



RAIL INDUSTRY DECARBONISATION TASKFORCE

INITIAL REPORT TO THE MINISTER FOR RAIL

JANUARY 2019 | WITH THE SUPPORT OF RSSB



Foreword


I am pleased to present, on behalf of the Rail Industry Decarbonisation Taskforce and RSSB, the interim report responding to the Minister for Rail's challenge to the industry to remove "all diesel only trains off the track by 2040" and "produce a vision for how the rail industry will decarbonise."

We have been privileged to be invited as a taskforce to shape an industry response to this challenging aspiration, and have found great enthusiasm within the industry to supporting innovative and enduring solutions. This initial report sets out a credible set of technical options to achieve this goal.

This Interim Report is one in a suite of reports due to be produced on the subject. It should be read in conjunction with the accompanying T1145 report (commissioned by RSSB) which goes into greater detail and research on traction. It will be followed in Spring 2019 by a further report which will address the economics and cost benefits of alternative technologies and approaches highlighted in this report, and set out a route map to deliver the final recommendations.

In this Interim Report we consider Traction, Property and Infrastructure and conclude:

- The current GB rail system is one of the lowest carbon modes of transport.
- The GB rail industry is already working collaboratively across private and public sectors to develop innovative solutions.
- There is 'no silver bullet', so different solutions (power sources) are better suited to specific operational challenges.
- There is no country, manufacturer or rail system clearly leading the way to a lower carbon network, although there are opportunities to learn from others.
- The removal of diesel only passenger trains from the national rail network by **2040 is achievable**.
 - » The best solution will be a **mix of new traction** options and **efficiency improvements** now under various stages of development and implementation, in areas where electrification is not, and is never likely to be, available.
 - » **Where it is cost-effective and appropriate, electrification** is currently the most carbon efficient power source. However, it is not a 'silver bullet' and can cause significant disruption and delays for passengers.
 - » Other power sources such as bi-mode, hydrogen, battery, etc are developing fast. We recommend a **concerted industry and government effort to support research and development** on these options. They should be **deployed in a targeted manner to achieve the lowest system-wide carbon outcome**.
 - » However, there is a very material difference between 'trial' and full commercial production.



“ALL DIESEL ONLY TRAINS OFF THE TRACK BY 2040” AND “PRODUCE A VISION FOR HOW THE RAIL INDUSTRY WILL DECARBONISE.”

- The removal of diesel only freight and maintenance (Yellow Rail) trains from the national rail network presents unique challenges.
 - » There is **no alternative independent power source available**, which delivers the power and range necessary to meet the specific demands of these uses.
 - » The introduction of bi-mode and battery technology, while a challenge, could deliver significant improvements.
 - » We recommend further **industry-led research and development** into solving this challenge.
 - » In the near term the freight industry will continue to reduce unit carbon emissions through further maximising payload per train, employing driver advisory systems, auto stop-start and other system-level innovations.
- In parallel with our decarbonisation work, the industry is developing an air quality strategy. We will ensure that the work streams on decarbonisation and air quality consider common issues.
- On Property and Infrastructure, Network Rail is already implementing cost effective, reliable changes. The report details a number of these delivering improvements in the near term.
- To achieve the lowest carbon emissions the industry and Government should improve how we work together to shape long-term policies that will drive practical and cost-effective decarbonisation.
- Care must be taken to **avoid unintended consequences** e.g., creating an artificial imbalance between the costs of rail freight and road haulage.
- There is more analysis to follow in the subsequent report.

We begin the report by setting out the context for the challenge. We explain rail's contribution to low carbon transport and how this will continue into the future with improvements already under way. We explain that the majority of energy use on the railway is in traction. We focus our work on traction accordingly, exploring the options which realistically have a credible chance of making a difference by 2040, while also looking at possible improvements in property and infrastructure. We consider the role of public policy, how government and the industry could work together to deliver a low carbon railway and both the risks and opportunities we anticipate. Finally, we set out a list of actions across five themes that we will look at in detail in our final report.

In summary, we believe that there is a real opportunity for the **Rail Industry in Great Britain to become a world leader in developing and delivering low carbon solutions.**

*Malcolm Brown
Taskforce Chairman*



Executive Summary

On 12 February 2018, Jo Johnson MP, then Minister for Rail, challenged the rail industry to remove all diesel-only trains from the network by 2040 and to provide a vision for how it will decarbonise. The rail industry decarbonisation taskforce, chaired by Malcolm Brown, then CEO of Angel Trains, was set up to answer the challenge.

We committed to providing an initial report on how the industry might address this challenge by the end of September 2018. We will provide a final report, including an economic appraisal and a route map for delivery of the taskforce's recommendations in spring 2019.

Our task has been to consider what technologies are available and under development that will enable the industry to remove diesel-only trains from the network by 2040 and provide a vision for how to decarbonise the GB railway so that it is the world's leading low carbon railway by this date. We have split our work into three areas: traction, property and infrastructure.

We have confirmed that the railway remains a very low carbon form of transport for both passengers and freight. It is among the lowest carbon modes of transport, particularly for heavily used commuter passenger journeys and for freight.

The industry uses its two principal traction modes, electricity and diesel, very efficiently. It continues to innovate both on how to improve these as well as on how to introduce new and improved technology. The industry's efficient use of existing traction modes sets a high hurdle for other technologies to pass in order to be established as low-cost, lower carbon alternatives. Nevertheless, we were excited to discover the scope and amount of innovation under way, both from large, well established industry players as well as from smaller businesses and in academic partnerships. Examples of this ongoing innovation are given in a series of case studies which showcase a pipeline of ideas, from those being trialled as well as where new ideas are at various stages of development. Where solutions to some parts of the challenge are not immediately apparent, there is strong commitment to encourage and fund further research and development leading towards demonstrator projects and trials. We have been reassured that the spirit of innovation in the rail industry is in good health. Accordingly, the rail industry has welcomed the challenge to continue to innovate towards a low carbon future.

The greatest challenge is on traction. There are some types of journeys where there are real possibilities for the introduction of new technology such as hydrogen fuel cells, on-board and lineside battery charging. Other journeys, such as high-speed intercity services and freight, have journey characteristics which demand very high energy and power delivery requirements, high acceleration and long periods between refuelling. Our research has shown that there are no suitable alternatives to electric and diesel traction available for these journey types within the timescales to 2040. Where no



WE HAVE CONFIRMED THAT THE RAILWAY REMAINS A VERY LOW CARBON FORM OF TRANSPORT FOR BOTH PASSENGERS AND FREIGHT.

alternatives exist for certain journey types, we recommend putting in place transitional arrangements that may, for example, life-extend existing vehicles while the industry, academia and government work together to define, fund and implement innovation programmes in these key areas. An ongoing challenge will be to keep under review the most cost-effective decarbonisation solutions, both as technology develops and as cost and practical implications for the best whole-system solution evolve.

We recommend that the core of the decarbonisation strategy should be to maximise the use of the existing electrified network and we propose a hierarchy of options to achieve this. Trains should run using the electrified network whenever this is possible. The electrified network should then be used to provide charging for on-board batteries to bridge electrification gaps on routes where this is technically feasible. Other traction modes, such as hydrogen, bi-mode and hybrid trains should be actively encouraged as the best low-carbon options where extension of the electrified network is not feasible or will not be the most cost- and carbon-effective whole system solution.

We recommend that further research and development on new technologies, such as hydrogen fuel cells and lineside charging, should be supported and incentivised for key journey types and network areas, where these show good potential to deliver more cost effective and lower carbon outcomes.

There are significant levels of support via RSSB R&D funding, Innovate UK, academic partnerships and other channels for innovation projects. We are seeing increased levels of interest in projects that support decarbonisation. We see there will be great benefit in encouraging further cooperation and collaboration between industry, academia and government in this critical area. We propose that the more likely options should be benchmarked in cost and carbon terms against the use of the existing electrified network and diesel. While we have made a thorough review of viable and potentially viable options by 2040, we recognise that the lowest cost and lowest carbon impact whole system solution may identify some additional electrification. The need to look at this possibility further has been recognised by the Government. On 28 June 2018 the Transport Select Committee inquiry into rail infrastructure investment found that the Department for Transport (DfT) and Network Rail “should engage with the Railway Industry Association’s (RIA) Electrification Cost Challenge initiative, and together produce a report on cost effective electrification within 12 months”. On 19 September 2018 the Government responded that it “will continue to engage with the industry and RIA on initiatives that could reduce the cost of enhancing the railway and improve the outcomes for its users. We will work with RIA to produce a report as recommended...” We would advocate that this would benefit from an explicit assessment of the carbon impact of electrification when compared with any other feasible traction options.

There are significant opportunities in both property, comprised primarily of stations and depots, and in infrastructure to achieve carbon reductions at a reasonable cost.

For stations and depots, this would be achieved primarily through putting in place the appropriate requirements and structures to decarbonise direct energy use for lighting and heating. Driving this change, particularly where payback periods stretch beyond franchise terms, will require that we make better use of residual asset value mechanisms, franchise asset transfers and other tools for investments that extend beyond the lifetime of the franchise. We also recommend that the application of BREEAM, a world-leading sustainable assessment method, be mandated for all new station and depot developments and for major refurbishments to minimise lifecycle carbon.

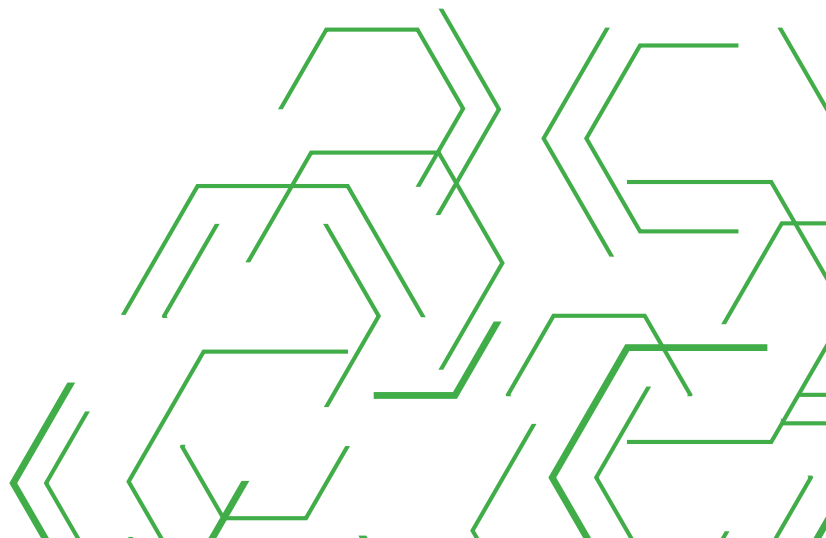
For infrastructure, most assets have long lifecycles and are heavily controlled for safety, performance and customer satisfaction purposes, so opportunities for early carbon reductions are limited. However, we see that there is a real opportunity to be innovative in replacing lineside diesel generators and emergency generators with battery storage and that this should be researched as a priority. The Network Rail road fleet is changing from an owned fleet to a leased fleet and supporting commitments to achieve zero tailpipe emissions from vans in cities by 2028. There are opportunities here for the company to drive innovation in fleet decarbonisation. We recommend that Network Rail meet pending government targets for introducing low emission cars into its fleet. We also recommend that they work with the Transport Systems Catapult and other potential innovation partners to leverage innovation within their fleet.

The need for a clear, consistent and predictable policy approach focused on decarbonisation was one of the most regularly repeated comments we received in our industry consultation. We recommend that the industry and DfT work together to review where policy may be developed to incorporate the need for decarbonisation in both capital and operational aspects. We explain that this policy approach will have to be aligned with appropriate incentives, including research and innovation co-funding, where the market size in rail is not big enough to spread the cost of innovation sufficiently to make improvements commercially viable. We set out why it will also need to be supported by consistent, reliable and robust carbon performance data collection, analysis and reporting back into the industry. Rail has a rightful reputation as a low carbon transport mode. While this is clear at a macro level from comparative statistics published by DfT and Office of Rail and Road (ORR) there has been relatively little pressure at the micro level to focus operational management, both within and outside franchise agreements, on a rigorous carbon management programme. The industry and DfT will need to make significant improvements. This will have to be at a level of granularity that allows the industry to compare good and bad performance across its operations and take action accordingly. In our final report, we will address in more detail the need for the rail industry to transfer new technology from other sectors, most notably the automotive sector to drive cost effective innovation. We will consider whether the rail industry will be a large enough market to fund and support the rollout of, say, a hydrogen infrastructure or a battery charging infrastructure, or whether it will have to work in tandem with other sectors.

In our final report, we intend to set out a series of stretching aspirations for the industry to aim to achieve by 2040, given the appropriate policy framework and support. The economic appraisal and route map that we will undertake for the final report will inform how the government and the industry, working together, will be able to achieve these aspirations.

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Definitions and explanatory notes

For the purposes of this report, we use the following definitions–

TRAINS

- **Bi-mode**

Bi-mode trains drive either on the electrified network or by some other form of traction power, such as a diesel engine or a battery. They use the energy sources separately so, for example, would run ‘under the wire’ (see explanatory note below) or using diesel, but not both at the same time.

- **Hybrid**

Hybrid trains are self-powered and do not use the electrified network. They use a combination of stored and rechargeable energy sources to power the trainset which provide a set of characteristics neither energy source can deliver on its own. They may use the energy sources separately or together. A typical hybrid in use now is a combination of diesel and battery, although a hybrid train may use a combination of other stored energy sources such as capacitors, flywheels, hydraulic accumulators, hydrogen or LPG.

- **Tri mode**

Tri-mode trains are a combination of bi-mode and hybrid in one trainset.

TYPES OF ELECTRIFICATION

- **Continuous electrification**

Continuous electrification refers to those sections of line where the electrified network is continuous. An electric train can run, stop and start at any section of the line under electric power only.

- **Discrete electrification**

Discrete electrification is where certain sections of the line are electrified, and others are not electrified at all. The gaps between electrified sections are often likely to be significant. With discrete electrification, the number of gaps between electrified sections are likely to be limited.

A train running on electric power only is unlikely reliably to be able to bridge gaps between sections of the electrified network. It will not be able to stop and start on non-electrified sections.

- **Discontinuous electrification**

Discontinuous electrification is electrically discontinuous, such as at an earthed section through an overbridge. This is most likely to occur in places such as older bridges, tunnels and other obstacles. Discontinuous electrification is likely to have much more frequent, much shorter breaks on particularly constrained sections of track when compared with discrete electrification.

A train running on electric power only may be able reliably to bridge gaps through momentum alone, although this is an operational risk, or through some limited energy storage, such as a flywheel. It is unlikely to be able to stop and start on non-electrified sections.

- By comparison, last mile journeys run on sections of line beyond any electrified stretches. The train will have to run self-powered there and back. It may be able to recharge or refuel at the end point and/or intermediate points of the journey if facilities are available. The 'last mile' is a loose term and is often much longer than the short stretch the term implies: on a journey from London to Aberdeen, for example, the 'last mile' stretch from Edinburgh to Aberdeen is about 127 miles. In considering traction options, the last mile stretch, as with the length of gaps in discrete electrification, is a significant factor in determining the most suitable existing and possible future traction options.

UNDER THE WIRE

- Electrification may be via overhead wire or via a third/fourth rail. In the text, unless otherwise stated, references to running 'under the wire' refer to any form of electrified network.

CARBON EMISSIONS MEASURES

- **CO₂**: the actual emissions of CO₂.

1.1. **CO₂e**: CO₂ equivalent.

The UK reports emissions for a basket of greenhouse gases in accordance with international agreements. These have different global warming potentials (GWP). CO₂e is used to report these GWP in a single number. Some gases break down much more quickly or slowly than CO₂ or have very much greater warming impacts. A given amount of methane, for example, has about 25 times the warming potential as CO₂ even though it breaks down faster in the atmosphere¹. Other gases have very much greater GWP than this. CO₂e is calculated as the equivalent amount of warming each gas produces when compared with the impact of the same quantity of CO₂ over 100 years. Every effort is made in this report to state figures as CO₂e as this is the more inclusive statistic. In some cases, data sources report only CO₂ and this is indicated accordingly.

- **CO₂e/seat km**: a measure of efficiency of engineering design. The number of seats on a train is constant so this statistic depends on the carbon emissions of the energy source driving the train. It is a measure of the inherent carbon efficiency of the vehicle. This will be constant for any vehicle under any given standard operating conditions.
- **CO₂e/passenger km**: a measure of utilisation rates. We note, where appropriate and where the source material states, the assumptions used to calculate CO₂e/passenger km. For rush hour commuter journeys, the number of passengers on a train may exceed the number of seats available and will therefore have relatively low emissions per passenger. For overall rail carbon emissions calculations, assumed utilisation rates are generally in the order of 30-40%. Generally, the greater the number of passengers on a train, the lower the CO₂e/passenger km.

There are very few reliable comparative studies of passenger carbon emissions across transport modes. We quote figures from a 2007 source for simple comparison purposes in the absence of any more recent reliable studies, while recognising that transport generally has become more carbon efficient since then and is likely to have become so at different rates for different transport modes.

¹ The Greenhouse Gas Protocol organisation cites a GWP for methane at around 25-28 (it has been revised upward in more recent studies) based on reports from the Intergovernmental Panel on Climate Change. See, for example, https://ghgprotocol.org/sites/default/files/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf



Introduction

Background

THE CHALLENGE AND REMIT

1. On 12 February 2018, Jo Johnson MP, the Minister for Rail, called for the rail industry to take more ambitious steps towards a cleaner future. Specifically, he challenged the industry to take “all diesel-only trains off the track by 2040” and to propose “a clear, long-term strategy with consistent objectives and incentives” with “ambitious and bold plans on decarbonizing the whole rail sector.”
2. The industry set up a decarbonisation taskforce under the Chair of Malcolm Brown, then CEO of Angel Trains. This comprised representatives from the major parts of the rail industry including Network Rail, the Rail Delivery Group, the Rail Freight Group, the Railway Industry Association and RSSB, which also provided the secretariat and technical authorship. The purpose of the taskforce was to draft a collective response to the challenge, including a route map to delivering the mission which will embed delivery in business as usual. The agreed Vision and Mission of the taskforce were -

VISION

For the UK to have the world’s leading low-carbon railway by 2040.

MISSION

To move UK rail to the lowest practicable carbon energy base by 2040, enabling the industry to be world leaders in developing and delivering low carbon transport solutions for rail.

3. The full remit and membership of the taskforce are set out in Annex A.

The methodology

4. To address the challenge to decarbonise the whole rail sector, and in line with the remit, the taskforce split the task into three sections -
 - 4.1. **TRACTION:** trains and how they are powered;
 - 4.2. **PROPERTY:** buildings such as stations and depots which have specific operational requirements, where greatest improvements are focused on discrete energy use of the building in use; and



“A CLEAR, LONG-TERM STRATEGY WITH CONSISTENT OBJECTIVES AND INCENTIVES”

- 4.3. **INFRASTRUCTURE:** all other elements of the railway necessary for trains to operate, including the rail lines themselves, points, signaling, power supplies, control systems, telecommunications, maintenance and renewal capability, and associated road fleets. These will have significant dependencies on traction types, the operation and management of trains on the network, and the maintenance and renewal of the network.
5. To support the first part of this work, the taskforce has received input from a research project, Options for traction energy decarbonisation in rail (T1145), commissioned by RSSB. The project team has produced an initial report on options evaluation which accompanies this report. The project will continue into the second stage of the work of the taskforce to generate two further key outputs, undertaking an economic analysis of the options and setting out a route map for implementation of recommended options.
6. Our approach has been to consider traction, property and infrastructure separately in this initial report to develop a credible range of options. We assess these purely in terms of technological readiness and maturity to consider which are most likely to achieve the greatest levels of carbon reduction by 2040. In the second phase of our work we will investigate how they interact to assess the whole life costs and the impacts of preferred options through the economic analysis and route map development.
7. In our work, we have developed thinking from prior studies, including the rolling stock strategy, on the efficient use of existing assets. We have proposed a decision-making hierarchy as summarised in Figure 1. This hierarchy maximises the use of the existing electrified network. Where it is cost-effective to do so, electrification is the benchmark for the most carbon efficient way to power trains. It will remain so as the carbon impact of grid electricity continues to fall, and traction comparisons have to be made in this light. This hierarchy aims to limit the need for additional infrastructure where the existing electrified network is able to support future traction needs. Additional infrastructure would include fuel generation, storage, distribution and refuelling facilities, for example. These needs will be addressed in detail in the final report. This applies a set of principles for passenger journeys–
- 7.1. any journey that can be run wholly on an electrified route should always use electric power;
- 7.2. any journey that runs partially on an electrified route, whether this is through

discrete, discontinuous or last mile sections, should maximise the use of grid electricity as a traction energy source when this is demonstrably the best long-term low carbon option. The most obvious way to do this is through the use of on-board batteries chargeable from the electrified network² ;

- 7.3. any last mile journey that can be run under sustainable battery usage (i.e., typically within a charging range of 30-70% capacity) there and back should do so;
- 7.4. any last mile journey that can be run there under battery within sustainable battery usage, but not back, should consider, as an option, charging facilities at the end of the journey so it may charge up to an adequate level to make the return journey within sustainable battery usage;
- 7.5. where there is access to wire for part of the journey but the 'last mile' distance is too great to use batteries, the train should be bi-mode to run under electrification for as long as practicable where this is a cost- and carbon-effective option; and
- 7.6. where there is no access to electrified sections, there should, to the maximum extent possible, be only one alternative, such as hydrogen or lineside battery charging, to avoid the cost of duplicating energy networks on the same stretch of track.

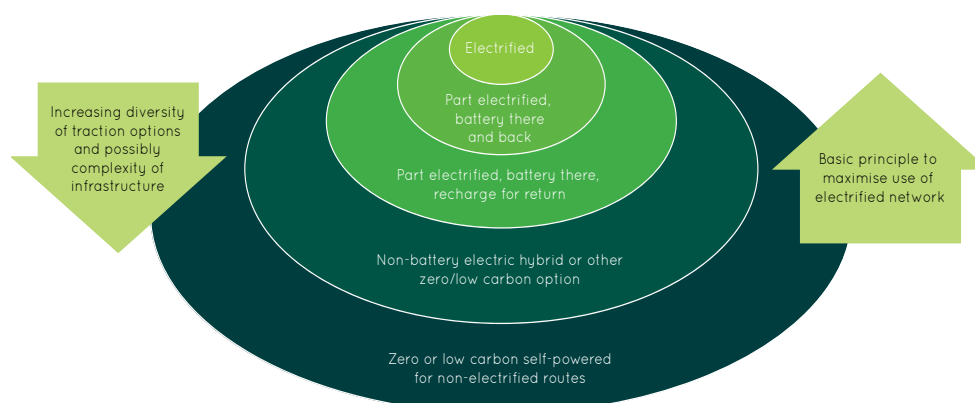


Figure 1: The decision-making hierarchy for traction options

8. Freight trains need 'go anywhere' capability to allow them to operate effectively within existing and probable future network constraints. A similar hierarchy could apply, providing that key freight routes are electrified and, for areas where this is not possible, appropriate innovation support and co-funding is given to drive the development of sufficiently powerful diesel bi-modes or suitable alternatives to continue to allow this 'go anywhere' capability.
9. Electric trains are inherently simple with lower capital and operating costs than diesel trains. However electric trains require an electrified network. This brings additional costs and therefore a whole system business case comparison is essential to make the right traction choices. In general, electrification is the better economic choice for an intensively used railway whereas diesel is currently the

² This will depend on the relative lengths of electrified and non-electrified sections. It may prove more cost-effective, subject to detailed study, to use an alternative traction option, such as hydrogen fuel cell, even when part of the journey is on electrified sections.

best economic solution on more lightly used stretches. As we seek options to decarbonise the railway, these choices become more complicated. It is inevitable that implementing options in addition to the electrified network will lead to increased system complexity as they will encompass a wider range of energy sources, traction options and infrastructure requirements. This should not prevent other options from being considered when it is sensible on carbon and cost grounds to do so. Any recommendations that we make regarding the use and possible extension of electrification will be because electrification makes economic and carbon reduction sense. Where it does not, particularly on remote or less well used parts of the network, we make this clear and highlight the need for different solutions.

10. The application of this hierarchy and the suitability of traction options, including the need for new infrastructure, against journey requirements shows that no single technology will provide a solution. The challenge will be to find the lowest carbon system at the most reasonable cost. It will be necessary to consider a whole system balance of –
 - 10.1. additional electrification where this is shown to be cost- and carbon-effective following an explicit assessment of the whole system carbon impact of electrification and any other feasible traction options;
 - 10.2. new battery technology, both on trains and lineside;
 - 10.3. hydrogen and other new (for the railway) or improved sources of energy generation and storage;
 - 10.4. transitional arrangements where technology is developing but not yet proven for the railway, such as life-extending existing diesel vehicles and introducing diesel vehicles that can be easily upgraded with low carbon traction systems to future proof them; and
 - 10.5. significantly more efficient and cleaner diesel, both in use on bi-modes and as a single traction energy source where no other options exist.
11. Later in the report we look at the capabilities of different traction options, as they are now and are likely to be in the medium term to 2040, when compared against journey requirements. We outline how this understanding will inform the economic analysis and route map we will develop in the next stage of our work for the final report.

The carbon footprint of rail and comparison with other modes

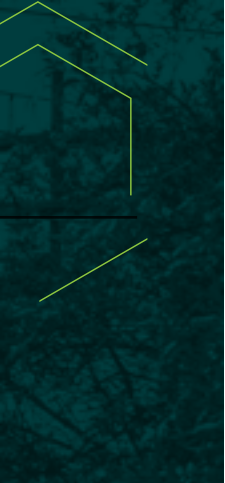
Carbon emissions in the rail industry

12. Table 1, based on 2008-09 data, shows that approximately 63% of greenhouse gas emissions in the rail industry were directly attributable to traction energy. 21% of the remainder were produced within subsystems dedicated to developing and managing the rail network and movements on it, and 13% were attributable to station and depot operations³.

	CO ₂ e (000 tonnes)	% of total
Total	5,700	
Traction energy	3,600	63%
Diesel (gasoil)	2,100	37%
Electricity	1,500	26%
Staffing and services	175	3%
Staff and offices	81	1%
Services	93	2%
Subsystems	1,920	34%
Track	490	9%
Rolling stock	165	3%
Stations	223	4%
Depots	539	9%
Structures	229	4%
Electrification	44	1%
Train control systems	233	4%

Table 1: Greenhouse gases on the railway by point of origin

³RSSB (September 2010). Whole life carbon footprint of the rail industry (T913). <https://www.sparkrail.org/Lists/Records/DispForm.aspx?ID=697>, p. iv. (login required) viewed 18 September 2018



63% OF GREENHOUSE GAS EMISSIONS IN THE RAIL INDUSTRY WERE DIRECTLY ATTRIBUTABLE TO TRACTION ENERGY

Rail's contribution to passenger and freight transport

13. The taskforce supports the need to find cost-effective means to decarbonise all sectors of UK society to contribute to statutory national carbon reduction targets. In considering how the rail industry may do this, and how quickly, we note that rail transport carries a disproportionately large element of passenger and freight traffic compared with its carbon impact. 6% of all journeys to work for the October to December 2017 reference period were by national rail⁴, while in 2015 only 1.6% of all greenhouse gas emissions from transport were from the rail sector. In 2014, these commutes were over significantly longer distances on average, at over 20 miles compared with 10 miles for road commutes. Almost 9% of total miles travelled by any form of motorised transport in 2017 were on mainline rail.
14. During 2016-17, passenger electric rolling stock consumed 3,524 million kWh of electricity and 501m litres of diesel. These generated 2,961 ktonnes of CO₂e emissions.
15. In 2016-17, freight services consumed 58 million kWh of electricity and 204 million litres of diesel. These resulted in 629 ktonnes CO₂e emissions.
16. ORR figures suggest that the relative impact of passenger movements has continued to improve, as shown in Figure 2. There had been a significant improvement in passenger rail emissions over the decade to 2016. This was due in part to increasing passenger numbers and in part to ongoing incremental improvements in the operation of the network through franchise-driven improvements, the introduction of new rolling stock and improvements in the operations of the railway through, for example, ongoing signalling improvements, traffic management and driver advisory systems that are more likely to have contributed to improved efficiencies on the passenger side. The reasons for the freight sector's carbon performance are not so clear-cut. As freight trains tend to run only when they are fully loaded, the major causes are likely to include the changing volumes and types of freight transported.

⁴ DfT (Last update 14 December 2017), Statistical data set: Modal comparisons (TSGB01), Statistics on transport comparisons, Table TSGB0108. <https://www.gov.uk/government/statistical-data-sets/tsgb01-modal-comparisons#table-tsgb0108>, viewed 25 August 2018

⁵ See https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/661678/env0201.ods, viewed 10 August 2018. Rail emitted 1.9m tonnes of a total 120m tonnes of CO₂e from the transport sector in 2015.

⁶ DfT (November 2017), Commuting trends in England 1988-2015, pp. 23 and 48.

⁷ DfT (Last update 26 July 2018), Statistical data set: How people travel (mode of transport), Data about people travelling by mode of transport, Table NTS0308: Average number of trips by trip length and main mode: England. <https://www.gov.uk/government/statistical-data-sets/nts03-modal-comparisons#trips-stages-distance-and-time-spent-travelling>, calculated from Table NTS0308, viewed on 26 August 2018

⁸ ORR (24 October 2017), *ibid.*, p.11

⁹ *Ibid.*, p.12



Figure 2: CO2e impacts for passengers and freight, 2005-2017

The extent of electrification on the network

17. The electrified network is a critical element in enabling lower carbon train operation, not only for direct energy use in electric trains but also in charging batteries.
18. In 2016-17, the network consisted of 15,811 route km (9,824 route miles). Much of this is multi-track, so overall there were 31,221 track km (19,399 track miles).¹⁰ The most recent Rolling Stock Strategy notes that 8,106 single track miles of the total 19,399 track miles, or 42%, are electrified. It has progressively reduced its expected further electrification from its 4th to 6th editions and now includes in its low scenario, based on Network Rail data, that 48% of track miles may be electrified by 2039.¹¹

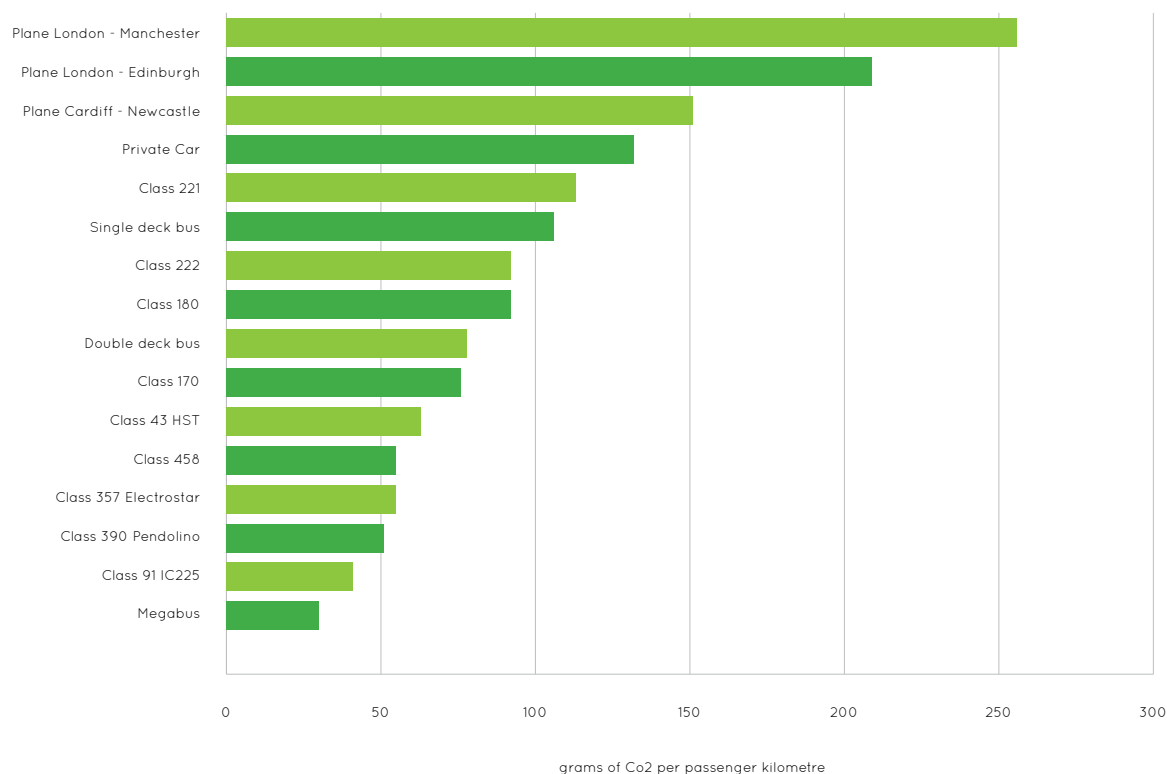
Intermodal comparison

19. Normalised per passenger carbon emissions comparisons for transport are notoriously unreliable and are discussed here for general guidance only. As previously illustrated in Figure 2, the ORR publishes statistics for passenger and freight emissions but does not make a direct comparison with other transport modes.

¹⁰ ORR (24 October 2017) Rail infrastructure, assets and environmental 2016-17 Annual Statistical Release, p. 2-3. See http://orr.gov.uk/__data/assets/pdf_file/0008/25838/rail-infrastructure-assets-environmental-2016-17.pdf, viewed on 9 August 2018

¹¹ Rolling Stock Strategy Steering Group, (March 2018), Long Term Passenger Rolling Stock Strategy for the Rail Industry Sixth Edition, p.15. See https://www.raildeliverygroup.com/files/Publications/2018-03_long_term_passenger_rolling_stock_strategy_6th_ed.pdf, viewed 25 August 2018.

In 2007, it was estimated that for rail transport, depending on the class of train, emissions varied from between about 40g and 115g CO₂ per passenger kilometre at a load factor of 40% for intercity rail and 30% for all other trains. By comparison, as shown in Figure 3,¹² private cars were typically producing over 130g per passenger kilometre at a load factor of 30%.¹³



Notes: Data assumes the following load factors: urban bus 20%, intercity coach 60%, intercity rail 40%, all other trains 30%, domestic airlines 70%, and cars 30%. Road, air and diesel-powered rail vehicles' emissions have been increased to take account of refinery losses and electric powered vehicles take into account losses in the grid. The aviation figures include a factor for radiative forcing

Figure 3: Domestic intermodal comparison of CO₂ emissions

¹² The figures in Figure 2 are for CO₂e, whereas those in Figure 3 are for CO₂ only. Given the comparison of the two figures in 2007, the absolute level of CO₂ emissions in 2016 is likely to be significantly less than 43.8g per passenger kilometre

¹³ RSSB (20 December 2007), T618 Traction energy metrics. See https://www.sparkrail.org/_layouts/15/Rssb.Spark/Attachments.ashx?id=75NEMTS3ZVHP-8-2815, p. 51, viewed 10 August 2018

Where we are now

Fleet: passengers

20. In April 2018, there were 14,025 passenger vehicles. Table 2 shows the split by train type and periods built. About half the vehicles were built post-privatisation (those entering service from 1996); over 72% of these are electric vehicles, 60% of which have been brought into service since privatisation.¹⁴

Train Type	Years built				Total by train type
	1970 -	1980 -	1990 -	1996 -	
A. Shorter Distance Diesel	0	876	177	2	1,055
B. Middle Distance Diesel	68	0	512	804	1,384
C. Long Distance Diesel	882	0	0	550	1,432
D. Shorter Distance Electric	414	792	722	593	2,521
E. Middle Distance Electric	0	1,282	289	4,640	6,211
F. Long Distance Electric	241	0	333	674	1,248
G. Very High Speed Electric	0	0	0	174	174
Total by period built	1,605	2,950	2,033	7,437	14,025

Table 2: Basic fleet data, April 2018

Rolling stock overview

21. Table 3¹⁵ illustrates all classes of passenger diesel rolling stock by end of lease and when, at 30 years of service, they would typically be due for their second major overhaul. This is for indicative purposes as it is common for vehicles to remain serviceable and in service beyond 30 years. This table shows that, once the Class 14x Pacers have been replaced, there will be a need to decide either to life extend or to replace the pre-privatisation Class 15x and similar diesel multiple units. These replacement programmes will generate enough orders to justify R&D demonstrators that lead to an affordable solution. Prior to this volume replacement programme, the re-engineering of mid-life EMUs, as illustrated in some of the case studies, might offer a cost-effective medium-term solution.

¹⁴ Rolling Stock Strategy Steering Group, (March 2018), Long Term Passenger Rolling Stock Strategy for the Rail Industry Sixth Edition, p.16, and related source material

¹⁵ Source: RIA

THERE IS SIGNIFICANT INVESTMENT UNDER WAY AND PROJECTED IN THE PASSENGER FLEET OVER THE COMING 30 YEARS.

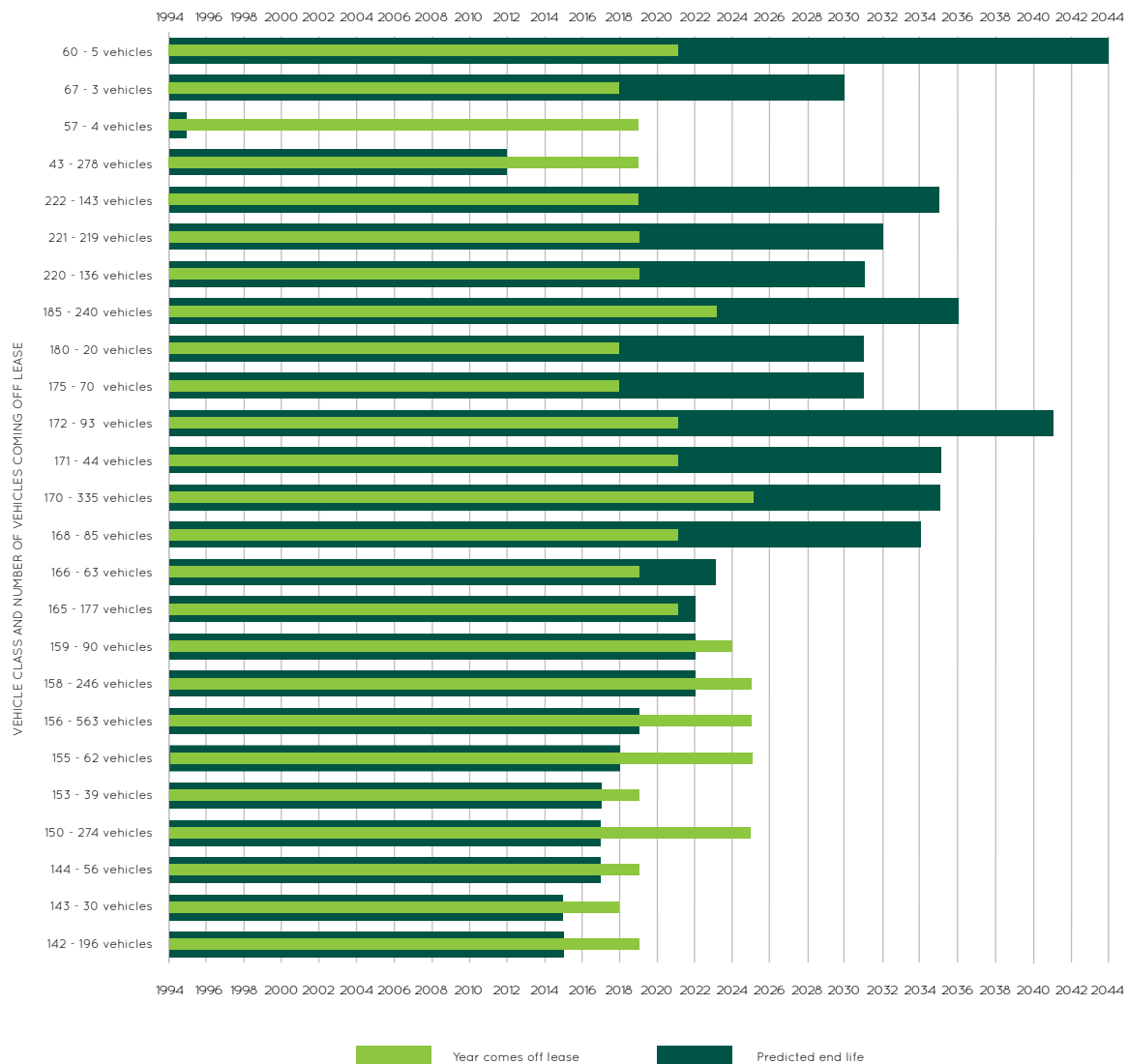


Table 3: Diesel passenger and freight rolling stock by class, end of lease and 30 years of service life

22. The age of the passenger rolling stock fleet is falling as the size of the fleet increases with the introduction of new trains and the displacement of mostly older vehicles. There is significant investment under way and projected in the passenger fleet over the coming 30 years. This is expected to reduce the age of the fleet as well as to increase fleet size, depending on actual growth, by between 40 and 85% -

“The average age of the national fleet is estimated to fall from 21 years to 15 years by March 2021, while the numbers of vehicles in service will grow by 6% next year and by a further 5% to 13% by 2024 [...].

Major orders for new build vehicles coupled with the reduced electrification programme has so far resulted in over 4,000 vehicles being displaced from service in the next 3 years. Many of these vehicles are near the end of their life, but 150 are brand new [...].

Pure electric vehicles now comprise 72% of the national fleet and over 80% of committed new vehicles. All 1,030 bi-mode vehicles on order or operating in the UK have diesel generators as their on-board power source...batteries or hydrogen cells are amongst future alternatives [...].

A successful hydrogen powered train has yet to be put into public service and there is currently no viable alternative to the diesel engine for rail traction application [...].

The long-term rolling stock outlook remains unchanged with a national fleet increase of between 40% (5,500 vehicles) and 85% (12,000 vehicles) forecast over the next 30 years.”^{16 17}

Fleet: freight

23. Similarly, there are about 850 freight locomotives that are in regular service.¹⁸ Table 4 illustrates the size of the fleet and categorises it by age range. Where not specified, the locomotives are diesel-powered. The replacement rate for freight locomotives is averaging less than 30 per year, or about 3.5% of the total freight locomotive fleet.

Freight locomotive fleet as submitted for ETCS fitment	When built/ age	Number
Pre-privatisation	1957-1993	180
Post privatisation	1998-2008	567
3rd rail diesel bi-mode	>50 years old	15
25kv AC diesel bi-mode	<5 years old	10
Electric	pre-1996	69
Electric parcel trains	1995	15
	Total	856

Table 4: Freight locomotive fleet by age range and traction type

¹⁶ Rolling Stock Strategy Steering Group, (March 2018), Long Term Passenger Rolling Stock Strategy for the Rail Industry Sixth Edition, p.1

¹⁷ The figures quoted include projections for Crossrail and HS2. They also include provision for open access operators which comprise less than 0.5% of the total national passenger fleet

¹⁸ Based on Freight Commercial Agreements between NR and the FOCs which define how many vehicles are to be fitted with ETCS as part of the national fitment programme

The ETCS - European Train Control System - is an automatic train protection system promoted by the European Commission for use throughout Europe, and specified for compliance with the High Speed and Conventional Interoperability Directives. The system aims to remedy the lack of standardization in the area of signalling and train control systems which constitutes one of the major obstacles to the development of international rail traffic. (<https://uic.org/etcs>, viewed 23 September 2018)

24. Freight movements in the UK amounted to 17 billion tonne kilometres in 2017-18, segmented as shown in Figure 4.¹⁹

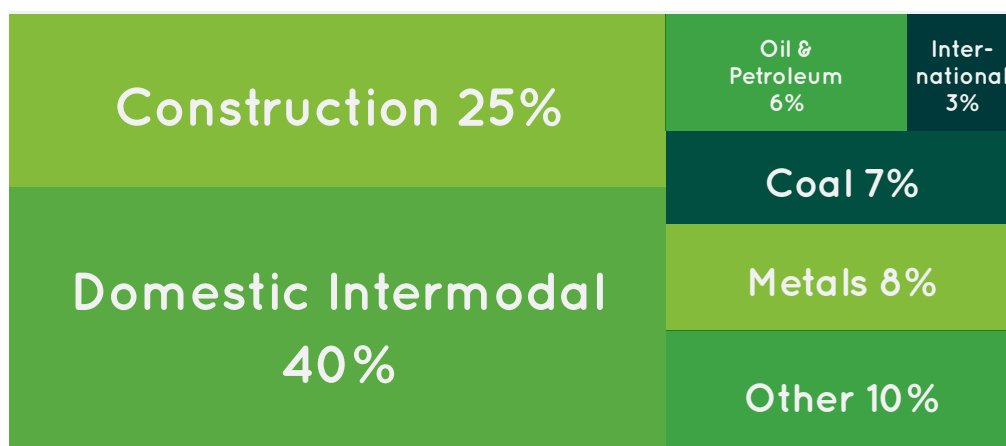


Figure 4: Breakdown of freight volumes by type of materials, 2017-18

Ongoing traction initiatives

25. The industry has made significant efforts to innovate in traction improvements, driven both by the desire to maximise the economic and service life of existing trains and in anticipation of the demand for new rolling stock in the light of policy changes. Examples of these include –
- 25.1. “Hitachi’s Class 800 and 802 trains, and the Stadler ‘Flirt’ bi-mode trains for East Anglia which can both collect power when in motion from an overhead or third rail source, and also generate power from an on-board source...
 - 25.2. ...the installation of Stage IIIB compliant engines on older vehicles. The D-Train project being developed by Vivarail demonstrates the feasibility and business case of fitting pairs of smaller Stage IIIB compliant automotive diesel engines beneath former LUL vehicles,²⁰ while the Class 769 (Class 319 Flex) units are EMUs that have undergone bi-mode conversion utilising Stage IIIB compliant engines...
 - 25.3. The diesel engines being fitted to the Class 800, 801, 802 and 803 trains being built by Hitachi for GWR²¹, VTEC²², TPE²³ and Hull Trains TOCs are compliant with Stage IIIB, as will be the diesel and bi-mode vehicles being procured for the ARN²⁴ and Greater Anglia franchises. The Class 68 locos now being used by Chiltern Railways and ScotRail and to be used by TPE are compliant with the previous Stage IIIA requirements...
 - 25.4. Porterbrook recognised the opportunity to create a bi-mode unit (Class 769) from its Class 319 vehicles, invested accordingly, and has thus far secured leases for 52 of these vehicles with the new Wales and Borders franchise and Northern.²⁵

¹⁹ ORR (7 June 2018), Freight Rail Usage, 2017-18 Q4 Statistical Release, p.5

²⁰ While this is converting an electric train to diesel, the refitted trains will replace older, less efficient diesel trains

²¹ Great Western Rail

²² Virgin Trains East Coast

²³ Trans-Pennine Express

²⁴ Arriva Rail North

²⁵ Rolling Stock Strategy Steering Group, (March 2018), Long Term Passenger Rolling Stock Strategy for the Rail Industry Sixth Edition, pp18-19

- 25.5. In the ARN franchise, the DfT's decision to eliminate the 214 Pacer vehicles contributed to the placing of an order with CAF for 140 new DMU vehicles, plus the first order for 32 newly converted Class 769 Flex bi-mode vehicles from Porterbrook, initially required to mitigate particular electrification delays. Stadler Rail entered the UK rolling stock market in 2016 through an electro-diesel bi-mode order for 138 vehicles for the Greater Anglia franchise, while CAF secured orders for 80 DMU vehicles in the West Midlands in October 2017. The new Wales and Borders franchise ordered 20 Class 769 Flex vehicles to facilitate the release of DMUs for PRMTSI work, while London Northwestern will be launch customers for the Vivarail Class 230 bi-mode. Together with Chiltern (refurbishment and loco haulage) and ScotRail (HST refurbishment), these are clear examples of the market response to the continuing demand for self-powered vehicles and using new technology to produce incremental benefits.”²⁶
- 25.6. In addition to those quoted in the report –
- 25.6.1. Porterbrook is collaborating with Rolls-Royce to introduce the MTU diesel-battery hybrid power pack for existing 16x and 17x diesels;²⁷
 - 25.6.2. Siemens has introduced a Battery EMU hybrid in Austria;^{28 29} and
 - 25.6.3. Alstom has introduced a Hydrogen Coradia iLint³⁰ into passenger service with a total order of 16 units and Porterbrook has announced a further development of their 319 Flex the ‘Hydro Flex’³¹.
26. Freight is applying similar ideas –
- 26.1. “freight operators are fitting class 66 diesel-powered locomotives with start-stop technology to turn off the engine while idling in depots. DB Cargo has achieved a 19% reduction in emissions from early implementation of this technology.
 - 26.2. driver advisory systems are used by some freight operators to reduce fuel use by encouraging better driving techniques.
 - 26.3. newer Class 68 and 88 locomotives meet recent emission standards.”³²
27. Network Rail has been working with environmental charity 10:10, Imperial College London, Community Energy South and Turbo Power Systems to assess the technical and economic feasibility of feeding large scale solar generation into the traction network. Initial feasibility results are positive and work is continuing to develop an initial pilot scheme to prove the concept.
28. Network Rail and Scotrail are investigating the feasibility of direct wire from large scale wind generation to the traction network in Scotland.
29. Where the opportunity exists, there is commitment from the industry to identify improvements to the carbon performance of traction units. There is a clear recognition of the long-term trends in the UK towards lower carbon forms of transport in compliance with the Climate Change Act and perceptions that, if carbon targets change, they are likely to become more stringent, not less. The case studies from Porterbrook, Eversholt and Angel Trains on the following pages illustrate how the industry is responding in innovative, cost-effective and practical ways.

²⁶ Ibid, p.28

²⁷ <https://www.porterbrook.co.uk/news/post.php?s=2018-09-19-rolls-royce-and-porterbrook-launch-first-hybrid-rail-project-in-the-uk-with-mtu-hybrid-powerpacks>

²⁸ <https://www.railwaygazette.com/news/traction-rolling-stock/single-view/view/battery-powered-desiro-ml-cityjet-eco-unveiled.html>

²⁹ <https://www.siemens.com/press/pool/de/feature/2018-09-oebb/db-desiro-ml-oebb-cityjet-eco-e.pdf>

³⁰ <https://www.alstom.com/coradia-ilint-worlds-1st-hydrogen-powered-train>

³¹ <https://www.porterbrook.co.uk/news/post.php?s=2018-09-19-porterbrook-and-university-of-birmingham-sign-partnership-to-develop-hydroflex-the-uks-first-hydrogen-train>

³² Source: Rail Freight Group personal communication

CASE STUDY

Porterbrook - Project Flex

AIM

Porterbrook is pioneering a retrofit conversion of the Class 319 fleet to create a bi-mode unit that uses both electric and diesel power. This will enable the train to operate seamlessly over electrified and non-electrified routes.

WHY?

The planned expansion of Network Rail's electrification of the UK network will lead to significant changes in the rolling stock strategy.

Vehicles that could use the overhead lines and run on their own power would reduce the number of different types of rolling stock an operator needs to overcome the partial electrification.

WHAT IS IT?

Porterbrook is converting the existing Class 319 units to Class 769 Flex units. This will include adding 2 MAN diesel engines (low emission stage IIIB compliant engines). These engines will drive 2 ABB alternators (one on each driving trailer car), which in turn will provide power to the existing traction and auxiliary equipment. These systems provide power through the DC bus, so that any significant equipment changes have been avoided. The design was developed to provide for a range of operations.

WHO IS INVOLVED?

Porterbrook, Wabtec Brush, Northern (Arriva Rail North)

UNITS ORDERED (BY TRAIN OPERATING COMPANIES)

- Northern (ARN) – 8 bi-mode units ordered
- Arriva Trains Wales (ATW) – 5 bi-mode units ordered
- Great Western Railway (GWR) – 19 tri-mode units ordered

BI-MODE VS TRI-MODE

The Class 769 Flex units are available as bi-mode units or tri-mode units. The bi-mode units for ARN and ATW will include diesel traction and overhead line equipment. Tri-mode units (GWR) will include diesel traction, overhead line and third rail equipment.

In Line with all four Cs in the Rail Technical Strategy

Reduce Cost

The class 769 will be cheaper to operate and maintain than an equivalent DMU fleet and the project has the potential to re-deploy existing DMUs to other parts of the network, avoiding the need for investment in new DMU rolling stock.

Increased Capacity

Longer 4-car units would be deployed instead of 2-car or 3-car DMUs.

Reduced Carbon

Diesel engines will only be used on the non-electrified sections

Improved Customer Experience

Options for new diagrams to match customer demand which enable through journeys on non-electrified and electrified routes reducing journey times and increasing convenience

CASE STUDY

Eversholt And Revolution Very Light Rail Vehicle

AIM

Eversholt Rail has joined the industry consortium that will develop, manufacture and market the Revolution VLR (very light rail) vehicle. The Revolution VLR vehicle, planned to enter series production in the early 2020s, is ideally matched to the need for lightweight, energy-efficient system solutions to deliver affordable service growth and extension of the UK's rail capacity.

WHY?

It will provide a modern and sustainable alternative to operating cascaded diesel multiple units that are heavier, have higher fuel consumption and produce significantly greater exhaust emissions.

WHAT IS IT?

A bi-directional, 18-metre-long railcar, with seating for 56 passengers and standing room for a further 60, Revolution VLR will use lightweight materials and a modular structure to achieve a tare weight of less than one tonne per linear metre. This allows it to run on lightweight modular slab track.



The vehicle will be self-propelled. Its diesel-electric hybrid powertrain comprises two independent power packs and bogie-mounted electric traction motors. Each power pack includes a Euro 6-compliant 3.8 litre Cummins diesel engine and ancillaries, lithium titanite batteries for energy storage, power electronics packages and a cooling system. The design allows full electric braking, with energy recovered into the battery packs. All-electric operation of auxiliaries at halts is supported from the batteries, as well as zero-emissions full electric launch from stations. The power packs are configured for ease of maintenance and to maximise residual mobility in the event of in-service damage.



WHO IS INVOLVED?

The consortium, led by Transport Design International Ltd (TDI), includes WMG at the University of Warwick, Cummins and other companies from the automotive and rail sectors.

Eversholt Rail's participation in the programme will provide the company with direct access to key light rail technologies, many of which draw upon automotive and aerospace industry best practice and also have potential application to its heavy rail portfolio.

CASE STUDY

Angel Trains – conversion to hybrid multiple unit

AIM

Angel Trains has begun a development programme to deliver a hybrid drive modification package which can be retro-fitted to existing diesel multiple unit fleets. A pilot unit (Class 165/0 on Chiltern) is due to enter service in September 2019.

In the short term, engine emissions will be reduced by at least 25% and will be eliminated from sensitive areas. In the longer term, low-cost replaceable engines will mean a greater choice of generators to meet the aspiration of reducing diesel engine use in rail.

WHY?

The key benefits of the hybrid drive include:

- significant improvement in fuel economy
- reduction of CO₂, NO_x, Particulate Matter and noise emissions
- the ability to switch off engine on the approach to stations and other sensitive areas.

WHAT IS IT?

The existing diesel engine, transmission and other redundant auxiliary systems will be removed. Small traction and auxiliary power diesel generators will be fitted, and power will be stored in a 160kWh Lithium Ion battery. This will be delivered to a permanent magnet 400kW traction motor.

The permanent magnet traction motor and generators, as well as the IGBT controllers, will be liquid cooled by a low temperature

cooling circuit. Compressed air will be delivered by an electric drive compressor. Energy from regenerative braking can also be stored in the traction battery. The hybrid drive will improve acceleration compared to the existing drivetrain.

Key features of the system are:

- Small generator engines are low cost and will be periodically replaced rather than overhauled.
- In future, diesel generator engines may be replaced by spark ignition gas engines or hydrogen fuel cells, without major change to the hybrid architecture.
- The new generator engines will meet the latest emission standards.
- Engines will be stopped during station approach, dwell and launch, removing emissions from sensitive areas, particularly covered stations.
- Overall fuel saving is predicted to be around 25%, giving a commensurate increase in range.
- Reduced whole life maintenance costs, with the overhaul interval for main electric components (other than the traction battery and compressor) at about 1.5m miles. Batteries will need to be replaced about every 7 years.

WHO IS INVOLVED?

Angel Trains is working with Sheffield-based Magtec and Chiltern Railways to deliver the hybrid conversion. Magtec has many years' experience of hybrid conversions for commercial, passenger service and military vehicles.

30. The taskforce sees that its task, therefore, need not be to catalyse a desire for change but to make recommendations on the conditions necessary to enable early, faster and effective change.

Property

STATIONS

31. As of 2016-17, there were 2,560 mainline stations in operation.³³ In 2011, when there were slightly fewer stations, DfT categorised them into six classes as illustrated in Table 5.³⁴ The smaller stations tend to use only energy from electricity supplies, primarily for lighting. Larger stations may also use gas, and the direct energy use (excluding offices, retail space and any other uses not controlled by the station operator) will be for more diverse purposes, such as vending machines, ticket machines, ticket offices and other non-lighting uses. One increasingly significant use of energy in stations is for necessary IT equipment.

Description	No. Stations	%	Av Daily Passengers (per station)	% of Customers	Criteria (per annum)
A. National Hub	25	1	90,000	42	Over 2m trips: over £20m
B. National Interchange	66	3	13,000	15	Over 2m trips: over £20m
C. Important Feeder	275	10	5,000	20	0.5 – 2m trips: £2-20m
D. Medium Staffed	302	12	2,500	13	.25-0.5m trips: £1-2m
E. Small Staffed	675	27	700	8	Under 0.25m trips: under £1m
F. Small Unstaffed	1,192	47	100	2	Under 0.25m trips: under £1m
TOTALS	2,535	100	111,300	100	

Table 5: Station types and numbers on the national rail network as at 2011

32. Much of rail's property portfolio has significant opportunity for carbon reduction. Network Rail and train operating companies recognise this and are undertaking energy efficiency initiatives across the estate. Interventions such as LED lighting, metering improvements including installation of automatic metering, thermal efficiency and heating/cooling control optimisation are improving carbon efficiency across the property portfolio.

³³ ORR (24 October 2017), *ibid.*, p. 4

³⁴ DfT, (June 2011) Better Rail Stations, Part A Consistent Standards, p.15. <http://webarchive.nationalarchives.gov.uk/20111005155332/http://www.dft.gov.uk/pgr/rail/passenger/stations/beterrailstations/pdf/parta.pdf>, viewed 10 August 2018

33. Category A and B stations present a significant challenge as these major transport hubs are complex in nature, particularly in relation to utilities. Specific projects are already underway in Network Rail's managed stations to improve utilities management and reduce operational energy use at these facilities.
34. Strategies for demand management are continually developing and the industry is applying more stringent energy and carbon reduction targets in order to contribute to the decarbonisation agenda. For example, Network Rail has set its targets for Control Period 6 (CP6) at a much more ambitious requirement of 18% reduction in operational energy use and 25% reduction in carbon emissions. They are also developing science-based targets and strategies which will reach out to 2050 and align their carbon reduction ambition with that of the Climate Change Act.
35. A recent study on station decarbonisation indicates that the extent of possible carbon savings depends on the size and usage of the station. This study considered the Type C, E and F stations described above. It found that about 60% of the electricity consumption in a Type C station is relatively difficult to impact through direct energy efficiency measures by the station operator, as the electricity consumption is primarily through operational activities such as vending and ticket machines, tenants and retailers. By comparison, over 95% of the energy used in a typical Type F station is for lighting.³⁵ The measures explored included draught proofing, LED lighting, heating controls, solar PV, air source heat pumps and battery storage. The marginal cost of full decarbonisation beyond about 30% decarbonisation is nearly zero. These findings have been used to inform requirements for recent franchise bids and RSSB is exploring the feasibility of trial projects.
36. Franchise agreements now require an average 2.5% per annum reduction in non-traction energy. These requirements are still relatively new. Our consultations suggest that one of the main challenges to train operators installing energy efficient technologies on the stations they lease from Network Rail is that the payback period can extend beyond the life of the franchise. As a result, there is limited commercial incentive for train operators to invest unless energy efficiency requirements are hardwired into the franchise specification.
37. The Midland Mainline Franchise requires the franchisee to pilot zero carbon stations. By the end of the second year of the franchise the franchisee should be delivering six zero carbon stations, being two each of –
 - 37.1. unstaffed stations;
 - 37.2. small staffed stations with annual entries and exits of under 250,000; and
 - 37.3. medium stations with annual entries and exits of between 500,000 and 2,000,000.
38. C2C have longer lease arrangements for their stations than other franchises and therefore do not need to consider rates of return on station energy saving interventions and residual values at the end of their franchise period. They are already implementing a programme to install solar PV at their stations as the

³⁵ Ricardo AEA for RSSB (6 November 2017), Zero Carbon Stations Feasibility Study for Category C, E and F stations, p.26 (in PDF: pages not numbered), unpublished

³⁶ For example, see the ITT for the West Midlands Franchise, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/553594/wmf-itt-attachment-b-franchise-agreement.pdf, p.627, viewed 26 September 2018

business case makes financial as well as carbon sense. By 2019, they will have substantially installed LED lighting in all public areas of stations and most back room areas, having been able to justify the business case fully on financial and emissions reductions grounds.³⁷

39. At larger stations, which include all 20 stations directly managed by Network Rail, there is a much greater diversity of energy demands. These include escalators, lifts, commercial concessions, ticket machines, vending machines and ticket offices, as well as the need to power on-site IT which is using an increasing proportion of energy at stations. Initial thinking is that site constraints for these larger stations means that they are unlikely to be able to implement all the interventions necessary to achieve zero carbon operation across all station operations. It may be necessary in the first instance to look only at directly-managed lighting and heating.
40. Wakefield Westgate Rail Station, opened in 2013, was awarded a BREEAM 'Excellent' rating. More recent franchise invitations to tender specify that the franchisee must use its reasonable endeavours to achieve a BREEAM Excellent rating for construction projects which exceed a capital value of £1 million.³⁸
41. Network Rail have suggested that they may be able to support a 'green managed station' pilot to help develop a better understanding of how to implement these ideas more widely.

DEPOTS

42. Depots have similar general needs for appropriate lighting and heating in buildings. Where only light maintenance work is done on site, these may be the major sources of energy use. Other depots may have significant heavy engineering work undertaken on site and may have extensive sidings which have to be lit for operational purposes.
43. RSSB has recently updated and published industry guidance on depot design.³⁹ Depots are bespoke buildings and to date there has been little standardisation in approach to building design. It is possible to achieve high standards of environmental performance. For example, Crossrail's new depot was designed, built and will be operated by Bombardier in accordance with the BREEAM standard applicable to light industrial buildings.⁴⁰

Infrastructure overview

44. Infrastructure includes all other elements of the railway necessary for trains to operate, including the rail lines themselves, points, signalling, power supplies, control systems, telecommunications, maintenance and renewal capability, and associated road fleets. Much of this fixed

³⁷ Personal communication, 28 August 2018

³⁸ For example, see the ITT for the West Midlands Franchise https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/553594/wmf-itt-attachment-b-franchise-agreement.pdf, p. 679, viewed 26 September 2018.

³⁹ <https://www.rssb.co.uk/rgs/standards/GIGN7621%20Iss%201.pdf>, viewed 27 October 2018

⁴⁰ See <https://www.breeam.com/> for further information. BREEAM is the world's leading sustainability assessment method for master planning projects, infrastructure and buildings.

infrastructure has long asset lives and operates in highly regulated environments for operational and safety reasons.

45. There is increasing evidence that rail infrastructure construction projects are able to attain high standards of sustainability performance.⁴¹ For our final report, we will research in more detail what standards of performance these projects are achieving in use and make recommendations on when it would be appropriate to mandate the application of sustainability assessment standards such as CEEQUAL.

MAINTENANCE AND RENEWAL PLANT AND MACHINES

46. Network Rail has a mixed fleet of over 2,600 vehicles comprising locomotives, coaches, self-propelled plant and wagons, which includes vehicles inherited from Railtrack and British Rail. Of these, 130 vehicles have diesel engines and are capable of self-powered movement on the railway and 375 have some form of generator on board for working purposes but are not self-powered. In addition, it regularly hires in around 80 other specialist vehicles and spot hire assets to undertake various tasks. These machines are used to undertake key maintenance, monitoring and renewal services without which the network would not be able to function or to operate safely.
47. Most of these machines operate across the whole network, both on and off electrified sections. They need to be able to work continuously for extended periods, often away from refuelling facilities and on electrified sections when the power has been turned off. Accordingly, those that have their own traction need to be self-powered for most of their operating time. For the work they do, they typically need hydraulic drives which can be configured to deliver slow speed, high power delivery. These drives are not compatible with electricity as the energy source. They may have limited electrical supplies to support the electrical control systems and supply for the staff amenities. For safety reasons, the working environment, particularly in confined spaces, cannot include low flash point, high combustibility fuels or spark risks, which will limit the availability of suitable fuels other than diesel and similar biofuels.
48. Network Rail is making provision under CP6 to survey the emissions levels of its fleet and is also seeking support to replace what are likely to be higher emissions engines based on 1950s designs. Future emissions reductions are likely to be driven by non-rail regulation as engines fitted to on-track machines are directly based on or adapted from engines used by the civil engineering and auto industries.
49. There are too few diesel engines used in the rail maintenance and renewal industry to justify bespoke development of either the engines or the emissions treatment systems. In addition to the low volumes, the US and European manufacturers of these specialist machines experience significant issues fitting their 'standard' equipment into the more restrictive GB loading gauge. International manufacturers are unlikely to take the lead in emissions reduction-focused development and innovation specific to the UK without strong incentives.
50. Like on-track machines, on-track plant is often developed or adapted directly from civil engineering plant and road machines such as diggers. Legislation that covers the much wider civil engineering and auto sectors will drive improvements in diesel engine technology and alternate energy sources for on track plant.

⁴¹ See <http://www.ceequal.com/category/case-studies/railways/> for a case study collection across a wide range of infrastructure projects.


RENEWABLE POWER AND LINESIDE POWER SOURCES

51. As one of the largest land-owners in the country, Network Rail recognises the potential of employing unused land to facilitate large-scale renewable generation in order to achieve further rail decarbonisation. Network Rail has issued a challenge statement to attract private-sector approaches to achieve this aim. Depending on site locations and proximity of assets, these initiatives may be either direct-wire or corporate Power Purchase Agreement (PPA) arrangements.
52. There are many facilities and pieces of equipment across the network that need power supplies. These include operating points heaters and remote switches, signals and control boxes. While many are in regular use, many are used only intermittently, such as points heaters. These are often operated by lineside diesel generators, either in primary mode or as emergency generators in the event of a mains power failure. Many of these use diesel generators which could be replaced by other options, such as renewable-sourced energy supplies combined with battery storage or other less carbon intensive options.
53. In the next stage of our work, we will report on opportunities for replacing lineside diesel generators in a manner that invites private investment through load balancing opportunities.


ROAD FLEET

54. Network Rail has a road fleet of over 8,000 vehicles categorised into cars, light goods vehicles and heavy goods vehicles. The company started moving away from an owned fleet to a leasing arrangement during 2017. It is developing a strategy for ongoing and future fleet renewal which will consider the implications of the decarbonisation challenge. Network Rail is, in principle, willing to match the likely requirement for 25% of government fleet cars to be low emissions vehicles by 2022. We will be able to report on this strategy and compliance with government targets in more detail in our final report. Network Rail is supporting the Clean Van Commitment which is aiming for zero tailpipe emissions from vans in cities by 2028 and for 16 of the UK's largest van fleets to more than double the number of electric vans put on the roads to date by 2020.⁴²
55. Initial discussions with innovation centres such as the Transport Systems Catapult indicate that there are good opportunities for Network Rail to collaborate to find ways to drive carbon emissions reductions across their fleet. Again, we will report on progress in our final report.

⁴² See commitment and supplementary material at <https://www.cleanairstay.org.uk/news/launch-of-clean-van-commitment-to-kickstart-a-revolution-on-our-roads>, viewed 24 September 2018



THERE IS INCREASING EVIDENCE
THAT RAIL INFRASTRUCTURE
CONSTRUCTION PROJECTS ARE
ABLE TO ATTAIN HIGH STANDARDS
OF SUSTAINABILITY PERFORMANCE.



Future rail

56. Our research shows that we need to look at the challenge on four levels, as shown in Figure 5.

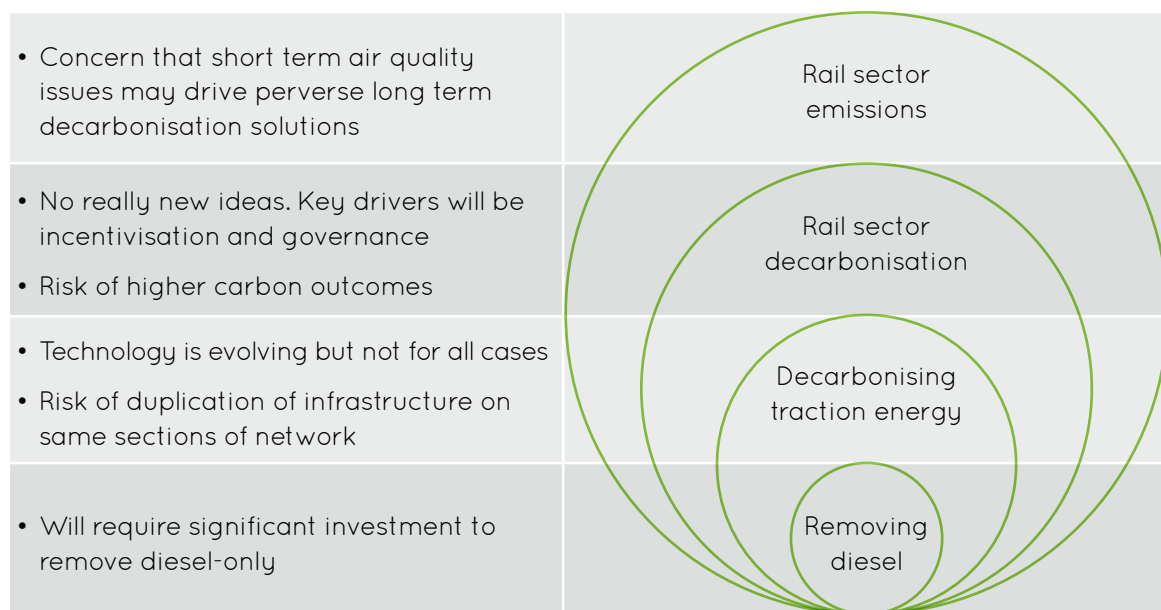


Figure 5: The main levels of analysis and the key concerns

57. The key issues at each level are driven by different factors –

- 571. Rail sector emissions** overlap with air quality (AQ) concerns, with both demanding action now. AQ is a more local and immediate threat to the health of people at risk, whereas carbon emissions are a global threat with more significant impacts, albeit over longer timeframes. There is an overlap of possible solutions, particularly focused on the removal of emissions from fossil fuels. The challenge to remove diesel only vehicles by 2040 may undermine the case for making short term improvements to diesel vehicles to meet AQ objectives. However, forcing the premature removal of diesel engines from the network to satisfy immediate AQ concerns may lead to more expensive and more carbon-intensive long-term outcomes;
- 572. Rail sector decarbonisation** has no single solution that will achieve substantial decarbonisation in the rail sector. We know that progress will have to be made through a wide range of initiatives. We also know the key technical solutions and how they might be implemented for both property and infrastructure. It is a question not of what to do, but how to do it cost effectively. We know where we can achieve significant decarbonisation in a cost-effective manner for property and, as explained earlier, we are developing an understanding of the reasons why these opportunities are not always pursued. This will require a fresh look at the incentivisation and governance mechanisms within and outside franchises;



THERE IS SIGNIFICANT INNOVATION TAKING PLACE WHERE THERE IS A BUSINESS CASE TO DO SO

57.3. Decarbonising traction energy could be achieved progressively through franchises and sending clear signals to the market through policy and other mechanisms. There is, as we have shown, significant innovation taking place where there is a business case to do so. Faster change will require the industry and government to work together to develop clearer, more consistent policies applied over timeframes that support decarbonisation and aligned, where the business case does not exist, with appropriate incentives; and

57.4. Removing diesel remains an aspiration in the absence of any plan to electrify key freight routes. Suitable replacement traction options do not yet exist to do this in a commercially viable manner. Any fast change will need significant research and development as well as funding of demonstrator projects to show proof of concept for bi-modes and other alternatives that meet the energy, power and range requirements for effective transport of freight on the UK rail network. There is a need for research into more sustainable fuels that compare with the energy density of diesel from fossil fuels; while this will not remove diesel from the railway, it will allow us to explore lower carbon impact options. One challenge is that certain alternative traction options, such as hydrogen, will require an additional fuel tank to be fitted to a train. As freight trains are length-limited, this would remove a freight car and the income that generates. Recognising that the decarbonisation aspiration will have specific challenges for rail freight, RSSB has commissioned a further technical study to look at options for freight in more detail than the technical study T1145, which accompanies this report, has been able to do. This will begin in early 2019.

58. We now look at traction, property and infrastructure in the light of these observations.

Traction: potential technologies and implementation needs

TRACTION

59. T1145 proposed a classification of various types of passenger train and rail freight locomotives. Using this classification, we may sub-divide the task to understand what is already available and what technologies are likely to be most suitable to reduce the carbon footprint, both operational and whole life, of each journey type. Table 5⁴³ shows the technical suitability of various traction options. It does not consider levels of demand for, or volume available or likely to be available of, fuels such as low carbon hydrogen or biodiesel. We will look at fuel availability issues in more detail in our final report when we consider route maps for implementation.

⁴³ While technically feasible, there are significant technical and design challenges to maintaining high-speed (i.e. 125mph+ intercity) train performance, including acceleration, off the wire with diesel bi-modes. As it is not certain that diesel electric bi-modes will be able to fulfil all these requirements, they are marked accordingly in the table.

FUTURE ROLLING STOCK CATEGORY	DESCRIPTION	TOTAL SELF-POWERED RANGE REQUIRED (MILES)	TOTAL MAX POWER PER VEHICLE (KW)	APPROX. ENGINE ENERGY OUTPUT PER VEHICLE PER DAY (KWH)	ELECTRIC		AUTONOMOUS POWER			
					AC ELECTRIC (OLE)	DC ELECTRIC (THIRD RAIL)	DIESEL	HYDROGEN	BATTERY	BIODIESEL
A	Shorter distance self-powered with 75mph maximum speed	500	275	1,200	✓	✓	✓	✓	✗	✓
B	Middle distance self-powered with 100 mph capability	800	400	2,400	✓	✓	✓	✗	✗	✓
C	Long distance self-powered with 125 mph capability	1,100	550	4,620	✓	✗	✓	✗	✗	✓
E-A	Electric to 100mph, self-powered to 75mph	250	300	600	✓	✓	✓	✓	✗	✓
E-B	Electric to 100mph, self-powered to 100mph	400	400	1,200	✓	✓	✓	✗	✗	✓
E-SH	Electric to 100mph with ability to do short hops 'off wire'	50	400	150	✓	✓	✓	✓	✓	✓
F-A	Electric to 125mph, self-powered to 75mph	250	300	600	✓	✗	✓	✓	✗	✓
F-B	Electric to 125mph, self-powered to 100mph	400	400	1,200	✓	✗	✓	✗	✗	✓
F-C	Electric to 125mph, self-powered to 125mph	550	550	2,310	✓	✗	?	✗	✗	?
F-SH	Electric to 125mpg with ability to do short hops 'off wire'	50	550	210	✓	✗	✓	✓	✓	✓
Freight	Freight loco capable of hauling 2,500 tonne trailing load	750	2,400	18,000	✓	✓	✓	✗	✗	✓

Table 4: Station types and numbers on the national rail network as at 2011

60. The T1145 study looked at traction options which are, or are likely to be, credible options for deployment before 2040. They include –
- “Diesel and likely advances in diesel technology, including hybridisation (i.e. the diesel engine working in tandem with an on-board battery or other energy store);
 - Electrification including the use of bi-mode trains (i.e. trains that can swap between using overhead wires and an on-board energy source);
 - Battery only traction;
 - Alternative fossil fuels;
 - Hydrogen fuel cells with hydrogen generated in different ways;
 - Biofuels, specifically including biodiesel.”⁴⁴
61. In reviewing options, the T1145 report concluded that there are more obvious options for further consideration and development –

“In the near term, a reasonable reduction in carbon emissions can be achieved by implementing the latest advances in diesel engine technology, ideally as a hybrid configuration. Commercially available solutions are available and these ought to be specified for future fleet procurements. The current trend toward using diesel bi-modes is also to be encouraged, with trains using their diesel engines for as limited a proportion of the journey as possible. This would also help support the case for a rolling programme of electrification as the proportion of time spent on diesel power (and hence carbon emissions) would fall wherever electrification is extended. It is, however, suggested that a lower level power be installed for off-wire operation in order to keep the weight, cost and carbon emissions to a minimum.

In the medium term, hydrogen fuel cells offer a better solution to reduce carbon emissions. But while Germany is about to introduce the fuel cell powered Alstom iLint into service, Britain has yet to operate a mainline hydrogen fuel cell powered train. The applicable standards and loading gauge in Britain present a hurdle to be overcome before hydrogen can become a commercial reality in the UK. It is therefore suggested that some form of central support be made available to support a ‘first of kind’ demonstrator to address these challenges, and further to support the provision of infrastructure required for bulk on-site generation of hydrogen at railway depots and stabling points.

The volume required for the storage of hydrogen realistically limits hydrogen fuel cells to around 75mph operation (although expected improvements in storage technology may push this higher), but for operation at 100mph or more, electrification is the obvious and only practical option to decarbonise Britain’s railways.

The advent of bi-mode trains for both passenger and freight service potentially alters the business case for electrification, and an upcoming report is expected to show that electrification projects can be delivered for a more reasonable cost than of the Great Western Electrification Programme. Work is also ongoing to minimise the clearances required for overhead electrification, which is also expected to impact the cost of electrification schemes in a positive manner.

⁴⁴ S Kent, S Iwnicki and T Houghton (24 August 2018), T1145: - Options for Traction Energy Decarbonisation in Rail, Interim Report for WP2.1: Options Evaluation, p.ii. RSSB, London

Freight is a particular challenge as a great deal of power and energy needs to be installed within a very limited space and weight envelope. Biodiesel could be a practical solution, but the biodiesel supply chain that would be required does not currently exist in the UK. A diesel bi-mode freight locomotive that could draw power from the overhead wires or third rail wherever possible is an appealing option. However, further study needs to be undertaken of the practicality of fitting sufficient on-board equipment to provide sufficient performance both on and off-wire.

It is worth noting that there is currently no low or zero carbon alternative to diesel for road haulage, other than for local delivery vans. This presents rail with a unique opportunity to offer low carbon freight transportation if greater use can be made of existing and future electrification. It follows that priority ought to be given to future electrification schemes for those mixed traffic lines that carry a significant volume of freight.”⁴⁵

62. In drawing conclusions, the report states –

“The ability of the technologies considered suitable for application in rail to reduce carbon emissions is summarised as follows:

- Electrification – electric traction produces significantly less than half the CO₂ per kWh output of diesel traction, with this set to fall further as the National Grid further decarbonises in coming years;
- Advanced hybrid diesel – it is estimated that 85% of the diesel engines on UK passenger trains pre-date any emissions regulations – a substantial reduction in CO₂ per kWh could be achieved by employing current state-of-the-art fuel efficiency measures along with hybridisation, of the order of 40%;
- Hydrogen fuel cell powered by brown hydrogen – this offers no reduction in CO₂ emissions;
- Hydrogen fuel cells with hydrogen produced from low/zero carbon electricity – these provide a low/zero carbon emissions option. However, the space required for the storage of fuel is a major drawback, requiring of the order of 10 times the volume of diesel when typical tank sizes are taken into account – this currently restricts their use to Type A trains;
- Batteries – while batteries can be recharged with low or zero carbon electricity, current battery technology requires of the order of 20 x the volume of diesel, and is many times heavier – this restricts their use to ‘short-hop’ bi-modes;
- Natural gas (combustion) – this offers a degree of reduction, but only of an order similar to that achievable by advanced hybrid diesel.

There is no realistic zero or near zero carbon alternative fuel that will provide the sort of power required for self-powered freight locomotives, with the possible exception of biodiesel. But there is a strong case for bi-mode passenger trains and freight locomotives which can make best use of overhead or third rail electrification where it exists.

⁴⁵ Ibid, pp.vi-vii

SUGGESTED APPROACH FOR PASSENGER SERVICES

For passenger services, the suggested strategy to decarbonise is as follows:

- The carbon emission from overhead electrification are currently less than half that of diesel, and expected to fall further as the UK power generation mix decarbonises further in coming years. It therefore makes sense to:
 - » make use of overhead electrification wherever available, which suggests that the use of bi-mode trains should continue to be pursued;
 - » plan to electrify those lines which are heavily used, but for which there is no credible alternative way of achieving zero (or near zero) carbon emissions – this would specifically include passenger lines with a linespeeds > 75mph, and mixed traffic lines that are likely to see significant freight flows into the future;
 - » in the near term, consider bi-modes with a clean, modern diesel engine for partially electrified routes, but the level of performance ‘off wire’ needs to be restricted in order to keep the size, mass, cost and emissions of the diesel mode to an acceptable size;
 - » in the medium term, bi-modes with a hydrogen fuel cell would be a better solution, but current fuel cell technology probably restricts this to 75mph operation ‘off wire’;
- For non-electrified lines, a significant reduction in carbon emissions of the order of 40% could be achieved using advanced hybrid diesel propulsion, but for a reduction beyond this, hydrogen fuel cells powered by hydrogen look to be the best option;
- However, the hydrogen would need to be so-called ‘green hydrogen’, produced by using low-carbon electricity – this could be off-peak electricity or excess electricity from renewables. The technology to produce hydrogen in large quantities through electrolysis exists and is well-proven;
- Biofuels have the potential to provide another alternative fuel, but the supply chain for these does not yet exist, and there is some question over the carbon emissions that ought to be associated with these.

SUGGESTED APPROACH FOR FREIGHT SERVICES

For freight, the suggested strategy is as follows:

- As with passenger trains, increased use of overhead electrification where it exists ought to be prioritised as the carbon emissions per kWh are considerably lower than diesel, while providing a substantial hike in traction power;
- As with passenger flows, future freight flows need to be mapped against current electrification provision (both overhead wire and third rail), and schemes developed accordingly that would allow maximum use of electrification for freight;
- This suggests bi-mode locomotives, as per passenger bi-modes, have a lower level of performance ‘off wire’;

- However, while there already exist bi-mode locomotives that would provide sufficient off-wire performance for freight only lines,⁴⁶ there remains a specific challenge for non-electrified mixed traffic routes where a freight train would need to be capable of more than the 25mph typical of freight only routes. There is currently no self-powered alternative to diesel that would provide the sort of power and on-board energy required, with the possible exception of biodiesel;
 - As mentioned above, biofuels do not have the necessary supply chain to be viable at present, but for freight application in particular, these warrant further investigation:
 - » there is no apparent alternative that would achieve zero or near zero carbon emissions;
 - » many locomotives are already refuelled by road tanker, so delivery of biofuels ought to be simpler than for passenger trains;
 - The industry already has a sufficiently large fleet of diesel locomotives that could potentially be converted to run on biodiesel.”⁴⁷
63. The taskforce has critically reviewed the findings from T1145, which have been widely considered within the industry. We accept these statements as an expert analysis of the position regarding alternative energy sources for vehicles. In this respect, we quote these conclusions verbatim, acknowledging the direct recommendations on electrification. We note that these are made from a technological maturity perspective and do not consider the wider political or financial questions that the taskforce has been asked to consider. As T1145 recommends, we would welcome positive support from the Department for a ‘first of a kind’ demonstrator which looks at the whole system, including on site generation of hydrogen and associated infrastructure.
64. It is probable that transitional arrangements will be necessary to maintain diesel-powered vehicles in service pending the development of suitable alternatives. These may be to life-extend existing vehicles and to introduce ‘future proof’ trains where it is possible to swap out power units as new traction options emerge. This is already being done in the UK, with Stadler’s FLIRT vehicle having been ordered for use in diesel bi-mode configuration initially on the East Anglia franchise.⁴⁸
65. It is also possible to implement improvements to the emissions of existing diesel units through engine management, end of pipe treatment and methane catalysis. An example of a range of technologies of this sort now in use or under trial on both road and rail can be found in the G-volution case study on p.41. Some of these are shortly to be trialled on the Grand Central route.
66. In considering the different traction options that may be applied across the network to maximise the use of electrified sections for different journeys and train abilities, the operators of the vehicles merit consultation. The traction decarbonisation challenge will affect train operating companies (TOCs) very differently, with several operating a diesel-only fleet and others all-electric as shown in Figure 7⁴⁹. The TOCs will be most familiar with the characteristics of trains in day to day operation and how these may be best managed across their routes and schedules. Most fleets are mixed diesel and electric.

⁴⁶ There are, in practice, no significant sections of track which are generally used by freight only. The bi-modes available and in development provide sufficient performance off the electrified network for ‘final mile’, shunting and recovery in the event of overhead wire failure. However, there remains a general challenge for non-electrified mixed traffic routes where a freight train would need to be capable of the 60 or 75 mph running compatible with other traffic. The taskforce will look further at this issue in the final report it will produce.

⁴⁷ Ibid, pp. 52-54

⁴⁸ See <https://www.stadlerail.com/en/meta/news-media/article/stadler-signs-largest-uk-order-abellio-east-anglia/>, viewed 18 September 2018

⁴⁹ Information from RIASteer Davies Gleave for ORR, (January 2015), Understanding the Rolling Stock Costs of TOCs in the UK ORR ref 22667501, p.37. http://orr.gov.uk/_data/assets/pdf_file/0003/20937/understanding-the-rolling-stock-costs-of-uk-tocs.pdf viewed 27 August 2018

CASE STUDY

G-volution diesel power unit improvements

AIM

To deliver a dual-fuel solution that reduces fuel use, particulate emissions and carbon footprint of existing and new diesel engines.

WHY?

G-volution's technology can reduce costs (30-40% fuel costs) at the same time as reducing carbon emissions (28-44% reduction) and contributing to higher air quality. Emissions from dual fuelled engines see much reduced particulates, lower CO and NOx but higher hydrocarbons. G-volution has pioneered a new technology that allows low temperature methane catalysis which addresses the issue of the increased hydrocarbons.

The technology allows diesel engines to run on diesel only where no secondary fuel is available. This flexibility will allow the cost effective roll out of the infrastructure needed to deliver secondary fuels, including compressed/liquified natural gas (LNG/CNG), propane (LPG) or, in future, hydrogen or ethanol.

Multiple fuels are possible: dual fuelling has been in use for 8+ years with G-volution including LPG, CNG/LNG as well as ethanol, methanol and hydrogen. The system gives flexibility allowing infrastructure to be built up during the use of the secondary fuel.

WHAT IS IT?

G-volution has a patented and proven system to dual-fuel diesel engines. The technology allows the engine to co-combust diesel and natural gas. G-volution can substitute up to 90% of diesel with natural gas, depending on the duty cycle.



G-volution technology can:

- be retrofitted or applied to a new engine
- ensure lower costs, lower particulate emissions (up to 90%) and lower carbon
- use natural gas (including bio-gas), LPG (including bio-LPG) and hydrogen.

This can be done immediately, and cost effectively, allowing a +/- 3-year payback. G-volution has dual-fuelled rail locomotives in the USA and run over 50m km in HGVs in the UK.

WHO IS INVOLVED?

G-volution and RSSB have delivered a feasibility study for this technology in UK Rail. G-volution, RSSB and Grand Central are now delivering a prototype which will be up and running on UK rail in the first half of 2019.

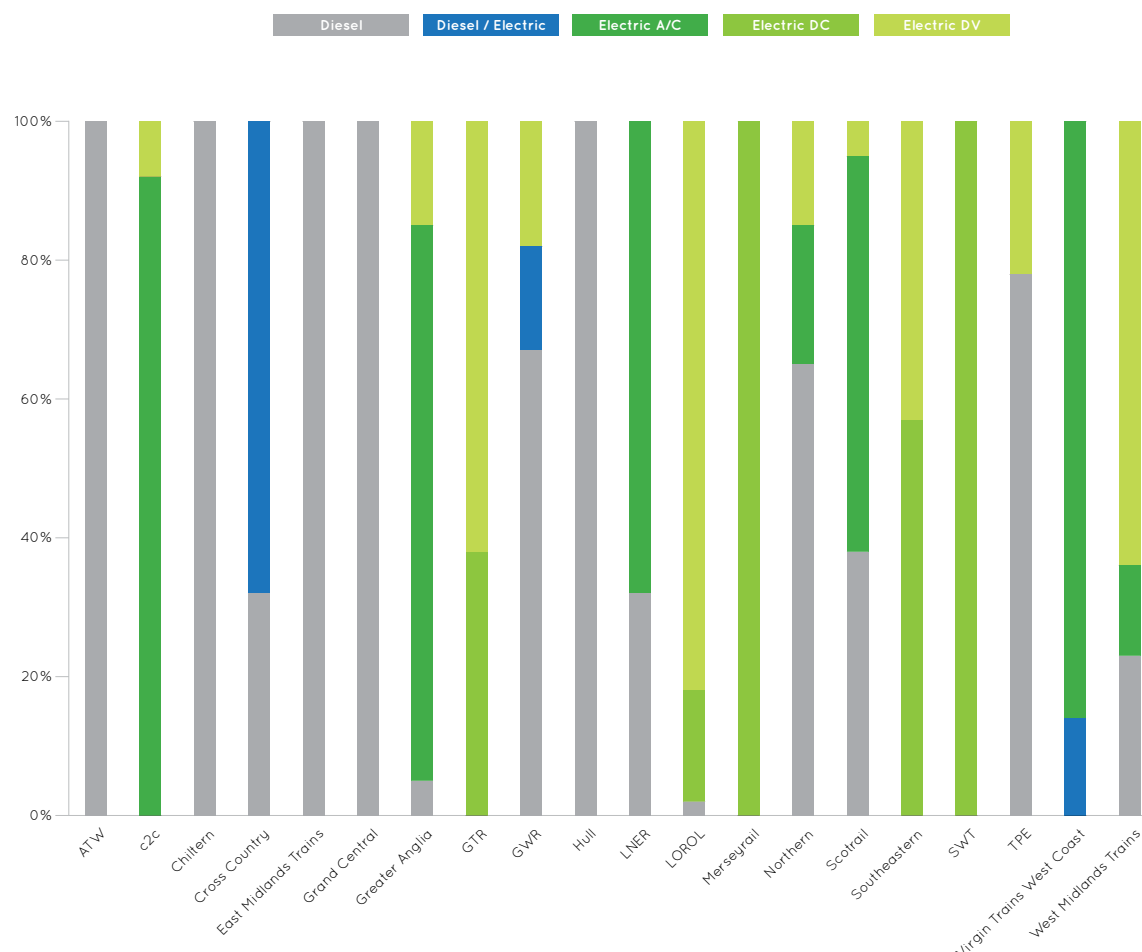


Figure 7: Traction mix by operator

67. In addition to the introduction of new traction options and more efficient use of existing traction options, other opportunities are available for further improvements. Studies on the carbon impacts of a new north-south line estimated that a 10% improvement in energy use and carbon emissions would be possible at the assumed 30-year replacement point for vehicles on such a line -

“On the basis of a 30 year rolling stock replacement cycle, the following efficiency innovations have been assumed:

- More efficient use of internal power (e.g., better heating / cooling);
- Cruise control or other methods of delivering more efficient driving styles;
- More use of regenerative braking;
- Better aerodynamic design; and
- Increased use of lighter materials, and other weight-saving design changes, as is seen in other modes of transport. We assume the recent trend for trains to become much heavier to be reversed in the near future. The most recent train orders, and the IEP specification, indicate that weight reduction is now a requirement of purchasers.

Whilst it is difficult to quantify energy savings triggered by these innovations, especially given the timeline involved, we have assumed a reduction in energy use of the order of 10% in year 30 (and thereafter) compared to the base assuming a reduction in energy usage is directly proportional to a reduction in emissions.

Adopting the view that a conventional rail service would operate new rolling stock after 30 years of service, it seems reasonable to assume that the same technological benefits as detailed above for high speed rail, would also occur for conventional rail (i.e. a 10% reduction from year 30 onwards).”⁵⁰

68. The taskforce has been asked to look at the current and projected costs (capital, projected and whole life) of the various technologies that are and may be available. We will examine these in more detail in the second stage of our work when we undertake the economic analysis. One important point is apparent, and that is that energy options which may appear low carbon relative to diesel and electric options may have a significant carbon as well as financial cost when the impacts of any infrastructure requirements and the whole life impacts, including those inherent in getting the energy from source to wheel, are fully taken into account.
69. For example, the energy requirements for producing hydrogen using existing techniques are significant. The brown hydrogen now available in the UK is a by-product of other industrial processes and its carbon impact is accounted for under the impacts of those processes. For UK carbon accounting purposes, this by-product hydrogen is treated as a zero-carbon fuel source. We need to understand how much hydrogen may need to be produced under various future traction options and where it will need to be used. If the points of production are remote from points of use to take advantage of, say, local off-peak renewable electricity generation, there will be a need for storage and distribution networks. It is possible that hydrogen could be produced locally at point of use from local renewables; this will require local storage and associated security and safety provisions. As hydrogen production, distribution and storage technology maturity stands, the lifecycle carbon impact for this as a potential energy source appears to be greater than the carbon impact of either diesel vehicles, particularly if these can be made significantly more efficient and cleaner in use, or electrification.
70. The taskforce has not been charged with the task of making the case either for continued use of diesel or for extensions to the electrified network. We are focused on examining the case for new traction options and combinations. However, we would be derelict in our duty if we do not attempt to make proper comparisons between new traction options and their costs, in both financial and carbon lifecycle terms, against the benchmark options of diesel and electrification. This report is focused on making robust assessments of current and future options and identifying preferred technological options accordingly. We will consider the financial and carbon costs in the next stage of our work when we undertake the economic analysis and development of the route map. We will highlight at that point what further decisions and research will need to be undertaken to make robust recommendations for preferred options.

Property

71. In the previous chapter we described the key findings of the recent research paper on zero carbon stations, as well as how some aspects of this are being implemented with one franchise based on both the carbon opportunity and a strong business case. In addition, we described how a new depot has been developed in accordance with BREEAM standards. We see no reasons why these

⁵⁰ Booz Allen Hamilton Ltd for DfT, (2007), Estimated carbon impact of a new north-south line, Draft Final, p.24. <http://webarchive.nationalarchives.gov.uk/+/http://www.dft.gov.uk/pgr/rail/researchtech/research/newline/carbonimpact.pdf>, viewed 21 August 2018

initiatives cannot be applied more generally, subject to appropriate arrangements being made for asset transfers and application of residual value mechanisms in franchises as a decarbonisation tool.

72. We will, as part of the development of the route map in the next stage of our work, consider whether there is any reason why it will not be possible to –

72.1. mandate the application of appropriate BREEAM standards for all new stations and depots, as well as the major refurbishment of any stations and depots of sufficient value for the application of BREEAM to be cost effective; and

72.2. require TOCs and Network Rail to implement the recommendations of the zero carbon stations report, and apply the same principles at least to heating and lighting in depots.

Infrastructure

73. Asset lifecycles for infrastructure are in many cases at least as long as for trains. The specification of assets is a highly controlled process to ensure the levels of safety, health, reliability and customer satisfaction demanded of the rail network. There are therefore few intervention opportunities available between now and 2040 where significant levels of decarbonisation are likely to be achievable. One notable exception is in the provision and use of lineside generators. There are likely to be opportunities not only to remove diesel generators, but also to put in place lineside storage solutions which would enable load balancing with the national grid. This will also help to reduce local noise nuisance. The study on p. 45 prepared by the Energy Managers Association considers this concept. This is at an early stage of development. We will assess the progress of this concept in our final report.

74. As noted earlier, CEEQUAL, the BREEAM counterpart for infrastructure projects, has been successfully applied to major transport projects. We see no reason in principle why this could not be applied to major rail infrastructure projects, with one benefit being a reduction in lifecycle carbon for infrastructure.⁵¹

⁵¹See <http://www.ceequal.com/>. CEEQUAL is now part of the BREEAM family of sustainability assessment tools.

CASE STUDY

Energy Managers Association - lineside storage concept

AIM

To develop a lineside energy storage capacity that can be used to power and recharge electric trains. The rail industry is one of the UK's largest users of electricity. By storing energy generated during off-peak periods, the industry can avert a substantial amount of the increasing peak demand that the country faces.

WHY?

Much of the current UK energy system will need to be rebuilt to meet future total energy demand and satisfy the UK's Climate Change commitments. The most expensive element of this rebuild is to satisfy peak demand. Network Rail has the ability, through investment in energy storage, to avert a significant element of this peak demand, and thus mitigate significant investment and system operating costs.

Multiple fuels are possible: dual fuelling has been in use for 8+ years with G-volution including LPG, CNG/LNG as well as ethanol, methanol and hydrogen. The system gives flexibility allowing infrastructure to be built up during the use of the secondary fuel.

WHAT IS IT?

A network of battery storage facilities that can be used to supply to the rail network. Guided by local need, these could be used to power trains and to operate network infrastructure and systems. This could include stations, points and signals.

Placing batteries trackside would allow energy to be stored and used directly to combat local power constraints and stress to the local grid. By load shifting, using

power generated off-peak to meet peak demand, the rail industry can influence and reduce the UK's overall investment in renewed energy generation infrastructure.

The cost of lineside storage becomes commercially viable when considered in this context. A full lineside energy storage system could reduce the country's overall generation need by 1 GWh.

As well as reducing peak generation demand, local storage has the potential to reduce delays caused by points and signalling system failures. This could enhance the overall customer experience for those using the railway; as would the reduced costs of the total energy used. Reduced energy consumption also

Storage linked to local solar or wind generation could help meet demand on areas of track where there may otherwise not be enough power. Batteries could be placed at trackside at points where there is greatest use of load. Stations would be the main locations, as power stored at off peak periods could be used to offset power used at peak periods. Batteries at stations could also be used to meet the high load caused by trains leaving stations. Batteries would range from 50 Kilowatts to multiple Megawatts. An added benefit is that batteries could replace standby diesel generation reducing local emissions.

WHO IS INVOLVED?

Recent and rapid developments in battery storage technologies mean that this is now being developed into a funded technical proposal by a consortium of battery manufacturers in collaboration with the rail industry.

How the industry and government should work together

COSTS AND BENEFITS

75. Research into the costs and implications of developing national grids for hydrogen fuelling for cars and for heat infrastructure indicate the difficulties of developing reliable cost estimates for these types of projects.⁵² For a hydrogen-based heating infrastructure, the difference between low and high cumulative additional system cost is about 30%, but with a caution that there is no clear upper limit on cost due to uncertainty on safety in buildings.⁵³ It is already apparent that the costs to the rail industry for any infrastructure, whether this is hydrogen, some form of synthesised natural gas, battery storage, charging or whatever, will be highly dependent on whether such a network is developed only for the rail industry or whether the rail industry is able to benefit from development and rollout costs being shared with others. We will consider the availability now and potentially to 2040 of alternative lower carbon energy sources such as hydrogen and biofuels, as well as the demand for these within other transport sectors and more widely. Any measures to promote biofuels in the rail sector will need to consider the availability of sustainable feedstocks and competing uses of the feedstocks and fuels in other sectors. This is to ensure that the biofuels deliver the highest possible greenhouse gas savings.
76. In the second stage of our work, we will seek to identify the major variables that the industry needs to consider in assessing the costs and benefits of any alternative traction options. This will need to be a key consideration in any benchmarking of alternative options against the much better-known costs and implications of diesel and electrification.

TECHNOLOGICAL MATURITY AND DEVELOPMENT

77. In considering options, the taskforce has looked at prior research, both through the T1145 project for traction options and directly for infrastructure and property. We have consulted with those who have and are developing new lines, such as Crossrail and HS2, and we have reviewed the developments in other transport sectors. We have concluded that the industry has taken into account the technologies and innovations that are likely to be able to make a material change in carbon emission by 2040.

⁵² LowCVP, (June 2015), *ibid*; and Element Energy and E4Tech for National Infrastructure Commission (March 2018), Cost analysis of future heat infrastructure options. <https://www.nic.org.uk/supporting-documents/cost-analysis-of-future-heat-infrastructure-options/>, viewed 2 September 2018

⁵³ *Ibid*, p.7



INDUSTRY AND GOVERNMENT WILL NEED TO ENSURE THAT INNOVATION OPPORTUNITIES ARE DEVELOPED

78. The question therefore is not what may have been overlooked that the industry must consider, but whether any of the identified technologies that are not yet in regular use are likely to be able to contribute to a wider solution by 2040 in a cost-effective manner. The most likely technologies appear to be hydrogen and batteries for traction, and lineside battery storage for infrastructure. Discussions are beginning on one concept proposal to consider how lineside storage may be developed at no upfront cost to the industry.
79. Industry and government will need to ensure that innovation opportunities are identified, agreed and funded to accelerate development of the most likely technologies to a demonstrator stage.

Unintended consequences

80. One of the challenges that will arise from accelerating decarbonisation will be to avoid unintended consequences of well-meant decisions that are premature or based on incomplete information. It is critical that when policy decisions are made, they complement the long-term nature of planning decisions on the railway and the long asset lifecycles that will be locked in. We see three major areas where unintended consequences might arise from adopting sub-optimal pathways to decarbonisation –
- 80.1. Modal shift. The aspiration to remove diesel-only vehicles by 2040 applies only to the rail industry. The road freight industry has not been challenged to remove diesel-only haulage by the same date. Asset lifecycles in road haulage are typically much shorter than on the railway so there are more frequent natural opportunities for adopting new innovations. The road freight industry may reasonably anticipate 4-5 vehicle replacement cycles between now and 2040 to be able to adopt newer, greener technology as it matures and costs reduce. By comparison, the next asset replacement across the rail industry, including freight traction, which receives little direct public support, would normally be expected to be the only replacement cycle before 2040. The implications are that the freight sector will –
- 80.1.1. likely have only one natural asset replacement opportunity for Class 66 locomotives;
- 80.1.2. be limited in options to diesel hybrids and diesel electrics due to the need for almost all locomotives to be flexible in their ability to run on electrified and non-electrified sections of railway;
- 80.1.3. need significant investment to be able to make this change without

having to increase freight charges to such an extent that modal shift to road will happen. Given that the natural turnover rate for freight locomotives is running at less than 30 per year, or only 3.5% of the freight fleet, the levels of innovation that the freight industry is going to be able to sustain, compared with the road freight industry with its much larger market, is negligible; and

- 80.1.4. need significant further research to bring any other technology, such as liquid natural gas, to a level where a successful demonstrator project may be delivered;
- 80.2. Increases in lifecycle carbon. While the operation of individual trains under alternative traction options may look attractive, we see three drivers of increases in absolute and relative lifecycle carbon over the current deployment of energy sources across the network –
 - 80.2.1. the installation of the necessary supporting infrastructure and its operational impact may exceed that of diesel, particularly where efficiencies in diesel are implemented, as well as electrification where electrification proves to be cost-effective to implement. On its own, the rail industry is unlikely to be able to achieve a cost-effective rollout of a completely new infrastructure for providing, say, hydrogen or some form of synthesised gas fuel, as it will not be able to amortise the development costs on a large enough scale. Any rollout of such integrated fuel production, distribution and fuelling systems will probably depend on what happens in the automotive sector;
 - 80.2.2. the deployment of new technologies does not take into account medium to longer term plans from various regional bodies to develop their regional energy systems. For example, Transport for Scotland has plans to extend electrification, as does Transport for the North on, say, the Trans-Pennine route. Leeds is exploring the feasibility of converting the city from gas to hydrogen. Regional initiatives such as these, if given the go-ahead, will inevitably have an impact on the economic case for particular options on the network on a much wider geographical basis; and
 - 80.2.3. the deployment of new technologies is not standardised and coordinated across the network, such that there may be a need to install a hydrogen infrastructure and a lineside battery charging infrastructure on the same stretch of rail. The combined costs and impacts of this duplication would need to be accounted for. In addition, if there is a loss of flexibility of fleet deployment across a network because different parts of the network use different traction options (e.g., hydrogen in one part, battery charging in another), there may be a need to deploy more vehicles than would otherwise be necessary with the commensurate increase in costs and carbon; and
- 80.3. Short term decisions on air quality leading to adverse long-term carbon outcomes. There are some technologies, such as diesel battery bi-modes, that could be rolled out more or less immediately to address air quality concerns in and around city and major suburban stations and within major population corridors. However, these may not prove to be the best long-term option

should the short to medium term drive to improve air quality locally take precedence over the longer term but much greater challenge of contributing to national and global decarbonisation efforts. RSSB is now carrying out further research into air quality issues and we will ensure that the two work streams on decarbonisation and air quality consider common issues.

81. It is possible that we could choose the optimal pathways but in choosing to implement them faster than is advisable, we could still find ourselves triggering one or more of these unintended consequences. This is, we believe, most likely to happen with the transition of freight to lower carbon pathways.

BARRIERS

82. Throughout this report, we have identified barriers to decarbonisation. These cover policy, funding, technology, standardisation and the constraints of existing infrastructure. We do not propose to address these again in detail in this section but we feel it is right to discuss five issues in more detail that encapsulate the interlinked nature of the challenge.

SLOW IMPROVEMENT ON NON-TRACTION PERFORMANCE AND LACK OF RELEVANT PUBLISHED PERFORMANCE DATA

83. A 2007 report on traction and non-traction energy savings opportunities noted that opportunities from non-traction energy were an order of magnitude less than for traction energy.⁵⁴ It highlighted some of the limitations, cultural and structural, towards making progress⁵⁵ –

“Barriers to implementing energy savings included:

- Time to undertake partnered initiatives within the limited franchise period
- Increased rent costs from improvements made by the tenant
- Suitability for purpose of capital investments – cheaper investments not supporting capital investment initiatives.”

84. We have heard similar comments in our industry consultations for this report. Outside traction energy, all other uses of energy pale in comparison. Given the complex performance requirements in franchises and the focus of resources on the big ticket items, we have been told anecdotally that many of the relatively easy but smaller items get overlooked unless there is either an overwhelming financial advantage to deliver them within a franchise period or a very clear requirement which is actively managed in some way. While franchises include requirements to improve energy efficiency in various non-traction areas, set carbon targets and put in place improvement plans, there is a general view that the results often fall short of what could be achieved. One of our aims in the economic analysis we will undertake as part of our final report will be to understand these reasons better. There is little clarity at sub-industry levels as to what good carbon performance looks like. Franchisees, Network Rail and others have been required for some time to report carbon emissions and these reports have formed the basis of KPIs generally reported by the ORR. RSSB is developing an environmental data

⁵⁴ RSSB (13 June 2007), T618 Improving the efficiency of non-traction energy use. See https://www.sparkrail.org/_layouts/15/Rssb.Spark/Attachments.ashx?id=75NEMTS3ZVHP-8-2816, pp. 5, viewed 10 August 2018

⁵⁵ Ibid, p. 6

reporting toolkit to enhance and streamline environmental data reporting. The intention is that this will allow users to generate more value and intelligence from the data, in part through datasets becoming more consistent, robust and of higher quality, and therefore suitable for environmental data analysis and performance at the organisation and industry levels.

85. While these data allow for good intermodal comparisons and time comparisons, they provide only limited feedback to the industry in a manner which is useful. We have been advised, rightly or otherwise, that a great deal of the source data is commercially sensitive and cannot be shared. This lack of performance data in a useable form for the industry means that opportunities to identify, in the normal course of operations, particularly good or poor areas of performance within the industry are lost. This is a challenge for all stakeholders. The industry needs to specify to DfT and ORR what data they can supply that is material for carbon performance reporting and management purposes. It also needs to specify in what form it wants the collated and analysed data fed back into the industry that will be useful for carbon emissions reduction purposes.
86. A related concern is that when franchisees can see a business case but believe that the return on benefits is going to extend past the end of their franchise, they are unlikely to implement an improvement that is not mandated in the franchise agreement. There is a Residual Value Mechanism (RVM) built into franchise agreements that is designed to encourage investments in non-traction assets where returns on benefits will accrue substantially beyond the end of the franchise period. All but one franchise bid has included proposals for RV assets, and every franchise has incorporated at least one RV asset at its outset. By contrast, in-life RV assets have to operate for at least three years within the franchise and, to date, only one of these has been agreed. While this RVM has been used in all franchises, we received several comments which suggest that it is not a practical franchise provision. It has been suggested that this is because RV assets cannot contractually encumber future franchisees, which limits, for example, the ability to bring in third party financing for renewable energy assets. Its use for improvements in depots and on trains is restricted. Others have suggested that some of the better uses become clear only when a franchisee has had time to become familiar with its assets. However, in contrast to well-staffed bid teams, in-operation teams are much leaner and focused on issues with greater commercial impact, so the franchisee's ability to be able to develop in-life RV assets is severely constrained. If it is to be better used as a decarbonisation tool, we need to work with the government to consider whether we should recommend any changes in the RVM. We will report on this in more detail in the final report.

REDUNDANT OR UNCLEAR STANDARDS ON VEHICLE OPERATIONS RESTRICTING IMPROVEMENTS IN VEHICLES

87. An issue highlighted during this project has been the compatibility of rolling stock and differential speeds in relation to track condition. The permitted speed of operation of trains on various sections of track is determined by a combination of factors, perhaps the two most important being axle weight and braking ability. There are sections of track with a maximum speed for most trains of 60mph, but for which Class 15x trains, generally designated 'Sprinter', were introduced which are permitted to run at 75mph and more. Broadly speaking, although a single agreed standard was never established, the Sprinter designation applied originally to a lighter train under 13.75t that caused less damage to vulnerable sections of track and was therefore allowed to run at higher speeds. These vehicles, now in wide use, will need either to be re-engined or displaced if the

industry is to maximise the extent of decarbonisation it can achieve. However, installing bi-modes, batteries or other modifications on these trains will mean that they no longer fall within the parameters for Sprinter designation and will, as things stand, only be able to run at 60mph. This will have a significant knock on effect on network capacity and scheduling if it is not reviewed. At the very least, some allowance for the general improvement in tracks in these restricted speed areas and the improved braking ability of modern trains should be allowed for in determining which trains are permitted to run at 75mph and more.

ASSET LIFECYCLES ACROSS INDUSTRIES AND AVAILABILITY OF INNOVATION FUNDING

88. We have considered asset lifecycles across the key automotive, aviation and rail industries. The rail industry is uniquely tied to a discrete and specific infrastructure which is integral to the way that vehicles operate. In many respects, this creates challenges for innovation that simply do not exist in the aviation and automotive industries. Both of these industries provide much larger markets in the UK for vehicles than does the GB rail industry. The ability to standardise vehicle and component design across a larger market not only in the UK but globally provides inherent advantages to the automotive and aviation sectors to innovate faster and amortise the cost of innovation across a much larger vehicle base. The market for new freight locomotives in the UK is running at less than 30 replacement vehicles annually, and for passenger trains of all traction modes at less than 1,000. In both cases, the anticipated vehicle life is generally regarded to be in the order of 30-40 years, although it is not unusual for vehicles to remain in service for significantly longer.
89. Road transport of any sort, including HGVs, has a much shorter lifecycle than rail so that, by 2040, the number of iterations for road vehicle replacement is likely to be a minimum of three and probably more. By comparison, a significant portion of the rail fleet now in service is anticipated to be in service in 2040, so the opportunities for applying and implementing innovation are severely restricted. In some cases, such as high speed, high intensity intercity passenger services and freight of all kinds, like for like, let alone improved, replacements to electric and diesel vehicles simply do not yet exist. There will probably be a need in these sectors of the rail industry to consider transitional arrangements while the industry awaits credible alternatives, particularly in the absence of further electrification.
90. The demands being made on the rail industry are more stringent than for HGVs in the road sector, as there is as yet no requirement for diesel-powered HGVs to stop being sold by 2040, let alone banned from the road network. As a taskforce, we have been advised repeatedly in our consultations that this imbalance between what is required of the rail industry in comparison to road transport is not a level playing field, that this is a real barrier to stimulating innovation and, if not addressed, will result in unintended modal shift from rail to road.
91. By contrast to the constraints, a simple search across the innovation opportunities published by Innovate UK suggests that the funding for automotive and aviation sectors is at least an order of magnitude greater than is available for the rail sector. Dedicated rail opportunities account for little more than £30m, whereas for automotive and aerospace, the value of opportunities appears to extend from £300m to over £1bn. For the period 2014-2020, RSSB has had access to a £100m innovation fund, comprising £80m from DfT and £20m from Network Rail. This is an area where the rail industry can learn from the automotive and aviation sectors in how they work with government to define and fund increased innovation opportunities for both transitional and long-term solutions.

92. The workhorse of the freight sector, the Class 66 diesel locomotive, is fuel efficient, reliable and easy to maintain. By comparison, the Class 88 is the only modern bi-mode diesel electric freight locomotive operating on the network. The diesel mode has about 20% of the power of the electric mode and so is only suitable for slow speed last mile operation. As we noted earlier, this is a limiting factor as freight locomotives need to be 'go anywhere' to work effectively across the network and to maintain speed and acceleration compatible with a mixed traffic railway. The limitations of the UK gauge mean that there is insufficient space, with current technology, to fit a diesel electric with sufficient installed power to supersede the Class 66. There is work under way which may lead to the development of locomotives which would use smaller diesels and supplement this with battery power⁵⁶ which might in due course be applied to freight locomotives. Further work is needed to develop suitable bi-mode options with sufficient versatility across the network to be viable. The sector would need innovation funding support to develop options such as these and to develop a clearer understanding that the necessary capital investment would lead to reasonable returns in reduced operating costs as well as reduced emissions. The lack of such support presents a significant barrier.

FRANCHISE RETENDERS

93. We need to consider the timing of franchise retenders and how these will drive investment for decarbonisation over a prolonged period or where a decision made as part of a new franchise agreement will lock in an investment beyond 2040. Six franchises are due for renewal between 2023 and early 2025 when several critical investment decisions, particularly around the purchase of new rolling stock, will need to be made or start to be delivered. Consultations within the industry suggest that decisions on preferred options for decarbonisation will have to be made in advance of the franchise tender periods. If this is the case, it may be advisable to consider what direction on future traction options should be given for these franchises well in advance so that the most cost-effective and carbon-efficient options may be considered and planned for now.

DISRUPTION

94. The implementation of any option, such as additional electrification, development of charging points, particularly at stations, the development of hydrogen generation, storage and refuelling facilities will result in some level of disruption to passengers, freight operators and lineside communities. These disruptions have to be weighed against each other and against the status quo. The levels of disruption will depend on how our taskforce recommendations may be implemented. While outside the scope of our work, we felt it worth noting that the best long-term solutions may, as with any major infrastructure projects, cause some disruption. It is our view that the relative levels of disruption should be considered in making decisions on preferred options and how they may be implemented, but should not prevent the best long-term low carbon options from being selected.

⁵⁶ For example, see <https://www.mtu-online.com/hybrid/>

RISKS AND OPPORTUNITIES

95. The key areas of risk principally arise from a failure to give full and proper consideration to the unintended consequences discussed earlier. We see three principal areas of risk –
- 95.1. wrong traction options choice leads to –
 - 95.1.1. greater lifecycle carbon emissions; and/or
 - 95.1.2. excessive costs to achieve targeted benefits;
 - 95.2. poor implementation of preferred options leads to increased costs to industry that are not funded, resulting in increased customer cost and modal shift to other forms of transport; and
 - 95.3. poor performance reporting, feedback and management leading to failure to realise full targeted benefits.
96. The opportunity is set out in the mission for the taskforce –
- “To move UK rail to the lowest practicable carbon energy base by 2040, enabling the industry to be world leaders in developing and delivering low carbon transport solutions for rail.”
97. The significant research undertaken to date and the clarity of options indicates that the opportunity is unlikely to lie in a pure technology solution. This statement assumes that there is convergence between technological, commercial and policy aspirations. For example, the Department for Transport has indicated acceptance of its willingness to consider supporting securing innovation funding for the freight sector if freight operating companies make proposals. There is a real opportunity to engage between the Department and the rest of the freight industry to establish the key areas for innovation research and development, and to show the industry that there is clear and strong policy support to find ways to decarbonise more radically than is currently possible.
98. The mission sets the aspiration for UK rail to be “world leaders in developing and delivering low carbon transport solutions for rail.” Our research has not identified any other collaboration of rail networks, national governments, academic communities and R&D communities who have set themselves a similar aspiration to produce integrated low carbon solutions.⁵⁷ In setting a vision and targets for the industry and defining a route map, it is essential that we achieve a shared commitment among rail industry stakeholders to deliver on this goal.
99. As we were finalising this initial report, on 20 September 2018, the Government announced the Rail Review. This will look at the structure of the whole rail industry, including increasing integration between track and train, regional partnerships and improving value for money for passengers and taxpayers, with plans for reform to be implemented from 2020.⁵⁸ This presents both risks and opportunities. We will seek early engagement with the Rail Review team to ensure that industry decarbonisation is properly considered in their work.

⁵⁷ We are aware of programmes elsewhere to develop low carbon solutions, but none that have engaged all these communities in the integrated manner suggested here

⁵⁸ <https://www.gov.uk/government/news/government-announces-root-and-branch-review-of-rail> viewed 26 September 2018

ROLE OF POLICY

100. Reports have been critical of the quality of development and implementation of policy,⁵⁹ the need for taking a system-wide perspective⁶⁰ and the need to take an integrated approach to the physical and regulatory elements of network development and operation.⁶¹ In our work as a taskforce, we have been repeatedly advised that the single biggest measure to enable effective decarbonisation of the railway in an integrated manner will be the adoption of a clear, consistent and predictable policy approach by the DfT. The industry recognises that it could and should give better feedback to the DfT to guide the development of the best policy options.
101. We believe that a rigorous policy framework should be established to enable the effective assessment of any preferred traction options to be considered on any part of the network. We have already recommended a clearly-defined optimisation hierarchy to set out how and when various traction options could be applied on the network. Further work on the full carbon, economic and social lifecycle implications, including disruption in implementation, of options is, in our view, a prerequisite for being able to show that the right choices are being made. As we have noted elsewhere, this will be best achieved through the industry and government working together.
102. In this report, the taskforce has presented technologically credible options for increasing the rate of decarbonisation immediately. We have outlined options which, subject to further technological development in some cases, will help the rail industry continue to decarbonise to 2040 and beyond. We have identified options which maximise the use of existing infrastructure. There are, we believe, credible arguments for undertaking further reviews of how carefully-planned extensions to electrified sections, as well as discrete and discontinuous electrification in some areas, will maximise the ability to exploit the implementation of battery-electric trains on the core rail network. We recommend this option should be considered as a reference case against which all other traction options should be considered for three reasons –
 - 102.1. It is likely to be the low emissions reference case for assessing the decarbonisation potential of other options;
 - 102.2. It taps into the decarbonisation of the wider UK power supply. This is a more singular and controllable form of lower emissions than some of the interventions we propose, which are dependent on human factors, complex and integrated systems development and other higher risk interventions;
 - 102.3. It is inherently more reliable in operation. While there is concern about higher levels of disruption to passengers in construction, it will be more likely in operation to satisfy complementary policy goals for passenger satisfaction, performance and meeting the Industrial Strategy Grand Challenges which we discuss below.
103. We see the role of policy is to guide the industry towards effective solutions through outcome specifications.

⁵⁹ National Audit Office, (9 November 2016), HC 781, Report by the Comptroller and Auditor General Department for Transport and Network Rail Modernising the Great Western railway, p.6.

<https://www.nao.org.uk/wp-content/uploads/2016/11/Modernising-the-Great-Western-railway.pdf>, viewed 25 August 2018

⁶⁰ Commons Committee of Public Accounts, (3 March 2017), HC 776, Modernising the Great Western Railway, Forty-fourth Report of Session 2016–17, Report, together with formal minutes relating to the report, p.3. <https://publications.parliament.uk/pa/cm201617/cmselect/cmpubacc/776/776.pdf>, viewed 25 August 2018

⁶¹Ibid., p.13

104. Policy at the macro level should give guidance in terms of objectives, which the decarbonisation challenge is doing. It is encouraging the industry to explore a range of ideas and assess their full economic, carbon, social and other implications. We will present these in our final report when we have undertaken an economic appraisal of the traction options and developed a route map.
105. Policy at the implementation level should supply clarity, consistency and certainty. This is imperative for the decarbonisation challenge, which requires decisions now that will dictate what we will achieve in carbon terms to 2040 and beyond. It would be a significant benefit if –
- 105.1. DfT were to agree to work on performance outcome specifications in franchises rather than tight input specifications which tend to constrain the industry to specific solutions. We have heard repeated concerns that the industry is being locked into sub-optimal solutions which will stifle opportunities for innovation in the shorter term. If other options allowing re-engineering of existing trains are entertained, it is likely that the next cycle of innovation for vehicles would happen much more quickly.
- 105.2. To encourage innovation, DfT were to announce an output specification for rolling stock emission performance perhaps a year in advance of issuing the tender so that the industry has time to research, develop and cost new ideas. The limited timeframes currently provided in the franchising process do not allow sufficient development time as bidders often do not know what will be required and cannot therefore invest the necessary time and money on a known option.
- 105.3. DfT consider agreeing to set and maintain emissions and carbon mitigation standards to apply for a determined time period which extends beyond the five years of a control period. While this may mean that later franchises to be let cannot be guaranteed to be at the leading edge of technology and standards, the certainty that this will provide the industry generally will provide a better, more stable environment to undertake significant research and development into new lower carbon options.
- 105.4. DfT supports exploration of ways to boost innovation funding that supports a move by the rail industry to focus more explicitly on decarbonisation. Low carbon innovation funding is skewed towards road and aviation when the levels of investment and research are much greater than in rail. There should be a commitment to increase innovation funding for rail alongside incentives to encourage more private sector investment in traction and infrastructure improvements.
- 105.5. If the UK is to become the leading low carbon railway by 2040 and seek to export skills and technology, we have to find ways to retain existing skills, especially as many of these rest within an ageing workforce. Before the Great Western Electrification Programme, which saw major cost overruns, the last major completed electrification schemes were carried out in the 1990s. These were planned and done as single big projects, which increased costs. We understand the forthcoming RIA Electrification Cost Challenge Report will examine the lessons learnt from Great Western. It will also review examples in the UK and internationally that demonstrate that electrification can be delivered affordably and which we believe support the case for ensuring electrification is fully considered as an effective option in our future low carbon railway. Research into better planning, techniques and standards suggests a more measured rolling programme of electrification would retain

and improve exportable skills and technology, particularly where these can be employed on ageing and sub-optimal networks. Few if any countries in the world have the ability to maintain and operate an older network as well as in the UK, but it is clear that other countries are able to minimise the costs of electrification by implementing a more measured mileage of electrification year on year than the UK has generally delivered. Where it turns out that it is the preferred solution, overseas experience suggests that costs and disruption are best minimised with a steadily managed programme rather than an intensive rollout of electrification.

We will work with the industry and with DfT to set out the policy ideas that we consider will best deliver these policy aspirations and report back on these in the final report.

ALIGNMENT TO GREEN GROWTH

106. In its November 2017 White Paper on the UK's Industrial Strategy, the Government noted that the UK's clean economy could grow at four times the rate of GDP.⁶² The Industrial Strategy proposes four grand challenges, of which two are to –

“maximise the advantages for UK industry from the global shift to clean growth; and become a world leader in shaping the future of mobility.”⁶³

107. For clean growth, the long-term goals “are to make clean technologies cost less than high carbon alternatives, and for UK businesses to take the lead in supplying them to global markets.” This will be accomplished in part by remodelling the national grid “so it can handle many different sources of clean energy, and use new technologies to store energy and manage demand.”⁶⁴

108. The approach we propose here aligns with these two challenges, these long-term goals and the proposal for the development of the national grid. Our approach –

108.1. seeks to maximise the use of grid electricity from the outset;

108.2. aims to achieve implementation pathways that respond flexibly, within the constraints of the long investment and operational cycles inherent within the rail industry, through –

108.2.1. maximising the use of grid electricity, which is, and will become increasingly so, the best means of providing, directly and indirectly, the core volumes of low carbon energy necessary for the effective operation of the rail network;

108.2.2. considering the benefits of transitional arrangements where no clear options yet exist; and

108.2.3. proposing the deployment, where appropriate, of trains that can be relatively easily retrofitted with alternative power packs as technology matures and cost-effective means of achieving lower carbon outcomes are available to come into service;

⁶²HM Government (Published 27 November 2017, last updated 28 June 2018), CM258 Industrial Strategy Building a Britain fit for the future, p.42. <https://www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future>, viewed 27 August 2018

⁶³Ibid, p.34. The other two grand challenges are to “put the UK at the forefront of the artificial intelligence and data revolution; and harness the power of innovation to help meet the needs of an ageing society.”

⁶⁴Ibid, p.43

108.3. seeks to ensure that the options we recommend are consistent with the move to clean growth. We are proposing that all options are evaluated for whole life impacts on both costs and carbon parameters to ensure that new ideas are clearly improvements on existing technologies and how are they are applied. This will be a key factor in demonstrating that ideas we generate for application on our railway are fit not only for our immediate purposes but also for application elsewhere around the world; and

108.4. considers the work that has been undertaken on several new lines, notably in London, where Crossrail is just coming into service, and HS2, where planning for a low carbon rail line is at a detailed stage. We are confident that the recommendations we make here incorporate cutting edge thinking as well as considering how they may best apply to what is, in places, a highly constrained railway infrastructure.

ROLE OF INDUSTRY

109. Core to resolving the decarbonisation challenge is the need for the industry to work with government to develop a cost-effective plan that maximises the opportunity provided by a clear, consistent and comprehensive policy framework. A proactive and complementary effort on planning and policy is more likely to provide a range of options which are technically effective and deliver the decarbonisation objective while achieving the best commercial outcome. Figure 8 illustrates this for the passenger sector; a similar model applies for freight. The industry should show how the right policy framework will help to deliver this at least cost and with the minimum of disruption to rail users, as well as illustrating more clearly where additional incentives will be necessary.

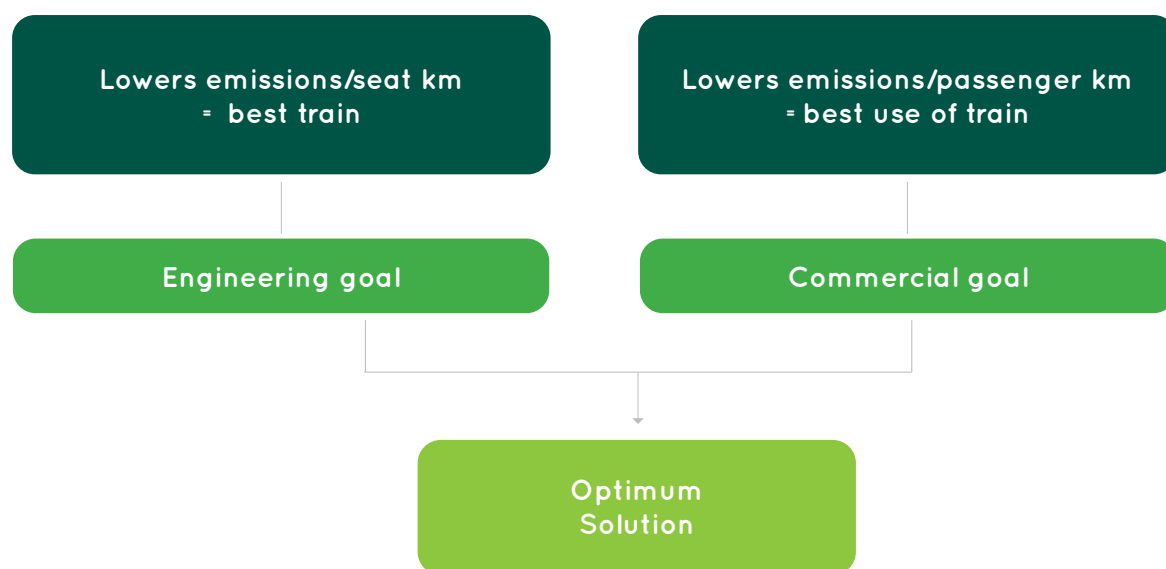


Figure 8: engineering and commercial balance

110. A further key role for industry is to make better use of the mechanisms available under franchises and to propose improvements to these as well as to highlight where franchise mechanisms conflict with carbon objectives or where mechanisms do not exist. One example noted earlier is the RVM. In 2013, the Brown Review recommended –

“To encourage the use and enhance the effectiveness of residual value provisions I recommend the Department issues guidance which explains the circumstances in which it will consider proposals and the mechanisms it would use to calculate residual value at franchise end.”⁶⁵ and

“Most important of all is a mature franchisee/franchise authority relationship which seeks to grow the value of the franchise to the benefit of both parties. Some of the mechanisms in the Franchise Agreements have been designed with the best of intentions but are then under-utilised. From my discussions with the industry, part of the issue is a lack of confidence amongst the franchisees that the Department will consider positively proposals for change or the use of residual value mechanisms.”⁶⁶

111. As we have noted, the industry should engage with the DfT to explain what is necessary to make the RVM an effective tool in the implementation of a long-term, visionary decarbonisation strategy.
112. Franchisees necessarily take a short-term view of innovation. Aside from the residual value mechanism, another concern that has been highlighted is their reluctance to embrace technology where the technology has not been tested and shown to be reliable to the extent necessary in the industry. There will continue to be resistance to innovation when technology is not available in the right way to achieve the right design outcome. The industry needs to work more closely with DfT to define what the necessary preconditions are for the industry in the decarbonisation strategy to adapt and implement technology which it considers sufficiently mature in application to implement.

COSTS: CAPITAL, OPERATIONAL AND WHOLE LIFE

113. There is no silver bullet to replace diesel for traction. We must ensure that consideration of alternatives benchmarks against this and electrification on both lifecycle cost and carbon impacts to ensure that perverse outcomes are not preferred. As technology progresses, this benchmarking must be updated periodically.
114. The two most likely options, hydrogen and batteries, have significant production costs and carbon implications and neither option is aligned to the needs of freight or high-speed rail.
115. We cannot predict with any certainty what the energy costs of hydrogen production at scale for the rail industry might be. This will be heavily influenced by decision in other transport sectors. If a hydrogen infrastructure is developed only for segments of the rail network, the total cost and the proportion of the development cost that will need to be borne by the rail industry will be very different than if a hydrogen infrastructure is rolled out on a national basis for the automotive sector or, as is being explored in Leeds, on a regional basis to replace gas as a heating and fuel source. Research on the development of a hydrogen refuelling network in the UK suggests three factors will be critical in influencing the take-up of hydrogen as a fuel –
 - 115.1. the transition from a publicly supported early stage network to one which is profitable in its own right. It is suggested that any hydrogen fuelling

⁶⁵ DfT (January 2013), The Brown Review of the Rail Franchising Programme, pp.33-34. <https://www.gov.uk/government/publications/the-brown-review-of-the-rail-franchising-programme>, viewed 2 September 2018

⁶⁶ Ibid, p.50

network will require significant public investment in its early stages; this has yet to materialise;

- 115.2. the availability of sufficient volumes of hydrogen; and
- 115.3. the speed at which any distribution network or local production might be rolled out across the country.
- 116. This would suggest that the viability of implementing hydrogen as a significant traction option on the rail network may well depend on decisions made for other transport sectors and perhaps district heating networks.
- 117. Similarly, if battery technology evolves so that battery cycles and capacity are durable enough to provide significant range between charges on the network, it is likely that the rail sector will have to compete with the automotive sector and power networks, for example, for access to batteries. These and other sectors are better resourced and able to use the technology much faster, which will make them more attractive markets.
- 118. The second phase of the work of the taskforce will include development of an economic appraisal model and decision route map that will consider these factors.

FURTHER R&D REQUIRED

- 119. On the traction side, we believe that further work research and development work needs to be undertaken on three key rail uses where there are no universally satisfactory alternatives to diesel or electrification yet available –
 - 119.1. high speed, high intensity, which broadly equate to trains travelling over 100mph for extended distances;
 - 119.2. freight;
 - 119.3. battery technology to maximise the use of the existing electrified network; and
 - 119.4. viable self-powered traction options such as hydrogen off the electrified network.

There is, in parallel, a need to rigorously assess how the industry might innovate to do electrification better. We have been advised repeatedly during our consultations that this should be the lowest cost, lowest carbon option for heavily used parts of the network. As mentioned earlier, RIA will shortly publish a study on the costs of electrification which may identify where improvements may be found. Nevertheless, we see a case for producing an effective benchmark cost for progressive electrification similar to how it is implemented in Germany.

- 120. R&D will need to consider how to bring technologies to a demonstrator point in order that TOCs, freight operators and others are not put into a situation where they have no choice but to implement new options in a high-risk commercial environment. Research will need to consider the infrastructure needs for new energy sources, such as hydrogen and both on-board and lineside battery

⁶⁷ LowCVP, (June 2015), Transport Energy Infrastructure, Roadmap to 2050, Hydrogen Roadmap, [http://www.lowcvp.org.uk/assets/reports/20150307_LowCVP%20Infrastructure%20Roadmap_HYDROGEN_Final%20\(with%20graphics\).pdf](http://www.lowcvp.org.uk/assets/reports/20150307_LowCVP%20Infrastructure%20Roadmap_HYDROGEN_Final%20(with%20graphics).pdf), viewed 2 September 2018

charging. It will also need to assess the feasibility of introducing new options to the railway in isolation and in conjunction with the rollout of similar systems for other purposes. Some options may be financially and operationally feasible only if the railway implements solutions in conjunction with other transport modes or regional development schemes.

121. Network Rail has encouraged suitable innovative ideas through its published Challenge Statements, responses to which will form the foundation of their infrastructure investment strategy for CP6. We will review our recommendations as we develop our final report and see which ones may be suitable.
122. We recommend, as new traction modes are considered for introduction on specific parts of the network, that they be assessed with reference to the most effective use of existing electrified track. One of the complicating issues is that, as new traction modes become more viable, the economic and carbon case for them as against diesel and electrification varies significantly, particularly with improvements in the carbon mix of grid electricity and the improving efficiency and cleanliness of diesels. To make the best use of new traction modes in financial and carbon terms, they will have to be benchmarked against these standards to ensure that the best carbon options are being preferred.
123. The focus of this initial report has been on practical solutions that are, or close to, the level of maturity necessary to deploy now or be tested in demonstrator projects. However, we recognise the need to pursue a strategy that accommodates and exploits technical and commercial innovation beyond the traditional railway environment. We will further research latest developments in other sectors, such as road freight, marine, aviation, hydrogen production and biofuels, for our final report.
124. Alongside technology developments to improve and extend the possibilities to manage, store and transmit energy from lineside to trains, new technologies and wider market changes may offer potential opportunities that go beyond replacing parts of the current system with improved products to open up different approaches, for example to fund and facilitate decarbonisation. A key example is the changing attitudes and expectations of customers and communities. An interconnected world and emerging new funding mechanisms offer the potential for local communities to become active partners in railway decarbonisation.
125. In this regard, Network Rail's 'open for business' initiative explores the potential for new value propositions that, while unlikely to offer a single simple means to decarbonise the network, may hasten convergence of solutions. This work goes beyond technologies and promotes different ways of working, promoting co-development and ownership. We will report on progress on this initiative and how it might support the decarbonisation objective in more detail in our final report.

ENSURING PROGRESS

126. The industry has recognised that there is a need for a monitoring mechanism to support and drive the decarbonisation programme. It does not, however, support the introduction of a new governance body to ensure progress solely on this agenda. The second stage of the work of the taskforce includes the development of a route map for implementation.

⁶⁶ See <https://www.networkrail.co.uk/industry-commercial-partners/research-development-technology/research-development-programmes/challenge-statements/> for details, viewed 26 September 2018

127. We will therefore undertake further consultation to consider the best governance mechanisms for implementing the decarbonisation programme and report back on these in the final report.
128. Part of this will be the continued development of consistent, relevant carbon emission metrics, and the rigorous review of their implementation. This should happen not only at a macro, industry-wide level, but also at a functional level where it is possible to compare performance across the industry on a normalised basis. This will allow us to identify outliers, both good and bad, to understand better areas of good practice which may be extended within the industry, and to identify areas of poor practice which need to be removed.

QUICK WINS

129. We see that there are clear opportunities to show the commitment of the rail industry to increasing the extent and rate of decarbonisation already ongoing within the industry –
 - 129.1. Network Rail has confirmed that it is developing a low carbon strategy for its road fleet. It is their intention that this is, at the very least, consistent with the Government's targets for the proportion of cars that will be classified as low emissions vehicles by 2022. Network Rail is also supporting the Clean Van Commitment to eliminate tailpipe emission from vans in cities by 2028. In addition, Network Rail and the Transport Systems Catapult, which are both headquartered in Milton Keynes, and other innovation bodies will explore opportunities for cooperation;
 - 129.2. Rapid decarbonisation of direct energy use in stations and depots, especially in heating and lighting, and using this as a means of testing and implementing residual value mechanisms;
 - 129.3. A review of the use of lineside diesel generators across the network to put in place a plan to replace these with batteries or other lower carbon options;
 - 129.4. RSSB launched a £600k feasibility study research call and a joint Knowledge Transfer Partnership competition with Innovate UK worth over £1m at the end of October 2018. These will consider the development challenges and impacts of alternative traction options. Critically, they will assess the impacts of infrastructure improvements necessary to support possible and preferred traction options. For example, hydrogen production, storage, distribution, fuelling and safety systems and networks, and lineside charging requirements for battery trains. These will aim to report back by early 2019 and work will begin in April 2019; and
 - 129.5. The development of robust carbon performance data measurement, collation, analysis and reporting back into the industry of sufficient granularity to give useful comparative feedback and guidance at a planning and operational level.



Next steps

INITIAL ROUTE MAP FOR RAIL DECARBONISATION: DECISION POINTS AND LEVERS

130. The route map will need to develop proposals for five themes: Technological, Financial, Policy, Innovation and Carbon targets.

TECHNOLOGICAL

- 130.1. What is available now which may be implemented in a cost-effective manner;
- 130.2. What is likely to be available by 2040, tested and proven, which the decarbonisation strategy should be flexible enough to accommodate when it is mature;
- 130.3. What transitional arrangements should be provided to bridge between current and probable future technologies;
- 130.4. Dependencies, such as infrastructure developments that are a prerequisite for the successful implementation of new technologies, both those which may be provided from within the rail industry and those that may require implementation elsewhere initially, such as in the automotive industry;

FINANCIAL

- 130.5. What can be implemented straight away within franchises as they stand, perhaps by encouraging implementation of projects with a rapid return on investment;
- 130.6. What can be implemented when franchises are retendered;
- 130.7. What can be implemented with the use of residual value mechanisms and asset transfers;
- 130.8. What will require new mechanisms outside franchise arrangement to realise;
- 130.9. What incentives should be provided to drive faster decarbonisation, particularly where there is no commercial case to make the necessary changes



POLICY

- 130.10. How policy can give clear, consistent, predictable direction for decarbonisation within the rail industry;
- 130.11. How policy can support innovation and technology transfer within and into the industry;
- 130.12. What governance mechanisms will need to be considered to oversee the implementation of the recommendations and route map that we will provide in the final report

INNOVATION

- 130.13. How can innovation for other sectors be guided to find application within the rail industry;
- 130.14. What potential dependencies might there be in the implementation of technologies in the rail industry and other industries, most notably the automotive sector. This particularly applies where there is a need to roll out a supporting infrastructure such as hydrogen fuelling or battery charging networks
- 130.15. How innovation can be supported in the most challenging areas for change, most notably high speed, high intensity passenger journeys, freight and lineside charging, and in areas where there are no obvious cost-effective low carbon solutions


CARBON TARGETS

- 130.16. What 2040 targets government should set for decarbonisation and the commitments the industry sees as essential to support progress towards these;
- 130.17. Targets may include interim targets, at least in areas such as property, infrastructure and road fleet, that will give clear short-term signals to the industry;
- 130.18. What detailed carbon metrics are necessary, and how these may be delivered, for the industry to be able to identify good and bad practice in key areas of carbon management.

Annex A: Remit

RAIL LOW CARBON TASKFORCE

1. Vision
 - 1.1. For the UK to have the world's leading low-carbon railway by 2040.
1. Mission
 - 1.1. To move UK rail to the lowest practicable carbon energy base by 2040, enabling the industry to be world leaders in developing and delivering low carbon transport solutions for rail.
2. Purpose of taskforce
 - 2.1. To draft the rail industry's response to the Minister's vision, including a route map to delivering the mission which will embed delivery in business as usual.
3. Scope
 - 3.1. Identify relevant current work being delivered or planned by the industry, identify gaps in knowledge or understanding and propose solutions to these.
 - 3.2. Identify current technology developments and any potential upgrades to Infrastructure which could be delivered more cheaply [at lower whole life cost] and more efficiently which can support the vision, outline the potential appropriateness and current understanding of costs and benefits in each. It is envisaged that there will not be 'one answer for all' and solutions should fit the challenge.
 - 3.3. Identify priority areas for resolution and options for addressing these.
 - 3.4. Identify key opportunities for achieving the vision and options for taking advantage of these.
 - 3.5. Identify a timeline of key milestones.
 - 3.6. Propose a governance and monitoring framework for achieving the vision.
 - 3.7. The strategy shall cover freight, franchised passenger services and non-franchised passenger services, non-traction energy including stations and fleet on the mainline network. It shall not cover heritage rail services (the strategy does not cover the UK electric grid mix).
 - 3.8. The strategy shall cover England, Wales and Scotland.
4. Operation and management
 - 4.1. The taskforce shall include members from relevant industry parties including ROSCOs, Network Rail, RDG, RSSB, RIA, RFG and RDG Freight Group and may co-opt other expertise / establish working groups as necessary.
 - 4.2. RSSB shall provide the secretariat.

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- 4.3. Meetings shall be quorate when at least three representative groups (including the Chairman) or authorised alternatives are present.
 - 4.4. Malcolm Brown, Angel Trains, shall chair the taskforce.
 - 4.5. Meetings shall be as required.

5. Timescales

- 5.1. Initial response by September 2018.

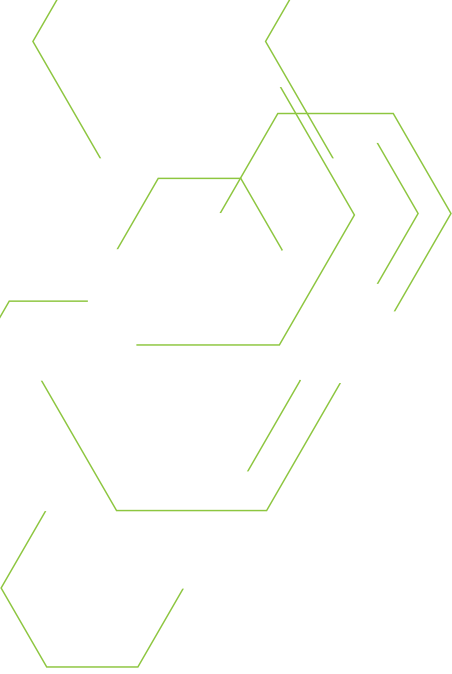
TASK FORCE MEMBERS AND SECRETARIAT

Name	Role	Organisation
Malcolm Brown, <i>Chair</i>	CEO/Senior Principal	Angel Trains/ AMP Capital Investors UK Ltd
Maggie Simpson	Executive Director	Rail Freight Group
David Clarke	Technical Director	Railway Industry Association
Wendi Wheeler	Energy & Carbon Strategy Manager	Network Rail
Gary Cooper	Director, Planning, Engineering, Operations	Rail Delivery Group
Paul Smart	COO Freightliner	RDG Freight Group
Tom Lee	Director of Standards	RSSB
Shamit Gaiger	Programme Director Sector Policy	RSSB

Secretariat

Anthony Perret	Head of Sustainable Development Programme	RSSB
Andrew Kluth <i>Technical author</i>	Lead Carbon Specialist	RSSB

The RSSB has made an invaluable contribution in the research and drafting of this initial report. The taskforce wishes to acknowledge this support, which exemplifies the wider contribution the RSSB makes to the rail industry.



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