. However, the case, is stronger still as the benefit case was based on previous appraisal rules and carbon arrangements. We know that the benefits of railways last beyond 60 years and the net zero goal and true carbon price changes should be reflected in how rail plans are assessed and delivered in the future.

The TDP itself does not fully reflect the potential of HS2. The TDP is based on the lower Clean Growth targets, not the (tougher) CCC targets and which HS2 will help meet. The TDP also references electric vehicles as zero emissions and a train as 29kg CO2e emissions in the example it gives of a journey from London to Edinburgh.[53] In the small print it explains that 'train emissions are based on an average for diesel and electric trains; if a route is fully electrified, emissions would be lower than those presented'. HS2 is an electrified railway and not diesel. Indeed, for both electric cars and electric trains emissions relate to the nature of the national energy grid mix for the input energy which currently is around 54% from low carbon sources. Railways though are looking to source energy directly from renewable sources and generate power such as using solar arrays to feed directly into the railway, further enhancing environment credentials. Furthermore, there is the embedded carbon to consider such as used in making the electric cars and roads that they travel on. As the UK looks to take the necessary net zero actions, there needs to be much more complete assessments and appraisals of the whole life costs, impacts and benefits of modes including the embedded carbon costs, energy inputs, and roles in modal shift and transport decarbonisation.

Significant change must take place within ten years and HS2 will enter service at the end of that period. It is a driver of how the transport system can and should change in the future and will provide a permanent change in how people travel, helping to secure an ongoing future low carbon system.

Carbon benefits and modal shift

HS2 is central to modal shift, including providing an alternative to planes. It is not going to be possible to achieve the modal shift needed unless there is sufficient capacity, and a reliable, quick service. HS2 is the path to that goal.

Significant gains have been seen in countries with high speed rail such as in Spain where high speed rail is key to travel between cities. The UK's only high speed line, HS1, has services between the UK and Europe run by Eurostar. These services have removed the equivalent of 60,000 flights or 750,000 tonnes of CO2 per year. Pre-COVID-19, the recently introduced London-Amsterdam Eurostar services made up 25% of journeys (rail and aviation) between the capitals—and with just three trains a day. High speed rail shifts people from air to rail to deliver big carbon benefits within two years of operation.

Less recognised is the amount of leisure travel that forms the majority of journeys by distance.[54] Rail should be the default longer-distance option as other modes such as flying and use of cars for these journeys contribute significantly to emissions.

HS2 is a dedicated, purpose build modern railway—the first north to south for over 100 years. It will provide a resilient, reliable and high capacity network that also frees up capacity for passenger and freight services and will help to achieve modal shift. One key route it frees up is the West Coast Main Line (WCML), the busiest mixed-use line in Europe—with inter-city, regional, commuter and freight routes all on the same track.

One of the beneficiaries of freeing up the WCML is Liverpool. HS2 would create a 'national step change' on freight and is essential to support the significant growth of the Port of Liverpool.[55] A large portion of goods currently come into ports in the south of the UK and then are carried by HGVs across the country. With its central UK location, more goods will be able to come into Liverpool port and with HS2 in place, a much greater portion of freight can be transported by rail. To maximise the benefits, Liverpool is also seeking twin-tracking and a major development of Lime Street station which is nearing capacity. This would bring many gains for the city and its regional transport network.

The benefits of HS2 are felt across other areas. As Midlands Connect has shown, 73 stations on the existing rail network—cities, towns and villages—stand to benefit from improved passenger services as a result of the capacity released by HS2, including 54 stations with no direct HS2 services.[56] HS2 will take long-distance rail journeys off the existing network, providing capacity for new routes, as well as faster and more frequent local and inter-regional services. It will also create space for 576,000 extra seats per day and release capacity essential to deliver major regional transport plans—MER and NPR. HS2 frees up space for 144 extra freight trains per day, enough to transport over 2.5 million more lorries' worth of cargo by rail each year.[57]

Journeys on HS2 will be faster and save considerable time. Manchester to London is almost halved from 127 minutes to 67 minutes and Birmingham to Leeds more than cut in half. These gains help make rail a much better option for travellers and to connect into regional and local transport schemes. In addition, HS2 is being designed so that high speed trains can run on the new high speed track as well as existing lines—as happens in France—so that high speed trains benefit a wider network. Alstom built the current trains that operate on the West Coast Main Line (WCML) serving Glasgow, Liverpool, Manchester, and Birmingham and is short-listed to build the new HS2 trains.

High speed rail has another transformative impact too, unlocking the opportunity of low carbon housing developments with an efficient use of land and low carbon, efficient transport networks. Many developments to date have locked in intensive forms of car-based transport. HS2 creates scope both on its own routes and in areas served today by the WCML but which do not have sufficient service capacity due to the congestion on that route.

High speed rail does have a carbon impact in construction. However, for each year of construction, HS2 will have a climate impact equivalent to less than a hundredth of UK aviation emissions or 0.5% of current road transport emissions.[58] In addition, through the construction to date there has been an outperformance of the embedded carbon reduction targets by 20%–30%.[59] Given the scale of HS2 this offers lessons for other projects, plus there are ambitious stretch targets to cut the carbon footprint of HS2 main works contracts by 50%.

When looking at transport's emissions there is insufficient recognition of the embedded carbon in roads, cars and HGVs, even if these are electric, given the amount of carbon in the construction of roads and of each vehicle as well as the rare minerals needed for batteries. Railways and trains compare very favourably when comparing whole life costs, not least through much longer asset utilisation.

With HS2 being built from new, it is also being constructed to be climate resilient. Too much of the existing transport system is not, which makes the new network even more important in meeting the net zero target to limit temperature increases to 1.5 degrees, as the country must live with the consequences of the significant temperature increase which is already baked in.

Building on the HS2 network

HS2's environment and carbon benefits can be expanded further. The big prize—which is achievable—is getting journey times from Scotland to London down to around three hours, which would dramatically reduce the appeal of flying. Alstom welcomes the HSRG report on how to achieve this through a series of targeted, smart, and cost-effective approaches which can be delivered more quickly.[60] The Anglo-Scottish links will help deliver carbon reductions reducing the need for aviation (London–Scotland is the busiest domestic air route and one of the busiest in Europe) and meet demand for cross border rail services, reducing demand for long-distance cross-border car travel—a significant source of emissions. The report highlights that between 2006 and 2016 Office of Rail and Road figures show cross border rail passengers increasing by 61% and Glasgow to London rail flows increasing by 120%. Since 2007, rail passenger travel levels between Manchester and Scotland were up +191% and between Birmingham and Scotland +261%. Connecting Scotland and England with these services will support improved economic and social connections, particularly between northern cities and Scotland.

The UK needs a long-term high speed rail plan as part of a national rail plan, building on the current HS2 scheme. The Scottish links are one area, another is to Bristol and Wales to create a 'X' shape across the country. NPR, MER and East West Rail would provide east-west links and provide further connectivity and joining up of the network. A rolling programme of high speed rail would mirror that of other countries. The Government should initiate development work to take the Scottish and the Bristol/Wales links to the next stage. In terms of Bristol/Wales this would build on the work of the Greengauge report 'Beyond HS2'.[61] In terms of Scotland this would be through an assessment of the deliverability of the options developed by DfT, Network Rail, HS2 Ltd and Transport Scotland to date and establish governance and structure to take the programme forward.

With the wide range of benefits, the UK needs a long-term high speed rail plan and a forward thinking programme to create a nationwide high speed rail network, building on the current HS2 scheme, as part of a national rail plan.

Removing the barriers, accelerating transformation and creating a step change

» Change appraisal systems to recognise the benefits of high speed rail in decarbonisation and modal shift
» Promote decarbonisation in construction using the model of HS2
» Bring forward a long-term comprehensive rail plan with further ambitions for high speed rail including to Scotland and Wales as part of a long term high speed rail plan

Case study—HS2 trains

Alstom builds high speed trains for networks across the world including the TGVs in France for the network that criss-crosses the country, the AGV in Italy and the Avelia-Liberty in the USA. High speed trains offer passengers comfort and many facilities. Alstom is one of the short-listed bidders to build the new HS2 trains.

Top image: AGV train in Italy
Bottom image: Alstom's HS2 design

A REGIONAL RENAISSANCE WITH GREEN TRANSPORT FOR ALL PLACES

New direction and voice

Transport for London's (TfL) 20-year anniversary took place during 2020. Its two decades have shown the value of a regional public transport authority overseeing and expanding a complex network, developing and delivering major programmes, long-term planning, integrating modes and improving services. TfL is at the heart of achieving modal shift and the London's net zero goals.

Many areas of the country have sought similar powers and structures to TfL and these are now taking shape. In recent years we've seen a new landscape. Sub-national transport authorities have been established, most noticeably Transport for the North (TfN) and Midlands Connect, covering wide geographical areas. Other regions are on a similar path with England's Economic Heartland, Transport East, Transport for the South East, Western Gateway and Peninsular Transport in various stages of development.

Significant schemes include MER and NPR and the integrated rail plan has looked at how these schemes combine with HS2. Other schemes include the East West railway, a new Trans-Pennine route and Network Rail's renewal and maintenance programme.

Metro-mayors and combined authorities provide further voice and direction in Greater Manchester, Liverpool City Region, Sheffield City Region, Tees Valley, West Midlands, Cambridge & Peterborough, West of England and North Tyne metro areas. The newest metro-mayor is set for West Yorkshire this year. Existing and reformed city transport bodies run networks and have drawn up new schemes. Wales and Northern Ireland there are devolved governments as well as cities with responsibilities including Glasgow and Edinburgh in Scotland.

Most of the authorities and governments above have set net zero targets ahead of the Government's 2050 target. Some areas are bringing forward Clean Air Zones which shape the transport landscape within a more immediate time span. The expanded Ultra Low Emission Zone (ULEZ) in London will come into force later in 2021, growing the current congestion charge zone to an area 18 times as large.[62] Manchester will introduce a similar sized zone.

This is a brief snapshot of the new structures and political voices across the complex landscape but also the important agency and leadership of regions and localities in relation to drawing up and delivering integrated transport and decarbonisation plans. These link to their powers in relation to land use planning, environment, housing and economic development.

Levelling up green transport

There are just 12 dedicated mass transit systems in the UK with three in London. The capital has the London Underground (Tube), Docklands Light Railway and Tramlink. Glasgow has its Subway, the third oldest underground in the world. Two other part-underground-metro systems are in Liverpool and Tyne & Wear. Trams are in Manchester, Nottingham, Edinburgh, Sheffield, West Midlands and Blackpool. Some places do have high frequency rail routes, which perform a similar role. However, many are also in Greater London. This chapter's main focus is on dedicated mass transit city systems and the opportunities for bringing forward these schemes and the benefits which would accrue.

Most areas do not have mass transit systems. Leeds is the largest urban area in Europe without a mass transit system, a fact highlighted in the Conservative 2019 manifesto. Leeds is within the wider West Yorkshire area covering 2.25 million people and which includes one of the UK's fastest growing cities, Bradford, and this whole area has a gap in green mass transport. Other urban and high population places without a system (and not exhaustively) include: Tees Valley; Hull City Region; Greater Leicester urban area; Coventry; Cambridge & Peterborough Combined Authority area; Stoke; Derby; Doncaster; Luton-Dunstable area; Reading-Wokingham urban area; Greater Brighton City Region; Southampton-Portsmouth urban area; Bournemouth; Christchurch & Poole Local Authority area; Plymouth; Bristol and the West of England Combined Authority area; Cardiff Capital Region; Swansea Bay City Region and Belfast City Region.

In outlining the above areas, it is not say that there aren't transport gaps elsewhere. For example there are transport gaps in areas which have systems such as in Greater Manchester and the West Midlands. Equally some of these gaps are set to be addressed through plans that are underway or are being developed in order to serve more places. Despite this, the green transport gap contrasts unfavourably with similar countries. Germany has 52 tram systems alone, four times the UK's total mass transit systems and France has 29 tram systems.[63] Schemes are not just coming forward in Europe but in Asia, Africa and North and South America too. Over the last decade trams have opened in Algeria, Morocco and Ethiopia and in Asia in Turkey, Uzbekistan and Dubai. New metros are also taking shape including in Vietnam and Ivory Coast. Alstom has a track record across continents and countries developing leading schemes and bringing forward new technologies to secure a range of benefits.

Case study – mass transit systems, a global progress

Metro, trams, light rail and very light rail systems are being established in cities and regions across the world. Manchester's Metrolink is the most extensive tram system in the UK with 99 stops along 65 miles track. In a consortium, Alstom constructed the first phase of the Metrolink network.

France is one of the European leaders on trams with 29 towns and cities having systems and with more planned. One of the largest systems is Bordeaux, the sixth largest city in France. It consists of four lines, with the fourth opened in early 2020, and for which Alstom delivered 130 new Citadis trams.

Tram systems are opening in many more countries. Over the last decade trams have opened in cities in Africa in Algeria, Morocco and Ethiopia and in Asia in Turkey, Uzbekistan and Dubai. New metros are also taking shape from Vietnam to Ivory Coast.

Left: Manchester's Metrolink, the UK's largest tram network
Right: Bordeaux tram running without overhead wires

The following page contains map 3 showing a snapshot of green mass transit gaps. It shows the UK's 12 designated mass transit systems—undergrounds, light rail and trams—alongside a snapshot of a number of the population centres—cities, regions and authority areas across the UK above 250,000 people—without a mass transit system. The populations have been rounded to the nearest 5,000 people.

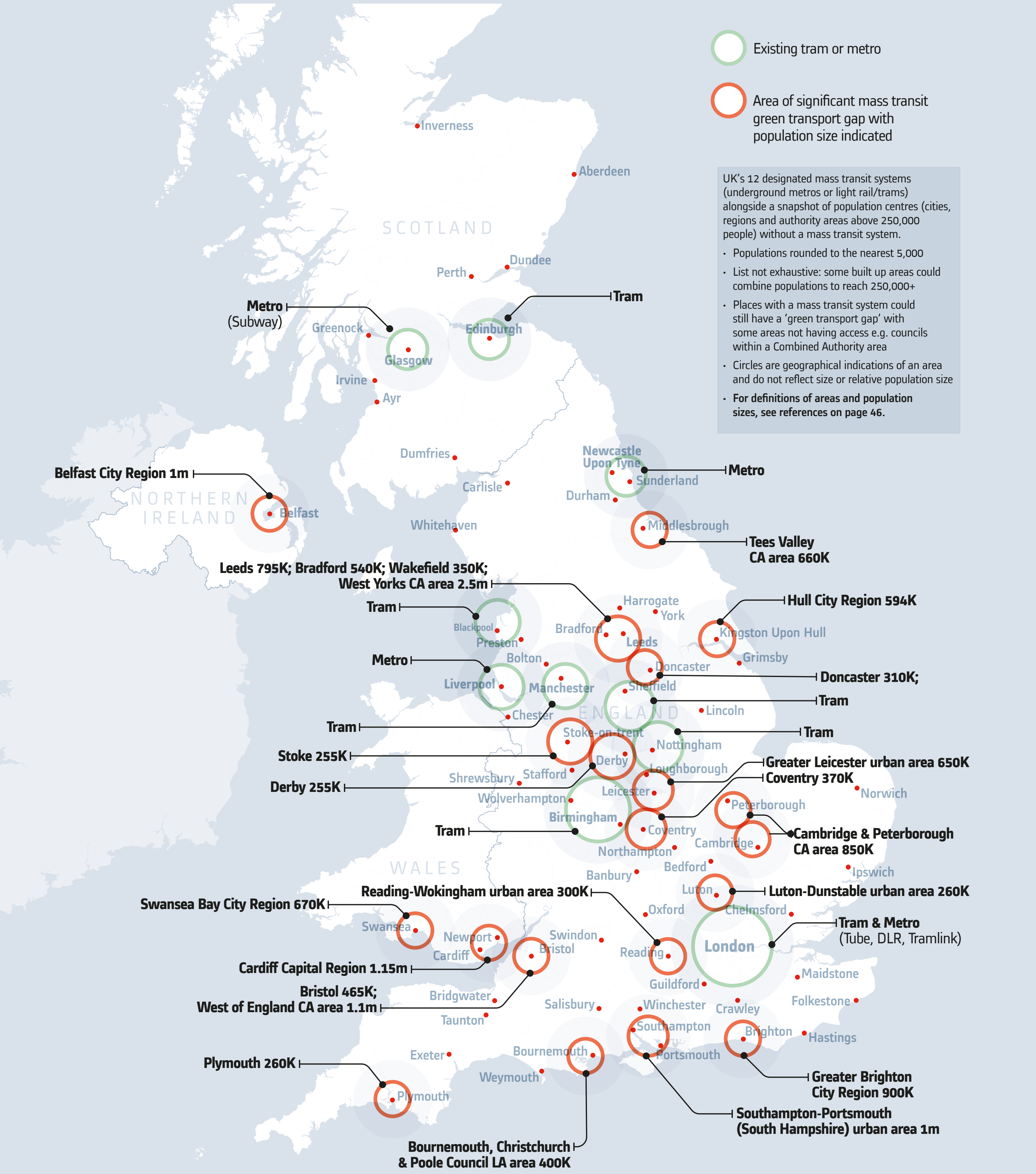
In looking at the UK's mass transit gaps, one can see the contrast in Europe with many countries having numerous systems as map 4 following outlines.

In the absence of these systems in the UK, the obvious decarbonisation benefits they bring cannot be realised and urban areas remain choked in traffic congestion and inefficient travelling conditions. Mass transit schemes provide a range of significant economic, social and green benefits. They improve productivity, unlock economic potential in an environmentally acceptable way and increase land value and investment opportunities.[64] Construction of schemes create skilled jobs in development and construction and bring corollary multiplier effects. These systems permanently change behaviours and create new, greener, efficient ways of living, altering how cities operate and are planned in greener ways including supporting sustainable housing development. Integrated mass transit systems enable people to make low carbon, sustainable choices and help address the structural barriers to lifestyle changes. They shape cities to be energy efficient, free up road infrastructure for those who most need it (including cyclists, pedestrians, those with mobility issues and final mile delivery) and reduce congestion and improve air quality.

The Nottingham tram has changed travel patterns with a rising number of people using public transport and despite an increasing population, traffic volumes in Nottingham have remained static for several years while Nottingham has the lowest car ownership for a city outside London.[65] The Tramlink in London introduced in 1995 has changed travel too with a study in 2004, four years after its opening, showing 20% of passengers had transferred from the car.[66]

Buses have an important role in transport networks although too often have been overlooked and lacked investment. Usage in England is down by 29m journeys or 0.7% in the year ending March 2019 and with a decline of 6.9% since 2008/09.[67] A third of all bus journeys are in London, showing the lack of services outside the capital. The Government's £5bn fund is welcome in seeking to reverse this and to green fleets including the delivery of Britain's first all-electric bus town or city. There are also powers that authorities can use through the 2017 Bus Act to regulate buses and run TfL style licensing models—Manchester and Liverpool are taking such models forward.

Map 3: Opportunities for levelling up the UK's green transport gaps



UK's 12 designated mass transit systems (underground metros or light rail/trams) alongside a snapshot of population centres (cities, regions and authority areas above 250,000 people) without a mass transit system.

- Populations rounded to the nearest 5,000
- List not exhaustive: some built up areas could combine populations to reach 250,000+
- Places with a mass transit system could still have a 'green transport gap' with some areas not having access e.g. councils within a Combined Authority area
- Circles are geographical indications of an area and do not reflect size or relative population size
- **For definitions of areas and population sizes, see references on page 46.**

Map 4: Selection of metro, trams and light rail networks across parts of western, central and eastern Europe

Source: information utilised from urbanrail.net

Mass transit, trams and light rail can be cheaper over their life span, are more effective and bring wider benefits. Buses need much greater levels of staffing and vehicles with additional costs and maintenance, a key factor on highly trafficked routes. In addition, most bus fleets need to move to hydrogen or electric power plus supporting infrastructure—only around 2% of the 35,000 buses in England are electric.[68] Trams are quiet, do not have emissions and run frequent, regular, reliable and consistent 'turn up and go' services that passengers want. It has also been shown that the permanency of tram routes means people relocate to use the routes, something they are unlikely to do when using bus transport with its potential to be re-routed. Mass transit systems should be integrated with green bus fleets and active travel programme that support walking and cycling.

Electric vehicles (EVs) have a role too. However, a wholesale move to EVs is not the solution. EVs still cause congestion, emit particulates through braking, embedded carbon is used in making EVs, and they are not used for the majority of the time. EVs also need considerable space, including parking and charging facilities. COVID-19 has enabled people to experience quieter streets and cleaner air. Public polling shows people want these benefits to continue.[69] Mass transit systems with active travel are an ideal way to help secure these.

Delivering schemes should focus on low carbon methodologies. Nottingham has moved to 100% renewable energy for its tram system and the network is a key contributor to its ambitious decarbonisation goal and to achieving modal shift. Modern trams systems, using new technologies such as those developed by Alstom, can mean trams are even more suitable for sensitive urban areas, without the need for overhead wires and with charging at stops and regenerative braking—as seen in the systems used in Nice and Bordeaux in France. In addition, Alstom has ensured that the construction of fleets is greener still with trams and metros almost completely recyclable—the Citadis X05 used in Nice reaches 99% recyclability.

Case study—Nottingham's transformational tram

Nottingham Express Transit (NET) tram system, opened in 2004 with 400,000 passengers using it in the first year of operation. In 2015, NET more than doubled in size. It now has two lines, 51 tram stops, visits seven park & ride sites, and carries nearly 19m passengers a year. It was the first UK tram to be fully accessible and serves the Queens Medical Centre, the country's only hospital with a direct tram link.[70] The NET serves 20 of the 30 largest employers in Greater Nottingham and boosts the local economy by £300m a year, creating and supporting thousands of jobs.[71] Three further extensions are proposed—one unlocking one of the East Midlands largest commercial and housing developments, another to Toton for the new HS2 station and a new route to Gedling.

Through a joint venture, Alstom built all infrastructure for the extension, including overhead wires, track and signalling. It also supplied 22 Citadis trams that now form part of the 37-strong tram fleet. As part of the Tramlink Nottingham Consortium, Alstom maintains all the vehicles.

Nottingham's tram system is at the heart of decarbonisation with the network now running on 100% renewable power.[72] The city is seeking to become the UK's first carbon-neutral city by 2028. Nottingham has seen emissions reductions of 41% since 2005, beating its 2020 target of 26%, with transport emissions more than 13% down.[73] It has changed travel patterns with a rising number of people using public transport and despite an increasing population, traffic volumes in Nottingham have remained static for several years.[74] Nottingham has the lowest car ownership for a city outside London.[75]

The NET links with other initiatives such as hydrogen and biogas buses, one of the UK's largest electric bus fleets and a cycle hire scheme and bike storage hubs. Innovatively, Nottingham introduced a Workplace Parking Levy for residents driving their cars to work, with all funds ring-fenced for public transport projects including the NET. Nottingham is now seeking to move further and faster to reach its 2028 goal.

Nottingham tram, the NET, which runs on renewable power

For transport schemes to be the most effective and bring the most decarbonising benefits, they need to be integrated. Systems such as Alstom's Mastria enables transport authorities to manage and orchestrate all transport modes—metros, trains, trams, buses, taxis, roads and e-scooters, and even walking—in a co-ordinated way to optimise the network capacity and efficiency and improve the user experience. The system also offers mobility data analysis, prediction and recommendations to support performance. Alstom's Optimet helps to redistribute passengers on platforms and trains, managing train occupation at busy city stations so passenger comfort, safety and social distancing can be maximised and demand and peak-time capacity managed. Integrating and optimising transport networks is a key part of the effective use of transport systems in response to COVID-19.

A government programme to establish these systems would improve transport delivery, upgrade systems and build resilience, including in managing future waves of COVID-19. Zaragoza and Panama City are two urban areas that are introducing these systems. A £50m programme could kick start these systems and be targeted at the largest city regions within the UK, which have the most need for efficient co-ordination. This could be enhanced through a financed solution harnessing private sector balance sheets and obviating the need for upfront capital.

The UK's biggest mass transit system, the London Underground is the world's oldest. Not all lines are automated. Automating all lines would boost reliability and capability with corollary environmental decarbonisation benefits too, including greater use of the system, using less energy and causing less pollution from braking dust. Despite the age of the Underground this would help transform the railway into a modern system.

Mass transit schemes can also now be designed to reduce street impacts and, for example, free up space. Alstom has designed trams without overhead wires and similarly there is a solution for electric buses, including new larger double decker buses. Alstom's SRS is a technological breakthrough in electric public transport, enabling cities to operate clean, quiet electric fleets without unsightly or obstructive catenary masts and overhead lines. This is an added advantage for cities with architectural heritage or constraints such as narrow streets or bridges. The charging system can be used at stops and also at line terminuses, in particular for electric buses that can fully recharge in the space of a few minutes. It enables buses to be in continuous use rather than having to go back to the depot to charge. The Alstom 'Hesop' system, which can be used for underground metros, trams and trains, can capture and recycle the energy from braking helping further reduce energy from transport and decarbonise operations.

Scaling regional and local mass transit transport schemes

The Government is committed to 'levelling up', devolution, decarbonisation and a green recovery. All these goals link together through the development of mass transport systems. The green public transport gaps across the country should be addressed to bring a step change in the reduction of transport emissions including meeting the Prime Minister's new 68% target for overall emission reduction by 2030 and to foster modal shift and meet regional and local ambitions.[76] This is achievable in a number of ways.

While many areas of the country have drawn up transport plans or identified ambitions, including expansion of existing networks, many schemes are in their infancy, are not funded and are not being developed at pace. These schemes include mass transit systems, trams and light rail, very light rail, undergrounds and intensification of urban railways networks to bring metro style services that act as a dedicated mass transit system. To create a step change the Government should initiate an audit of the public transport deficit to use as a basis for working with cities, areas and regions to develop a comprehensive plan of new and expanded green systems.

As a starting point Alstom recommends that urban centres with a population of more than 250,0000 should be supported to have access to a mass transit system. In Germany and France even smaller cities and town have such systems. Mass transit systems do require upfront investment and a £10bn, ten year programme could kickstart these schemes. There are also opportunities for financed solutions bringing private sector investment and balance sheets through Joint Ventures (JVs), without the need for government upfront capital or in providing additional capital funding. This model helped deliver the Nottingham tram. The Government's Infrastructure Strategy, published alongside the CSR, also promotes and seeks to deliver more infrastructure through private financed models. There is a considerable opportunity to use these for new mass transit systems, which the Government should promote and initiate.

As well as a funding programme, support should be given to mayors, regions and authorities to draw up and develop programmes. A coordinated approach across government would see joining up of relevant departments including DfT, MHCLG, DEFRA, BEIS and HMT and linking transport schemes and other programmes such as housing. The development of schemes and decision-making including procurement should be accelerated and could benefit from the 'Project Speed' approach and the DfT's Acceleration Unit can focus on these schemes too. As an example of need for pace, a DfT call for evidence on bringing forward light rail closed in May 2019, but no response has yet been published (as of January 2021). The green recovery infrastructure stimulus and plan could offer a point for change.

The TDP has one reference to trams to highlight the £2.5bn Transforming Cities Fund. Within the fund £1.28bn of capital is for shortlisted city regions to support projects up to 2022–23, not all of these being trams and light rail schemes. The fund does not represent a comprehensive plan or an at scale funding programme. The new £4bn 'Levelling Up' fund announced as part of the 2020 Comprehensive Spending Review, which can be used to fund anything from a road bypass to a library or town centre improvements to a new railway station, will inject some additional funds into local areas. However, it does not represent a comprehensive plan or funding programme either for mass transit systems. Funding and appraisals for projects should also reflect the full economic, environmental, social and health benefits of schemes.

A pipeline of schemes gives certainty, brings down costs and enable a skills, jobs and supply chain programme to be developed and private sector expertise to be harnessed. Companies like Alstom have a strong balance sheet which can be used at a time of financial challenge. Equally, as mass transit systems increase land value there are opportunities for land value capture which could support financed solutions. Mayors and local leaders can also harness the private sector expertise to help plan and deliver schemes. Authorities can speed their processes to reflect the climate imperative and be given more freedom by the Government to develop funding packages and borrowing powers as they have on housing to generate new sources of local revenue to support transport schemes.

A step change is possible. Addressing the mass transit green transport gaps would enable the country to reduce carbon emissions faster, bring permanent positive change and enable a 'green levelling up.'

Removing the barriers, accelerating transformation and creating a step change

- Audit the green transport gaps and opportunities across the country, and regional and local climate aims to build a pipeline of schemes and enable places to 'level up' and 'go green', supporting a green recovery
- Support a £10bn, 10 year programme to kickstart and take forward schemes
- Establish a proactive approach with government structures to support local and regional transport scheme development and delivery and rapid deployment of technologies
- Speed up development and procurement processes, enable local funding models, harness private sector expertise, and back the development of UK expertise and supply chains
- Reflect the economic, environmental, social and health benefits of mass transit schemes in funding assessments

CONCLUSION—A NEW GREEN AGE

At scale transport decarbonisation and modal shift is not just desirable, but essential to address the climate imperative. It is also achievable.

The opportunity is to bring forward a transport strategy outlining the purpose of the transport system including the role of different modes and the weighting of each. As part of such a plan there should be a strategy for rail and the greater path it should play. Such a strategy could anchor the role of rail in decarbonisation and its potential for changing the nature of travel. The TDP consultation is a positive step in moving to such a plan.

Green rail and mass transit systems as well as transporting people, support economic growth, improve productivity, reshape economic geographies and are key tools in helping areas level up. Initiating green transport programmes now as part of a green recovery, anchors and creates skilled jobs and brings significant multiplier effects. An improved and decarbonised railway through electrification, hydrogen and a new high speed rail network, integrated with new light rail and tram systems would represent a step change and enable significantly more people and freight moving from road and air to non-polluting rail and reduce transport carbon emissions, the largest source of UK emissions. It would also bring healthier travel options, embed more sustainable land use and bring health gains, including to air quality.

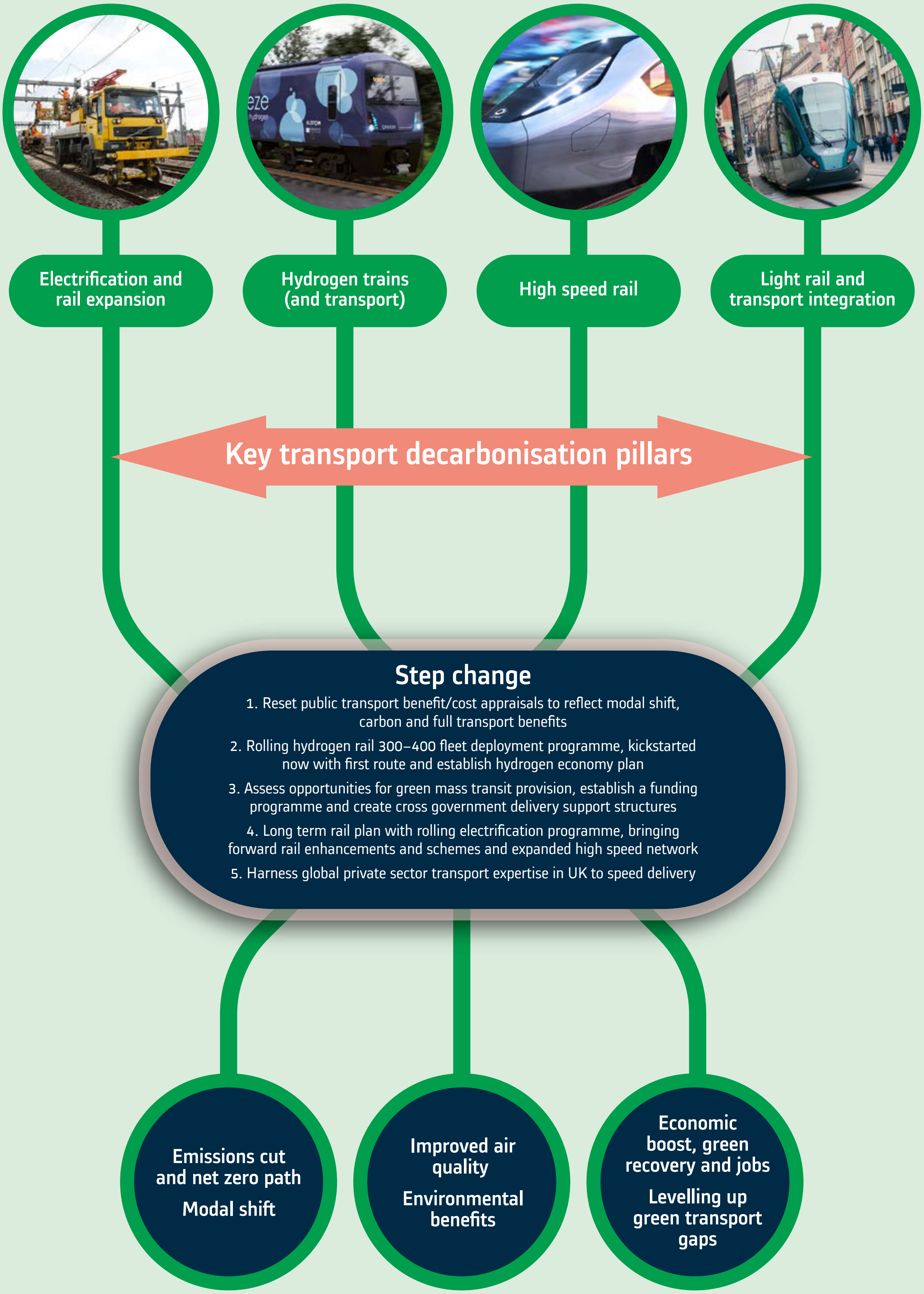
Committing to a hydrogen at scale deployment programme and strategy to support the hydrogen economy will deliver a significant acceleration in achieving rail decarbonisation and to replacing polluting diesels. It is also a key element in building a home grown industry, bringing jobs in areas across the country.

Alongside this, there is a huge opportunity to 'level up' the green transport gaps across the country and bring forward new mass transit systems. Auditing the green gaps, bringing together existing plans into a pipeline, fully reflecting the benefits of schemes in funding appraisals, creating structures across government to work with localities and putting in place a funding kickstart programme will create a step change.

As the Government seeks a 'Global Britain', the country can develop expertise and root it in the UK, with export potential and supply—no more so than in hydrogen. As a world leader in sustainable mobility and new technologies including hydrogen, Alstom can provide advice and strategic input at national and regional levels and build capacity. With a strong rail industry, and pillars such as Alstom's centre of hydrogen conversion expertise based in Widnes, the UK can move quickly to be a leader in the development of a hydrogen economy.

Taking forward this programme would signal a green transport renaissance and the dawn of a new green age.

Accelerating net zero and transport decarbonisation



Acronyms

BEIS	Department for Business, Energy and Industrial Strategy
CCC	Committee on Climate Change
CSR	Comprehensive Spending Review
DEFRA	Department Environment, Farming and Rural Affairs
DfT	Department for Transport
GHG	Greenhouse gas
HMT	HM Treasury
HSRG	High Speed Rail Group
MER	Midlands Engine Rail
MHCLG	Ministry of Housing, Communities and Local Government
NPR	Northern Powerhouse Rail
RDG	Rail Delivery Group
RIA	Railway Industry Association
RSSB	Rail Safety and Standards Board
TDP	Transport Decarbonisation Plan

City regions and population references for Map 3

The following are the links to the population levels in each area. ONS estimates (figure 3 in link below) have been used for most places: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/bulletins/annualmidyearpopulationestimates/mid2019estimates

For wider agglomerated urban areas such as City Regions and more recent Combined Authority areas there are not the equivalent ONS estimates and so the population figure is referenced from a relevant local or national government report or website. All figures are rounded to the nearest 5,000.

Belfast City Region 1m (2019 report)
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/789253/HoT-_City_Deals-_Final_-_with_signatures___1_.pdf

Tees Valley Combined Authority area 660k (2016 estimate)
https://teesvalley-ca.gov.uk/InstantAtlas/DISTRICTS/report_District_I161.html

Hull City Region 594k (2017 report)
https://www.york.gov.uk/downloads/file/1032/greater-yorkshire-devolution-a-proposal-to-yorkshire-and-the-uk-government

Greater Leicester urban area 650k (2017 report)
https://news.leicester.gov.uk/news-articles/2017/september/exhibitions-give-information-about-local-plan/

Coventry 370k (ONS 2019 estimate)

Cambridge & Peterborough Combined Authority area 850k (2019 report)
https://cambridgeshirepeterborough-ca.gov.uk/assets/Transport/Appendix-D-Baseline-Review-rev-B.pdf

Greater Brighton City Region 900k (2020 website)
https://greaterbrighton.com/%EF%BB%BFclean-growth-and-transport-among-new-greater-brighton-chairmans-priorities/

Southampton-Portsmouth (South Hampshire/PUSH) urban area 1m (2010)
https://www.centreforcities.org/wp-content/uploads/2014/09/10-03-16-Charting-the-course-Growing-South-Hampshires-economy.pdf

Bournemouth, Christchurch & Pool Local Authority area 400k (ONS 2019 estimate)

Plymouth 260k (ONS 2019 estimate)

Bristol 465k (ONS 2019 estimate)

West of England Combined Authority area 1.1m (2020 website)
https://www.westofengland-ca.gov.uk/

Cardiff Capital Region 1.15m (2017 estimate)
https://www.cardiffcapitalregion.wales/wp-content/uploads/2020/03/ccr-state-of-the-region-part-3-resilient-con-1-3-compressed.pdf

Swansea Bay City Region 670k (2017 report)
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/611685/Swansea_City_Deal_-_English.pdf

Stoke 255k (ONS 2019 estimate)

Derby 255k (ONS 2019 estimate)

West Yorkshire Combined Authority 2.5m (2020 website)
https://www.westyorks-ca.gov.uk/about-us/west-yorkshire-area/

Leeds 795k (ONS 2019 estimate)

Bradford 540k (ONS 2019 estimate)

Wakefield 350k (ONS 2019 estimate)

Doncaster 310k (ONS 2019 estimate)

Luton-Dunstable urban area 260k (2020 website)
https://lutonbid.org/about-luton/#:~:text=Luton%20is%20a%20large%20town,a%20population%20of%20about%20258%2C000.

Reading-Wokingham urban area 300k (2017 report)
https://uk-air.defra.gov.uk/assets/documents/no2ten/2017-zone-plans/AQplans_UK0016.pdf

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