Network RUS: Electrification Strategy

Draft for Consultation

May 2009

Foreword

I am pleased to present this draft Electrification Strategy, which forms part of the Network Route Utilisation Strategy (RUS). The Network RUS looks at issues affecting the whole network rather than in specific geographical areas.

Approximately 40 per cent of the network in terms of track miles is currently electrified, though several main lines, much of the cross country network, as well as key freight links and diversionary routes remain un-electrified. This document therefore sets out a potential longer-term strategic approach to further electrification of the network.

Electrification presents a huge opportunity for the industry, for those who use the railway and for the country as a whole. Our analysis shows the long-term benefits of electrifying key parts of the network in terms of both reducing its ongoing cost to the country and improving its environmental performance are significant.

Governments in London, Edinburgh and Cardiff are looking to reduce both the operational cost of the railway and overall carbon emissions, as well as encouraging modal shift. Our analysis identifies the benefits a strategic approach to electrification would bring in each of these areas.

In the current economic climate, any investment will inevitably raise significant questions about affordability even where there are clear longer term cost savings. The industry will therefore need to work with government and other funders on this issue.

Electrification also has a potentially significant role to play in reducing carbon emissions from rail transport as well as improving air quality and reducing noise. Electric trains, on average, emit 20 to 30 per cent less carbon than diesel trains, and their superior performance in terms of braking and accelerating can help reduce journey times. In addition, they provide more seats for passengers, making a greater contribution to increasing the overall capacity of the railway. Passengers and freight operators would also both benefit from an improved service in other ways, such as through the creation of more diversionary routes.

In England and Wales, two options in particular – the Great Western and Midland Main Lines – are shown to have high benefit to cost ratios. These options, along with a key strategic infill scheme, are both presented in the proposed strategy. In the case of the Great Western Main Line, the work required to the existing network at the western end of the Crossrail route could, in effect, be the first stage of electrifying the line.

In Scotland, the main focus is on electrification of priority schemes in the Central Belt, allowing electric traction between Edinburgh and Glasgow via Falkirk, and an extension to Dunblane and Alloa.

As with each RUS, this has been developed with the full input of the rest of the rail industry including train and freight operators, as well as government and passenger representatives. I thank everyone for their contribution to date. This is a draft for consultation so we are now seeking feedback and comments to support and inform our further analysis. Comments are invited before a deadline of 14 July and we are working towards publication of the final strategy later this year.

Iain Coucher

Executive Summary

At present approximately 40% of the British rail network (measured in track miles) is electrified. These lines carry a little under half of the passenger train miles operated and around 5% of the freight train mileage. Several main lines, much of the cross country network, many key freight links and diversionary routes remain un-electrified. Consequently, a large number of passenger and freight services are operated by diesel hauled trains. In many cases diesel trains operate on the electrified network (a practice known as 'running under the wires') because their diverse range of origins and destinations involve running on unelectrified sections.

As a consequence, a significant proportion of passengers and the majority of freight are carried by diesel operation which is more costly and produces more pollution than its electric equivalent.

In the last two years, both the Department for Transport and Transport Scotland have published their long term visions for the rail network. Both governments wish to increase usage of the network, whist lowering its operating costs and minimising its environmental impact. The Welsh Assembly Government is committed to the same objectives under the Wales Transport Strategy. This Route Utilisation Strategy considers whether the expansion of the proportion of the UK railway operated under electric traction should be increased to help realise the visions.

Other than the Freight RUS, which was established in May 2007, the Network RUS is the only RUS which covers the entire network. Its network wide perspective – supported by a stakeholder group with network wide expertise – enables the development of a consistent approach to issues which underpin the development of the network. It enables strategies to be developed by the rail industry, its funders, users and suppliers which are underpinned by a network wide perspective to planning. The outputs of the RUS will used in subsequent industry planning, including the geographical RUSs, thereby ensuring that the key issues are dealt with consistently throughout the RUS programme.

The Network RUS is overseen by a Stakeholder Management Group consisting of Network Rail, The Department for Transport, Transport Scotland, the Welsh Assembly Government, Transport for London, the Passenger Transport Executive (PTE) Group, the Association of Train Operating Companies (ATOC), freight operating companies, Passenger Focus, London TravelWatch, the RoSCos and the Rail Freight Group. The Office of Rail Regulation (ORR) attended Stakeholder Management Group meetings as observers. The Electrification Strategy was developed by a working group consisting of Network Rail, the Department for Transport, Transport Scotland, the Welsh Assembly Government, ATOC, DB Schenker, Transport for London, the PTE Group, the Rail Industry Association, RoSCos and the Rail Freight Group, again with the ORR as observers.

Despite the unique role of the Network RUS in the RUS programme, the process followed is consistent with that adopted throughout the RUS programme. It has involved an understanding of the current electrified network, consideration of the 'gaps' in current electrification, the drivers of change and the development of business cases for further electrification.

The potential for reduction in whole industry costs is one of the key drivers of change. Compared to a diesel operation, an electric service will have lower rolling stock operating costs (fuel savings currently estimated as between 19 and 26 pence lower per vehicle mile and maintenance costs at approximately 20 pence less per vehicle mile for passenger vehicles), have higher levels of vehicle reliability and availability and lower leasing costs. The superior performance of electric vehicles can provide journey time savings. Whilst these may be modest for high speed long distance services, they can be more significant in urban areas where frequent stops make acceleration savings more significant and, if the savings are significant on a particular route, diagrams could be saved. For freight services the use of loops may be avoided. Electric trains have more seats than diesel loco hauled trains, making a greater contribution to accommodating anticipated growth in demand.

Electrification also has a significant role to play in reducing carbon emissions. Electric vehicles, on average, emit 20% to 30% less CO2 emissions than their diesel counterparts. In addition, they tend to be quieter in operation.

The service reliability, journey time and environmental benefits of electrification result in an improved product for the passenger. Similarly, there is potential for freight operators to provide a superior product, potentially with lower operating costs. The ability of freight operators to do this potentially increases as more of the network is electrified. It is envisaged that infill electrification would enable cost savings to be achieved on some routes for operators with existing electric locos. Further electrification potentially increases the availability of diversionary routes for electric vehicles, reducing the need for bus substitution for passenger services, improving the freight product and easing the provision of access for maintenance work. Any further electrification of the network would involve highly reliable and easily maintainable equipment. It would be delivered efficiently at low benchmarked unit costs with minimal disruption to users. The application of modular techniques to construction and the deployment of rapid delivery systems would enable as much work as possible to be carried out within standard eight hour possessions. The efficient delivery units would be flexible, capable of working individually or in combination, and would be able to play a useful on-going role in the maintenance of the electrified network.

Appraisal of the options suggested that further electrification represents good value for money. Two options – the Great Western Main Line and the Midland Main Line – have high benefit to cost ratios. Indeed they potentially involve a net industry cost saving rather than net cost over the appraisal period of 60 years. There would be a requirement for upfront investment by Network Rail but this would be offset by lifetime cost savings, largely in the costs of train operation. Electrification of the London to Maidenhead section of the Great Western Main Line as part of the Crossrail project will present an opportunity to ramp up production and to start using the recommended efficient delivery techniques,

These options, along with a strategic infill scheme – Gospel Oak to Woodgrange Park and the Thameshaven branch – with the best business case are presented as the potential Core Strategy for England and Wales and will be discussed further with the DfT. Progression of schemes will be dependent on their affordability.

A number of Scottish schemes are identified as priority schemes. The strategy would start with electrification from Edinburgh to Glasgow via Falkirk and be extended to Dunblane and Alloa, and to allow Glasgow to Falkirk and Motherwell to Cumbernauld services to run under electric traction.

It is recommended that the improved knowledge of implementation techniques and the emerging costs of the Core Strategy be used to inform a decision on whether there would be a case for the implementation of further schemes. Geographical RUSs will provide detailed understanding of demand, service structures and rolling stock deployment. Taken together, the updated knowledge of costs and demand will enable business cases to be updated to inform an updated Network RUS Electrification Strategy which would identify the strongest candidates to take forward. It is also recommended that funding for early implementation of strategic infill electrification schemes is sought from a variety of sources.

Active provision will be made to ensure that current investment programmes will be consistent with a programme of electrification. This would include all works for both physical clearance and electrical immunisation. In addition, it is proposed that electrification reconstruction works on routes proposed for gauge clearance in the Freight RUS and the Strategic Freight Network should take any opportunities for more efficient delivery through the integration of relevant works.

1 Background

1.1 Background

Following the Rail Review in 2004 and the Railways Act 2005, the Office of Rail Regulation (ORR) modified Network Rail's licence in June 2005 (as further amended, April 2009) to require the establishment of Route Utilisation Strategies (RUSs) across the network. Simultaneously, ORR published guidelines on RUSs. A RUS is defined in Condition 1 of the revised Licence, in respect of the network or part of the network, as a strategy which will promote the route utilisation objective.

The route utilisation objective is defined as:

'the effective and efficient use and development of the capacity available on the network, consistent with the funding that is, or is likely to become, available'

Extract from ORR Guidelines on Route Utilisation Strategies, April 2009

The ORR Guidelines explain how Network Rail should consider the position of the railway funding authorities, their statements, key outputs and any options they would wish to see tested.

The guidelines set out principles for RUS scope, time period, and process to be followed and assumptions to be made. Network Rail has developed a RUS Manual which consists of a consultation guide and a technical guide. These explain the processes we will use to comply with the Licence Condition and the guidelines. These and other documents relating to individual RUSs and the overall RUS programme are available on the Network Rail website at www.networkrail.co.uk.

The process is designed to be inclusive. Joint work is encouraged between industry parties, who share ownership of each RUS through its industry Stakeholder Management Group.

RUSs occupy a particular place in the planning activity for the rail industry. They use available input from Government Policy documents such as the DfT's Rail White Papers and Rail Technical Strategy, the Wales Rail Planning Assessment, and Transport Scotland's Scottish Planning Assessment. The recommendations of a RUS and the evidence of relationships and dependencies revealed in the work to reach them in turn form an input to decisions made by industry funders and suppliers on issues such as franchise specifications, investment plans or the High Level Output Specifications.

Network Rail will take account of the recommendations from RUSs when carrying out its activities and the ORR will take account of established RUSs when exercising its functions.

1.2 Document structure

This document starts by describing, in Chapter 2, the role of the Network RUS in the RUS programme. It describes the scope of the Network RUS Electrification Strategy including its geographical coverage, the time horizon which it addresses, and the key issues which it will consider. It outlines the policy context and the relationship between the RUS and related policy issues which are being considered concurrently by our funders.

The extent and characteristics of the existing electrified railway are considered in Chapter 3. Chapter 4 considers the drivers which may lead to the development of a strategy for further electrification in the context of a policy to develop an efficient growing railway. Consideration of the current provision in the context of these drivers gives rise to a number of 'gaps' between the electrified railway currently in operation and what will be required in the future. These gaps are presented in Chapter 5.

Chapter 6 outlines the options which were proposed by the RUS Working Group to bridge the potential gaps in provision identified in Chapter 5. Chapter 7 presents the strategy itself. It covers the key considerations and recommendations for a future electrification programme. Finally Chapter 8 discusses the mechanisms for implementing the RUS and how you can respond to the consultation.

The appendices contain supporting data.

2 Scope and Planning context

2.1 The role of the Network RUS within the RUS programme

Other than the Freight RUS which was published in March 2007, the Network RUS is the only RUS which covers the entire network. Its network wide perspective – supported by a stakeholder group with network wide expertise – enables the development of a consistent approach on a number of key strategic issues which underpin the future development of the network.

The nature of the Network RUS, the broad range of its stakeholders and its inevitable interface with other key strategic workstreams make it somewhat different from the geographical RUSs. To this end, the Network RUS team has developed a meeting structure, industry consultation and programme to ensure that it produces key, timely and thoroughly consulted deliverables.

Network wide perspective

The Network RUS enables strategies to be developed by the industry, its funders, users and suppliers which are underpinned by a network wide perspective of rail planning. The development of such strategies, which will subsequently act as inputs into the geographical RUSs, will ensure that key issues are dealt with consistently throughout the RUS programme.

This approach enables strategies to be developed which by their very nature cross RUS boundaries (e.g. the development of future rolling stock families and electrification) or benefit from the development of strategies for best practice for different 'sectors' of the railway (e.g. strategies for inter-urban, commuting, rural stations).

Organisation: Stakeholder Management Group and Working Groups

In common with all other RUSs, the Network RUS is overseen by a Stakeholder Management Group (SMG). The Stakeholder Management Group is chaired by Network Rail. It has members from:

- Department for Transport (DfT)
- Transport Scotland (TS)
- Welsh Assembly Government (WAG)
- Transport for London (TfL)
- The Passenger Transport Executive Group (PTEG)
- Association of Train Operating Companies (ATOC)
- Freight Operating Companies
- Passenger Focus
- London TravelWatch
- Rail Freight Group (RFG)
- RoSCos
- ORR (observers)

The majority of the work and detailed stakeholder consultation, however, is carried out within Working Groups which have been formed to steer each of the Network RUS workstreams. The Working Groups manage each of the workstreams as if it were a 'mini' RUS. The groups vary in size but are all small enough to ensure effective levels of engagement between the participants. However, given that each is composed of individuals with a relevant expertise or strategic locus for the specific 'mini RUS' strategy, they play an important role in recommending a strategy for endorsement for the SMG.

The SMG is the endorsement body for the outputs of the individual workstreams. Its agenda concentrates on key decisions – from endorsement of the Working Group remits to approval of key documents and ultimately the resulting strategy. If the SMG has comments or questions on papers these would be referred back to the Working Group which contains each of the SMG organisations' specialist representatives.

Each geographical RUS will use the strategies recommended by the established Network RUS when developing its route based strategy. The strategies identified by the Network RUS will be considered further by the geographical RUS in the light of other factors identified by that RUS which effect the utilisation of the route concerned. It is envisaged that the Network RUS strategy will usually be adopted by the geographical RUS.

Network RUS workstreams

The first meeting of the SMG identified those elements of strategy which it wished to include in the Network RUS. A Working Group was formed to take forward each chosen element of strategy. The Electrification Working Group consists of members of the following organisations:

- Network Rail
- ATOC
- FOCs
- DfT
- Transport Scotland
- Welsh Assembly Government
- TfL
- PTEG
- RFG
- RoSCos
- Rail Industry Association
- ORR (observers)

The Rolling Stock Working Group has worked closely with the Electrification Working Group to ensure that synergy exists between the strategies. The Network RUS Rolling Stock and Light Maintenance Depots Strategy is clearly dependent on the Electrification Strategy and will be published following the formal establishment of the latter.

2.2 Time horizon

The Network RUS takes a thirty year perspective to be consistent with the long term views of transport planning taken by UK governments in their recent strategy documents, notably the DfT's Rail White Paper and Rail Technical Strategy (2007) and Transport Scotland's Strategic Transport Project Review (2008).

The infrastructure which powers electric traction has an operational life of approximately 40 years. It is important therefore that any strategy for its development should consider the prospective uses of the railway over this period.

2.3 Planning context

The DfT published its 'Delivering a sustainable railway' White Paper in July 2007. It provided a vision for the next thirty years for rail planning in England and Wales. Over this period, it envisaged a doubling of passenger numbers and of freight transported by rail. It envisaged a railway which would expand to meet the increased demand, reduce its environmental impact, and meet increasing customer expectations, whilst at the same time continuing to improve its cost efficiency.

The White Paper stated that the case for network – wide electrification would be kept under review but that, at the point of publication, it had not been made.

It said that:

'*the right long term solution for rail would be one that minimises its carbon footprint and energy bill. That depends on the relative rates at which the carbon footprint of electricity generation declines and the rate at which options become available for low-carbon, self-powered trains, neither of which can be forecast at present'.*

The DfT's 'Rail Technical Strategy' (RTS) was produced to accompany the White Paper. The RTS brings together a long-term vision of the railway which optimises the use of existing technology and predicts the impact of new technology.

It identifies a number of long term themes for change:

- optimised track-train interface
- high reliability, high capacity
- simple, flexible, precise control system
- optimised traction power and energy
- an integrated view of safety, security and health
- improved passenger focus
- rationalisation and standardisation of assets
- differentiated technical principals and standards.

The most directly relevant theme to this RUS is the optimisation of traction power and energy. This includes reference to the selective extension of existing electrification where there is a business need and raises the prospect of bi-mode trains capable of running on or off wire with the facility for energy storage and with on-board power. A number of other themes, however, are relevant, notably the optimisation of track-train interface theme which makes reference to a vision of light but strong rolling stock and the 'high reliability, high capacity' theme.

The RTS describes electrification as a 'mature and available technology' and 'an efficient way of transferring energy from power station to train' but also points out that its 'high capital costs' would need to compete with other spending priorities and that any decision to electrify the whole network would be 'vulnerable in the long term to the development of a renewable source of portable energy'.

The DfT is seeking to replace the diesel Intercity high speed trains (HST) procured by British Rail during the 1970s with a new, higher capacity, more environmentally friendly train. This provides an early opportunity to introduce trains which would fit with the Government's long term vision. A fleet of new long trains known as Super Express is to be procured as part of an Intercity Express Programme (IEP). The DfT has announced that the fleet will consist of electric diesel and bi-mode variants. The development of an electrification strategy has direct relevance to decisions on the balance of the different types of trains within the new fleet.

Transport Scotland has published its long term "Strategic Transport Projects Review" which sets out Scottish Ministers priorities for future transport investment in the period 2012 – 2022 and beyond. Project 6 Electrification of the Rail Network sets out the concept of a rolling programme of electrification of the bulk of the network. The key drivers identified were transport related (reduced journey times) and environmental (reduced emissions). The reduced emissions outcome is a combination of the inherently better emissions arising from the use of electric traction compared with diesel plus a move towards lower carbon power generation.

These objectives are consistent with the Scottish Governments objective of 'sustainable economic growth' and a 'Greener Scotland.'

The Strategic Transport Projects Review envisaged that electrification would be delivered on a phased process. In the short term this would include:

- Phase 1 : Edinburgh – Glasgow Improvement Project which is a package of service driven route enhancements which include infrastructure enhancements and electrification of the Edinburgh-Glasgow via Falkirk, the routes to Stirling / Dunblane / Alloa and the Glasgow-Cumbernauld-Falkirk route (EGIP Project STPR Project 15)
- Phase 2: Electrification of the remaining routes in the Central Belt.

In the longer term, in the period beyond their Strategic Transports Projects Review process, Transport Scotland would include:

- Phase 3: Electrification of the routes between Edinburgh, Perth and Dundee including the Fife Circle
- Phase 4: Electrification from Dunblane to Aberdeen
- Phase 5: Electrification from Perth to Inverness

The Scottish National Planning Framework (NPF) includes the Scottish Ministers' long term aspiration to electrify the whole Scottish rail network.

The Welsh Assembly Government is committed to the objectives of increased usage of the network, whist lowering its operating costs and minimising its environmental impact, under the Wales Transport Strategy.

2.4 Scope of the RUS

At the outset of the work on this RUS, the Working Group agreed a remit which gave an overarching objective and identified key issues to be addressed at each stage in the RUS. This section outlines the agreed remit.

1. The objective of this RUS is to establish a strategy for further electrification of the railway.

2. It will provide baselining information to show the current extent of the electrified network, together with an indication of current traffic densities on both the electrified and non-electrified parts of the network. The part of the electrified network suitable for regenerative braking will also be shown.

3. The baselining phase will include an understanding of:

- factors influencing the capital cost of electrification (differentiated by route type as appropriate) and the maintenance cost of fixed equipment
- availability rates for diesel and electric trains
- maintenance, fuelling and fuel costs of diesel and electric trains, including the effect of regenerative braking in the case of electric trains
- emissions produced by diesel and electric trains
- weight of diesel and electric trains
- reliability performance differences between diesel and electric trains
- where applicable, differences in passenger capacity between diesel and electric trains
- understanding of spare capacity in power supplies on the existing electrified network
- understanding of current regenerative braking and where the capability does not exist
- dates for major resignalling schemes on the non-electrified parts of the network

4. Gaps in current capability will be classified in relation to the role that electrification may play in delivering an improved service, that is:

- in order that an existing (or proposed) passenger service may be converted to electric traction
- to enable freight services to be converted to electric traction or to provide alternative routes for freight trains which are currently electrically hauled
- in order to provide a diversionary route for a route which is already electrified
- in order to provide a new pattern of passenger services.

5. Options to address gaps would be likely to be:

- lower whole life cost urban electrification
- lower whole life cost interurban electrification
- infill electrification
- tram type operation / regional electrification

depending on location and traffic type. The business case will be evaluated against a base of do-nothing, and appraised according to current DfT guidelines. A preliminary evaluation of schemes will establish a priority list for appraisal.

The option of not providing electrification at "difficult" locations, in conjunction with rolling stock designed to accommodate gaps in electrification should be included.

Having established the key determinants of the business case for electrification, an indicative assessment will be made of the geographical extent of the programme. A strategy for delivery of the programme will be developed.

In constructing a programme of electrification, the following will influence the ordering of schemes:

- capital cost of scheme
- benefits of the scheme
- synergy between schemes
- timing of track and or signalling renewals on the route to be electrified
- timing of gauge clearance works
- requirement for, and suitability of, diesel rolling stock displaced by the scheme
- desirability for steady workload for electrification teams.

As mentioned in Chapter 1, the RUS outcome will help inform the Department for Transport (DfT) and Transport Scotland's High Level Output specifications.

This RUS takes into account relevant findings from a number of on-going workstreams: notably the DfT’s Technical Strategy Advisory Group (TSAG) and the on-going technical and strategic thinking underlying the development of a new Intercity Express train have been recognised.

3 Baselining

3.1 Today's electrified network

Approximately 40% of the British rail network (measured in track miles) is currently electrified. Of this two thirds is equipped with overhead line alternating current electrification, whilst the remainder of the system is predominantly third rail direct current electrification with some small local systems.

Figure 3.1 illustrates the extent of the electrified network.

In addition, Network Rail is funded within the current control period to deliver schemes which involve electrification from Barnt Green to Bromsgrove and Airdrie to Haymarket. The Glasgow Airport Rail Link will also be electrified.

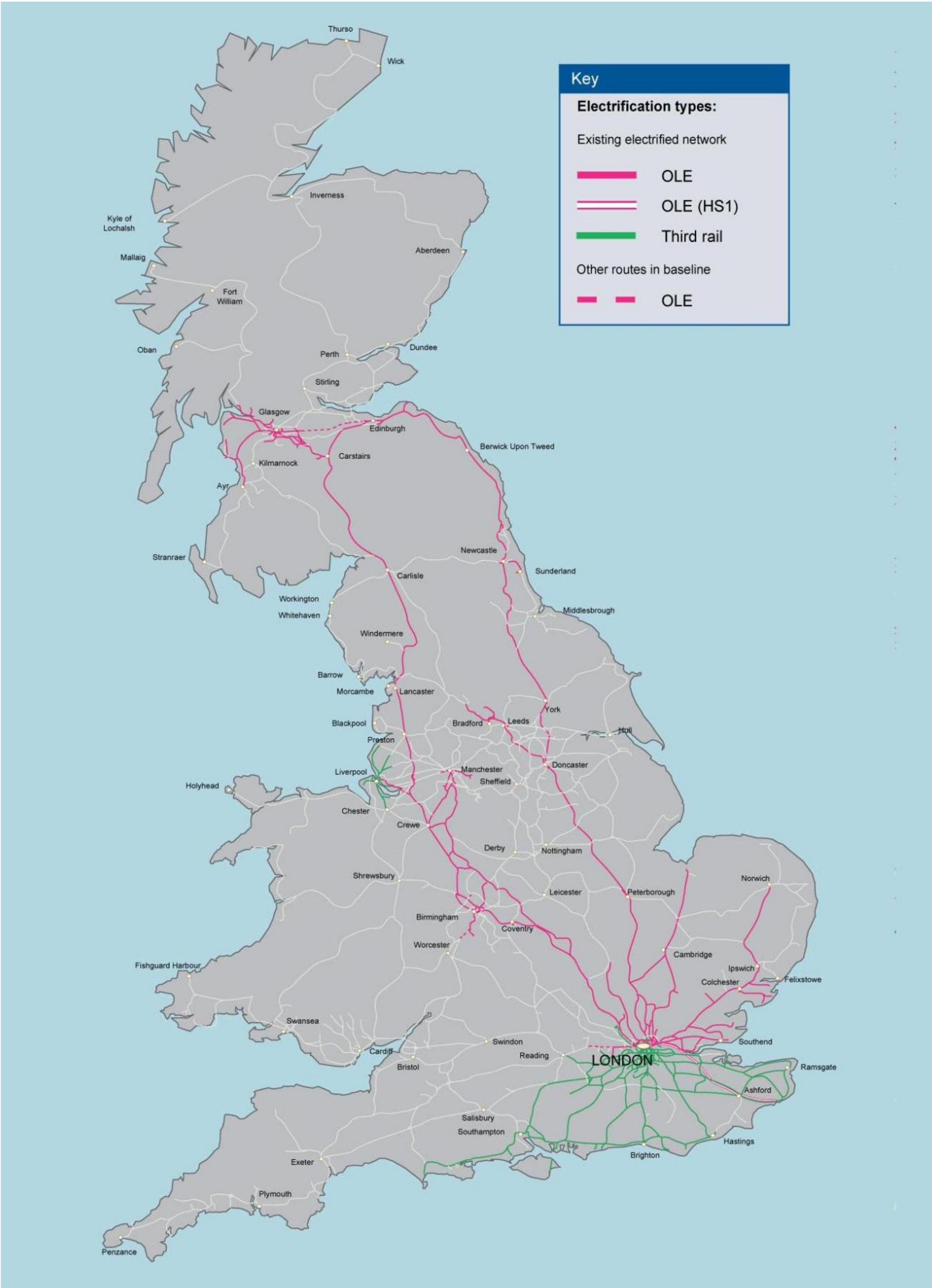
The baselining also assumes that the Great Western Main Line between Airport Junction and Maidenhead will be electrified under the Crossrail project.

The West Coast Main Line, East Coast Main Line, Great Eastern Main Line and part of the Midland Main Line are electrified with an overhead line system. Overhead line electrification is also provided on most of the remaining London suburban network north of the River Thames, and parts of the suburban networks of Birmingham, Glasgow, Leeds and Manchester. The route from Newcastle to Sunderland is electrified at 1500V DC for the Tyne and Wear metro trains, which share the route.

The overhead line system distributes power in an efficient way by using a high voltage of 25kV. The power is provided to the train via a pantograph which runs along the contact wire. The contact wire is suspended from a catenary cable which is in turn supported by a series of lineside structures, such as cantilevers. The train has a transformer on board to lower the voltage to a level suitable for the traction system and various train service supplies. The train returns the current via its wheels to the rails. The power feeding system enables the route to be sectioned which allows for effective control of the power and backup feeding to be switched in times of disruption.

In designing an effective electrification system there are a number of objectives which need to be balanced, for example the need to distribute as much power as necessary to sustain the rail service and minimising the interference from the electrification system into other sensitive systems such as the signalling and telecommunications equipment along the route. As a general rule, the interference is greater where there is a high electric current.

Figure 3.1 Baseline: Electrification types



Traditionally a solution to these issues has been achieved by limiting the power at each feeder station in the classic configuration illustrated in Figure 3.2 This design included 'booster' transformers and a return wire. These act to draw the return current from the rails thus reducing the level of interference in nearby lineside systems. These two configurations have been extensively and successfully used in the UK. However, they have a number of disadvantages in that the 'booster transformers' reduce the efficiency of the system and limit the power that can be distributed. They also cause the electrification system to react with and amplify the electrical noise created by modern traction packages. This configuration requires a series of connections to the national grid, typically at the relatively low voltages of 132kV. At these levels the fact that the railway only uses one of the three phases of current supplied can cause a problematic imbalance to the grid supplier.

To improve on these arrangements moving forward, it will be possible to apply two configurations that could be used to address these issues. Firstly we can take advantage of more electrically 'robust' telecommunication and signalling systems.

The use of optical fibre rather than copper wire for transmission and the application of more resilient train detection systems, such as axle counters, means that much of the interference is eliminated. This allows more power to be provided by the classic arrangement and avoids the use of the wasteful booster transformer arrangement. For more intensively used routes an Autotransformer system could be applied. This configuration allows more power to be fed into the system at 50kV instead of 25kV. Power is transferred by two wires (the contact wire and the auxiliary feeder as shown in Figure 3.3).

Figure 3.2 Classic Overhead System

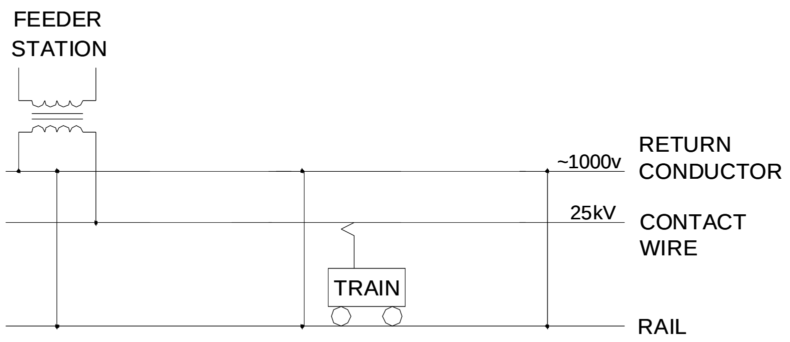
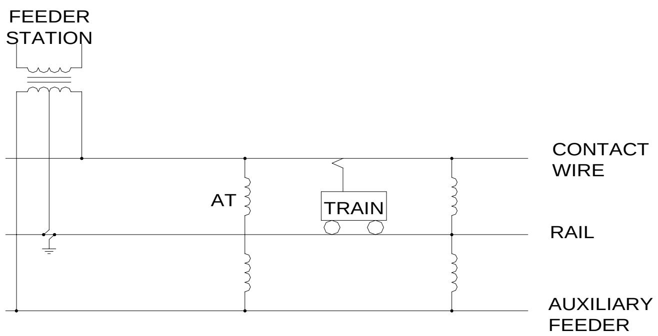


Figure 3.3 Autotransformer System



Autotransformers (marked ‘AT’) at points along the track then provide power to the train at 25kV. Booster transformers are not used.

The connection to the grid is made at either 275kV or 400kV where the traction load is proportionally smaller thus reducing the impact of the single phase load on the three phase grid. Due to their ability to supply much more power, AT systems effectively provide future-proofing against future growth in demand for passenger and freight.

Third rail electrification is provided on London suburban routes south of the River Thames and routes between London and the south coast, as well as between Euston and Watford, parts of the North London Line and parts of the Merseyrail suburban network.

With a third rail system, power is taken form the national grid at 132kV three phase AC. It is then transformed to 33kV or lower and distributed along the railway, normally in concrete troughing. Due to the low conductor rail voltage substations have to be close to each other, typically every five kilometres. The power is delivered to these lineside substations where it is converted to 660/750V DC. From the substations, the DC current is connected to a third rail, called the conductor rail, and the trains are fitted with ‘shoes’ which slide on the conductor rail to collect the current. The current is returned to the substations via the wheels and the rails. Route sections used by London Underground rolling stock are equipped with a fourth rail for the return current.

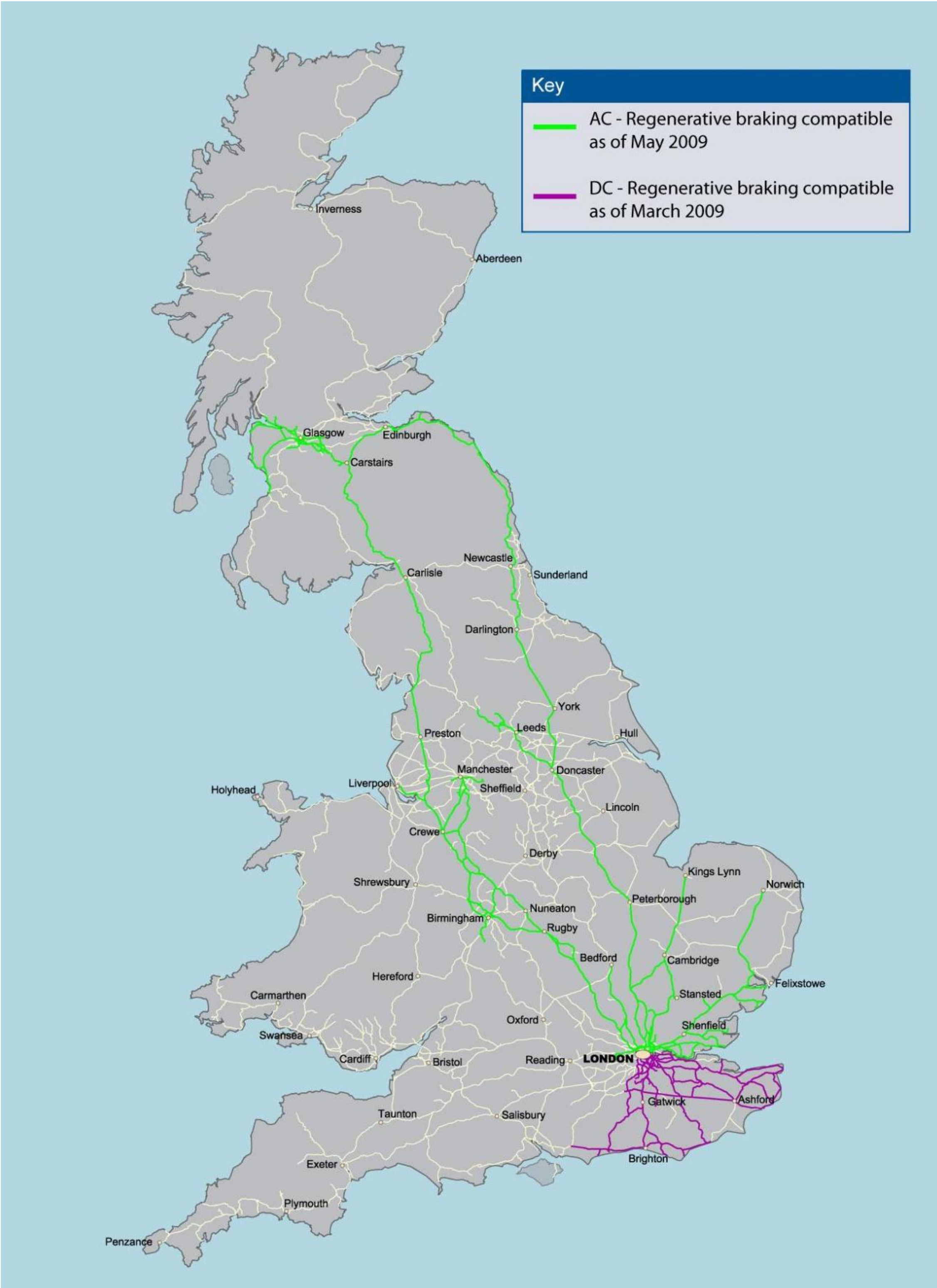
The overhead line system is generally the first choice used for new electrification schemes, with the exception of infill schemes in areas already equipped with the third rail system.

The AC electrified network is equipped for regenerative braking, whereby the kinetic energy of the train is converted to electrical energy and fed back into the power supply system, leading to a saving in energy consumption of 10% to 15%.

Regenerative braking is gradually being introduced to the DC network and is expected to secure similar savings in consumption.

Figure 3.4 shows the extent of the network which is equipped for regenerative braking.

Figure 3.4 Regenerative Braking



3.2 Today's usage

The existing electrified lines tend to serve the busiest parts of the network and consequently carry a greater density of traffic than the non-electrified parts of the network. Currently a little under half of total train miles are operated by electric traction.

Table 3.1 shows the train miles and tonne miles which are operated by electric traction for passenger and freight trains respectively.

Electric trains tend to be operated in longer formations than diesel trains, reflecting the demand in the markets they serve. Consequently, whilst they operated 49% of passenger train miles in 2006/7, they accounted for 59% of tonne miles.

Only 6% of freight train mileage (or 5% of freight tonne miles) were operated under electric traction in 2006/07. More intermodal traffic than bulk traffic is electric loco-hauled, hence the proportion of train miles operated by electric traction is a little higher than the proportion of tonne miles.

Figures 3.5 and 3.6 indicate the density of traffic (measured by tonnes passing over each route section) on both the electrified and non electrified parts of the network. The most heavily used unelectrified routes are the Midland Main Line, the Great Western Main Line, South Humberside, the Edinburgh to Glasgow route and the core cross country routes.

Table 3.1 Traffic operated by electric traction

	Passenger		Freight	
	Operated by electric traction	Proportion of total	Operated by electric traction	Proportion of total
Train miles million per annum	142	49%	2	6%
Tonne miles 000 million per annum	40	59%	2	5%

Source Network Rail's Infrastructure cost model 2006/7 data

Figure 3.5 Tonnage carried on the electrified network 2007/08

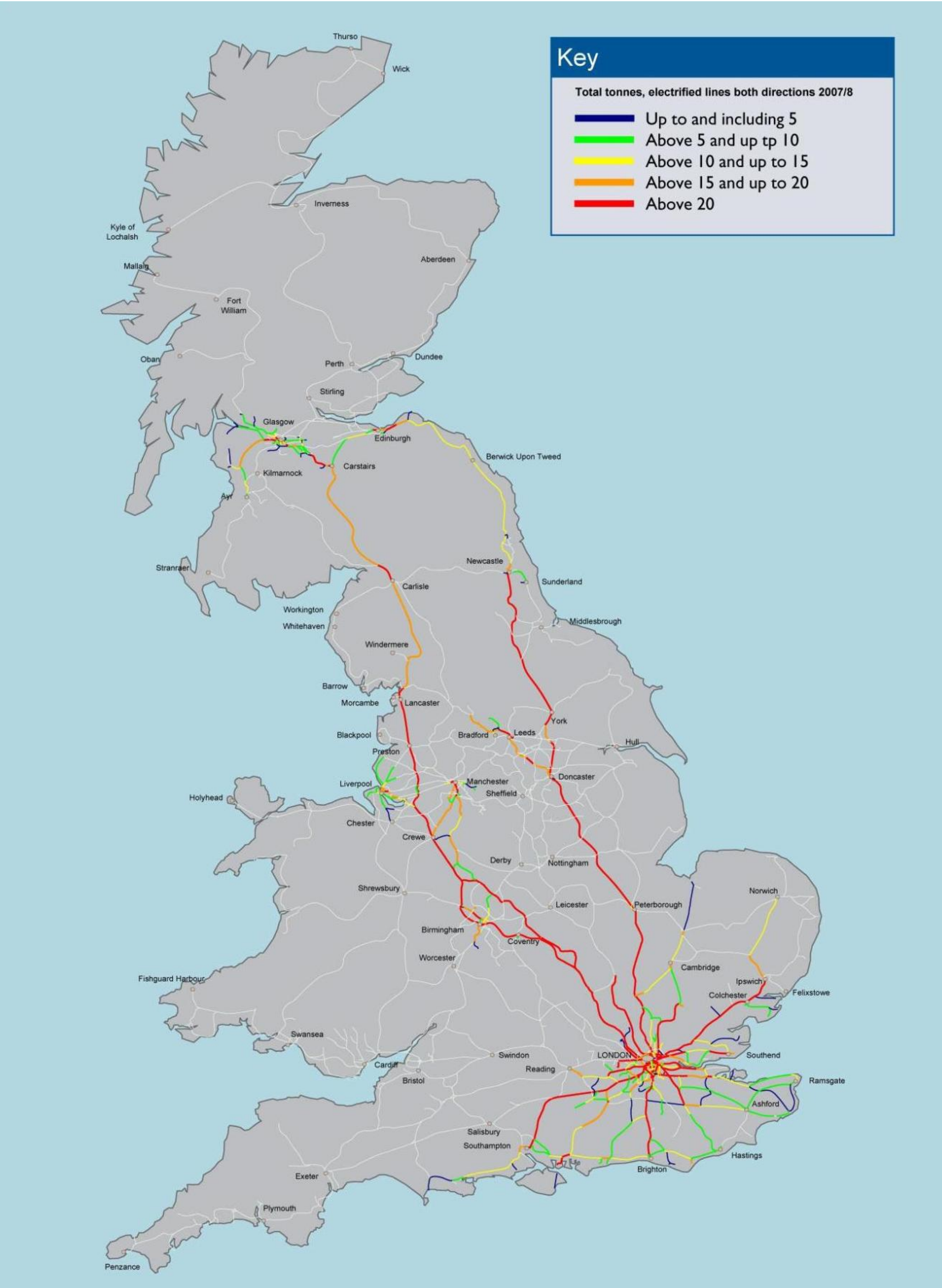
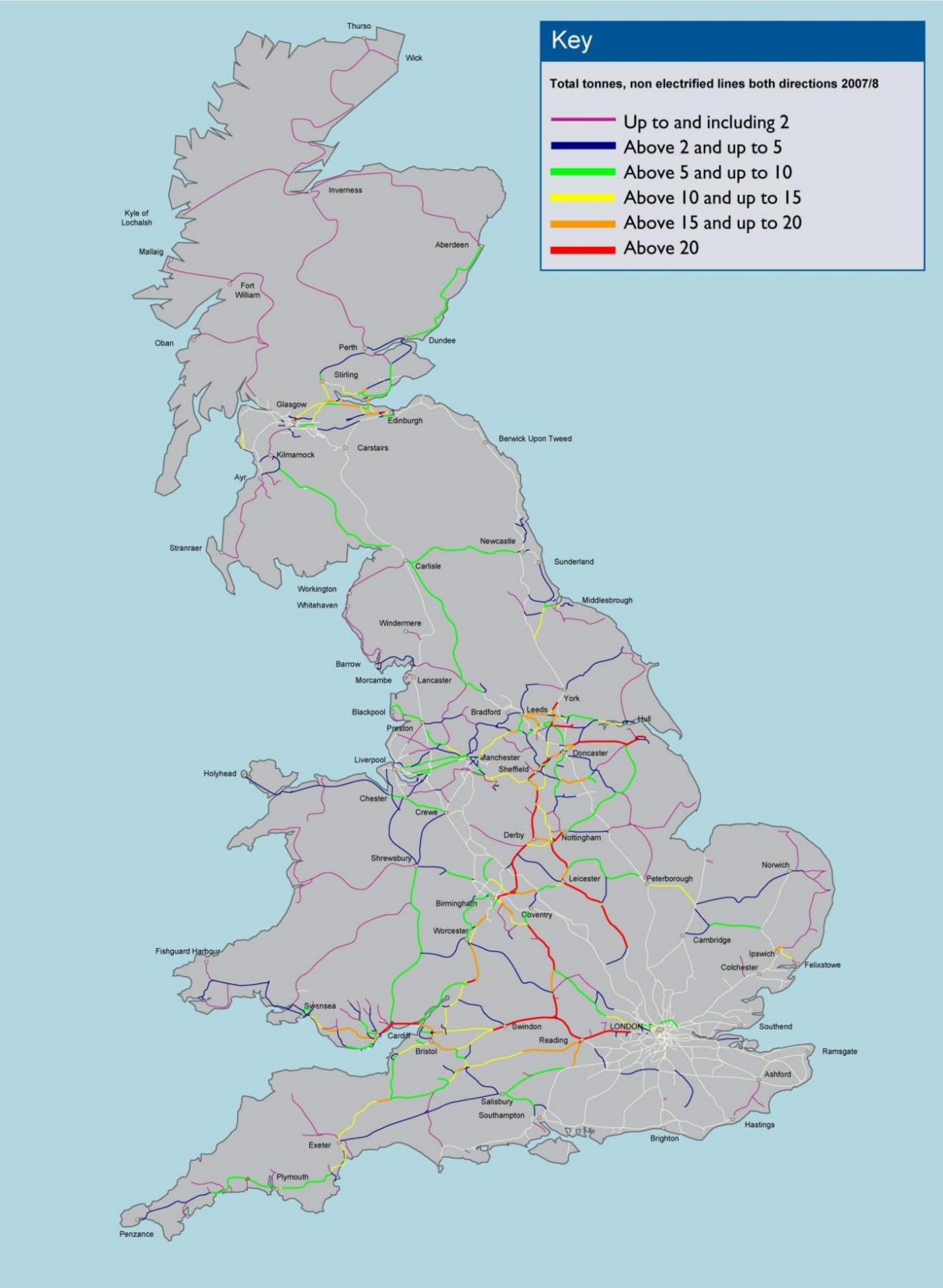


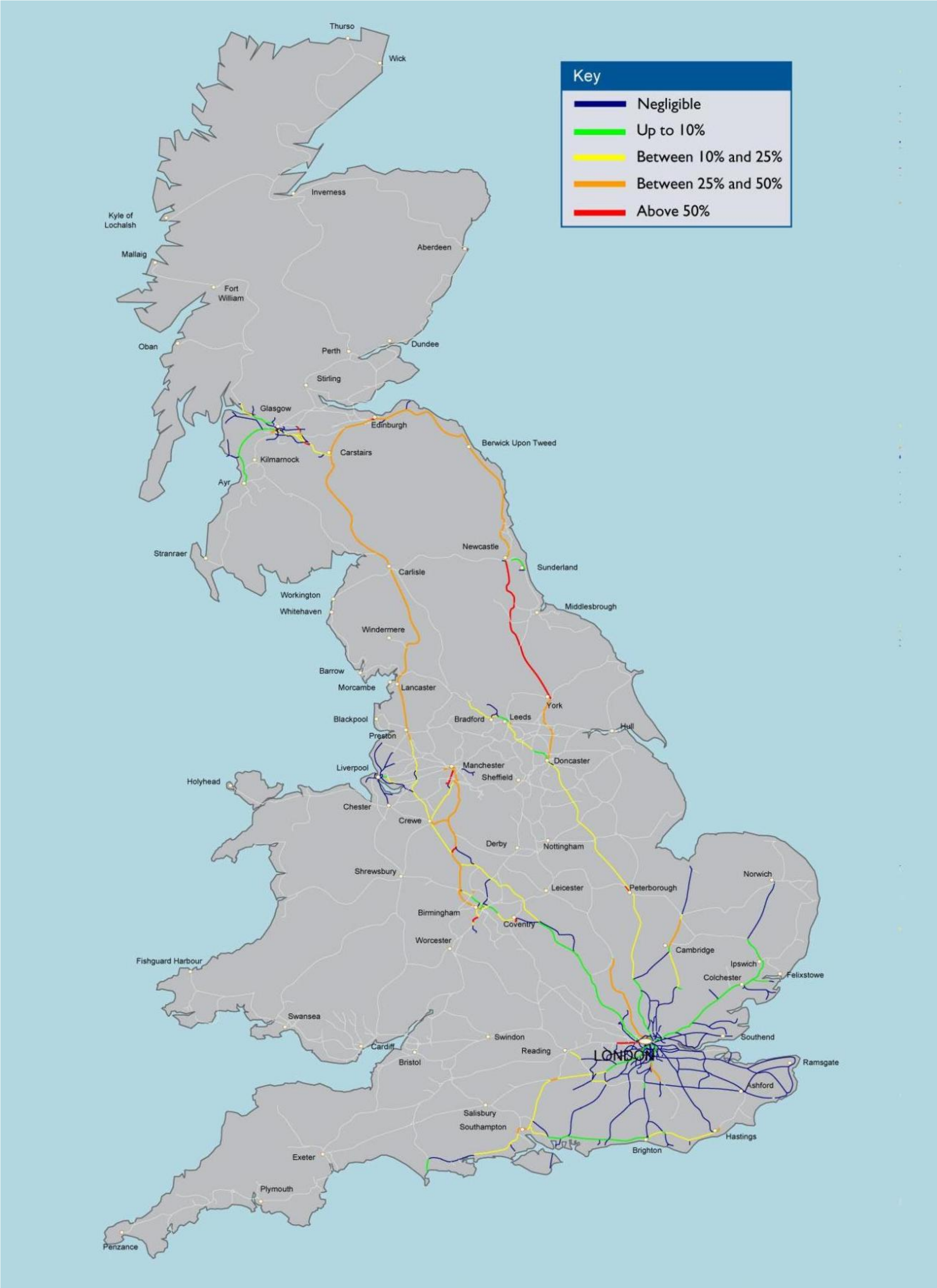
Figure 3.6 Tonnage carried on the unelectrified network 2007/08



A substantial number of diesel hauled trains run on the electrified network (a practice referred to in the industry as ‘running under the wires’). This may take the form of a diesel train operating as a replacement for an electric train or, more commonly, a scheduled service with an origin or destination outside the electrified portion of the network. The latter practice often results from the comparatively limited extent of the electrified network, together with the diverse range of origins and destinations of services, which in turn led to a preference in some cases for ‘go anywhere’ diesel trains. There are thus some services on fully electrified routes which are at present operated with diesel trains. Consequently, whilst electrified routes account for approximately 60% of train miles, less than half of train miles are actually operated by electric traction. This presents an opportunity for any extension of the electrified network to convert more services to electric traction than may have been expected.

Figure 3.7 shows the proportion of passenger tonnes on the electrified network which are operated by diesel traction.

Figure 3.7 Proportion of passenger tonnage carried on the electrified network by diesel passenger trains 2007/08

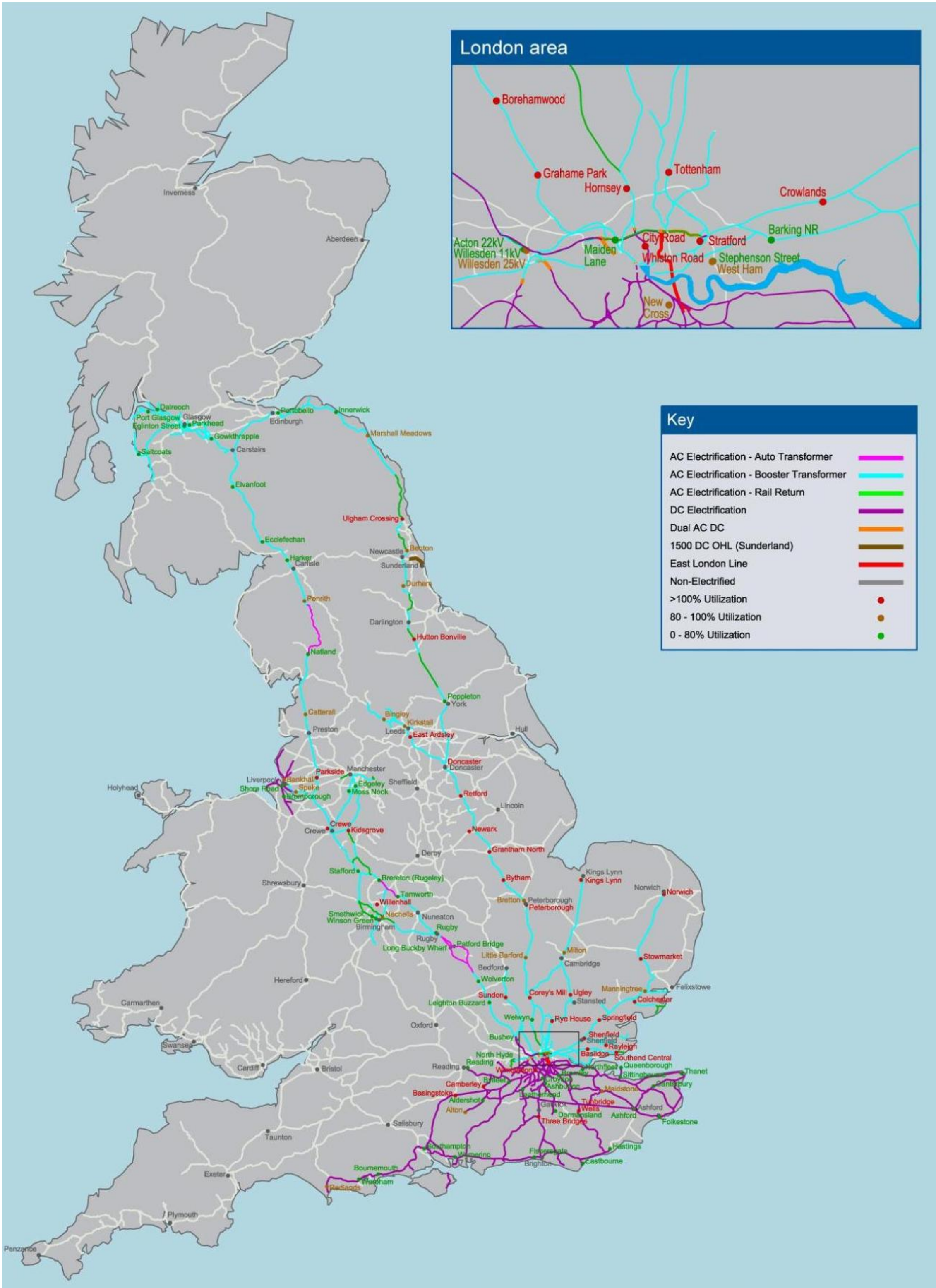


3.3 Power supply on the existing network

Figure 3.7 shows that certain parts of the electrified network carry a significant amount of diesel traffic. Further electrification would allow some of the diesel traffic currently operating on the electrified network to convert to electric traction. If this were the case there would be a significant increase in the demand on the power supply of the existing electrified network. It is therefore important to understand the extent of spare capacity in the current power supply. This is also important for the provision for growth with existing electric services; in many cases the existing power supplies provide an electrical power capacity that is less than the train capacity of the route. The spare capacity is shown in Figure 3.8.

Schemes are under development for strengthening power supplies on the West Coast Main Line, the Midland Main Line and the East Coast Main Line, as well as a number of locations on the DC network south of London.

Figure 3.8 Power Supply



3.4 Costs of installing and maintaining electrification fixed equipment

The costs of installing equipment are driven by two factors the scope of electrification works required and the efficient use of the construction resources. The scope elements include:- provision and installation of lineside equipment (overhead or third rail), gauge clearance works, provision of appropriate grid connections, distribution and supervisory control systems, signalling immunisation works, track enabling works and other minor works.

The efficient deployment of resources allows the contiguous use of skilled installation teams, the acquisition of plant and the implementation of effective logistic arrangements such as depots and material supply.

Electrification unit rates can differ significantly by route dependent upon the characteristics of that route. The major determinants are outlined in Table 3.2.

Table 3.2 Elements of infrastructure cost

Item	Comments	% of Overall Cost*
Length of route and number of tracks, depots and sidings	Calculated in single track kilometres and used to derive overhead line equipment costs delivered by production line approach.	25-35
Number of crossovers (junctions)	To derive costs for the more complex overhead line equipment (not delivered by factory approach).	
Bridges	Dependent upon the existing gauge, work may be required to achieve the clearances required to accommodate the OLE. There is a wide range of solutions which include:- demolition and reconstruction, track lowering and deck raising. For routes with many structures this can be an expensive element particularly where public utilities are also present.	30-40
Tunnels	Inadequate gauge can be addressed by track lowering or realignment or other solutions including provision of rigid overhead bars. Solutions can be expensive; issues concerning water ingress may need to be addressed too. Access to deliver tunnel works can also be a major constraint.	
Grid supply requirements	Unless it is possible to use existing OLE supplies in the vicinity, new feeds will be required from utility supply systems or the National Grid. Costs for provision of these services vary considerably depending upon location, access and the available supply.	25-35
Distribution	The cost of off-line traction power distribution from the National Grid terminals to the OLE feed points above the track is driven by length of route.	
Provision of autotransformers	The Auto Transformer feeding arrangement requires these additional lineside transformers to transform the voltage from 50kV to 25kV.	
Scale of signalling and telecommunication immunisation works	Dependent upon the type of existing S&T systems in situ – in the case of major incompatibility; recommendation would be to programme electrification works to follow resignalling.	5-15
Signal sighting	Any issues with structures or signals needing to be moved or adapted to sustain sight lines to the signals.	
Traction interfaces	In some cases provision of an interface between 25kV AC to pre-existing 3rd Rail 750V or DC is required. Complex technical solutions are usually required to avoid stray DC current which can cause electrolytic corrosion.	5-10
Other civils	Typically a small cost element including alterations to station structures (e.g. canopies).	
Other	This includes the cost of deployment of the wiring train (driven by route length), provision of wiring train depots.	

* Percentage splits are illustrative based on estimate samples. They assume that the signalling system does not require complete replacement and that there are no exceptional structures items.

Electrification costs are usually summarised as a rate per single track kilometre and the report 'T633: Study on Further Electrification on the UK railway' undertaken for DfT by Atkins in 2007 quoted a range of rates from £500k to £650k. This figure was used as a starting point for the RUS evaluations and further developed by comparison with current cost estimates, proof of concept studies into new delivery techniques and outline evaluation of route specific features. This additional work has shown some opportunity for reducing the costs which could be realised during the detailed development of specific routes.

The main purpose for OLE inspection and maintenance is to support the delivery of the specified route reliability and availability targets aligned with the Asset Stewardship Index and to preserve system safety as required by the Electricity at Work regulations. Inspection and fixed interval maintenance frequencies are evaluated using a process of cost versus risk optimisation which takes into account factors such as system design, wear factors / time to failure, failure modes and effects, cost and performance impact of intervention tasks such as rapid response and repair time, and engineering access.

Maintenance costs for all OLE components are driven by degradation rates. Other than the long term wearing out of contact wire, degradation rate is complex and not easily predictable, so inspection led maintenance regimes are utilised. The understanding of the cause and impact of this degradation enables optimisation of inspection regimes and allows the most effective remedial action to be carried out to prevent premature failure of the asset. For contact wire and catenary wire, repair and maintenance, other than small scale localised replacement, is not usually effective, hence renewal by wire run / tension length is the preferred and most cost effective option.

3.5 Characteristics of diesel and electric rolling stock

In general the equipment to provide electric traction is simpler than that required for diesel traction and this is reflected in the capital cost, maintenance cost and weight of the vehicles. Electric vehicles have a higher power to weight ratio than diesel vehicles which carry their own heavy power sources on board. There are performance benefits of electric traction, which give rise to shorter journey times, and in the case of locomotive hauled freight traffic, the ability to haul greater trailing loads. Fuel costs tend to be lower for electric vehicles and they tend to be more reliable, leading to higher levels of availability. However, this advantage is reduced by the risk of failure in the electrification fixed equipment. Carbon dioxide emissions are lower for electric trains. These features are discussed further in Chapter 4, Drivers of Change.

Table 3.3 shows estimates of operating costs of diesel and electric rolling stock, based on those vehicles currently operating on the network. Costs will vary by the class of unit. However, on average, electric vehicles have considerably lower rates than their diesel equivalents, particularly for fuel cost and maintenance cost.

The capability for regenerative braking increases the energy efficiency of electric trains.

The weight of trains varies considerably by class, but for a range of modern diesel and electric multiple unit classes a weight of 46 tonnes per DMU vehicle and 42 tonnes per EMU would be typical. This is reflected in the lower track wear and tear cost shown above.

The frequency of maintenance is lower in the case of electric trains, and this manifests itself in higher availability, i.e. the ratio of the number of vehicles available to operate the service to the total number of vehicles in the fleet. This is shown in Table 3.4.

Table 3.3 Typical operating costs of diesel and electric vehicles

	Typical value for diesel vehicle	Typical value for electric vehicle
Maintenance cost per mile	60 pence	40 pence
Fuel cost per vehicle mile	47 pence	26 pence
Lease cost per vehicle per annum	£110,000	£90,000
Track wear and tear cost per vehicle mile	9.8 pence	8.5 pence

Source: ATOC and Variable Track Access Charge rates

The characteristics of electric traction mean that electric trains have superior acceleration compared with diesel trains, which allows them to reach full speed more quickly following a station call, and potentially brake later. This in turn gives rise to journey time savings. ATOC estimates that journey time savings are in the region of a quarter of a minute per station stop for typical suburban services and half a minute for long distance services, although the precise time savings will depend on the characteristics of individual classes of rolling stock.

The simpler design of electric trains manifests itself in greater reliability for electric vehicles compared with diesel vehicles. NFRIP Statistics show that on average modern diesel trains run for 11,000 miles per casualty whilst electric trains run for around 21,000 miles per casualty.

Emissions of carbon dioxide are lower for electric vehicles than diesel. Table 3.5 shows the typical values of emissions estimated in 2007 based on the then current electricity generating mix.

Table 3.4 Typical availability for diesel and electric vehicles

	Typical value for diesel fleet	Typical value for electric fleet
Availability	88 percent	91 percent
Source: ATOC		

Table 3.5 Typical carbon dioxide emissions for diesel and electric vehicles

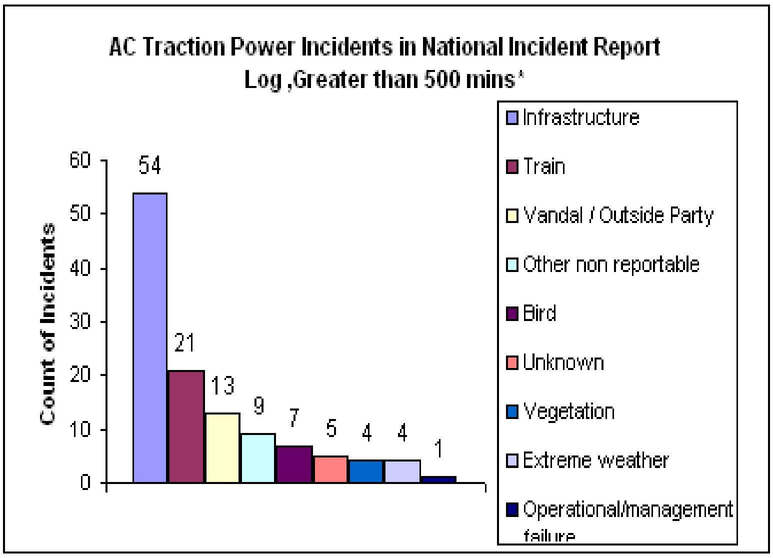
	Typical value for diesel vehicle	Typical value for electric vehicle
Carbon dioxide per vehicle mile	2,100g	1,664g
Source Atkins report T633, 2007 published by RSSB		

Electric trains are more energy efficient than diesel ones. Assessments as to the scale of the advantage vary and are highly dependent on a range of assumptions but the DfT's 'Delivering a Sustainable Railway' document of July 2007 estimated the savings to be in the region of 18 per cent. High speed electric trains also have a higher carrying capacity than diesel trains leading the DfT to conclude that the overall advantage of electric over diesel trains to be between 20 and 40 per cent depending on load factor and generation mix. We expect this benefit to be further emphasised as the emissions levels are tightened in 2012 which will require additional filtration, and hence space, for diesel engines.

3.6 Reliability of electrification fixed equipment

As noted above, electric trains have a lower failure rate than diesel trains. However, while the net effect of electrification is an improvement in whole system reliability, failures of overhead line equipment can cause significant delays to trains. In 2007/08, 5% of infrastructure related delay minutes were caused by Overhead Line Equipment faults. The 2007/08 UK rail performance impacts of OLE reliability are shown in Figure 3.9.

Figure 3.9 AC traction power incidents 2007/08



4 Drivers of change

4.1 Introduction

Both the Department for Transport's Rail White Paper and Transport Scotland's Strategic Transport Projects Review have outlined the importance of the role of transport in delivering economic and environmental objectives. Further electrification potentially has a key role to play advancing both objectives.

This chapter outlines those factors which could potentially drive a move to further electrification of the network given the objectives of the rail industry's stakeholders. These include the need to reduce industry costs, particularly if electrification could be carried out in conjunction with a programme of carefully phased rolling stock replacement, to improve the product offered to customers, with the associated revenue benefits, to efficiently accommodate growth, to provide a more environmentally friendly product, to be less reliant on potentially insecure energy sources and to comply with changing environmental legislation.

4.2 Reduction of whole industry costs

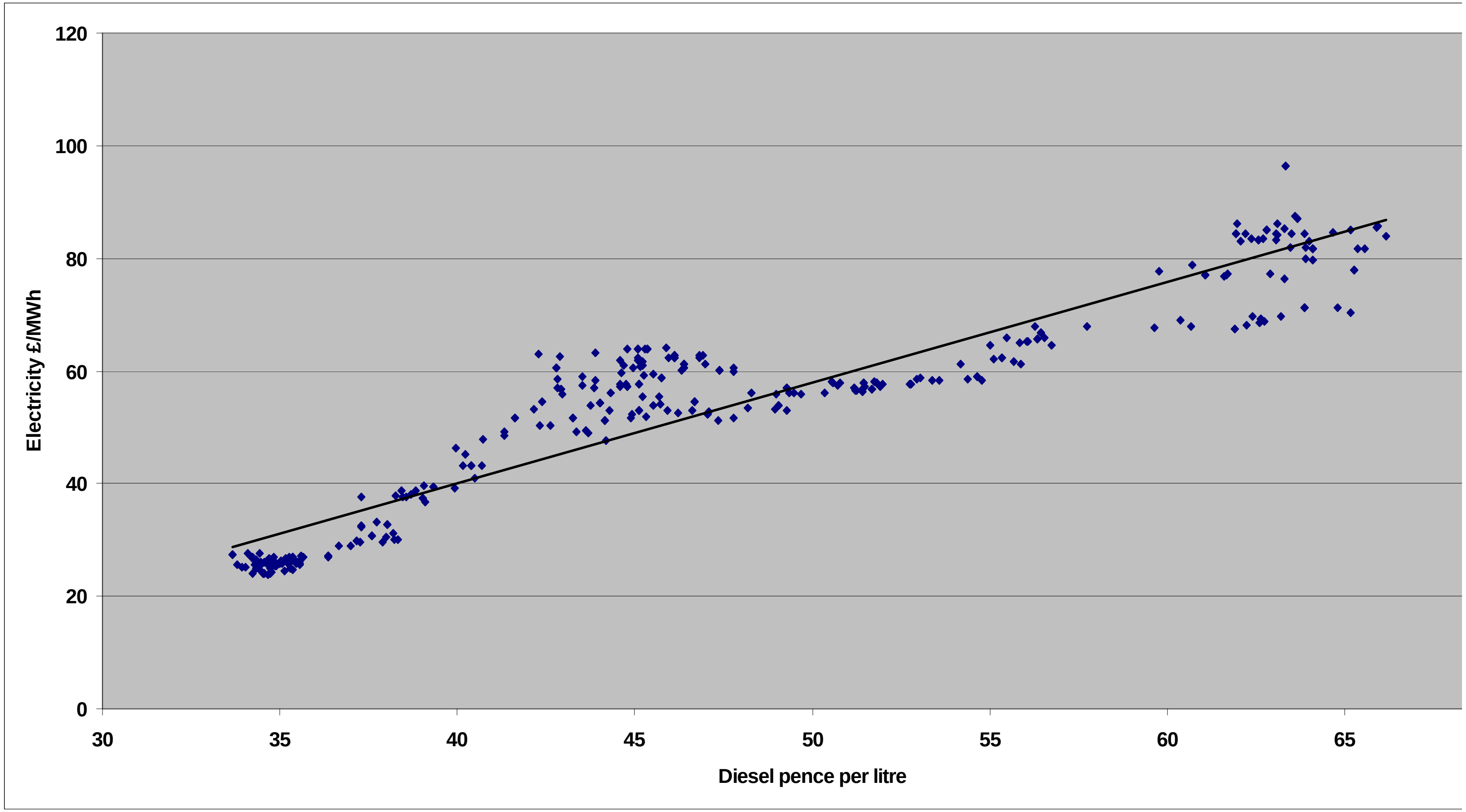
Further electrification has the potential to reduce whole industry costs of operating the railway. The size of the potential savings is directly related to the volumes of traffic which could operate over the converted railway and as such, these savings are greater as the traffic levels grow.

There are a number of generic changes to costs which apply when electrification permits a change of traction from of a service from diesel to electric. The potential savings can be categorised as reductions in rolling stock operating costs (including fuel), infrastructure operating costs, increases in rolling stock availability rates, extensions to vehicle life and reduction in the capital costs of new vehicles.

a) Reduction in rolling stock operating costs

Examination of trends in diesel and electric fuel costs over recent years shows that the fuel cost per vehicle mile is less for electric vehicles than for diesel vehicles. Although the price of fuel itself is volatile, there has been an historic correlation between the cost of diesel fuel and the price paid for traction electricity. The variability in the difference between the prices of the two fuel types has been considerably less than the variability in the absolute value. This is illustrated by the graph in Figure 4.1, which plots the diesel and electric costs at different points in time. While the costs of diesel and electricity both vary within wide ranges, the difference in fuel cost is generally within a range of 19 to 26 pence per vehicle mile.

Figure 4.1 Diesel and electric traction costs



Source: ATOC

As discussed in section 3.5, electric vehicles are generally lighter than diesel vehicles for an equivalent train formation. In the case of many passenger services, the lighter weight contributes to fuel cost savings.

The maintenance requirements are more straightforward for electric trains, and this is reflected in the maintenance costs: the cost per vehicle mile is approximately 20 pence less for electric trains than their diesel equivalents.

On long distance passenger routes, where a diesel electric train with a separate power car would operate (as opposed to a multiple unit with under-floor engines), the need for this power car, and the associated cost, is avoided where electric traction is used.

The superior acceleration of electric trains may, in certain instances, facilitate sufficient journey time savings to allow the service to be operated with fewer diagrams. This would allow reductions in fleet size, and associated rolling stock capital cost savings and train crew cost savings. This is most likely to apply on suburban services where stops are frequent.

Conversely, where an existing diesel fleet is only partially replaced by electric trains, the number of diagrams required to operate the service may increase.

Where electrification completely eliminates the need for diesel trains to be operated on services from a particular depot, there may be significant savings in depot operational costs. Again, these savings will not be completely realised if the existing diesel fleet is only partially replaced.

b) Reduction in infrastructure operating costs

The introduction of lighter weight electric vehicles, compared to their diesel equivalents, will reduce the amount of traffic related wear and tear of track. As noted in Chapter 3, the cost of track damage is approximately one penny per vehicle mile less in the case of electric vehicles.

Set against these savings, electrification incurs an ongoing increase in infrastructure maintenance costs, associated with the fixed equipment.

c) Increase in rolling stock availability

Electric trains require shorter times for maintenance than diesel trains and require maintenance less frequently. Consequently they are generally cheaper to maintain than equivalent diesel vehicles and the availability for service operation is higher, with typical values for diesel and electric trains of 88% and 91% respectively, as noted in Chapter 3. This in turn reduces the size of fleet required to operate a service and the associated capital cost.

d) Reduction in vehicle leasing costs

Electric trains generally have lower leasing costs then diesel trains for trains of comparable age and type. This derives from a combination of lower capital cost and longer commercial life. Typically the leasing cost of an electric vehicle would be approximately £20,000 per annum less than for a comparable diesel vehicle.

e) Cost savings to freight operators

Freight operators would, of course, benefit from the fuel cost savings discussed above if they were able to run under electric haulage. Running an entire end-to-end journey as an electrically hauled service would avoid the need to change locomotives, thereby achieving operational cost savings and reducing any associated risk of perturbation.

The superior performance of electric traction can provide journey time savings, especially where the need for trains to be held in loops is avoided. Where these journey time savings are sufficient to allow the service to be operated with fewer diagrams, reductions in locomotive and wagon fleet size may be possible, together with associated capital cost savings, and train crew cost savings.

The superior power: weight ratio of electric haulage may in certain instances, where suitable locomotives are available, enable freight operators to run with longer trailing loads. This may lead to operational cost savings compared to the alternative of running two train loads or double heading of trains.

f) Increase in availability of diversionary routes

Network Rail and its stakeholders have expressed an aspiration to move towards a seven day railway: i.e. to have a railway which is available to customers when they wish to use it. Given the need to maintain the railway, an important element of this strategy is to provide diversionary routes for use in times of disruption.

Where an electrification scheme provides a diversionary route for passenger services for a route that is already electrified, it enables the avoidance of the cost of providing alternative traction, or even substitute buses, in the event of planned diversion. This will be an improvement in the quality of service to the passenger. As such, it should also lead to a revenue increase. In addition, operating cost savings may arise from reduced journey time in the event of planned diversion. The availability of a diversionary route may allow greater access for maintenance work, allowing such work to be provided more efficiently.

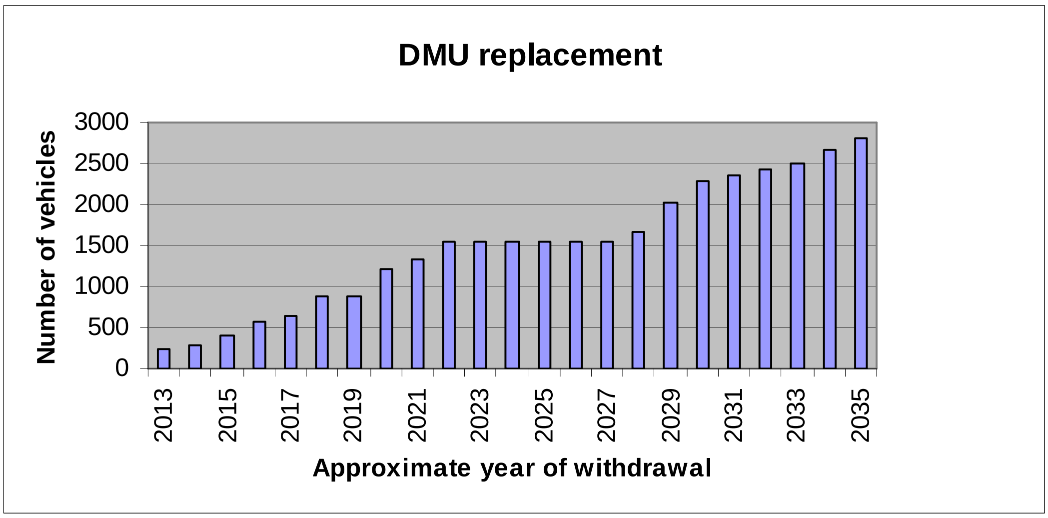
4.3 Passenger rolling stock replacement

A significant driver of electrification is the requirement to replace ageing diesel passenger rolling stock on the network.

The current fleet of diesel High Speed Trains was built in the late 1970s and early 1980s, and these trains are now approaching the end of their commercial life. The Intercity Express Programme (IEP) is addressing the replacement of these trains by the Super Express Train. The mix of this fleet between diesel and electric traction will depend on the extent of further electrification.

There is also a sizeable fleet of diesel multiple units which will eventually require replacement. The on-going Network RUS Rolling Stock Strategy has identified the factors which determine vehicle life, and on that basis, has estimated the profile of withdrawal of existing diesel multiple unit vehicles. This is shown in Figure 4.2. The profile shown assumes that those vehicles which are currently not compliant with the Rail Vehicle Accessibility Regulations (RVAR), but which are capable of being modified to comply with RVAR, will be so modified.

Figure 4.2 Cumulative number of DMU vehicles to be withdrawn

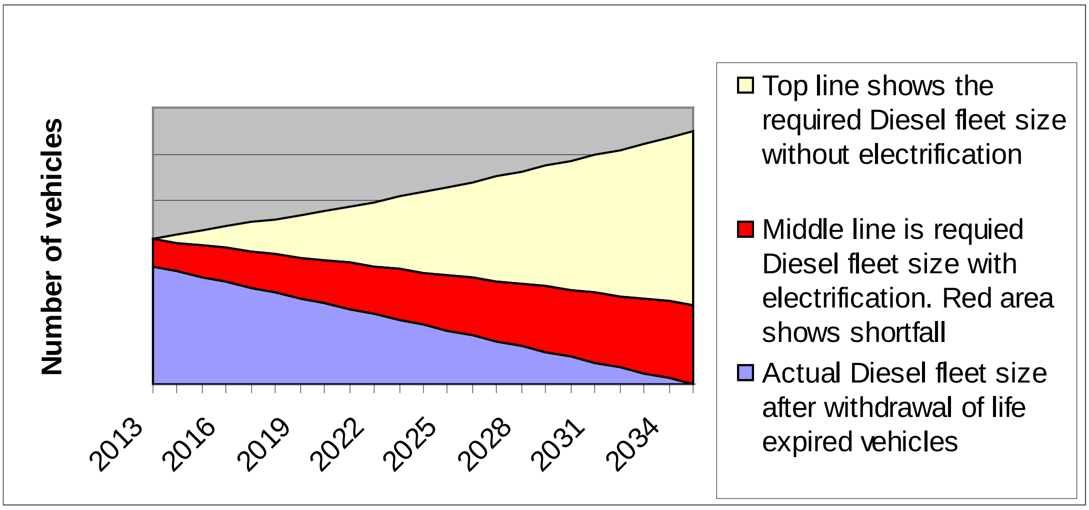


The timing of rolling stock replacement and the procurement of new rolling stock to accommodate growth affects the economic case for further electrification and *vice versa*.

To illustrate this concept Figure 4.3 shows the relationship between the rate of electrification and the impact on the size of the diesel fleet. The top line in the diagram represents the total fleet requirement for vehicles on services which are currently operated by diesel trains. The area shaded blue represents the diesel fleet available, given the gradual withdrawal of vehicles in the current fleet. The yellow area represents electric vehicles which would be deployed on services which are currently operated by diesel trains if there were to be a rolling programme of electrification. The red area then represents the residual requirement for diesel trains.

It would be economically desirable to avoid the requirement for a large diesel fleet which is largely replaced before the end of the life of the vehicles in that fleet, thereby foregoing residual value of those vehicles.

Figure 4.3 The relationship between DMU fleet replacement and electrification



4.4 Improvement of the passenger product

Electrification can significantly improve rail's product offering to its customers. The key improvements of the electric service product offer, over a diesel offer from the passenger's perspective can include

- Reduced journey times: The acceleration and deceleration performance characteristics of electric trains are such that journey times are reduced relative to comparable journeys operated by diesel trains. Journey time reductions can be particularly significant on suburban services with frequent station calls where improved acceleration and deceleration give proportionately large decreases in journey time. This would also be the case on routes with steep gradients where the power : weight ratio gives significant improvements.
- Station ambience: The ambience of stations will be improved where electrification allows a reduction or elimination of diesel trains from stations. This effect would be particularly marked in stations with enclosed train sheds in which diesel fumes can become trapped.
- On-train ambience: Where diesel multiple unit trains with under floor engines are replaced by electric trains, an improvement in ride quality is experienced. Electric trains are also quieter.
- Reliability: Electric trains generally have a lower failure rate than diesel trains, with miles per casualty for electric trains typically being more than double that for diesel trains, as noted in Chapter 3. Although the electrification fixed equipment introduces a potential additional risk of failure, the net effect of electrification is an improvement in whole system reliability.
- Reduction in bus substitution: Where an electrification scheme provides a diversionary route for a route that is already electrified, the instances of bus substitution could be reduced, giving a more pleasant and reliable journey experience for passengers. Similarly the availability of an electrified diversionary route would provide performance benefits in the event of unplanned disruption.
- New journey opportunities: If electrification is combined with service recasts, it could potentially provide new through journey opportunities. This would benefit existing users of the rail service who would no longer have to interchange and may attract new users.
- Additional seating capacity: On long distance high speed routes, where a diesel train with a separate power car would operate, electrification schemes eliminate the need for a diesel power car. As a result, electric trains on such routes generally provide additional passenger seating capacity within the same overall train length. For example, the two end vehicles of Class 390 (Pendolino) trains contain a total of 64 seats. On busy routes this may mean that more passengers can get a seat and avoid the unpleasant ambience of crowded vehicles.

4.5 Efficient accommodation of passenger growth

Electrification can contribute to the efficient accommodation of traffic growth that the DfT and Transport Scotland aspire to over the next thirty years.

On long distance high speed routes, where a diesel train with a separate power car would operate, there will be additional passenger carrying capacity on electric trains compared with diesel trains of the same length, because the power car can be replaced by a passenger carrying vehicle. A new Super Express electric vehicle for example, would contain in excess of 20% more seats than the diesel vehicle it replaced. On routes where there are constraints on the maximum train length, electrification can delay the point at which infrastructure enhancements need to be provided to accommodate longer (or more) trains.

The superior acceleration of electric trains potentially reduces the speed differential between fast and slow trains. This would enable more trains to operate. This would potentially have performance benefits, and again where routes are at capacity, it can potentially delay the point at which infrastructure enhancements need to be provided to accommodate longer (or more) trains.

4.6 Passenger revenue

Each of the factors outlined in Sections 4.3 and 4.4 combine to improve the product offer to the passenger and as such attract additional rail passengers, bringing additional revenue to the railway.

4.7 Improvement in the rail freight product

Freight operators' savings would arise from electrification where the change in the extent of the electrified network is sufficiently significant to trigger changes in operational practice. Clearly, the ability of freight operators to take advantage of operational cost savings depends on whether an operator can run an entire end to end service under electric haulage. The ability to do this greatly increases as more of the network is electrified. It is envisaged that infill schemes would enable cost savings on some routes for operators with existing electric locos. Extensive electrification would give a long term step change in benefits which could be gained if the programme were to be sufficiently large to encourage the purchase of electric locos where diesel locos currently operate.

Electrification may have the following benefits to the operators:

Reduction in whole industry costs

- Operating and infrastructure cost benefits may arise from the avoidance of the need to change locomotives, where electrification allows the journey to be electrically hauled throughout.
- In the case of freight operation, unit cost savings may arise from ability to haul greater trailing loads.
- Operating cost savings can be made where infill schemes provide alternative routes for trains which are currently electrically hauled and where those alternative routes allow a reduction in mileage or journey time.
- Where infill electrification allows an existing electric fleet to be used more efficiently, reductions in fleet size, and associated capital cost savings may be realised. Where the last diesel rolling stock in an area can be eliminated, depot savings such as abolition of fuelling facilities may occur.
- Potential operating costs savings (such as fuel and maintenance costs) may arise from use of electric traction for whole route where diesel traction is currently used.

Diversionary route benefits

- Where an electrification scheme provides a diversionary route for a core route that is already electrified, benefits will arise from the avoidance of the need to change traction, reduced journey time (and possible avoidance of bus substitution in case of passenger operation). There will also be performance benefits in the event of the need for unplanned diversion.
- In some cases the availability of an electrified diversionary route may ease the provision of access for maintenance work.

Capacity Benefits

- In the case of freight services the ability to haul greater trailing loads will allow a reduction in train paths required and hence capacity benefits. These capacity benefits and associated reduced road mileage could be quantified using sensitive lorry miles.
- The superior performance of electric traction can provide significant journey time savings, sometimes eliminating the need for trains to he held in loops.

An increase in the extent of the electrified network can make it worthwhile to electrically haul trains which would otherwise be diesel hauled throughout their journey. Consequently these benefits may be realised beyond the route which is being electrified.

4.8 Environmental benefits

Rail transport currently accounts for approximately 2% of Carbon dioxide emissions from the UK domestic transport sector *(source: Low Carbon Transport Innovation Strategy, DfT May 07).* It is currently a more environmentally friendly method of travel than its major competitor (road) but it is important that it improves its environmental credentials even further in the light of government initiatives to reduce emissions-related climate change. Figure 4.4 shows the comparison of carbon performance between rail and other modes as outlined in the Rail White Paper and the Rail Technical Strategy[1].

Electrification potentially has an important role to play. Electric vehicles tend to be more environmentally friendly than their diesel counterparts, and the capability for regenerative braking increases their energy efficiency. As discussed in Chapter 3, on average there are less emissions from electric trains at the point of use, i.e. 20 to 30% less CO_2 emissions than diesel vehicles (source: RSSB 2007).

Note that the electric class Intercity 225, the Pendolino and the Electrostar emit less carbon than their diesel counterparts.

Electrification makes a greater contribution to environmental policy when it exploits low-carbon methods of electricity generation. Network Rail currently purchases 90% of its traction electricity from such sources.

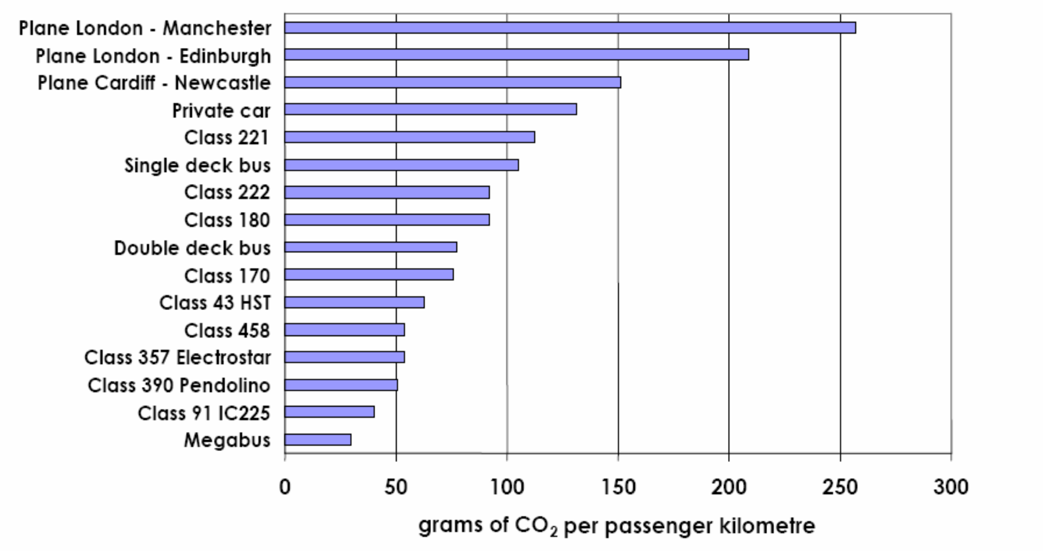
Electrification also reduces the need to transport fuel.

Electric trains are generally quieter in operation that diesel stock of the same age although neither type of train is louder than the recommended limit in residential areas. The Atkins study for RSSB of 2007 stated the Calculation of Railway Noise (CRN) factors for a Pendolino EMU as +10.7dB and the equivalent figure for a Voyager DMU of +13.8dB.

4.9 Environmental policy and Legislation

European legislation controlling emissions from diesel engines comes in to force in two stages (3A and 3B) during CP4 and this will also affect the efficiency of running self-powered vehicles. For 3A regulations, in force in 2009, engines will need to be re-tuned and could actually use more fuel rather than less, operating at lower efficiencies to keep levels of particulates down or replaced completely if alterations cannot be made.

Figure 4.4. Relative carbon performance of rail and other modes.



[1] Data in Figure 4.4 assumes the following load factors: urban bus 20%, intercity coach 60%, intercity rail 40%, all other trains 30%, domestic airlines 70%, and cars 30%.

However, further advances in engine technology may also be able to meet these requirements without a detrimental effect on fuel consumption levels.

3B regulations due for implementation in 2012 are being technically reviewed at present by the EU. This relates to the physical works required to enable engines to be fitted with exhaust cleaning apparatus to improve levels of NO2, oxides and diesel particulates.

The location, size and design of some DMU engines makes the replacement difficult or too expensive, resulting in the loss of the vehicle; this is likely to affect regional and rural markets.

4.10 Security of energy supply

Rail transport currently accounts for 2% of domestic oil consumption in the UK. *(source Energy consumption in the United Kingdom: 2008 data tables, BERR.)* The White Paper on Energy (Meeting the Energy Challenge May 07) recognises that the heavy dependence of the transport sector on oil at a time when the UK will increasingly rely on imported oil carries potential consequences for the security of energy supply.

Electricity can be generated from a variety of primary sources. The greater flexibility in the sources of energy available, (particularly the potential to source from within the UK) would enable electrification to contribute to fuel security, reducing the exposure to the risk of future scarcity and the volatility of oil prices.

5 Gaps

5.1 Introduction

This chapter outlines the key gaps which can be identified between today's railway and a future railway which could exploit the benefits of electrification outlined in Chapter 4.

It could be argued that the principal gap is the 60% of the network (in track miles) which is not at present electrified. Given that the baselining section has identified that benefits of electrification are greater in the more heavily used sections of the railway, it is more helpful to the development of a strategy to classify the gaps in terms of the potential opportunities that electrification could provide to different parts of the network.

To this end, four gap 'types' have been developed i.e.

- Type A : where electrification may enable more efficient operation of passenger services;
- Type B : where electrification may enable more efficient operation of freight services;
- Type C: where electrification could provide diversionary route capacity
- Type D: where electrification could enable a new service to operate

Chapter 6 identifies options for these gaps, and provides evaluation to indicate which should be considered for inclusion in an electrification programme.

5.2 Type A : Electrification to enable efficient operation of passenger services

Type A gaps are those routes where there is a significant level of passenger services which could be converted to electric operation. As a threshold, self contained routes with a current passenger vehicle tonnage of less than 1m p.a. (on single track routes) or less than 2m p.a. (on double track routes), are taken as having a traffic level too low for electric traction to be an efficient form of operation for passenger traffic, unless electrification would also address one or more of the other gaps below. At these traffic levels, electrification would not achieve a BCR of 2 even where the costs of electrification are at the low end of the likely range.

An exception to this rule is made to include routes with low current levels of passenger traffic where funders / customers have expressed aspirations for electrification as a catalyst for a significant enhancement of traffic and hence service level.

5.3 Type B: Electrification to enable efficient operation of freight services

Type B gaps are those routes where electrification would facilitate the efficient operation of freight services by electric traction or would provide alternative routes for freight trains which are currently electrically hauled. These are routes where there is a significant level of freight traffic which could be hauled by electric traction were the route to be electrified or where there is a significant level of freight traffic which could be beneficially rerouted to take advantage of the electrification.

5.4 Type C: Electrification to increase diversionary routes available

Type C gaps are those routes which would provide viable diversionary capacity for a route which is already electrified.

5.5 Type D: Electrification to enable new patterns of service to operate

These gaps could apply to passenger or freight operations. This includes passenger routes which extend beyond a currently electrified area, and whose electrification would enable a corresponding extension of services currently operated by electric traction.

5.6 Summary of the gaps

Figure 5.1 shows the gaps identified, i.e. those parts of the network which satisfy at least one of these criteria above. The gaps are listed in Tables 5.1 to 5.4 below. To help to identify the location of the gaps, they are numbered according to the Network Rail strategic route on which they lie. A map of the strategic routes is shown as Appendix 1.

The tables group routes according to the principal type of gap they address. In some cases, a route section could equally well be classified as more than one type of gap. Where this is the case it is also indicated in the table. In some cases the type of gap addressed by a scheme will depend on whether other schemes have previously been implemented, for example, when one route is electrified, a further route may become a candidate to provide an electrified diversionary route.

It should not be inferred that the absence of a route from the list below would mean that it would never be a gap, but that current traffic patterns and levels – and our expectations of future demand - mean that it is unlikely to be a candidate for electrification in the short or medium term. It is acknowledged that traffic patterns and levels do change over time, and the list of gaps will be kept under review as the strategy develops.

Figure 5.1: Gaps

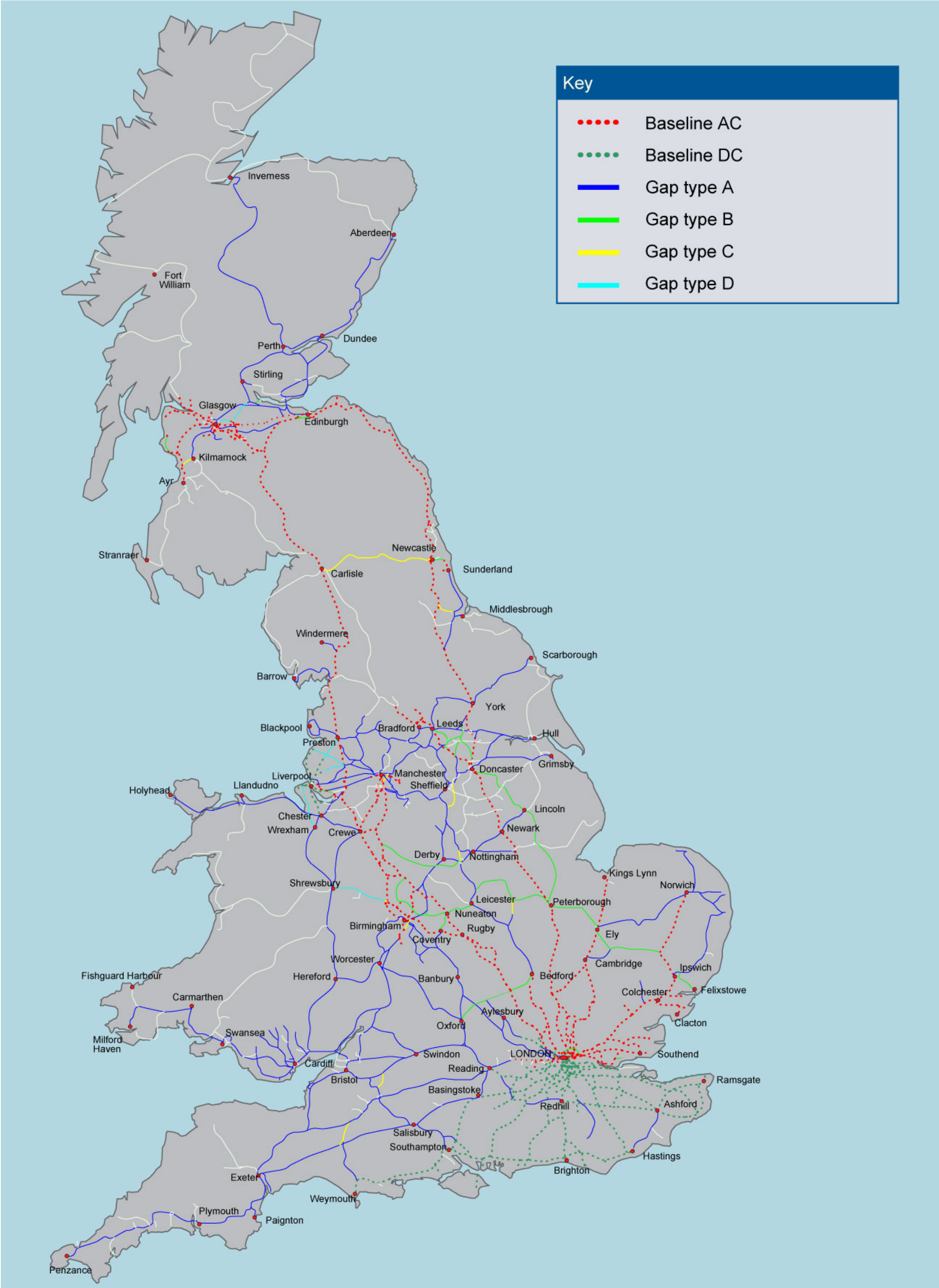


Table 5.1 List of Type A Gaps: Electrification primarily to enable efficient operation of passenger services					
Gap Number	**Gap name**	**Efficient operation of passenger service**	**Efficient operation of freight service**	**Provision of diversionary route**	**New passenger service opportunity**
A1.1	Ashford to Ore	**Y**			
A2.1	Uckfield to Hurst Green	**Y**			
A3.1	Wokingham to Ash and Shalford to Reigate	**Y**		Y	
A4.1	Basingstoke to Salisbury	**Y**		Y	
A4.2	Salisbury to Exeter	**Y**		Y	
A4.3	Eastleigh to Romsey and Redbridge (Southampton) to Salisbury	**Y**	Y	Y	Y
A4.4	Salisbury to Bathampton Junction (Bath)	**Y**	Y	Y	
A4.7	Yeovil Pen Mill to Dorchester	**Y**			
A5.2	Chippenham Junction (Newmarket) to Cambridge	**Y**			
A5.3	Ely to Norwich	**Y**		Y	
A7.2	Westerfield to Lowestoft	**Y**			
A7.3	Marks Tey to Sudbury	**Y**			
A7.4	Norwich to Lowestoft and Yarmouth	**Y**			Y
A7.5	Norwich to Sheringham	**Y**			
A9.1	Northallerton to Middlesbrough	**Y**	Y	Y	Y
A9.2	Thornaby to Sunderland	**Y**	Y		

Table 5.1 List of Type A Gaps: Electrification primarily to enable efficient operation of passenger services

Gap Number	Gap name	Efficient operation of passenger service	Efficient operation of freight service	Provision of diversionary route	New passenger service opportunity
A10.1	North cross Pennine (Guide Bridge to Leeds, Leeds to Hull / Colton Junction, and Temple Hirst to Selby)	**Y**	Y	Y	
A10.2	York to Scarborough	**Y**			
A10.3	Leeds to Manchester via Calder Valley	**Y**		Y	
A10.4	Wakefield Westgate to Thornhill LNW Junction (Mirfield) and Heaton Lodge Junction / Bradley Junction to Milner Royd Junction / Dryclough Junction (Halifax)	**Y**	Y	Y	
A10.5	Leeds to York via Harrogate	**Y**			
A10.11	Doncaster to Gilberdyke	**Y**			
A11.1	Newark Northgate to Lincoln	**Y**			
A11.2	Dore to Hazel Grove	**Y**	Y	Y	
A11.3	Thorne Junction (Hatfield and Stainforth) to Cleethorpes	**Y**	Y		
A11.4	Meadowhall to Horbury Junction (Wakefield) via Barnsley	**Y**			
A12.1	Bristol to Plymouth and Paignton	**Y**	Y		
A12.2	Reading to Cogload Junction (Taunton)	**Y**	Y		
A12.3	Plymouth to Penzance	**Y**			

Table 5.1 List of Type A Gaps: Electrification primarily to enable efficient operation of passenger services					
Gap Number	**Gap name**	**Efficient operation of passenger service**	**Efficient operation of freight service**	**Provision of diversionary route**	**New passenger service opportunity**
A12.4	Exmouth Junction (Exeter) to Exmouth	**Y**			
A13.1	Great Western Main Line Maidenhead to Oxford and Bristol via Bath	**Y**	Y		
A13.2	Great Western Main Line Wootton Bassett Junction to Swansea	**Y**	Y		
A13.3	Swindon to Cheltenham	**Y**		Y	
A13.4	Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke	**Y**	Y	Y	Y
A13.5	Bromsgrove to Cheltenham and Standish Junction to Westerleigh Junction (Bristol Parkway) including Worcester Shrub Hill loop	**Y**	Y		
A13.6	Gloucester to Severn Tunnel Junction	**Y**	Y	Y	
A13.7	Oxford to Worcester	**Y**			
A14.1	Newport to Crewe	**Y**			
A14.2	Shrewsbury to Chester	**Y**			
A14.3	Swansea to Milford Haven	**Y**			
A15.1	Cardiff Valleys routes including Cardiff to Maesteg via Barry and Ebbw Vale line	**Y**		Y	
A16.1	Marylebone to Aynho Junction and Aylesbury via High Wycombe, and Old Oak	**Y**	Y	Y	

Table 5.1 List of Type A Gaps: Electrification primarily to enable efficient operation of passenger services

Gap Number	Gap name	Efficient operation of passenger service	Efficient operation of freight service	Provision of diversionary route	New passenger service opportunity
	to Northolt				
A16.2	Neasden Junction to Aylesbury via Harrow	**Y**	Y		
A16.3	Aylesbury to Claydon	**Y** for new potential new service	Y	Y	
A17.1	Birmingham Snow Hill suburban (Hereford to Stratford and Bearley Junction to Hatton)	**Y**	Y	Y	
A19.1	Midland Main Line (Bedford to Sheffield via Derby, Trent Junction to Nottingham and Kettering to Corby)	**Y**	Y	Y	
A19.2	Doncaster to Sheffield, South Kirkby Junction (Moorthorpe) to Swinton, Derby to Birmingham and Wichnor Junction to Lichfield	**Y**	Y	Y	
A19.3	Ambergate to Matlock	**Y**			
A19.4	Newark to Nottingham	**Y**			
A19.5	Grantham to Nottingham	**Y**	Y	Y	
A19.6	Nottingham to Clay Cross Junction	**Y**	Y	Y	
A20.1	Euxton Junction to Manchester	**Y**		Y	
A20.2	Preston to Blackpool North	**Y**			Y
A20.3	Salford Crescent to Wigan NW and Lostock Junction to Crow Nest Junction	**Y**		Y	

Table 5.1 List of Type A Gaps: Electrification primarily to enable efficient operation of passenger services

Gap Number	Gap name	Efficient operation of passenger service	Efficient operation of freight service	Provision of diversionary route	New passenger service opportunity
A20.4	Manchester Deansgate to Liverpool (Edge Hill) via Chat Moss route	**Y**	Y	Y	Y
A20.5	Huyton to Wigan	**Y**		Y	Y
A20.6	Manchester South Suburban (Ashburys to New Mills and Rose Hill Marple to Hyde Junction)	**Y**		Y	
A20.7	Manchester to Liverpool (Hunts Cross to Trafford Park)	**Y**	Y	Y	
A20.8	Kirkham and Wesham to Blackpool South	**Y**			Y
A20.9	Bolton to Clitheroe	**Y**			
A20.10	Hazel Grove to Buxton	**Y**			
A22.1	Crewe to Chester	**Y**		Y	Y
A22.2	Chester to Acton Grange Junction (Warrington)	**Y**		Y	Y
A22.3	Chester to Holyhead and Llandudno	**Y**			
A23.1	Oxenholme to Windermere	**Y**			
A23.2	Preston to Hall Royd Junction (Todmorden)	**Y**			
A23.3	Carnforth to Barrow	**Y**			Y
A23.4	Rose Grove to Colne	**Y**			

Table 5.1 List of Type A Gaps: Electrification primarily to enable efficient operation of passenger services

Gap Number	Gap name	Efficient operation of passenger service	Efficient operation of freight service	Provision of diversionary route	New passenger service opportunity
A24.1	Edinburgh to Glasgow Queen Street via Falkirk High and Grahamston	**Y**		Y	Y
A24.2	Carmuirs Junctions to Dunblane and Alloa	**Y**			Y
A24.3	Haymarket to Inverkeithing and Fife circle	**Y**			
A24.4	Thornton Junction to Aberdeen	**Y**	Y		
A24.5	Dunblane to Dundee	**Y**	Y		
A24.6	Ladybank to Hilton Junction (Perth)	**Y**		Y	
A25.1	Perth to Inverness	**Y**	Y		
A26.1	Rutherglen to Coatbridge Junction / Whifflet	**Y**	Y	Y	Y
A26.2	Midcalder Junction to Holytown via Shotts	**Y**	Y	Y	
A26.3	Corkerhill to Paisley Canal	**Y**			
A26.4	Cowlairs Junction to Anniesland	**Y**		Y	Y
A26.6	Glasgow Central to East Kilbride	**Y**			
A26.7	Busby Junction to Kilmarnock	**Y**			

Table 5.2 List of Type B Gaps : Electrification primarily to enable efficient operation of freight services					
Gap Number	**Gap name**	**Efficient operation of passenger service**	**Efficient operation of freight service**	**Provision of diversionary route**	**New passenger service opportunity**
B5.1	Haughley Junction (Stowmarket) to Peterborough	Y	**Y**	Y	
B6.1	Woodgrange Park to Gospel Oak, Harringay Park Junction – Harringay Junction and Junction Road Junction to Carlton Road Junction	Y	**Y**	Y	Y
B6.2	Ripple Lane sidings		**Y**		
B6.3	Thameshaven branch		**Y**		
B6.4	Willesden Acton Branch and SW Sidings to Acton Wells Junction		**Y**	Y	
B6.5	Acton Wells Junction to Acton West Junction		**Y**	Y	
B6.6	Old and New Kew Junctions to South Acton Junction		**Y**		Y
B6.7	Acton Canal Wharf Junction to Cricklewood / Brent Curve Junctions (Dudding Hill Line)		**Y**	Y	Y
B7.1	Felixstowe to Ipswich	Y	**Y**		Y
B9.5	Tyne Dock branch		**Y**		
B10.6	Hare Park Junction to Wakefield Europort		**Y**	Y	
B10.7	Altofts Junction to Church Fenton		**Y**	Y	
B10.8	Altofts to Leeds via Woodlesford + Methley-Whitwood		**Y**	Y	

Table 5.2 List of Type B Gaps : Electrification primarily to enable efficient operation of freight services

Gap Number	Gap name	Efficient operation of passenger service	Efficient operation of freight service	Provision of diversionary route	New passenger service opportunity
B10.9	Shaltholme Junction to Milford Junction		**Y**	Y	
B10.10	Moorthorpe to Ferrybridge Junction (Knottingley)		**Y**	Y	
B11.5	Peterborough to Doncaster via Joint Line		**Y**	Y	
B17.3	Nuneaton to Water Orton and Whiteacre to Kingsbury	Y	**Y**	Y	Y
B17.4	Coventry to Nuneaton	Y	**Y**	Y	
B17.7	Walsall to Rugeley Trent Valley	Y	**Y**	Y	Y
B17.8	Castle Bromwich Junction and Water Orton West Junction to Walsall / Pleck Junction		**Y**	Y	Y
B18.1	Oxford – Bletchley – Bedford (in conjunction with Claydon Bletchley reopening)	Y for new potential new service	**Y**	Y	Y
B18.2	Ditton yard to terminal		**Y**		
B19.10	Peterborough to Nuneaton	Y	**Y**	Y	
B19.11	Sheet Stores Junction to Stoke on Trent	Y	**Y**	Y	
B20.15	Seaforth branch (Liverpool)		**Y**		
B24.7	Edinburgh Suburban lines		**Y**	Y	
B24.8	Grangemouth branch		**Y**		
B26.5	Hunterston to Ardrossan	Y	**Y**		

Table 5.2 List of Type B Gaps : Electrification primarily to enable efficient operation of freight services					
Gap Number	**Gap name**	**Efficient operation of passenger service**	**Efficient operation of freight service**	**Provision of diversionary route**	**New passenger service opportunity**
B26.8	Glasgow: Shields Junction to High Street Junction	Y	**Y**		

Table 5.3 List of Type C Gaps: Electrification primarily to increase diversionary routes available

Gap Number	Gap name	Efficient operation of passenger service	Efficient operation of freight service	Provision of diversionary route	New passenger service opportunity
C4.5	Bradford South Junction to Thingley Junction via Melksham		Y	**Y**	
C4.6	Castle Cary to Yeovil Junction	Y		**Y**	
C9.3	Newcastle to Carlisle	Y	Y	**Y**	
C9.4	Norton South Junction (Stockton) to Ferryhill Junction		Y	**Y**	
C17.2	Oxley Junction to Bushbury Junction (Wolverhampton)	Y	Y	**Y**	
C17.6	Birmingham Camp Hill line	Y	Y	**Y**	Y
C19.7	Trent to Trowell via Erewash Valley route		Y	**Y**	
C19.8	Tapton Junction to Masborough Junction (Rotherham)		Y	**Y**	
C19.9	Corby to Manton Junction	Y	Y	**Y**	
C20.11	Ashton Moss / Guide Bridge to Heaton Norris Junction		Y	**Y**	
C20.12	Philips Park to Ashburys		Y	**Y**	
C20.13	Manchester Victoria to Stalybridge	Y	Y	**Y**	
C26.10	Kilmarnock to Barassie	Y		**Y**	

Table 5.4 List of Type D Gaps: Electrification primarily to enable new patterns of service to operate					
Gap Number	**Gap name**	**Efficient operation of passenger service**	**Efficient operation of freight service**	**Provision of diversionary route**	**New passenger service opportunity**
D17.5	Wolverhampton to Shrewsbury	Y	Y		**Y**
D20.14	Kirkby to Wigan	Y			**Y**
D22.4	Wrexham Central to Bidston	Y			**Y**
D23.5	Ormskirk to Preston and Wigan to Southport with new chord at Burscough	Y			**Y**
D26.9	Cowlairs South Junction / Gartsherrie South Junction to Greenhill Junction via Cumbernauld	Y	Y	Y	**Y**
D26.11	Paisley Canal to Elderslie (including reinstatement)		Y	Y	**Y**

6 Options

6.1 Introduction

This section identifies options to meet the gaps outlined in Chapter 5. The options were developed by Network Rail and members of the Network RUS Electrification Strategy Working Group. They were then analysed to identify those which potentially offer high value for money.

6.2 Option Generation

Options were identified to address the categories of gaps discussed in the previous sections. In each case, the option selection process was undertaken with the aim of delivering a strategy which provides high value for money and falls within affordability criteria.

For each gap identified, the basic option choice is whether to electrify or not. In almost all cases the geographical location of the gap will determine whether AC or DC is the appropriate type of electrification. In many cases there are options around the ordering or grouping of schemes, and these are noted in the table of options.

Table 6.1 shows the option or options considered for each gap or group of gaps. In some cases an option applies to two or more gaps. In these cases the gaps are grouped, with the option or options listed below them.

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.	
Gap A1.1	**Ashford to Ore**
Option A1.1 Electrify Ashford to Ore with DC electrification. Convert Brighton to Ashford service to electric traction.	
Gap A2.1	**Uckfield to Hurst Green**
Option A2.1 Electrify Uckfield to Hurst Green with DC electrification. Convert Uckfield to London service to electric traction.	
Gap A3.1	**Wokingham to Ash and Shalford to Reigate**
Option A3.1 Electrify Wokingham to Ash and Shalford to Reigate with DC electrification. Convert Reading to Gatwick Airport and Reading to Redhill local services to electric traction.	
Gap A4.1	**Basingstoke to Salisbury**
Gap A4.2	**Salisbury to Exeter**
Option A4.1a Electrify Basingstoke to Salisbury[2]. Convert Waterloo to Salisbury service to electric traction.	
Option A4.2 Electrify Salisbury to Exeter following Basingstoke to Salisbury. Convert Waterloo to Exeter service to electric traction.	
Option A4.1b Electrify Basingstoke to Exeter. Convert Waterloo to Salisbury and Exeter service to electric traction.	
Gap A4.3	**Eastleigh to Romsey and Redbridge to Salisbury**
Gap A4.4	**Salisbury to Bathampton Junction (Bath)**
Option A4.3a Electrify Eastleigh to Romsey and Redbridge to Salisbury[3]. Convert Romsey to Salisbury service to electric traction.	
Option A4.4 Electrify Salisbury to Bathampton Junction (Bath) following Redbridge to Salisbury and GWML . Convert Cardiff to Portsmouth service to electric traction.	
Option A4.3b Electrify Eastleigh to Romsey and Redbridge to Bathampton Junction (Bath), following GWML. Convert Romsey to Salisbury and Cardiff to Portsmouth services to electric traction.	

[2] In view of the route length and service density, AC electrification is considered likely to be the more cost effective option for this route. This would be further examined in the detailed development of a scheme

[3] The electrification type would be further examined in the detailed development of a scheme

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.

Gap A 4.7	**Yeovil Pen Mill to Dorchester**
Option A4.7 Electrify Yeovil Pen Mill to Dorchester following GWML, Redbridge to Bathampton Junction and Castle Cary to Yeovil Junction. Convert Bristol to Weymouth service to electric traction.	
Gap A 5.2	**Chippenham Junction (Newmarket) to Cambridge**
Option A5.2 Electrify Chippenham Junction (Newmarket) to Cambridge following Haughley Junction to Peterborough. Convert Ipswich to Cambridge service to electric traction.	
Gap A 5.3	**Ely to Norwich**
Gap A 19.5	**Grantham to Nottingham**
Gap A 19.6	**Nottingham to Clay Cross Junction**
Option A5.3. Electrify Ely to Norwich and Grantham to Clay Cross Junction following Liverpool to Manchester, Haughley Junction to Peterborough, Midland Main Line, and Dore to Hazel Grove. Convert Cambridge to Norwich and Liverpool to Norwich services to electric traction.	
Gap A 7.2	**Westerfield to Lowestoft**
Option A7.2 Electrify Westerfield to Lowestoft following Felixstowe to Ipswich. Convert London and Ipswich to Lowestoft services to electric traction.	
Gap A 7.3	**Marks Tey to Sudbury**
Option A7.3 Electrify Marks Tey to Sudbury. Convert Marks Tey to Sudbury services to electric traction.	
Gap A 7.4	**Norwich to Lowestoft and Yarmouth**
Option A7.4 Electrify Norwich to Lowestoft and Yarmouth. Convert Norwich to Lowestoft and Yarmouth services to electric traction.	
Gap A 7.5	**Norwich to Sheringham**
Option A7.5 Electrify Norwich to Sheringham. Convert Norwich to Sheringham services to electric traction.	
Gap A 9.1	**Northallerton to Middlesbrough**
Gap A 9.2	**Thornaby to Sunderland**
Gap A 10.1	**North cross Pennine (Guide Bridge to Leeds, Leeds to Hull / Colton Junction, and Temple Hirst to Selby)**

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.	
Gap A 10.2	**York to Scarborough**
Gap A 20.4	**Manchester Deansgate to Liverpool (Edge Hill) via Chat Moss route**
Option A20.4 Electrify Manchester Deansgate to Liverpool (Edge Hill) via Chat Moss route. Convert Liverpool to Manchester Airport and Liverpool to Warrington Bank Quay service to electric traction.	
Option A10.1a Electrify Guide Bridge to Leeds, Leeds to Colton Junction and Hull, and Temple Hirst to Selby following Manchester Deansgate to Liverpool (Edge Hill). Convert Hull to London and cross Pennine services to electric traction. Modify cross Pennine services so that they run between Liverpool and Manchester via the Chat Moss route, and so that through Middlesbrough services are split at York, and Scarborough is served by services from Preston rather than by North cross Pennine services.	
Option A 9.1 Electrify from Northallerton to Middlesbrough and Thornaby to Sunderland. Reinstate through North cross Pennine services to Middlesbrough, and convert London to Sunderland and Middlesbrough to Newcastle service to electric traction.	
Option A 10.2 Electrify York to Scarborough. Convert York to Scarborough to electric traction.	
Option A10.1b Electrify Guide Bridge to Leeds, Leeds to Colton Junction and Hull, Northallerton to Middlesbrough and Temple Hirst to Selby following Manchester Deansgate to Liverpool (Edge Hill). Convert Hull to London and cross Pennine services to electric traction. Modify cross Pennine services so that they run between Liverpool and Manchester via the Chat Moss route, and so that Scarborough is served by services from Preston rather than by North cross Pennine services.	
Option A9.2 Electrify Thornaby to Sunderland following Northallerton to Middlesbrough. Convert London to Sunderland service to electric traction.	
Option A10.1c Electrify Guide Bridge to Leeds, Leeds to Colton Junction and Hull, Northallerton to Middlesbrough, York to Scarborough and Temple Hirst to Selby following Manchester Deansgate to Liverpool (Edge Hill). Convert Hull to London and cross Pennine services to electric traction. Modify cross Pennine services so that they run between Liverpool and Manchester via the Chat Moss route.	
Option A10.1d Combination of Option A10.1a with Option A20.4.	
Option A10.1e Combination of Option A10.1b with Option A20.4.	
Option A10.1f Combination of Option A10.1c with Option A20.4.	
Gap A 10.5	Leeds to York via Harrogate
Option A 10.5 Electrify Leeds to York via Harrogate. Convert Leeds to York via Harrogate service to electric traction.	
Gap A 10.11	**Doncaster to Gilberdyke**
Gap A11.2	**Dore to Hazel Grove**

<table>
<tr><th colspan="2">Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.</th></tr>
<tr><td>Gap A11.3</td><td>Thorne Junction (Hatfield and Stainforth) to Cleethorpes</td></tr>
<tr><td colspan="2">Option A10.11 Electrify Doncaster to Gilberdyke following Doncaster to Sheffield and Leeds to Hull. Convert Sheffield to Hull service to electric traction.</td></tr>
<tr><td colspan="2">Option A11.2 Electrify Dore to Hazel Grove following Midland Main Line. Split Manchester Airport to Cleethorpes service at Doncaster and convert resulting Manchester Airport to Doncaster service to electric traction. Reroute Hope Valley local service to run via Hazel Grove and convert to electric traction.</td></tr>
<tr><td colspan="2">Option A11.3 Electrify Dore to Hazel Grove, Doncaster to Gilberdyke and Thorne Junction to Cleethorpes, following Midland Main Line, Doncaster to Sheffield and Leeds to Hull. Convert Sheffield to Hull, Sheffield to Scunthorpe, Goole to Doncaster and Manchester Airport to Cleethorpes services to electric traction. Reroute Hope Valley local service to run via Hazel Grove and convert to electric traction.</td></tr>
<tr><td>Gap A10.3</td><td>Leeds to Manchester via Calder Valley</td></tr>
<tr><td colspan="2">Option A10.3 Electrify Leeds to Manchester via Calder Valley. Convert Leeds to Manchester via Calder Valley service to electric traction.</td></tr>
<tr><td>Gap A10.4</td><td>Wakefield Westgate to Thornhill LNW Junction (Mirfield) and Heaton Lodge Junction / Bradley Junction to Milner Royd Junction / Dryclough Junction (Halifax)</td></tr>
<tr><td colspan="2">Option A10.4 Electrify Wakefield Westgate to Thornhill LNW Junction (Mirfield) and Heaton Lodge Junction / Bradley Junction to Milner Royd Junction / Dryclough Junction following North cross Pennine and Leeds to Manchester via Calder Valley. Convert Leeds–Hebden Bridge via Mirfield and Huddersfield to Wakefield services to electric traction.</td></tr>
<tr><td>Gap A11.1</td><td>Newark Northgate to Lincoln</td></tr>
<tr><td colspan="2">Option A11.1 Electrify Newark Northgate to Lincoln. Convert projected London to Lincoln service to electric traction.</td></tr>
<tr><td>Gap A11.4</td><td>Meadowhall to Horbury Junction via Barnsley</td></tr>
<tr><td colspan="2">Option A11.4a Electrify Meadowhall to Horbury Junction via Barnsley following Midland Main Line, Nottingham to Clay Cross Junction, Sheffield to Doncaster, Wakefield to Thornhill Junction and Wakefield to Leeds via Altofts. Convert Leeds–Barnsley–Sheffield–Nottingham services to electric traction.</td></tr>
<tr><td colspan="2">Option A11.4b Electrify Meadowhall to Leeds via Barnsley, Wakefield Kirkgate and Altofts following Midland Main Line, Nottingham to Clay Cross Junction and Sheffield to Doncaster. Convert Leeds–Barnsley–Sheffield–Nottingham services to electric traction.</td></tr>
<tr><td>Gap A12.1</td><td>Bristol to Plymouth and Paignton</td></tr>
<tr><td>Gap A12.2</td><td>Reading to Cogload Junction (Taunton)</td></tr>
</table>

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.	
Gap A13.5	**Bromsgrove to Cheltenham and Standish Junction to Westerleigh Junction (Bristol Parkway) including Worcester Shrub Hill loop**
Option A12.2a Electrify Reading to Bedwyn following Paddington to Reading. Convert London to Newbury and Bedwyn services to electric traction.	
Option A12.2b Electrify Reading to Plymouth and Paignton and Bristol to Cogload Junction following Paddington to Reading. Convert London to West of England services to electric traction, with loco haulage for services west of Plymouth. Convert London to Newbury and Bedwyn, Exeter to Paignton and Cardiff to Taunton services.	
Option A13.5a Electrify Bromsgrove to Cheltenham and Standish Junction to Westerleigh Junction (Bristol Parkway) following Birmingham to Doncaster, Swindon to Cheltenham, Bristol to Cogload Junction and Reading to Plymouth and Paignton. Convert cross country services to the west country to electric traction with loco haulage for services west of Plymouth. Convert Bristol to Gloucester services to electric traction.	
Option A13.5b Electrify Bromsgrove to Cheltenham and Standish Junction to Westerleigh Junction (Bristol Parkway) and Bristol to Plymouth and Paignton following GWML, Birmingham to Doncaster and Swindon to Cheltenham. Convert cross country services to the west country to electric traction with loco haulage for services west of Plymouth. Convert Bristol to Gloucester, Exeter to Paignton and Cardiff to Taunton services to electric traction. Reinstate through Cardiff to Taunton service and operate with electric traction.	
Option A12.2c Electrify Reading to Cogload Junction following Paddington to Reading, and Bristol to Plymouth and Paignton. Convert London to West of England services to electric traction, with loco haulage for services west of Plymouth. Convert London to Newbury and Bedwyn, Exeter to Paignton and Cardiff to Taunton services to electric traction.	
Gap A12.3	**Plymouth to Penzance**
Option A12.3b Electrify Plymouth to Penzance. Run through services without the need to attach a loco at Plymouth. Convert Plymouth to Penzance local services to electric traction.	
Gap A12.4	**Exmouth Junction to Exmouth**
Option A12.4 Electrify Exmouth Junction to Exmouth following Basingstoke to Exeter. Convert Exeter to Exmouth services to electric traction.	
Gap A13.1	**Great Western Main Line Maidenhead to Oxford and Bristol via Bath**
Gap A13.2	**Great Western Main Line Wootton Bassett Junction to Swansea and Filton Junction to Bristol Temple Meads**
Option A13.1a Electrify Great Western Main Line from Maidenhead to Oxford and Bristol via Bath, following Airport Junction to Maidenhead (electrified under Crossrail scheme). Run Paddington to Bristol service with Super Express trains as part of the Intercity Express Programme. Convert Paddington to Reading and Oxford suburban services to electric traction.	

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.	
Option A13.1b Electrify Great Western Main Line from Maidenhead to Oxford and Bristol via Bath and Bristol Parkway, following Airport Junction to Maidenhead (electrified under Crossrail scheme). Run Paddington to Bristol service with Super Express trains as part of the Intercity Express Programme. Convert Paddington to Reading and Oxford suburban services to electric traction.	
Option A13.1c Electrify Great Western Main Line from Maidenhead to Bristol via Bath, following Airport Junction to Maidenhead (electrified under Crossrail scheme). Run Paddington to Bristol service with Super Express trains as part of the Intercity Express Programme. Convert Paddington to Reading suburban services to electric traction.	
Option A13.1d Electrify Didcot to Oxford following Great Western Main Line from Maidenhead to Bristol. Convert Paddington to Oxford services to electric traction.	
Option A13.2a Electrify Great Western Main Line Wootton Bassett Junction to Swansea, following Maidenhead to Bristol via Bath. Run Paddington to Cardiff and Swansea service with Super Express trains as part of the Intercity Express Programme. Split Cardiff to Taunton service at Bristol, and convert Cardiff to Bristol service to electric traction.	
Option A13.2b Electrify Great Western Main Line Bristol Parkway to Swansea, following Maidenhead to Bristol via Bath and Bristol Parkway. Run Paddington to Cardiff and Swansea service with Super Express trains as part of the Intercity Express Programme. Split Cardiff to Taunton service at Bristol, and convert Cardiff to Bristol service to electric traction.	
Gap A13.3	**Swindon to Cheltenham**
Option A13.3. Electrify Swindon to Cheltenham following GMML to Bristol and operate Paddington to Cheltenham service with Super Express trains as part of the Intercity Express Programme. Convert Swindon to Cheltenham service to electric traction.	
Gap A13.4	**Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke**
Option A13.4 Electrify Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke following GWML to Oxford. Convert cross country service from Southampton and Reading to Birmingham and Manchester to electric traction. Convert Basingstoke to Reading local services to electric traction.	
Gap A13.6	**Gloucester to Severn Tunnel Junction**
Option A13.6 Electrify Gloucester to Severn Tunnel Junction following GWML, and cross country. Convert Cardiff to Birmingham and Nottingham services to electric traction.	
Gap A13.7	**Oxford to Worcester**
Option A13.7 Electrify Oxford to Worcester following GWML to Oxford and Birmingham Snow Hill suburban services. Convert London to Worcester and Hereford services to electric traction.	
Gap A14.1	**Newport to Crewe**
Option A14.1 Electrify Newport to Crewe following GMWL, Shrewsbury to Chester and Chester to North	

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.	
Wales. Split Milford Haven via North and West route at Swansea, and convert Swansea and Cardiff to Manchester and North Wales services to electric traction.	
Gap A14.2	**Shrewsbury to Chester**
Option A14.2 Electrify Shrewsbury to Chester following Wolverhampton to Shrewsbury and Chester to North Wales. Convert Shrewsbury to North Wales services to electric traction.	
Gap A14.3	**Swansea to Milford Haven**
Option A14.3 Electrify Swansea to Milford Haven following GWML and Newport to Crewe. Reinstate through services to Milford Haven and operate services with electric traction.	
Gap A15.1	**Cardiff Valleys routes including Cardiff to Maesteg via Barry and Ebbw Vale line**
Option A15.1 Electrify Cardiff Valleys routes. Convert all services to electric traction.	
Gap A16.1	**Marylebone to Aynho Junction and Aylesbury via High Wycombe, and Old Oak to Northolt**
Gap A17.1	**Birmingham Snow Hill suburban (Hereford to Stratford and Bearley Junction to Hatton)**
Option A16.1a Electrify Marylebone to Aynho Junction, and Aylesbury via High Wycombe, Hatton to Stratford upon Avon and Old Oak to Northolt following Oxford to Birmingham. Convert Marylebone to Birmingham and Marylebone to Aylesbury via High Wycombe services to electric traction.	
Option A16.1b Electrify Marylebone to Birmingham Snow Hill, Stratford upon Avon and Aylesbury via High Wycombe, and Old Oak to Northolt . Convert Marylebone to Birmingham and Marylebone to Aylesbury via High Wycombe services to electric traction.	
Option A17.1a Electrify Hereford to Bearley Junction following Oxford to Birmingham and Hatton to Stratford upon Avon. Convert Birmingham Snow Hill suburban services to electric traction.	
Option A17.1b Electrify Birmingham Snow Hill suburban network (Hereford to Leamington Spa, Tyseley to Stratford, and Bearley Junction to Hatton.) Convert Birmingham Snow Hill suburban services to electric traction.	
Gap A16.2	**Neasden Junction to Aylesbury via Harrow**
Option A16.2 Electrify Neasden Junction to Aylesbury via Harrow following Marylebone to Birmingham Snow Hill. Convert Marylebone to Aylesbury via Harrow services to electric traction.	
Gap A16.3	**Aylesbury to Claydon**
Option A16.3 Electrify Aylesbury to Claydon following Claydon to Bletchley reopening and electrification.	

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.	
Run new passenger service with electric traction.	
Gap A19.1	**Midland Main Line (Bedford to Sheffield via Derby, Trent Junction to Nottingham and Kettering to Corby)**
Option A19.1 Electrify Midland Main Line and run St Pancras to Nottingham, Sheffield, Derby and Corby services with electric trains, using cascaded trains for the long distance services.	
Gap A19.2	**Doncaster to Sheffield, South Kirkby Junction (Moorthorpe) to Swinton, Derby to Birmingham and Wichnor Junction to Lichfield**
Option A19.2 Electrify Doncaster to Sheffield, South Kirkby Junction (Moorthorpe) to Swinton, Derby to Birmingham and Wichnor Junction to Lichfield following GWML Midland Main Line and Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke. Convert cross country services from Edinburgh via ECML , Newcastle and Leeds to Reading and Southampton to electric traction. Convert Sheffield to Leeds via Moorthorpe and Birmingham to Nottingham services to electric traction.	
Gap A19.3	**Ambergate to Matlock**
Option A19.3 Electrify Ambergate to Matlock following Midland Main Line. Convert Nottingham to Matlock service to electric traction.	
Gap A19.4	**Newark to Nottingham**
Option A19.4 Electrify Newark to Nottingham following Midland Main Line and Newark to Lincoln. Convert Leicester to Lincoln service to electric traction.	
Gap A20.1	**Euxton Junction to Manchester**
Gap A20.2	**Preston to Blackpool North**
Option A20.1a Electrify Euxton Junction to Manchester (Deansgate and Victoria.) Convert Manchester to Scotland and Hazel Grove to Preston service to electric traction.	
Option A20.2 Electrify Preston to Blackpool North following Euxton Junction to Manchester. Convert Manchester to Blackpool North service to electric traction.	
Option A20.1b Electrify Euxton Junction to Manchester and Preston to Blackpool North. Convert Manchester to Scotland and Blackpool North and Hazel Grove to Preston service to electric traction.	
Gap A20.3	**Salford Crescent to Wigan NW and Lostock Junction to Crow Nest Junction**
Option A20.3 Electrify Salford Crescent to Wigan NW and Lostock Junction to Crow Nest Junction following Manchester to Euxton Junction. Convert Manchester to Wigan service to electric traction.	
Gap A20.5	**Huyton to Wigan**

<table>
<tr><th colspan="2">Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.</th></tr>
<tr><td colspan="2">Option A20.5a Electrify Huyton to Wigan following Edge Hill to Manchester and Preston to Blackpool North. Convert Liverpool to Wigan and Blackpool North services to electric traction.</td></tr>
<tr><td colspan="2">Option A20.5b Electrify Edge Hill to Wigan following Preston to Blackpool North. Convert Liverpool to Wigan and Blackpool North services to electric traction.</td></tr>
<tr><td>Gap A20.6</td><td>Manchester South Suburban (Ashburys to New Mills and Rose Hill Marple to Hyde Junction)</td></tr>
<tr><td colspan="2">Option A20.6 Electrify Ashburys to New Mills and Rose Hill Marple to Hyde Junction. Convert Manchester South Suburban services to electric traction.</td></tr>
<tr><td>Gap A20.7</td><td>Manchester to Liverpool (Hunts Cross to Trafford Park)</td></tr>
<tr><td colspan="2">Option A20.7 Electrify Manchester to Liverpool (Hunts Cross to Trafford Park.) Convert Manchester to Liverpool via Warrington service to electric traction.</td></tr>
<tr><td>Gap A20.8</td><td>Kirkham and Wesham to Blackpool South</td></tr>
<tr><td>Gap A23.2</td><td>Preston to Hall Royd Junction</td></tr>
<tr><td>Gap A23.4</td><td>Rose Grove to Colne</td></tr>
<tr><td colspan="2">Option A20.8 Electrify Kirkham and Wesham to Blackpool South, Preston to Hall Royd Junction and Rose Grove to Colne following North cross Pennine, Preston to Blackpool North and Leeds to Manchester via Calder Valley. Convert Blackpool North to York and Blackpool South to Colne service to electric traction.</td></tr>
<tr><td>Gap A20.9</td><td>Bolton to Clitheroe</td></tr>
<tr><td colspan="2">Option A20.9 Electrify Bolton to Clitheroe following Euxton Junction to Manchester. Convert Manchester to Blackburn and Clitheroe service to electric traction.</td></tr>
<tr><td>Gap A20.10</td><td>Hazel Grove to Buxton</td></tr>
<tr><td colspan="2">Option A20.10 Electrify Hazel Grove to Buxton. Convert Manchester to Buxton service to electric traction.</td></tr>
<tr><td>Gap A22.1</td><td>Crewe to Chester</td></tr>
<tr><td colspan="2">Option A22.1 Electrify Crewe to Chester. Convert Euston to Chester services to electric traction, with some rearrangement of destinations of Chester and North Wales services to separate electric and diesel diagrams</td></tr>
<tr><td>Gap A22.2</td><td>Chester to Acton Grange Junction (Warrington)</td></tr>
</table>

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.

Gap A22.3	**Chester to Holyhead and Llandudno**
Option A22.2 Electrify Chester to Acton Grange Junction and Chester to Holyhead and Llandudno following Crewe to Chester and Edge Hill to Manchester. Convert London to North Wales and Manchester to Llandudno and Holyhead services to electric traction.	
Gap A23.1	**Oxenholme to Windermere**
Option A23.1 Electrify Oxenholme to Windermere following Euxton Junction to Manchester. Convert Manchester to Windermere and Oxenholme to Windermere services to electric traction.	
Gap A23.3	**Carnforth to Barrow**
Option A23.3 Electrify Carnforth to Barrow following Euxton Junction to Manchester. Convert Manchester and Lancaster to Barrow services to electric traction.	
Gap A24.1	**Haymarket to Glasgow Queen Street via Falkirk High and Grahamston**
Gap A24.2	**Carmuirs Junctions to Dunblane and Alloa**
Option A24.1a Electrify Edinburgh to Glasgow Queen Street via Falkirk High and Grahamston. Convert Edinburgh to Glasgow services to electric traction.	
Option A24.2 Electrify Carmuirs Junctions to Dunblane and Alloa following Edinburgh to Glasgow Queen Street. Convert Glasgow and Edinburgh to Dunblane and Alloa services to electric traction.	
Option A24.1b STPR Project 15: Electrify Edinburgh to Glasgow Queen Street via Falkirk High and Grahamston and Carmuirs Junctions to Dunblane and Alloa. Convert Edinburgh to Glasgow services and Glasgow and Edinburgh to Dunblane and Alloa services to electric traction.	
Gap A24.3	**Haymarket to Inverkeithing and Fife circle**
Gap A24.4	**Thornton Junction to Aberdeen**
Option A24.3a Electrify Haymarket to Inverkeithing and Fife circle. Convert Edinburgh to Fife circle services to electric traction.	
Option A24.4 Electrify Haymarket to Aberdeen. Convert Edinburgh to Aberdeen services to electric traction. Electrically haul London to Aberdeen services throughout.	
Option A24.3b Electrify Haymarket to Aberdeen and Fife circle. Convert Edinburgh to Fife circle and Aberdeen services electric traction. Electrically haul London to Aberdeen services throughout.	
Gap A24.5	**Dunblane to Dundee**
Option A24.5 Electrify Dunblane to Dundee following Glasgow to Dunblane and Edinburgh to Aberdeen.	

Table 6.1 List of Options to address Type A Gaps: Electrification to enable efficient operation of passenger services. Unless otherwise stated, the electrification option uses the AC system.	
Convert Glasgow to Aberdeen services to electric traction.	
Gap A24.6	**Ladybank to Hilton Junction (Perth)**
Gap A25.1	**Perth to Inverness**
Option A24.6 Electrify Ladybank to Hilton Junction (Perth) following Edinburgh and Glasgow to Dunblane and Dundee and Haymarket to Aberdeen. Convert Edinburgh to Perth services to electric traction.	
Option A25.1 Electrify Ladybank to Inverness following Edinburgh and Glasgow to Dunblane and Dundee and Haymarket to Aberdeen. Convert Glasgow and Edinburgh to Inverness services to electric traction. Electrically haul London to Inverness services throughout.	
Gap A26.1	**Rutherglen to Coatbridge Junction / Whifflet**
Option A26.1 Electrify Rutherglen to Coatbridge Junction / Whifflet. Convert Glasgow-Whifflet services to electric traction and divert to Glasgow Central Low Level.	
Gap A26.2	**Midcalder Junction to Holytown via Shotts**
Option A26.2 Electrify Midcalder Junction to Holytown via Shotts. Convert Glasgow-Edinburgh via Shotts services to electric traction.	
Gap A26.3	**Corkerhill to Paisley Canal**
Option A26.3 Electrify Corkerhill to Paisley Canal. Convert Glasgow Central to Paisley Canal services to electric traction.	
Gap A26.4	**Glasgow Queen Street to Anniesland**
Option A26.4 Electrify Cowlairs Junction to Anniesland. Convert Glasgow Queen Street to Anniesland service to electric traction.	
Gap A26.6	**Glasgow Central to East Kilbride**
Gap A26.7	**Busby Junction to Kilmarnock**
Option A26.6a Electrify Glasgow Central to East Kilbride. Convert Glasgow Central to East Kilbride service to electric traction.	
Option A26.7 Electrify Busby Junction to Barrhead / Kilmarnock following Glasgow Central to East Kilbride. Convert Glasgow Central to Kilmarnock service to electric traction.	
Option A26.6b Electrify Glasgow Central to East Kilbride and Busby Junction to Barrhead / Kilmarnock. Convert Glasgow Central to East Kilbride and Kilmarnock services to electric traction.	

Table 6.2 List of Options to address Type B Gaps : Electrification to enable efficient operation of freight services.	
Gap B5.1	**Haughley Junction (Stowmarket) to Peterborough**
Gap B7.1	**Felixstowe to Ipswich**
Gap B19.10	**Peterborough to Nuneaton**
Option B5.1 Electrify Felixstowe to Ipswich and Haughley Junction to Nuneaton following Midland Main Line and Nuneaton to Water Orton. Also convert Felixstowe to Ipswich, London to Peterborough via Ipswich and Birmingham to Stansted Airport passenger services to electric traction.	
Gap B6.1	**Woodgrange Park to Gospel Oak, Harringay Park Junction – Harringay Junction and Junction Road Junction to Carlton Road Junction**
Option B6.1 Electrify Woodgrange Park to Gospel Oak, Harringay Park Junction – Harringay Junction and Junction Road Junction to Carlton Road Junction. Also convert Gospel Oak to Barking passenger service to electric traction.	
Gap B6.2	**Ripple Lane sidings**
Gap B6.3	**Thameshaven branch**
Option B6.3 Electrify Ripple Lane sidings and Thameshaven branch.	
Gap B6.4	**Willesden Acton Branch and SW Sidings to Acton Wells Junction**
Gap B6.5	**Acton Wells Junction to Acton West Junction**
Option B6.4 Electrify Willesden Acton Branch and SW Sidings to Acton Wells Junction and Acton Wells Junction to Acton West Junction.	
Gap B6.6	**Old and New Kew Junctions to South Acton Junction**
Option B6.6 Electrify Old and New Kew Junctions to South Acton Junction with DC electrification.	
Gap B6.7	**Acton Canal Wharf Junction to Cricklewood / Brent Curve Junctions (Dudding Hill Line)**
Option B6.7 Electrify Acton Canal Wharf Junction to Cricklewood / Brent Curve Junctions.	
Gap B9.5	**Tyne Dock branch**
Option B9.5 Electrify Tyne Dock branch.	
Gap B10.6	**Hare Park Junction to Wakefield Europort**

Table 6.2 List of Options to address Type B Gaps : Electrification to enable efficient operation of freight services.	
Option B10.6 Electrify Hare Park Junction to Wakefield Europort.	
Gap B10.7	**Altofts Junction to Church Fenton**
Option B10.7 Electrify Altofts Junction to Church Fenton following Hare Park Junction to Wakefield Europort and North cross Pennine.	
Gap B10.8	**Altofts to Leeds via Woodlesford + Methley-Whitwood**
Option B10.8 Electrify Altofts to Leeds via Woodlesford + Methley-Whitwood following Hare Park Junction to Wakefield Europort and Altofts Junction to Church Fenton.	
Gap B10.9	**Shaltholme Junction to Milford Junction**
Option B10.9 Electrify Shaltholme Junction to Milford Junction following Altofts Junction to Church Fenton.	
Gap B10.10	**Moorthorpe to Ferrybridge Junction (Knottingley)**
Option B10.10 Electrify Moorthorpe to Ferrybridge Junction following Shaltholme Junction to Milford Junction.	
Gap B11.5	**Peterborough to Doncaster via Joint Line**
Option B11.5 Electrify Peterborough to Doncaster via Joint Line.	
Gap B17.3	**Nuneaton to Water Orton and Whiteacre to Kingsbury**
Option B17.3a Electrify Nuneaton to Water Orton and Whiteacre to Kingsbury following Birmingham to Derby.	
Option B17.3b Electrify Nuneaton to Birmingham.	
Gap B17.4	**Coventry to Nuneaton**
Option B17.4 Electrify Coventry to Nuneaton following Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke.	
Gap B17.7	**Walsall to Rugeley Trent Valley**
Option B17.7 Electrify Walsall to Rugeley Trent Valley. Also convert Birmingham to Rugeley passenger service to electric traction.	
Gap B17.8	**Castle Bromwich Junction and Water Orton West Junction to Walsall / Pleck Junction**

Table 6.2 List of Options to address Type B Gaps : Electrification to enable efficient operation of freight services.	
Option B17.8 Electrify Castle Bromwich Junction and Water Orton West Junction to Walsall / Pleck Junction.	
Gap B18.1	**Oxford – Bletchley – Bedford (in conjunction with Claydon Bletchley reopening)**
Option B18.1 Electrify Oxford – Bletchley – Bedford following Claydon to Bletchley reopening. Also convert Bletchley to Bedford passenger service to electric traction.	
Gap B18.2	**Ditton yard to terminal**
Option B18.2 Electrify Ditton yard to terminal.	
Gap B19.11	**Sheet Stores Junction to Stoke on Trent**
Option B19.11 Electrify Sheet Stores Junction to Stoke on Trent following Felixstowe to Nuneaton. Also convert Derby to Crewe passenger service to electric traction.	
Gap B20.15	**Seaforth branch (Liverpool)**
Option B20.15 Electrify Seaforth branch (Liverpool).	
Gap B24.7	**Edinburgh Suburban lines**
Option B24.7 Electrify Edinburgh Suburban lines.	
Gap B24.8	**Grangemouth branch**
Option B24.8 Electrify Grangemouth branch following Cowlairs South Junction / Gartsherrie South Junction to Greenhill Junction via Cumbernauld.	
Gap B26.5	**Hunterston to Ardrossan**
Option B26.5 Electrify Hunterston to Ardrossan for freight services.	
Gap B26.8	**Glasgow: Shields Junction to High Street Junction**
Option B26.8 Electrify Glasgow: Shields Junction to High Street Junction.	

Table 6.3 List of Options to address Type C Gaps : Electrification to increase diversionary routes available	
Gap C4.5	**Bradford South Junction to Thingley Junction via Melksham**
Option C4.5 Electrify Bradford South Junction to Thingley Junction via Melksham following GWML and Salisbury to Bathampton Junction.	
Gap C4.6	**Castle Cary to Yeovil Junction**
Option C4.6 Electrify Castle Cary to Yeovil Junction following Reading to Plymouth and Basingstoke to Exeter.	
Gap C9.3	**Newcastle to Carlisle**
Option C9.3 Electrify Newcastle to Carlisle.	
Gap C9.4	**Norton South Junction (Stockton) to Ferryhill Junction**
Option C9.4 Electrify Norton South Junction to Ferryhill Junction following Northallerton to Middlesbrough and Stockton to Sunderland.	
Gap C17.2	**Oxley Junction to Bushbury Junction (Wolverhampton)**
Option C17.2 Electrify Oxley Junction to Bushbury Junction.	
Gap C17.6	**Birmingham Camp Hill line**
Option C17.6 Electrify Birmingham Camp Hill line in conjunction with Bromsgrove to Westerleigh Junction.	
Gap C19.7	**Trent to Trowell via Erewash Valley route**
Option C19.7a Electrify Trent to Trowell via Erewash Valley route following Midland Main Line and Nottingham to Clay Cross Junction.	
Option C19.7b Electrify Trent to Clay Cross Junction via Erewash Valley route following Midland Main Line.	
Gap C19.8	**Tapton Junction to Masborough Junction (Rotherham)**
Option C19.8 Electrify Tapton Junction to Masborough Junction following Midland Main Line and Doncaster to Sheffield.	
Gap C19.9	**Corby to Manton Junction**
Option C19.9 Electrify Corby to Manton Junction following Midland Main Line and Felixstowe to Nuneaton.	

Table 6.3 List of Options to address Type C Gaps : Electrification to increase diversionary routes available	
Gap C20.11	**Ashton Moss / Guide Bridge to Heaton Norris Junction**
Option C20.11 Electrify Ashton Moss / Guide Bridge to Heaton Norris Junction.	
Gap C20.12	**Philips Park to Ashburys**
Option C20.12 Electrify Philips Park to Ashburys.	
Gap C20.13	**Manchester Victoria to Stalybridge**
Option C20.13 Electrify Manchester Victoria to Stalybridge following North cross Pennine. Also convert Liverpool to Stalybridge via Manchester Victoria passenger service to electric traction.	
Gap C26.10	**Kilmarnock to Barassie**
Option C26.10 Electrify Kilmarnock to Barassie following Glasgow via Kilmarnock. Convert Kilmarnock to Ayr services to electric traction.	

Table 6.4 List of Options to address Type D Gaps : Electrification to enable new patterns of service to operate	
Gap D17.5	**Wolverhampton to Shrewsbury**
Option D17.5 Electrify Wolverhampton to Shrewsbury. Extend Euston to Wolverhampton services to Shrewsbury and run Mid and North Wales services to Shrewsbury instead of Birmingham.	
Gap D20.14	**Kirkby to Wigan**
Option D20.6 Electrify from Kirkby to Wigan with DC electrification. Extend Liverpool to Kirkby service to Wigan, replacing Kirkby to Wigan shuttle service.	
Gap D22.4	**Wrexham Central to Bidston**
Option D22.4 Electrify from Bidston to Wrexham Central Extend Liverpool to Bidston service to Wrexham Central, replacing Bidston to Wrexham Central shuttle service[4].	
Gap D23.5	**Ormskirk to Preston and Wigan to Southport with new chord at Burscough**
Option D23.5 Electrify Ormskirk to Preston and Wigan to Southport with new chord at Burscough. Run through service from Liverpool to Preston.	
Gap D26.9	**Cowlairs South Junction / Gartsherrie South Junction to Greenhill Junction via Cumbernauld**
Option D26.9 Electrify Cowlairs South Junction / Gartsherrie South Junction to Greenhill Junction via Cumbernauld following Edinburgh to Glasgow. Also convert Glasgow Queen Street to Falkirk via Cumbernauld and Motherwell to Cumbernauld passenger services to electric traction. Divert services to Glasgow Queen St Low Level.	
Gap D26.11	**Paisley Canal to Elderslie**
Option D26.11 Electrify Paisley Canal to Elderslie following Corkerhill to Paisley Canal if line from Paisley Canal to Elderslie is reinstated as outlined in STPR.	

[4] AC and DC are both options for this route

6.3 Ranking of schemes for Gap Type A

As a threshold, self contained routes with a current passenger vehicle tonnage of less than 1m per year (on single track routes) or less than 2m per year (on double track routes), are taken as having a traffic level too low for electric traction to be an efficient form of operation for passenger traffic unless electrification would also address one or more of the other gap types, or aspirations have been expressed to electrify them on the grounds that electrification could be a catalyst for a significant enhancement of traffic and hence service level. Such routes are typically worked with trains formed of 2 carriages and the replacement of these trains by electric trains of 3 carriages or more would increase operating costs.

In order to provide a rapid assessment of the ranking of options, a 'conversion ratio' has been used. To a first order of magnitude, the benefit of electrification is broadly in proportion to the number of vehicle miles which can be converted from diesel to electric operation (this forms a proxy for passenger benefits, environmental benefits and operating cost savings), and the cost is broadly proportional to the number of track miles to be electrified. It follows that the ratio of:

number of vehicle miles which can be converted from diesel to electric operation

to:

track miles to be electrified

will provide an initial indication of the relative benefit : cost ratios of options.

Options have been grouped into six tiers on the basis of this conversion ratio. Tier 1 options, potentially offering the highest value for money, are those which enable the most passenger vehicle miles to convert to electric traction per single track mile electrified.

The conversion ratio is used to:

- identify which options should be prioritised for more rigorous appraisal;
- indicate where the value of an option might be enhanced where another option has already been implemented, and hence guide the ordering of schemes;
- indicate where the value of an option might be enhanced by adding a further scheme, and hence guide the grouping of schemes.

The tiers for the options to address gap type A are shown in Appendix 3.

6.4 Approach to economic appraisal

High ranking options – generally those in tiers 1 and 2 – have been subject to socio-economic appraisal to illustrate their potential value for money. Options for the longer term – generally those options featuring in the lower tiers – have not been appraised.

The appraisals are compliant with DfT's Transport Analysis Guidance (webTAG), Scottish Transport Appraisal Guidance (STAG) and Welsh Transport Planning and Appraisal Guidance (WelTAG). The RUS identifies the strength of the socio-economic case through the calculation of Benefit Cost Ratios (BCRs), and also indicates where a scheme is likely to have a positive financial case.

The BCRs presented in the RUS result from high-level feasibility work (broadly equivalent to GRIP1) to determine whether or not a *prime facie* case for electrification exists. For some options, value for money could be improved, perhaps significantly, through scheme optimisation. This may include restructuring electrified services to increase net revenue, or further decrease operational costs.

The appraisals consider the following financial impacts of electrification, typically using the values described in section 3:

- capital costs, including depot conversion where appropriate, and applying optimism bias;
- RAB financing costs;
- maintenance and renewal costs of electrification assets;
- industry disruption costs during construction;
- traction fuel costs;
- rolling stock maintenance costs;
- rolling stock lease costs;
- rolling stock availability benefits;
- benefits associated with diagram savings where appropriate;
- track wear and tear costs;
- journey time changes;
- punctuality and reliability changes;
- benefits associated with additional capacity.

The benefits considered in the appraisals include modal shift, the value of travel time savings and reduced carbon emissions.

The appraisals also reflect indirect taxation impacts. The latter can impose significant costs on electrification appraisals, following a reduction in diesel duties payable by the industry. DfT have recently announced changes that are being made to the New Approach to Appraisal (NATA) framework in the light of the Stern Review, the Eddington Transport Study and the NATA Refresh consultation. These changes will be implemented from April 2010, and include moving indirect taxation impacts from the Present Value Cost (PVC) calculation to the Present Value Benefits (PVB). We expect this change to improve the electrification business cases.

The RUS appraisals do not quantify any potential benefits from use as a diversionary route for an electric service, or benefits to the freight market. These benefits are discussed in sections 6.5.2 and 6.5.3.

Many of the BCRs quoted are sensitive to input assumptions. These include the treatment of diesel fuel duties payable by the industry, assumptions regarding future vehicle growth on the network, and rolling stock operating cost assumptions. Some main line appraisals are also subject to specific uncertainty regarding the characteristics of the next generation of long distance rolling stock. In particular, the relative cost and operational characteristics of diesel and electric Intercity Express Programme (IEP) trains are not yet clear. For this reason the business case for electrification of the Great Western Main Line is presented as a range of BCRs.

BCRs should therefore be regarded as indicative of value for money, and in almost all cases both upside and downside risks exist.

6.5 Results of economic appraisal

6.5.1 Gap A Options – Conversion of an existing passenger service

Appendix 3 ranks options to address Type A Gaps into six tiers, on the basis of a conversion ratio.

The analysis of schemes in Scotland shows that the highest ranking Type A schemes are the electrification of the routes from Edinburgh to Glasgow Queen Street via Falkirk High and Grahamston and Carmuirs Junctions to Dunblane and Alloa (Option A24.1b) and Corkerhill to Paisley Canal (Option A26.3). As noted in section 2.3, these schemes are included in phases 1 and 2 of the electrification element of the Strategic Transport Projects Review.

For high ranking options (plus a selection of options sampled from lower tiers to confirm that the ratio analysis provides a robust indication of the strength of the business case) in England and Wales, socio-economic appraisal has been used to demonstrate potential value for money. The results of these appraisals are summarised in Table 6.5.

Of the detailed appraisals completed, Midland Main Line, Great Western Main Line (Maidenhead to Oxford, Bristol and Swansea), cross country, Basingstoke to Exeter St. Davids, Berks and Hants, and Manchester to Euxton Junction, Preston to Blackpool North and Oxenholme to Windermere all potentially offer high value for money. The North cross Pennine Option A10.1e has a BCR of 1.2. However this would increase to 5.8 if the option were treated as an add on to the cross country scheme, with the capital expenditure associated with Leeds to Colton Junction allocated to the cross country scheme instead.

The North cross Pennine appraisal reflects the financial impact of electrification upon all train operators, both franchised and open access. However, benefits to open access operators are not necessarily reflected in industry costs to Government in the same way as for franchised operators.

Table 6.5 – Socio-economic appraisal of high ranking Gap A options		
Description	Option	BCR
Basingstoke – Exeter	Option A4.1b: Overhead AC electrification from Basingstoke to Exeter, following cross country electrification to Plymouth. Option enables conversion of Waterloo to West of England services.	BCR 3.1
North cross Pennine	Option A10.1e: Overhead AC electrification from: Liverpool to Manchester Oxford Road via St. Helens Junction. Guide Bridge to Leeds Leeds to Colton Junction. Micklefield to Hull Selby to Temple Hirst Junction. Northallerton to Middlesbrough Hambleton East to North, Hambleton South to West Option permits the following services to convert to electric traction: Newcastle to Manchester Airport Hull to Manchester Piccadilly Middlesbrough to Manchester Airport Scarborough to Liverpool becomes a York to Liverpool service (via St. Helens Junction.), extending Blackpool North-York services to Scarborough Leeds to Huddersfield London to Hull (franchise and open access operators) Selby to Wakefield (splitting at Leeds) Liverpool Lime St. to Manchester Airport (via St. Helens) Liverpool – Warrington Bank Quay York – Selby / Hull	BCR 1.2 (includes financial benefits to open access operators) (Assuming Leeds to Colton Junction. costs are allocated to cross country scheme: BCR 5.8)
Cross country	Options A13.4, A13.5b and A19.2: Overhead AC electrification of the following track sections in three phases, following Great Western, North cross Pennine and Midland Main Line electrification: Birmingham to Basingstoke via Coventry and Solihull, and north of Birmingham enabling access to Central Rivers depot (via Water Orton and Lichfield routes) Infilling the route between Central Rivers and the North East / Scotland, including the route to Derby, Doncaster to Sheffield, and Moorthorpe to Swinton Bromsgrove to Plymouth, including the short spur to Gloucester Option permits the following services to convert to electric traction: Cross country long distance services to / from South Coast, South West, North West, North East and Scotland Reading-Basingstoke Oxford-Banbury Bristol Parkway / Temple Meads to Weston Super Mare / Taunton services, and reinstatement of Cardiff to Taunton services which were assumed to be split at Bristol following Great Western electrification Paignton to Exeter St. Davids Paddington to West of England services (including Weston Super Mare) which operate via Bristol Temple Meads	BCR 5.1 (Assuming Leeds to Colton Junction. costs are also allocated to cross country scheme: BCR 3.4)
Berks and Hants	Option A12.2c: Overhead AC electrification of Reading to Cogload Junction, following GWML electrification and cross country electrification to Plymouth. This permits long distance West of England services from Paddington to convert to electric traction. Beyond Plymouth, the RUS assumes that through services will be maintained by attaching a diesel loco at Plymouth. London suburban services between Paddington and Newbury / Bedwyn are also assumed to convert to electric traction.	Positive financial case over appraisal period (effectively infinite socio-economic BCR)

Table 6.5 – Socio-economic appraisal of high ranking Gap A options

Description	Option	BCR
Great Western Main Line	Option A13.1b and 13.2b: Overhead AC electrification from Maidenhead to Oxford, Bristol (via Bath and Westerleigh Junction.) and to Swansea. Electrification between Paddington and Maidenhead is assumed under Crossrail. This enables conversion of the following services: Long distance services from Paddington to Bristol, Cardiff and Swansea London to Oxford services Services from Paddington to Cheltenham and Worcester are assume to be operated by IEP Bi-Mode trains, running under electric traction under the wires Cardiff to Taunton services, splitting the service at Bristol Temple Meads.	BCR lies in the range between • 'High' value for money (> 2.0); and • Positive financial case over appraisal period depending upon IEP cost assumptions
Snow Hill Lines	Option A17.1a: Overhead AC electrification of Snow Hill lines (Hereford to Worcester, Droitwich Spa to Small Heath, and Tyseley South Junction. to Stratford-Upon-Avon), following cross country electrification to Leamington Spa. Services assumed to convert to electric traction are Snow Hill lines services between Stratford-Upon-Avon and Dorridge (with Leamington Spa extensions) to Stourbridge Junction, Kidderminster and Worcester, plus Hereford to Birmingham New St. services.	BCR 1.0
Midland Main Line	Option A19.1: Overhead AC electrification from Bedford to Corby, Nottingham and Sheffield. Convert all long distance East Midlands services from St. Pancras to electric traction.	Positive financial case over appraisal period (effectively infinite socio-economic BCR)
Manchester to Preston, Blackpool North and Windermere	Option A20.1b and Option A23.1: Overhead AC electrification of Manchester (Ordsall Lane Junction.) to Euxton Junction, Manchester Victoria to Salford Crescent (via Salford Central), Preston to Blackpool North, and Oxenholme to Windermere. Services assumed to convert to electric traction are Manchester / Preston / Windermere / Scotland and Manchester Airport to Blackpool North trains, plus Manchester Victoria to Blackpool North and Hazel Grove to Preston services.	BCR 2.3

6.5.2 Gap B Options - Freight in-fill options

Section 4 discusses a broad range of benefits which may result from in-fill electrification for freight services.

Standard socio-economic appraisal rules do not necessarily capture all of these benefits, for example, reduced costs of freight operations. Other benefits, such as the value of improved infrastructure maintenance access, can be difficult to quantify.

The RUS considers the merits of in-fill electrification for freight by qualitatively grading the options against a list of potential benefits.

To a first order of magnitude, the costs and benefits of the options are reflected by the following proxies and classifications:

- capital cost: number of single track miles electrified;
- efficiency of freight operations:
    - ♦ relative volume of freight services able to convert to electric traction (high / medium / low);
    - ♦ provision of a diversionary route for electric freight services (yes / no);
    - ♦ enabler of reduced mileage for electric freight services (yes / no);
    - ♦ ability to haul greater trailing loads – assumed to be proportional to the volume of freight services able to convert;
- improved infrastructure maintenance access (high / medium / low);
- efficiency of passenger services – indicated by the passenger conversion ratio discussed in section 6.3;
- environmental benefits are assumed to be proportional to:
    - ♦ the relative volume of freight and passenger services able to convert to electric traction;
    - ♦ the efficiency of rail freight operations, assuming a lower cost base encourages modal shift in price sensitive freight markets (generating benefits measured using 'sensitive lorry miles').

The freight in-fill electrification options have been graded using this classification. The results are shown in Appendix 4

Appendix 4 suggests that Option B6.1 - electrification of Woodgrange Park to Gospel Oak, Harringay Park Junction. to Harringay Junction. and Junction Road Junction. to Carlton Road Junction. - may deliver significant benefits to both passenger and freight.

Table 6.6 shows the socio-economic appraisal of this option, assumed to be packaged with Option B6.3 - electrification of Ripple Lane sidings and Thameshaven branch.

Electrification of Gospel Oak to Barking plus the Thameshaven Branch and Ripple Lane sidings represents high value for money. This assumes implementation of TfL's plans to increase the frequency of passenger services to four trains per hour between Gospel Oak and Barking. One of the significant benefits delivered by this option is the elimination of some North Thameside freight services crossing the Great Eastern Main Line between Forest Gate and Stratford. This will improve infrastructure capacity and performance on the Great Eastern Main Line and Crossrail. The scheme would also deliver a step increase in capacity assuming the replacement of 2-car DMUs with 3-car EMUs.

The scheme delivers further benefits not reflected in the appraisal, including:

- •Provision of a diversionary route across North London for electrically hauled freight
- •Benefits enabling freight operators to provide a more efficient service (see Appendix 4)

Table 6.6 – Socio-economic appraisal of Gap B option

Description	Option	BCR
Gospel Oak to Barking and Thameshaven Branch	Options B6.1 & B6.3: Overhead AC electrification Woodgrange Park to Gospel Oak, Harringay Park Junction. to Harringay Junction. and Junction Road Junction. to Carlton Road Junction. and Ripple Lane sidings / Thameshaven Branch. Conversion of Gospel Oak to Barking passenger services to electric traction.	BCR 2.4 (this excludes both revenue and user benefits generated from increased capacity)

6.5.3 Gap C Options - Provision of a diversionary route

A number of schemes have been identified whose primary purpose would be to provide diversionary capability, either for the existing electrified network, or for parts of the network proposed for electrification under the strategy.

The benefits will depend upon a number of factors:

- fit with other schemes within the strategic options
- the existence of a passenger service regularly using the diversionary route, which could be converted to electric traction were the route electrified;
- density of freight traffic on the corridor
- density of passenger traffic on the route for which a diversion would be provided
- length of route for which a diversion would be provided

Appendix 5 shows the options considered for diversionary routes, together with an indication of their benefits.

6.5.4 Gap D Options - New passenger service opportunity

The principal benefit for schemes which enable a new passenger service to be introduced (gap type D) derives from additional passenger traffic generated by new journey opportunities. One indication of the strength of the scheme is given by the additional passenger revenue which may be generated by the service change. For these schemes a full economic appraisal is required to indicate the strength of the case.

Table 6.7 summarises the economic appraisal of electrification from Wolverhampton to Shrewsbury.

For the remaining gap type D schemes, the RUS has considered the strength of the case by analysing the conversion ratio ranking and existing passenger demand.

Option D20.6: Electrify Kirkby to Wigan with DC electrification. Extend Liverpool to Kirkby service to Wigan, replacing Kirkby to Wigan shuttle service.

This option was ranked as tier 6 on the basis of the conversion ratio. This ranking suggests that the scheme is unlikely to provide high value for money, unless:

- Electrification could be delivered for less than roundly £100k per single track km; or
- The new pattern of service delivers significant net benefits

Electrification would enable direct services to operate between Liverpool and Wigan Wallgate via Kirkby. Wigan North West and Liverpool Lime St. are currently connected by three direct trains per hour in each direction via Huyton. The fastest service takes less than 40 minutes.

Given the relatively low level of existing demand from stations between Wigan Wallgate and Kirkby, it seems unlikely that the market could be grown sufficiently to deliver value for money from the scheme, although RUS timescales have not allowed these issues to be analysed in detail.

The Merseyside RUS noted that Skelmersdale is the second most populous town in the North West Region without a railway station. Skelmersdale lies 13 miles north-east of Liverpool, close to the Kirkby – Wigan line. The

Table 6.7 – Socio-economic appraisal of Gap D option

Description	Option & Description of Service Restructuring	BCR
Wolverhampton to Shrewsbury	Option D17.5: Overhead AC electrification from Oxley Junction. to Shrewsbury. This appraisal assumes the following service pattern change: Extension of hourly West Coast Euston to Wolverhampton services through to Shrewsbury. Conversion of hourly Birmingham New Street to Shrewsbury services to electric. The services from Birmingham International to Machynlleth (for the Cambrian Coast) and North Wales, which together form an hourly Birmingham to Shrewsbury service, would start/terminate at Shrewsbury.	BCR 1.0

Merseyside RUS recommended that options for improving the connectivity of Skelmersdale are developed as far as GRIP 3. Extension of the electrified network beyond Kirkby should be considered in conjunction with these options.

Options D22.4: Electrify Wrexham Central to Bidston with either third rail DC or overhead AC electrification. Run a through service between Wrexham Central and Bidston to Liverpool.

The Merseyside RUS reported that a DC scheme would not be value for money or affordable.

In this RUS the scheme has been ranked as tier 6 on the basis of the conversion ratio. This ranking suggests that an AC scheme is unlikely to provide high value for money, unless:

- The scheme could be delivered for less than roundly £100k per single track km; or
- The new pattern of service delivers significant net benefits

Electrification would enable direct services to operate between Wrexham and Liverpool. A study is underway to assess the effect on demand.

Option D23.5: Electrify Ormskirk to Preston and Wigan to Southport with new chord at Burscough. Run through service from Liverpool to Preston, replacing Ormskirk to Preston shuttle.

This scheme was ranked as tier 6 on the basis of the conversion ratio. This ranking suggests that the scheme is unlikely to provide high value for money, unless:

- The scheme could be delivered for less than roundly £100k per single track KM; or
- The new pattern of service delivers significant net benefits

Electrification would enable direct services to operate between Liverpool and Preston via Ormskirk.

Currently, Liverpool and Preston are connected by an hourly service in each direction via Huyton, providing an end to end journey time of roundly one hour.

Given the relatively low level of demand from stations between Ormskirk and Preston, it seems unlikely that the market could be grown sufficiently to deliver value for money from the scheme, although RUS timescales have not allowed these issues to be analysed in detail.

Option D26.9 Electrify Glasgow to Cumbernauld and Greenhill Lower Junction plus new Garngad curve giving direct access from Cumbernauld to Glasgow Queen St Low Level. This is part of the EGIP project as the key driver is to remove two trains per hour from Glasgow Queen St High Level to facilitate running more trains on the main Edinburgh and Glasgow route.

This will also give a wider range of journey options from the Cumbernauld route to central Glasgow and west thereof.

Option D26.11 Electrify Paisley Canal to Elderslie. This would allow electric trains to use the line following reinstatement as outlined in STPR.

7 Strategy

7.1 Introduction

The Network RUS Electrification Strategy has considered the extent of existing electrification and has identified key drivers of change which, when taken together, suggest a good case for further electrification of the network. The drivers include economic factors (including the potential for significant operational savings), environmental factors and timing with other activity such as rolling stock and infrastructure renewals. The effects of the drivers are amplified by anticipated growth in passenger numbers and the freight which governments expect will need to be carried in Britain in the next thirty years.

The RUS has looked at how future electrification could lead to the effective and efficient accommodation of growth in accordance with Network Rail's Licence. It has considered stakeholder aspirations, particularly the interest in electrification expressed by the Government funders, the Department for Transport and Transport Scotland, of Transport for London and the PTE group who wish to extend electrification within their areas, and of the passenger and freight operators who have identified key routes and infill between routes which would significantly improve the efficiency of their businesses. Manufacturers and RoSCos worked along side Network Rail's teams to ensure that delivery issues are fully understood.

Options for further network electrification were identified which were expected to offer high value for money. Where appropriate linkages and dependencies between the proposals and with other schemes on the network were identified and exploited.

Given its national coverage the Network RUS Electrification Strategy plays a central role in the RUS programme. The on-going geographical RUSs and the next generation of RUSs will take the consideration of electrification one step further, when they consider individual proposals in conjunction with detailed agreed passenger forecasts.

This chapter outlines the resulting strategy. It brings together the key strategic electrification issues of concern to Network Rail, its customers and stakeholders and identifies a strategy to take them forward.

Section 2 of this chapter outlines proposals for improved equipment design and factors which will affect the delivery of further electrification. This is followed in Section 3 by an outline of the principles adopted in developing the strategy. It proposes that the strategy would include infill electrification, identifying its benefits and proposing how it could be progressed alongside a strategy for core route electrification.

This is followed in Sections 4 and 5 of this chapter by the recommended strategy for England and Wales, and Scotland respectively. Section 6 outlines the impact that the proposals would have on the proportion of the network electrified and carbon emissions produced. Finally Section 7 outlines Network Rail's proposals to ensure that active provision is made for the works.

7.2 Design and delivery

7.2.1 Improved equipment design

The focus of the strategy is to develop a highly reliable and easily maintainable electrification system which can be delivered efficiently at benchmarked low unit costs and with minimal disruption to users.

Work has been progressing with the Rail Industry Association and Network Rail's suppliers to identify how electrification design can eradicate known failure modes, reduce the requirements for maintenance and simplify construction. By incorporating these innovations into the detailed equipment design very early in the lifecycle there should be little impact on capital costs. Focus should be placed on how failure modes will be designed out and what processes will be employed to check that component level failures are being avoided. This approach will deliver a robust electrification product which addresses the major causes of OLE infrastructure failure, namely equipment design, construction delivery failure and maintenance delivery failure. The reliability and cost targets will be benchmarked against British and international experience and evidence.

Examples of the issues needing to be addressed to provide a reliable and affordable electrification system include: elimination of restricted electrical clearances (reducing incidence of flashover / shorting), avoidance of conductor tension / dynamic movement, reduction in conductor creep and conductor corrosion, and failsafe designs for span assemblies and pivot pins.

Work is underway to improve knowledge of the dynamic interface between the pantograph and the contact wire. Simulation models will be used to better predict the pantograph to catenary dynamics in normal and perturbed states. The understanding can then be applied during the design stage to design out failure modes and also subsequently once OLE systems are in use to understand any performance issues. It will aid understanding about the use of multiple pantographs on a train which enable more flexibility in the use of the system. The developments will continue to be benchmarked against emerging evidence from elsewhere.

It is proposed that routine deployment of intelligent electrification monitoring systems / infrastructure including the new measurement train and other measurement systems will enable the move away from 'find and fix' to 'predict and prevent' maintenance.

7.2.2 Delivery factors

Five major items of work are required to deliver an electrified railway:

- wiring the 'open route' – between major junctions
- wiring the complex / major junctions
- establishing clearance for the overhead wires from bridges and other fixed structures
- establishing power supply points and distributing power along the route
- protecting (immunising) other electrical equipment from the electrification system.

The overall approach is common for all these works. It would be necessary to use construction techniques which minimise disruption and make extensive use of blocks (to traffic) of not more than 8 hours. The application of modular techniques to construction and the deployment of rapid delivery systems to improve the rate of production are two key activities in achieving this objective.

Past experience shows that electrification does not, in itself, require large numbers of disruptive blocks that cause significant delay to passengers and freight operators. The proposed construction methodology is designed to operate within normal 'rules of the route' possessions. To achieve this it is expected that construction techniques which are capable of working with the adjacent line open to traffic will be required.

Work is underway with the supply base to establish construction techniques and designs which draw on national and international experience. It is equally important to develop a shared understanding how the teams and skill will be developed and sustained by the supply base. A "ramp up" phase will be required to refine the needs of the delivery teams and their supply chain.

Within this shared overall objective of minimal disruption and skilled delivery, each element of the work will require a slightly different solution. For the 'open route', Network Rail's work on delivery mechanisms suggests that the use of 'factory trains' would be the most efficient way to proceed. This possible solution is described in Appendix 2. Such a solution, for the open route works, would enable automation and standardisation as far as possible. This delivery option has been developed In conjunction with suppliers to the point where there is confidence that the electrification work can be delivered within midweek night possessions (equivalent of one tension length per six-hour productive shift) and with the adjacent line open, so minimising disruption. This approach has parallels with the high output track techniques already successfully in use. The factory trains would be flexible units, capable of working individually or in combination, and as such, will play a useful on-going role in the efficient maintenance of the electrified network.

Where the railway layout is complex, such as at principal junctions and some stations, the high output train would be unable to work due to the complexity of the track layout and logistical limitations of blocking points etc. These areas would need to be identified precisely in the early planning stages of the project and alternative means for carrying out the OLE installation identified. Application of the modular designs, the improved provision of plant and the application of some of the systems from the open route delivery systems will reduce the service impact in these sections. For example, a single piling or crane unit may be able to gain access into a junction area for installation of foundations and steelwork. It is recognised that installation work in these restricted areas will be slower and more expensive and due allowance will be made within the programme. The ratio of high output installation to conventional installation has only been approximately estimated for some of the routes listed in this document but is unlikely to exceed 20% requiring conventional installation methods.

For route clearance works there would be some need for more extensive blocks for demolition and erection of new structures e.g. bridge works. Generally these do not require exceptional possessions and even these can usually be planned to coincide with other works. Also, as these works are planned a number of years in advance, it is possible to plan a possession regime to accommodate any exceptional possessions.

Development of a long term relationship with the electricity supply industry will be crucial to ensuring a mutual understanding of expected electrical demand and supply points. It is intended that this would foster the integration of work programmes between the two industries.

Procurement of National Grid supply points and the associated 25kV distribution system would be undertaken in parallel to the design and construction of the OLE. The availability and commissioning of the necessary power supply points drives the testing and commissioning programme for the OLE and will therefore require careful integration into the overall programme. A key consideration will be the risk of theft of overhead line conductor and other valuable components if the OLE is left un-energised for any length of time. In the past, the risk of theft has driven many new electrification projects to consider early energisation of the system on an incremental basis, as each new section becomes available.

Other planned works such as re-signalling and renewals of switches / crossings will create longer possession opportunities for electrification work, for example in station and junction areas. It is expected that by integrating the electrification renewal activity the need for extensive immunisation work will be minimised.

Once the extent of any programme or stage has been established an economic approach to construction can be derived. There are obvious economies of scale provided by the use of mechanised solutions and their support systems, over a reasonably sized group of projects. Efficient materials rates and supply chains are enabled by a predictable and regular throughput. The capabilities of the labour skill base, both at depots and in construction can be refined through constant practice of their set-up and installation techniques.

The interaction of delivery efficiency, affordability and delivery rate (volume) has been considered in developing the benefits of the strategy. It is considered that two rapid delivery units could be utilised to achieve an appropriate output rate and volume.

7.3 Developing the Strategy

7.3.1 Approach

The Network RUS Electrification Strategy has been developed to include those electrification schemes which would be expected to most reduce the operating costs of the railway, have clear environmental benefits and demonstrate high value for money. It has been developed separately for England and Wales, and for Scotland, to reflect the separate funding streams and value for money criteria.

The appraisal results in Chapter 6 suggest that a number of the schemes examined are candidates for inclusion in the strategy on the basis of current cost estimates. The core England and Wales strategy has been developed to include three schemes – the two main line routes which offer the greatest value for money and the strategic infill scheme which offers the highest value for money. It is recommended that emerging costs from the core strategy and updated demand forecasts and views on service structures and rolling stock deployment from the geographical RUSs would be used to further inform business cases in an updated Network RUS Electrification Strategy. This would enable a revised view of network-wide priorities to be taken. The timing of updates to the strategy would take account of the development timescales for future schemes

The development of the strategy has considered a number of key factors, which when taken together impact on its value for money:

- prioritisation of those routes which have the strongest business cases
- reduction of diesel train operation on the electrified network
- identification of key infill schemes which would give early operational efficiency benefits
- exploitation of synergies with rolling stock replacement and cascade
- consideration of delivery factors, such as minimising disruption, taking advantage of the economies of scale of using factory train formations, making efficient use of each depot provided for them
- ramp up and sustaining delivery capability

- exploitation of synergies with other enhancement projects.

7.3.2 Prioritisation of routes which have the strongest business cases

Chapter 6 outlined the results of appraisals of the value of electrification of each route which had been identified as a RUS option i.e. a candidate for electrification. Those options which have Benefit : Cost ratios in excess of the Government's hurdle rate of 2.0, defined as high value for money in the DfT's Guidance on Value for Money, are recommended as part of the Core Strategy or as key candidate schemes for feeding into an updated Network RUS Electrification Strategy as emerging costs become available.

Two schemes – the Great Western Main Line and the Midland Main Line – have particularly high BCRs without dependency on further electrification. In the case of Midland Main Line the value is technically infinite given that it involves a net industry cost saving rather than a cost. The Great Western Main Line BCR lies in the range from 'high value for money' to 'financially positive' over the appraisal period, depending upon IEP cost assumptions. There is an upfront investment requirement for Network Rail which is potentially offset by lifetime cost savings, largely in the costs of train operation. It is clearly logical to move forward on these schemes first. Five additional route options have BCRs above the high value for money hurdle rate on the basis of current cost estimates if delivered as part of a longer term rolling programme.

7.3.3 Reduction of diesel train operation on the electrified network

The strategy aims to improve the match between rolling stock and infrastructure by reducing the extent of diesel train operation on the electrified network.

7.3.4 Exploitation of synergies with rolling stock replacement

Chapter 4 identified the replacement of diesel locomotives with their electric equivalents as one of the key drivers of change, reflecting the advantages of electric traction for the economics of operation, environmental impact and compatibility with European legislation. An electrification programme could potentially enable large numbers of diesel vehicles to be replaced and, where they are not life expired, to be cascaded to other parts of the network, again avoiding the purchase of diesel vehicles.

A key decision for the DfT is the choice of traction type (or types) to replace the diesel Intercity 125 High Speed Train (HST) fleet which currently operates on the Great Western Main Line. In addition a significant proportion of the current diesel powered passenger rolling stock fleet, used on local and regional services away from London, will be due for replacement by 2020.

It may also be appropriate to deploy part of the rolling stock fleet cascaded as a result of the Thameslink scheme on one or more routes electrified in the future.

7.3.5 Inclusion of key freight infill schemes which would give early operational benefits

Chapter 6 includes a list of infill electrification schemes which have been identified as providing potential operational benefits to freight operators. The majority of the schemes are modest in scale compared with main line electrification. The sections of track which fall into this category can be used by passenger or freight services alike, if service specifiers so chose. Examples are electrification of the Gospel Oak to Barking route and Walsall to Rugeley. Electrification of each of the routes potentially facilitates reductions in operating costs and environmental benefits wherever they facilitate a shift from diesel to electric traction and in many cases improves performance by providing diversionary capability.

It is recommended that the core strategy includes an option for an infill scheme early in the programme which would benefit both freight and passenger operators. It is anticipated that further schemes would be included if a decision was made to adopt a long term strategy. This could provide economies of scale, enabling delivery units to deliver infill schemes whilst working on other schemes in the vicinity.

In addition, as individual schemes are developed, opportunities to electrify associated yards and sidings will be identified and evaluated.

7.3.6 Exploitation of synergies with other enhancement projects

The strategy presented aims to achieve synergies with other projects wherever there are economic advantages in doing so. The principal synergies are with gauge clearance work and resignalling projects. Synergies may be in the scope of work (in the case of gauge clearance) or in phasing (in the case of re-signalling).

The established Freight RUS published in March 2007 identifies a network of routes which the freight operators would like to be gauge cleared. That RUS specified that W12 should be the gauge that Network Rail should take as a starting point whenever structures on the specified W12 network were to be renewed or rebuilt. This has been adopted as Network Rail policy. That RUS acted as the starting point for the Strategic Freight Network which is now also considering European gauge.

Where the electrification strategy outlined below involves conversion of a route which has also been identified for future gauge clearance as part of the Strategic Freight Network, synergies will be sought between the two projects. The guiding principle will be that any structure which has to be rebuilt for electrification should be rebuilt only once. The starting point should be that the structure should be specified for gauge clearance as well as electrification.

Programme synergies have also been identified where a route with a high value for money business case for electrification is due for resignalling. The guiding principle is that the route should only be disrupted once and that any signalling installed be compatible with electrification. In cases where significant immunisation issues would be expected to arise as a consequence of the incompatibility of existing signalling and telecommunications cables with potential electrical interference from the new electrification systems, careful phasing of electrification and resignalling would be important to achieve an acceptable business case. A key example is Leicester re-signalling which is scheduled to be carried out in 2015 and would need to be carried out in conjunction with Midland Main Line electrification.

On the Great Western Main Line there are a numbers of signalling installations which are becoming due for renewal and which in their current form are not suitable for use with electrification. The GWML is also one of the few routes fitted with Automatic Train Protection which is due to be replaced with an ETCS level 2 solution shortly. A programme is being developed which meshes all these activities and incorporates the introduction of the Super Express Trains and has minimal impact on current rolling stock. The dependency for electrification is that the renewal of the trackside signalling equipment has been completed prior to electrification.

7.4 Electrification Strategy for England and Wales

7.4.1 Overview

The factors outlined in Section 7.3 have been carefully considered in conjunction with the appraised options outlined in developing the strategy. The strategy for England and Wales is shown in Figure 7.1. Subject to affordability, the strategy consists of:

- a core strategy consisting of a strategic infill electrification scheme and electrification of the Midland and Great Western Main Lines
- consideration of additional funding sources for early implementation of additional infill schemes
- a decision point where emerging costs and updated views of demand would enable business cases to be reviewed to establish whether there is a case for further electrification.

It is assumed that the strategy would be delivered by an efficient delivery mechanism. The factory train approach is one possibility. Electrification of the Great Western Main Line and the Midland Main Line would require two such delivery units, which will be described throughout this chapter as 'Western' and 'Midland' units respectively to reflect the two major main line electrification projects with the highest benefit – cost ratios.

Implementation of the strategy would require the purchase of new electric vehicles and have implications of for the cascade of existing vehicles. The rolling stock strategy will need to be carefully considered in conjunction with funders' decisions on the phasing of investment.

7.4.2 Core strategy

a) Strategic infill

The strategy recommends early implementation of an infill electrification scheme. Chapters 5 and 6 showed that there are a number of candidate schemes. It is recommended that these are taken forward as part of geographical RUSs and that funding should be sought from a variety of sources e.g. the Network Rail Discretionary Fund, the Strategic Freight Network Fund, the European Commission.

Whilst further work is required to develop the costs of the alternative schemes, a possible early candidate for early implementation can be identified from the range of infill options reported in Chapters 5 and 6 on the basis of strong support from stakeholders and its indicative business case. It comprises two related AC infill electrification schemes in the London area. Electrification of the Gospel Oak to Woodgrange Park line would allow Transport for London's aspiration of a 4 train per hour passenger service on the Gospel Oak to Barking route to be converted to electric traction – the scheme falls in tier 3 when measured on the conversion of passenger vehicle miles. Electrifying associated links to the East Coast Main Line and the Midland Main Line route would allow electric freight trains from Thameside to avoid the congested North London Line, with capacity benefits on that route and on the Great Eastern Main Line. The Thameside branch and sidings in the Ripple Lane area would also need to be electrified to allow additional electric operation of freight trains from the port, and greater operational flexibility.

It is assumed that freight services operating over the line would be operated by electric traction and that the route could be used for diversions. Freight from Tilbury, Barking, Ripple Lane, High Speed 1 and London Gateway would be primary beneficiaries. There would also be consequential performance benefits on the Great Eastern from rerouteing of electric services between North Thameside and the North London Line which currently cross the main line between Woodridge Park and Stratford.

b) Main lines

The core strategy includes the electrification of two main line routes: the Great Western Main Line and the Midland Main Line. These are the two routes which have the strongest business cases without dependency on further electrification. In both cases, the initial capital outlay is offset by long term operational cost

Table 7.1 Key Candidate for Strategic Infill scheme in the Core Strategy

Option	Scheme
B6.1	Woodgrange Park to Gospel Oak, Harringay Park Junction – Harringay Junction and Junction Road Junction to Carlton Road Junction.
B6.2	Ripple Lane sidings and Thameshaven branch

savings. Network Rail is discussing with government the extent to which the schemes could be funded through the Regulatory Asset Base in a way that avoids unnecessary funding requirements at the outset.

In both cases, the business cases are robust to a range of costs.

The business case for the Great Western Main Line is most efficient when brought in line with the introduction of the Super Express fleet as part of the Intercity Express Programme, thereby enabling purchase of electric rather than diesel IEP and allowing the benefits of electrification to be taken from day one of their introduction. The business case for electrification from Maidenhead (where the Crossrail electrification is assumed to stop) to both Bristol and Swansea is in the range of high value for money to financially positive. Not surprisingly, the case is stronger for Maidenhead to Bristol given that it involves the conversion of less mileage and carries more traffic. The incremental electrification from Bristol Parkway to Swansea is a relatively low value for money element of the overall scheme. The extension from the main line to Oxford is high value for money and would be recommended for implementation.

The electrification of some short sections of route in West London, to provide connectivity between freight routes, would be examined as part of the Great Western Main Line scheme.

The early electrification of the non-electrified lines between Paddington and Maidenhead as part of the Crossrail project will present an early opportunity for ramping up production.

The Midland Main Line scheme also has a strong business case. Although the costs per single track kilometre are higher, reflecting the many tunnels and bridges on the route, the mileage is less (given that the route is already electrified south of Bedford) and the scheme would release of a fleet of Class 222 diesel trains and enable the replacement of High Speed Trains with electric trains when these become available.

The strategy recommends electrification from Bedford to Sheffield via Derby, Nottingham and Corby. It is recommended that, subject to business case, the Midland Main Line is simultaneously gauge cleared. The Freight RUS has identified the Midland Main Line as part of a future W12 network. The Strategic Freight Network Steering Group is examining whether it would be feasible to clear it to European gauge. The starting point for the electrification work would be to clear the route to European gauge if this can be achieved at an acceptable incremental cost. There are clear advantages in minimising disruption by rebuilding structures only once.

The electrification of the short branch to Matlock currently has a marginal business case, and its inclusion within the scope of the Midland Main Line scheme will depend on the cost estimates as they are refined.

To minimise disruption it is most attractive to spread the enabling works for both schemes, notably civils gauge clearance works, over a long time period and utilise possessions booked for other works. The two longest lead items enabling this are the procurement of grid supply points (which can take up to seven years) and the specification, procurement, manufacture and testing of the efficient delivery units.

7.4.3 Further options.

It is recommended that improved knowledge of implementation techniques and emerging costs from the Core Strategy be used to inform whether there would be a case for implementation of further schemes. Similarly, geographical RUSs can provide detailed understanding of demand, service structures and rolling stock deployment. The improved knowledge of costs and demand will enable business cases to be updated to inform an updated Network RUS Electrification Strategy. The updated strategy would identify the

Table 7.2 Main Line Schemes recommended in the core strategy

Option	Scheme
A13.1b	Great Western Main Line: Maidenhead to Oxford and Bristol via Bath and Bristol Parkway,
A13.2b	Great Western Main Line: Bristol Parkway to Swansea
A19.1	Midland Main Line: Bedford to Sheffield via Derby, Trent Junction to Nottingham and Kettering to Corby

strongest candidates to take forward.

Given the lead times for scheme development, the decision point on further electrification would ideally be made several years before the completion of core strategy to ensure power supply is secured, skills retained and necessary works can be scheduled.

As any programme of electrification advances it is expected that differentiated systems would be developed which allow electrification to be achieved at reduced costs. This may improve the business case of the less favourable routes to a position where they could be candidates for inclusion in the programme. Possible advances may include systems for discontinuous catenary (avoiding expensive structures - where those structures are not required to be modified or rebuilt to maintain or enhance freight gauge - and avoiding complex areas of wiring) and a more basic electrification system for lightly used or low speed routes.

The further options recommended for review at this stage include those schemes which have a less favourable business case than Great Western or Midland Main Line but are currently believed to have a BCR in excess of 2.0 on the basis of high level cost estimates. As the understanding of outturn costs develops, it is possible that additional schemes would clear a high value for money hurdle. A number of schemes to convert passenger services currently marginally fail the DfT's high value for money hurdle but could reasonably be expected to qualify as the cost estimates are refined. Similarly refinement of costs and traffic forecasts may facilitate a decision to include further infill schemes. Changes proposed to the appraisal framework for April 2010 may also strengthen the case for electrification.

It is recommended that at this stage the business cases of the schemes listed below are reviewed to inform the decision point. The AC electrification schemes are classified into 'Western' or 'Midland' schemes, reflecting the delivery units required for the core strategy which might be expected to deliver them if they were to go forward.

a) Western delivery unit

- Swindon to Cheltenham – which (following electrification of Great Western in the core option) would enable electric operation from Paddington to Cheltenham
- The two cross country routes south of Birmingham
  - ♦ via Coventry to Reading and Basingstoke (enabling Bournemouth to Birmingham and Manchester services to be operated by electric traction) and
  - ♦ Bromsgrove to Cheltenham and Westerleigh Junction and the Birmingham Camp Hill line (thus, if implemented in conjunction with the Birmingham to Derby and Sheffield to Doncaster routes, enabling the rest of the cross country services to be operated by electric traction except for extensions to Penzance and Aberdeen)
- Severn Tunnel junction to Gloucester (enabling Cardiff to Birmingham and Nottingham services to run on electric traction and providing a diversionary route from Swindon to South Wales avoiding the Severn Tunnel)
- The Berks and Hants line
- Basingstoke to Exeter (enabling electric traction on services from Waterloo to Salisbury and Exeter)
- West London infill schemes (bridging a gap between the Great Western Main Line, the Midland Main Line and the West London Line) for traffic to the south of London and the Channel Tunnel.

b) Midland Delivery unit

- The Matlock branch (which currently has a marginal business case if included in the Midland Main Line scheme)
- North cross Pennine from Liverpool to Manchester (via Chat Moss) and Hull (via Guide Bridge and Colton Junction); Temple Hirst Junction to Selby); Northallerton to Middlesbrough – enabling conversion of services from Liverpool to Manchester Airport and Warrington Bank Quay, London to Hull and North cross Pennine services, and providing diversionary routes from the West Coast Main Line to Liverpool, and a 30 mile section of the West Coast Main Line from Crewe to Golborne Junction and from the East Coast Main Line between Doncaster and Colton Junction.
- Ditton (to enable access to Ditton Freight terminal)
- Extension of electrification of the Middlesbrough route northwards to Sunderland (allowing conversion of London to Sunderland services, and potentially Middlesbrough to Newcastle trains)
- Hare Park (on the Doncaster to Wakefield route) to Wakefield Europort
- Crewe to Chester (enabling electric traction for Euston to Chester services)

- Manchester to Euxton Junction, Preston to Blackpool and the Windermere branch (enabling conversion of Manchester to Windermere and Scotland services and Manchester to Preston and Blackpool North local services) and providing a diversionary route for the West Coast Main Line
- Huyton to Wigan (enabling conversion of Liverpool to Wigan and Blackpool services)
- Stalybridge to Manchester Victoria (enabling diversionary capability for cross Pennine services)
- Birmingham to Derby and Sheffield to Doncaster (enabling electric traction on cross country routes if implemented in conjunction with conversion of the southern sections by a western delivery unit)
- Newark Northgate to Lincoln (enabling the projected London to Lincoln service to be operated with electric traction)
- Chiltern route between Marylebone and Aynho Junction; from Princes Risborough and the branch from Hatton to Stratford-upon Avon (enabling conversion of all Chiltern services via High Wycombe)
- Walsall to Rugeley (enabling the conversion of the Birmingham to Rugeley service and providing an alternative electrified route for freight trains from Birmingham to the West Coast Main Line)
- the Sutton Park line from Water Orton and Castle Bromwich Junctions to Ryecroft Junction near Walsall (providing diverse routeing options for electric freight trains)
- Nuneaton to Water Orton (linking with the cross country route into Birmingham, and providing electrified diversionary capability for the Rugby to Birmingham route)
- Nuneaton to Coventry (providing another electrified link from the Leamington direction to the West Coast Main Line, and additional electrified diversionary capability for the West Coast Main Line between Rugby and Nuneaton)
- Wolverhampton to Shrewsbury (allowing conversion of the local Birmingham to Shrewsbury service and potentially enabling a restructuring of services which would provide through trains from London Euston to Shrewsbury and releasing capacity on the Birmingham International to Wolverhampton corridor)
- the remaining Snow Hill suburban routes (allowing the conversion of the remaining Birmingham suburban services)
- Felixstowe to Ipswich and Haughley Junction to Nuneaton (providing an electric route for freight trains from the Haven Ports to the East Coast Main Line, the West Midlands and the West Coast Main line and providing an electrified diversionary route for the East Coast Main Line between Hitchin and Peterborough. This would enable the Birmingham to Stansted Airport, London to Peterborough via Ipswich and Felixstowe to Ipswich services to be operated by electric trains)
- Corby to Manton Junction (which would complete an electrified diversionary route for the Midland Main line avoiding Leicester)
- Cambridge to Chippenham Junction (allowing the Cambridge to Ipswich service to be operated with electric trains).

If innovative low cost forms of electrification, such as a form of discontinuous electrification which would have gaps in electrification at certain locations which would otherwise be particularly expensive to electrify, were to be developed, it is possible that the list of candidate schemes for further examination would increase.

c) DC schemes

Two DC schemes could be considered subject to satisfactory business cases. DC electrification between New Kew Junction and South Acton Junction would provide an electrified diversionary route for freight trains between Wembley and the Channel Tunnel when the West London Line is unavailable. Electrification with DC of the Hurst Green to Uckfield route would allow conversion of the London to Uckfield service to electric traction. The first of these schemes would ideally be implemented at a similar time to the package of West London in-fill schemes described above. The timing of the Uckfield line electrification schemes would be independent of the timing of the AC schemes in the strategy.

The schemes recommended for review are shown along with their option number (for cross reference to Chapter 6) in Appendix 6.

7.5 Strategy for Scotland

Transport Scotland has already developed a policy driven and evidence based electrification programme, which is defined in STPR Project 6, and are implementing the first phase (the EGIP Project) as STPR Project 15. The findings of that review are reinforced by the work in this RUS.

This includes the Edinburgh-Glasgow via Falkirk High and Grahamston, Carmuirs Junctions to Dunblane / Alloa, plus Glasgow-Cumbernauld-Greenhill Lower Junction. This electrification has been developed to support a wide ranging service and capacity upgrade, including 6 trains per hour between Edinburgh and Glasgow, with a fastest journey time of around 35 minutes.

It will also allow the conversion of other suburban services in the area including Motherwell-Cumbernauld to electric traction, and facilitate the operation of electric freight services which would follow from the electrification of the Grangemouth branch.

STPR Project 6 and Scotland's Railways set out Phase 2 which is electrification of the remaining Central Scotland diesel operated passenger routes:

- Corkerhill-Paisley Canal
- Rutherglen – Whifflet / Coatbridge
- Holytown to Midcalder Junction via Shotts
- Glasgow Central to East Kilbride and Barrhead / Kilmarnock
- Cowlairs Junctions to Anniesland / Westerton.

This programme will enable the replacement of life expired diesel units with electric units, and in some cases will provide freight capability and diversionary routes.

The Rutherglen-Whifflet electrification will enable the diversion of this service to Glasgow Central Low Level thus releasing capacity in the High Level Station.

In addition electrification of the Grangemouth branch and the Edinburgh Suburban lines will permit electric haulage of freight services. Glasgow Shields – High Street is an infill route offering diversionary routes, but with limited current freight use. Electrification of the Hunterston – Ardrossan South Beach (freight line) could be worthwhile should Hunterston develop as a container handling port.

Beyond the Central Belt STPR sets out an aspiration to electrify routes from Edinburgh through Fife to Aberdeen, Dunblane to Dundee and Ladybank to Perth and Inverness.

Apart from the conversion of the internal Scottish services to electric traction this will permit full electric operation of London to Aberdeen and Inverness services and also cross country services. These routes will also permit the electric operation of freight services. These schemes are summarised in Tables 7.3 and 7.4

Table 7.3 EGIP project

Option	Scheme
A24.1a	Edinburgh to Glasgow Queen Street via Falkirk High and Grahamston
A24.2	Carmuirs Junctions to Dunblane and Alloa
D26.9	Cowlairs South Junction / Gartsherrie South Junction to Greenhill Junction via Cumbernauld

Table 7.4 Other STPR proposals

Option	Scheme
A26.3	Corkerhill to Paisley Canal
A26.1	Rutherglen to Coatbridge Junction / Whifflet
A26.4	Cowlairs Junction to Anniesland
A26.2	Midcalder Junction to Holytown via Shotts
A26.6b	Glasgow Central to East Kilbride and Busby Junction to Kilmarnock.
B24.7	Edinburgh Suburban lines
B26.8	Glasgow: Shields Junction to High Street Junction
B24.8	Grangemouth branch
B26.5	Hunterston to Ardrossan
A24.3b	Haymarket to Aberdeen and Fife circle
A24.5	Dunblane to Dundee
A25.1	Ladybank to Hilton Junction (Perth) and Perth to Inverness

7.6 Impact of strategy

Figure 7.1 illustrates the core strategy. The strategic options presented would contribute to reducing the UK's carbon emissions. Table 7.5 shows estimates of the annual amount of carbon emissions which would be avoided by passenger trains following the implementation of the strategic options in this chapter. For illustrative purposes, the definition of the England and Wales scenario assumes that the package of Gospel Oak to Woodbridge Park, the Thameside Branch and the Ripple Lane sidings, would be the selected infill scheme. The figures presented are conservative. They could be increased if the UK moves towards a lower carbon form of electricity generation. The figures quoted are based upon current traffic levels on the network and assume no growth. Carbon benefits would increase if future traffic growth were to be provided by electric vehicles. The figures only include the carbon benefit of converting from diesel to electric traction. Further carbon benefits would be realised from modal shift (from road and air), following an improvement to the rail product.

Reductions in freight emissions have not been included in the calculation whilst the industry works together to understand their impact. Their inclusion will clearly raise these figures further.

Figure 7.1 England and Wales core strategy and Scotland schemes

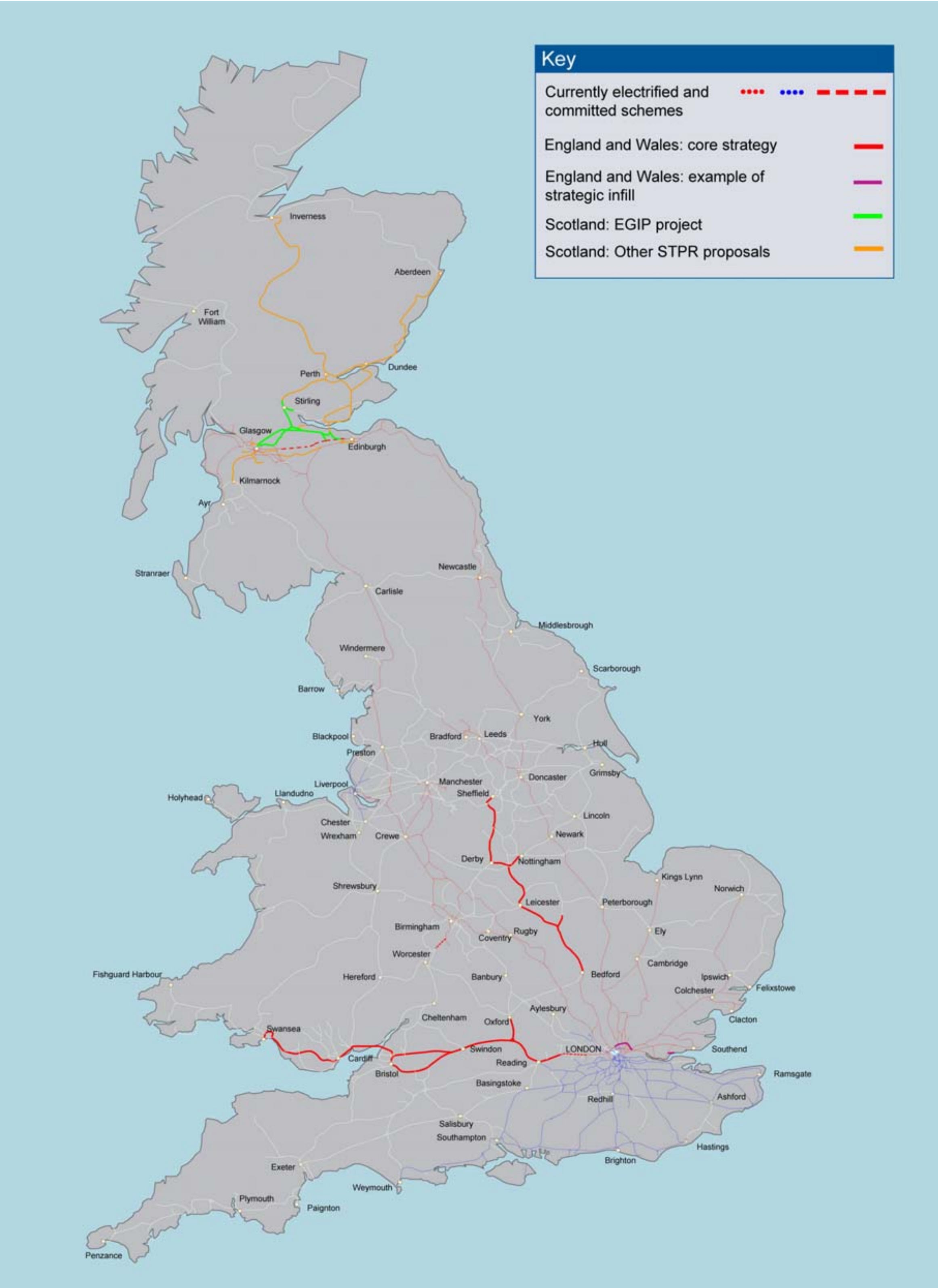


Table 7.5 Reduction in carbon released per year resulting from the strategy

Option	Reduction in carbon released per annum (tonnes)
England and Wales Core Strategy	20600
EGIP project	2500
STPR proposals	4800

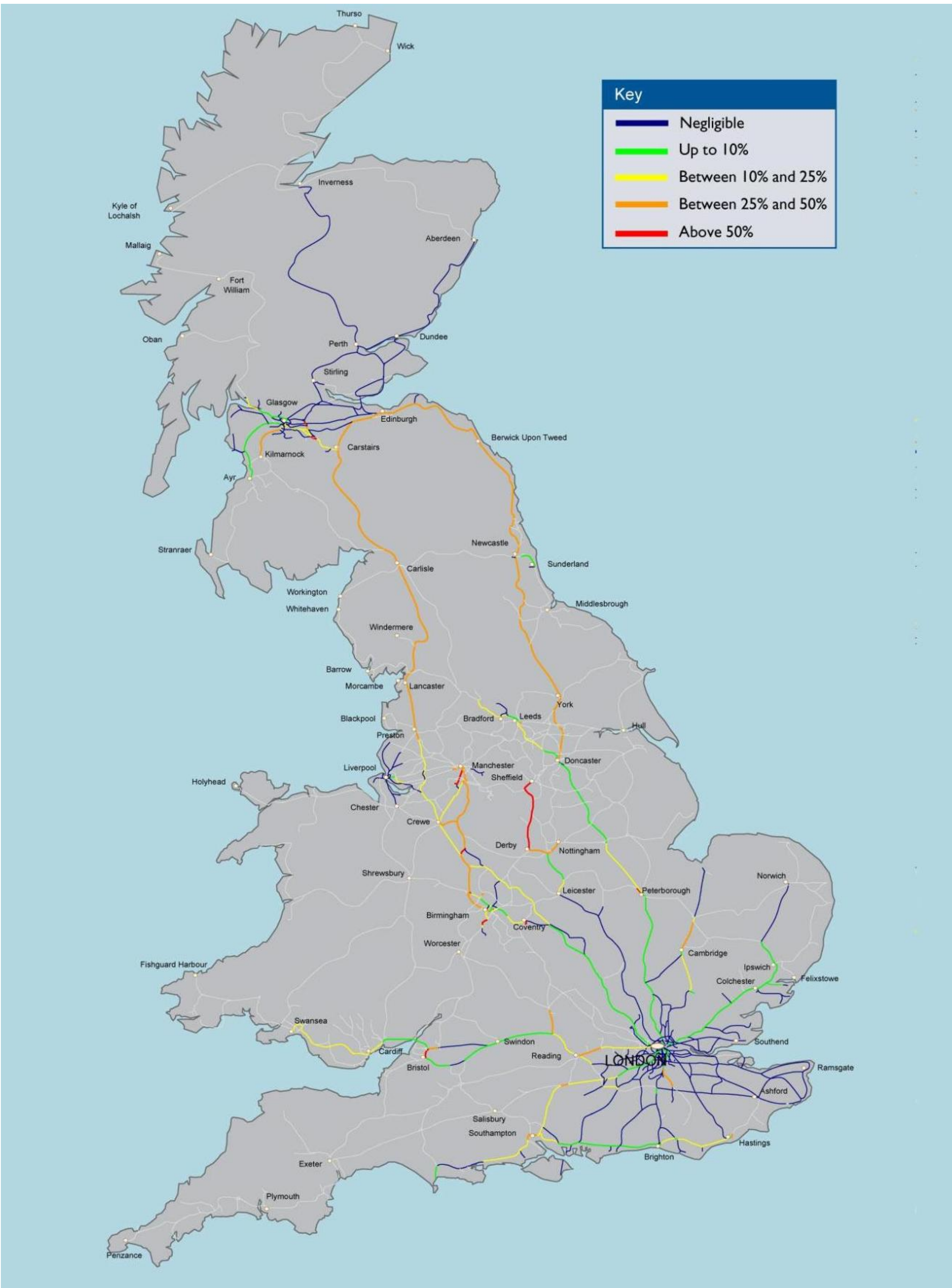
Figure 7.2 indicates the approximate proportion of diesel passenger tonnage on the electrified network should the core strategy outlined in this chapter be delivered.

Table 7.6 shows the impact of the strategy on the electrified mileage of the network and an estimate of its impact on the vehicle mileage operated by electric traction, delivered cumulatively by different options.

Table 7.6 Electrified track and vehicle mileage

Option	Percentage of track miles electrified	Percentage of passenger vehicle miles electrically operated
Current network and committed schemes	41%	65%
England and Wales Core strategy	46%	72%
EGIP project	47%	73%
STPR proposals	51%	75%

Figure 7.2 Estimated proportion of passenger tonnage carried on the electrified network (following England and Wales core schemes and Scotland schemes) by diesel trains



7.7 Active provision for electrification schemes

To demonstrate that current investment programmes are consistent with our proposed electrification programme, Network Rail will formalise the provision that should be made for the electrified railway. This will also cover the consequential benefits that electrification should deliver for a route.

The following will be the starting point for works being carried out in a route which is included in any of the strategic options outlined in this Chapter:

- All works on a route identified in the Core Strategy and in the strategy for Scotland shall be specified for both physical clearance and electrical immunisation.
- All works on other routes to be reviewed after the decision point shall be specified for physical clearance.
- Electrification reconstruction works shall leave a W12 cleared route for those routes identified in the Freight RUS and the Strategic Freight Network.

8 Next Steps

8.1 Stakeholder consultation

Consultation with stakeholders is essential to the successful development of a Route Utilisation Strategy. Close involvement of stakeholders helps to ensure that:

- the widest range of options is considered
- the resulting decision approaches optimality
- the delivery of the outcomes is faster

The recommendations of a RUS – and the evidence of relationships and dependencies revealed in the work to meet them – form an input into the strategic decisions made by the industry's funders.

8.2 Funding

It is recommended that those schemes in the England and Wales core strategy and Scottish priority schemes are developed further with DfT and Transport Scotland. If further investigation of their costs indicates that their business case is robust, a funding mechanism for their delivery will be sought. Consideration would need to be given to flows of funds given that Network Rail will bear the up front delivery costs and most of the benefits are long term in nature and will be to the train operators, freight operators and Governments.

It is recommended that discussions are progressed on other schemes if funding is available.

8.3 Network Rail's CP4 Delivery Plan

Network Rail's funding for CP4 does not include funds for electrification beyond committed schemes in the baseline. Should funding be allocated for ramp up of resources and / or implementation of schemes in CP4, this would be included in a revision to the March 2009 Delivery Plan and associated Route Plans.

8.4 Development of further schemes

As discussed in Chapter 7, it is proposed that the schemes in the list of further options are developed further within geographical RUSs which would be able to take an informed view of local demand. Each RUS would consider service patterns which would maximize the benefits of electrification and consider any further development in understanding the costs of conversion of the line concerned.

Emerging costs and updated demand forecasts would be used to further inform business cases in an updated Network RUS Electrification Strategy which would enable a revised view of network-wide priorities to be taken. The timing of updates to the strategy would take account of the development timescales for future schemes

The RUSs will inform High Level Output Specifications (HLOSs) prepared by the Department for Transport and Transport Scotland) to define the outputs that they wish to buy over the next control period (CP5 from 2014 to 2019). These statements alongside the accompanying Statement of Funds Available (SoFA) will be used to set the funding requirements for Network Rail over this period.

8.5 How you can contribute

We welcome contributions which will help us develop this RUS. Specific questions have not been set as we would appreciate your comments on the document as a whole. We would particularly welcome views on the overall approach to electrification: the proposed core programme and individual schemes in the list of further options which will be developed further within geographical RUSs.

This draft RUS is available for consultation for 60 days. The deadline is therefore 14th July 2009. After this period, Network Rail will consider each of the responses it receives and, where appropriate, amend the document in consultation with the stakeholder Working Group. Consultation responses can be submitted either electronically or by post to the addresses below and these will be published on our website following the completion of the consultation process.

electrificationrus@networkrail.co.uk

Network RUS Consultation Response
National RUS Manager
Network Rail
Kings Place
4th Floor, Section O
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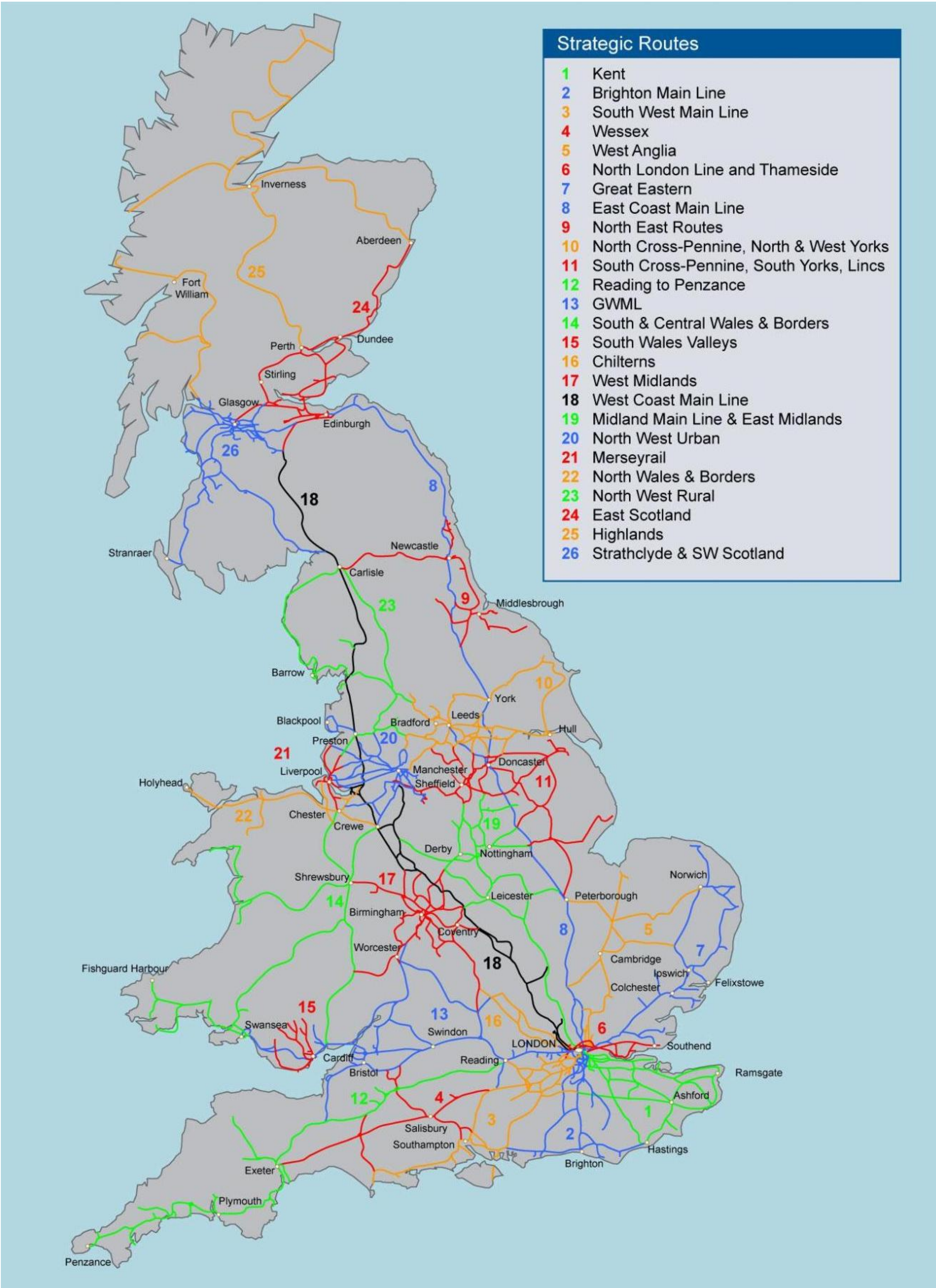
The final RUS document will be published once the changes are approved by the Stakeholder Management Group. The RUS will become established 60 days after publication unless the Office of Rail Regulation (ORR) issues a notice of objection in this period.

Appendices

Appendix 1: Network Rail Strategic Routes

Appendix 1 :Network Rail Strategic Routes



Appendix 2: The Factory System – A potential delivery system

A factory train is proposed to comprise of four modules which can be further separated as required. The make up of the train consist is proposed as:

1(a). First piling or structures module

1(b). Second piling or structures module, identical to 1(a)

1(c). Third piling or structures module, identical to 1(a)

2. Feed, aerial earth, cantilever frame and balance weight installation module

3. Contact and catenary installation module

4(a). Completion works unit / multi purpose module

4(b). Identical to 4(a)

Module 1 - Piling and Structures Installation Module

Module 1 will consist of four parts, two master vehicles both capable of operating as either a piling vehicle or a structures mounting vehicle and two flat bed match wagons for transporting piles (min 15 of) and mast structures (min 15 of). The module can be split effectively providing into two separate piling / structures vehicles.

Module 1 - Piling and Structures Installation Module

Module 2 – Feed / Aerial Earth Wire Cable and Registration Assembly Installation

This module comprises three vehicles. One master vehicle will house eight cable drum carriers and two manipulator arms capable of positioning the cables behind, above or in front of the masts. One slave vehicle will be fitted with welfare facilities and a Mobile Elevated Working Platform (MEWP) basket for attaching the cables to the mast. The second master vehicle is fitted with racking, a crane and a MEWP basket.

Module 2 - Feed/Aerial Earth Wire Cable and Registration Assembly Installation

Module 3 - Contact and Catenary Wire Installation Vehicle

This module has a master vehicle with four cable drum mounts and two manipulator arms capable of positioning the contact and catenary wire at different heights between 4m and 6m, a self powered access vehicle with MEWP basket and welfare facilities and a further master vehicle with long scissor platform.

Module 3 - Contact and Catenary Wire Installation Vehicle

Module 4 - Completion Works / Measurement / Multi-Purpose Module

The final multi-purpose module provides flexibility to complete final pieces of work using versatile MEWP basket capable of reaching anywhere in the OLE structure area as well as a crane capable of lifting transformers etc. Additionally measuring systems and a measuring pantograph will be used to record accurate as built data.

The factory concept has been developed to the point where there is confidence that high output electrification work can be delivered within midweek night possessions (equivalent of one tension length per six-hour productive shift) and with the adjacent line open, so minimising disruption.

The factory train requires restocking at the end of each shift and so will return to its main depot to be re-loaded with materials ready for the next shift. As far as possible equipment is pre-configured at the depot and loaded on to the train ready to expedite installation on site. In cases where it is impractical for the train to return to the main depot at the end of each shift, satellite depots will be used.

Once the electrification programme is complete, most of the factory train modules will be used for maintenance and renewal activity.

Appendix 3: Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
Option A1.1 Electrify Ashford to Ore with DC electrification. Convert Brighton to Ashford service to electric traction.	4
Option A2.1 Electrify Uckfield to Hurst Green with DC electrification. Convert Uckfield to London service to electric traction.	3
Option A3.1 Electrify Wokingham to Ash and Shalford to Reigate with DC electrification. Convert Reading to Gatwick Airport and Reading to Redhill local services to electric traction.	4
Option A4.1a Electrify Basingstoke to Salisbury. Convert Waterloo to Salisbury service to electric traction.	3
Option A4.2 Electrify Salisbury to Exeter following Basingstoke to Salisbury. Convert Waterloo to Exeter service to electric traction.	2
Option A4.1b Electrify Basingstoke to Exeter. Convert Waterloo to Salisbury and Exeter service to electric traction.	3
Option A4.3a Electrify Eastleigh to Romsey and Redbridge to Salisbury. Convert Romsey to Salisbury service to electric traction.	6
Option A4.4 Electrify Salisbury to Bathampton Junction (Bath) following Redbridge to Salisbury and GWML. Convert Cardiff to Portsmouth service to electric traction.	3
Option A4.3b Electrify Eastleigh to Romsey and Redbridge to Bathampton Junction (Bath), following GWML. Convert Romsey to Salisbury and Cardiff to Portsmouth services to electric traction.	4
Option A4.6 Electrify Yeovil Pen Mill to Dorchester following GWML, Redbridge to Bathampton Junction and Castle Cary to Yeovil Junction. Convert Bristol to Weymouth service to electric traction.	5
Option A5.2 Electrify Chippenham Junction (Newmarket) to Cambridge following Haughley Junction to Peterborough,. Convert Ipswich to Cambridge service to electric traction.	2
Option A5.3. Electrify Ely to Norwich and Grantham to Clay Cross Junction following Liverpool to Manchester, Haughley Junction to Peterborough, Midland Main Line, and Dore to Hazel Grove. Convert Cambridge to Norwich and Liverpool to Norwich services to electric traction.	5
Option A7.2 Electrify Westerfield to Lowestoft following Felixstowe to Ipswich. Convert London and Ipswich to Lowestoft services to electric traction.	5
Option A7.3 Electrify Marks Tey to Sudbury. Convert Marks Tey to Sudbury services to electric	5

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
traction.	
Option A7.4 Electrify Norwich to Lowestoft and Yarmouth. Convert Norwich to Lowestoft and Yarmouth services to electric traction.	6
Option A7.5 Electrify Norwich to Sheringham. Convert Norwich to Sheringham services to electric traction.	6
Option A20.4 Electrify Manchester Deansgate to Liverpool (Edge Hill) via Chat Moss route. Convert Liverpool to Manchester Airport and Liverpool to Warrington Bank Quay service to electric traction.	4
Option A10.1a Electrify Guide Bridge to Leeds, Leeds to Colton Junction and Hull, and Temple Hirst to Selby following Manchester Deansgate to Liverpool (Edge Hill). Convert Hull to London and cross Pennine services to electric traction. Modify cross Pennine services so that they run between Liverpool and Manchester via the Chat Moss route, and so that through Middlesbrough services are split at York and Scarborough is served by services from Preston rather than by North cross Pennine services.	2
Option A 9.1 Electrify from Northallerton to Middlesbrough and Thornaby to Sunderland. Reinstate through North cross Pennine services to Mibblesbrough, and convert London to Sunderland service to electric traction.	2
Option A 10.2 Electrify York to Scarborough. Convert York to Scarborough service to electric traction.	6
Option A10.1b Electrify Guide Bridge to Leeds, Leeds to Colton Junction and Hull, Northallerton to Middlesbrough and Temple Hirst to Selby following Manchester Deansgate to Liverpool (Edge Hill). Convert Hull to London and cross Pennine services to electric traction. Modify cross Pennine services so that they run between Liverpool and Manchester via the Chat Moss route, and so that Scarborough is served by services from Preston rather than by North cross Pennine services.	2
Option A9.2 Electrify Thornaby to Sunderland following Northallerton to Middlesbrough. Convert London to Sunderland service to electric traction.	1
Option A10.1c Electrify Guide Bridge to Leeds, Leeds to Colton Junction and Hull, Northallerton to Middlesbrough, York to Scarborough and Temple Hirst to Selby following Manchester Deansgate to Liverpool (Edge Hill). Convert Hull to London and cross Pennine services to electric traction. Modify cross Pennine services so that they run between Liverpool and Manchester via the Chat Moss route.	3
Option A10.1d Combination of Option A10.1a with Option A20.4	2
Option A10.1e Combination of Option A10.1b with Option A20.4	3
Option A10.1f Combination of Option A10.1c with Option A20.4	3

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
Option A 10.5 Electrify Leeds to York via Harrogate. Convert Leeds to York via Harrogate service to electric traction.	5
Option A10.11 Electrify Doncaster to Gilberdyke following Doncaster to Sheffield and Leeds to Hull. Convert Sheffield to Hull service to electric traction.	4
Option A11.2 Electrify Dore to Hazel Grove following Midland Main Line. Split Manchester Airport to Cleethorpes service at Doncaster and convert resulting Manchester Airport to Doncaster service to electric traction. Reroute Hope Valley local service to run via Hazel Grove and convert to electric traction.	4
Option A11.3 Electrify Dore to Hazel Grove, Doncaster to Gilberdyke and Thorne Junction to Cleethorpes, following Midland Main Line, Doncaster to Sheffield and Leeds to Hull. Convert Sheffield to Hull and Manchester Airport to Cleethorpes services to electric traction. Reroute Hope Valley local service to run via Hazel Grove and convert to electric traction.	4
Option A 10.3 Electrify Leeds to Manchester via Calder Valley. Convert Leeds to Manchester via Calder Valley service to electric traction.	5
Option A 10.4 Electrify Wakefield Westgate to Thornhill LNW Junction (Mirfield) and Heaton Lodge Junction / Bradley Junction to Milner Royd Junction / Dryclough Junction following North cross Pennine and Leeds to Manchester via Calder Valley. Convert Leeds-Hebden Bridge via Mirfield and Huddersfield to Wakefield services to electric traction.	5
Option A11.1 Electrify Newark Northgate to Lincoln. Convert projected London to Lincoln service to electric traction.	2
Option A11.4a Electrify Meadowhall to Horbury Junction via Barnsley following Midland Main Line, Nottingham to Clay Cross Junction, Sheffield to Doncaster, Wakefield to Thornhill Junction and Wakefield to Leeds via Altofts. Convert Leeds–Barnsley–Sheffield–Nottingham services to electric traction.	3
Option A11.4b Electrify Meadowhall to Leeds via Barnsley, Wakefield Kirkgate and Altofts following Midland Main Line, Nottingham to Clay Cross Junction and Sheffield to Doncaster. Convert Leeds–Barnsley–Sheffield–Nottingham services to electric traction.	5
Option A12.2a Electrify Reading to Bedwyn following Paddington to Reading. Convert London to Newbury and Bedwyn services to electric traction.	5
Option A12.2b Electrify Reading to Plymouth and Paignton and Bristol to Cogload Junction following Paddington to Reading. Convert London to West of England services to electric traction, with loco haulage for services west of Plymouth. Convert London to Newbury and Bedwyn Exeter to Paignton and Cardiff to Taunton services.	3
Option A13.5a Electrify Bromsgrove to Cheltenham and Standish Junction to Westerleigh Junction (Bristol Parkway) following Birmingham to Doncaster, Swindon to Cheltenham, Bristol to Cogload Junction and Reading to Plymouth and Paignton. Convert cross country services to the west country to electric traction with loco haulage for services west of Plymouth. Convert Bristol to	1

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
Gloucester services to electric traction.	
Option A13.5b Electrify Bromsgrove to Cheltenham and Standish Junction to Westerleigh Junction (Bristol Parkway) and Bristol to Plymouth and Paignton following GWML, Birmingham to Doncaster and Swindon to Cheltenham. Convert cross country services to the west country to electric traction with loco haulage for services west of Plymouth. Convert Bristol to Gloucester, Exeter to Paignton and Cardiff to Taunton services to electric traction. Reinstate through Cardiff to Taunton service and operate with electric traction.	2
Option A12.2c Electrify Reading to Cogload Junction following Paddington to Reading, and Bristol to Plymouth and Paignton. Convert London to West of England services to electric traction, with loco haulage for services west of Plymouth. Convert London to Newbury and Bedwyn, Exeter to Paignton and Cardiff to Taunton services to electric traction.	1
Option A12.3b Electrify Plymouth to Penzance. Run through services without the need to attach a loco at Plymouth. Convert Plymouth to Penzance local services to electric traction.	4
Option A12.4 Electrify Exmouth Junction to Exmouth following Basingstoke to Exeter. Convert Exeter to Exmouth services to electric traction	4
Option A13.1a Electrify Great Western Main Line from Airport Junction to Oxford and Bristol via Bath. Run Paddington to Bristol service with Super Express trains as part of the Intercity Express Programme. Convert Paddington to Reading and Oxford suburban services to electric traction.	1
Option A13.1b Electrify Great Western Main Line from Maidenhead to Oxford and Bristol via Bath and Bristol Parkway. Run Paddington to Bristol service with Super Express trains as part of the Intercity Express Programme. Convert Paddington to Reading and Oxford suburban services to electric traction.	2
Option A13.1c Electrify Great Western Main Line from Maidenhead to Bristol via Bath, following Airport Junction to Maidenhead (electrified under Crossrail scheme). Run Paddington to Bristol service with Super Express trains as part of the Intercity Express Programme. Convert Paddington to Reading suburban services to electric traction.	2
Option A13.1d Electrify Didcot to Oxford following Great Western Main Line from Maidenhead to Bristol. Convert Paddington to Oxford services to electric traction.	1
Option A13.2a Electrify Great Western Wootton Bassett Junction to Swansea, following Airport Junction to Bristol via Bath. Run Paddington to Cardiff and Swansea service with Super Express trains as part of the Intercity Express Programme. Split Cardiff to Taunton service at Bristol, and convert Cardiff to Bristol service to electric traction.	1
Option A13.2b Electrify Great Western Main Line Bristol Parkway to Swansea, following Maidenhead to Bristol via Bath and Bristol Parkway. Run Paddington to Cardiff and Swansea service with Super Express trains as part of the Intercity Express Programme. Split Cardiff to Taunton service at Bristol, and convert Cardiff to Bristol service to electric traction.	1
Option A13.3. Electrify Swindon to Cheltenham following GMML to Bristol and operate Paddington to Cheltenham service with Super Express trains as part of the Intercity Express Programme.	3

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
Convert Swindon to Cheltenham service to electric traction.	
Option A13.4 Electrify Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke following GWML to Oxford. Convert cross country service from Southampton and Reading to Birmingham and Manchester to electric traction. Convert Basingstoke to Reading local services to electric traction.	3
Option A13.6 Electrify Gloucester to Severn Tunnel Junction following GWML, and cross country. Convert Cardiff to Birmingham and Nottingham services to electric traction.	3
Option A13.7 Electrify Oxford to Worcester following GWML to Oxford and Birmingham Snow Hill suburban services. Convert London to Worcester and Hereford services to electric traction.	4
Option A14.1 Electrify Newport to Crewe following GMWL, Shrewsbury to Chester and Chester to North Wales. Split Milford Haven via North and West route at Swansea, and convert Swansea and Cardiff to Manchester and North Wales services to electric traction.	5
Option A14.2 Electrify Shrewsbury to Chester following Wolverhampton to Shrewsbury and Chester to North Wales. Convert Shrewsbury to North Wales services to electrification.	5
Option A14.3 Electrify Swansea to Milford Haven following GWML and Newport to Crewe. Reinstate through services to Milford Haven and operate with electric traction.	6
Option A15.1 Electrify Cardiff Valleys routes. Convert all services to electric traction.	5
Option A16.1a Electrify Marylebone to Aynho Junction, and Aylesbury via High Wycombe, Hatton to Stratford upon Avon and Old Oak to Northolt following Oxford to Birmingham. Convert Marylebone to Birmingham and Marylebone to Aylesbury via High Wycombe services to electric traction.	2
Option A16.1b Electrify Marylebone to Birmingham Snow Hill, Stratford upon Avon and Aylesbury via High Wycombe, and Old Oak to Northolt . Convert Marylebone to Birmingham and Marylebone to Aylesbury via High Wycombe services to electric traction.	4
Option A16.3 Electrify Aylesbury to Claydon following Claydon to Bletchley reopening and electrification. Run new passenger service with electric traction.	2
Option A17.1a Electrify Hereford to Bearley Junction following Oxford to Birmingham and Hatton to Stratford upon Avon. Convert Birmingham Snow Hill suburban services to electric traction.	4
Option A17.1b Electrify Birmingham Snow Hill suburban network (Hereford to Leamington Spa, Tyseley to Stratford, and Bearley Junction to Hatton.) Convert Birmingham Snow Hill suburban services to electric traction.	5
Option A16.2 Electrify Neasden Junction to Aylesbury via Harrow following Marylebone to Birmingham Snow Hill. Convert Marylebone to Aylesbury via Harrow services to electric traction.	4

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
Option A19.1 Electrify Midland Main Line and run St Pancras to Nottingham, Sheffield, Derby and Corby services with electric trains, using cascaded trains for the long distance services.	1
Option A19.2 Electrify Doncaster to Sheffield, South Kirkby Junction (Moorthorpe) to Swinton, Derby to Birmingham and Wichnor Junction to Lichfield following GWML Midland Main Line and Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke. Convert cross country services from Edinburgh via ECML, Newcastle and Leeds to Reading and Southampton to electric traction. Convert Sheffield to Leeds via Moorthorpe and Birmingham to Nottingham services to electric traction.	1
Option A19.3 Electrify Ambergate to Matlock following Midland Main Line. Convert Nottingham to Matlock service to electric traction.	3
Option A19.4 Electrify Newark to Nottingham following Midland Main Line and Newark to Lincoln. Convert Leicester to Lincoln service to electric traction.	4
Option A20.1a Electrify Euxton Junction to Manchester. Convert Manchester to Scotland and Hazel Grove to Preston services to electric traction.	3
Option A20.2 Electrify Preston to Blackpool North following Euxton Junction to Manchester. Convert Manchester to Blackpool North service to electric traction.	1
Option A20.1b Electrify Euxton Junction to Manchester and Preston to Blackpool North. Convert Manchester to Scotland and Blackpool North and Hazel Grove to Preston service to electric traction.	2
Option A20.3 Electrify Salford Crescent to Wigan NW and Lostock Junction to Crow Nest Junction following Manchester to Euxton Junction. Convert Manchester to Wigan service to electric traction.	6
Option A20.5a Electrify Huyton to Wigan following Edge Hill to Manchester and Preston to Blackpool North. Convert Liverpool to Wigan and Blackpool North services to electric traction.	3
Option A20.5b Electrify Edge Hill to Wigan following Preston to Blackpool North. Convert Liverpool to Wigan and Blackpool North services to electric traction..	4
Option A20.6 Electrify Ashburys to New Mills and Rose Hill Marple to Hyde Junction. Convert Manchester South Suburban services to electric traction.	5
Option A20.7 Electrify Manchester to Liverpool (Hunts Cross to Trafford Park.) Convert Manchester to Liverpool via Warrington service to electric traction.	5
Option A20.8 Electrify Kirkham and Wesham to Blackpool South, Preston to Hall Royd Junction and Rose Grove to Colne following North cross Pennine, Preston to Blackpool North and Leeds to Manchester via Calder Valley. Convert Blackpool North to York and Blackpool South to Colne service to electric traction.	5
Option A20.9 Electrify Bolton to Clitheroe following Euxton Junction to Manchester. Convert	5

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
Manchester to Blackburn and Clitheroe service to electric traction.	
Option A20.10 Electrify Hazel Grove to Buxton. Convert Manchester to Buxton service to electric traction.	5
Option A22.1 Electrify Crewe to Chester. Convert Euston to Chester services to electric traction, with some rearrangement of destinations of Chester and North Wales services to separate electric and diesel diagrams.	1
Option A22.2 Electrify Chester to Acton Grange Junction and Chester to Holyhead and Llandudno following Crewe to Chester and Edge Hill to Manchester. Convert London to North Wales and Manchester to Llandudno and Holyhead services to electric traction.	4
Option A23.1 Electrify Oxenholme to Windermere following Euxton Junction to Manchester. Convert Manchester to Windermere and Oxenholme to Windermere services to electric traction.	1
Option A23.3 Electrify Carnforth to Barrow following Euxton Junction to Manchester. Convert Manchester and Lancaster to Barrow services to electric traction.	4
Option A24.1a Electrify Edinburgh to Glasgow Queen Street via Falkirk High and Grahamston. Convert Edinburgh to Glasgow services to electric traction.	3
Option A24.2 Electrify Carmuirs Junctions to Dunblane and Alloa following Edinburgh to Glasgow Queen Street. Convert Glasgow and Edinburgh to Dunblane and Alloa services to electric traction.	1
Option A24.1b Electrify Edinburgh to Glasgow Queen Street via Falkirk High and Grahamston and Carmuirs Junctions to Dunblane and Alloa. Convert Edinburgh to Glasgow services and Glasgow and Edinburgh to Dunblane and Alloa services to electric traction.	2
Option A24.3a Electrify Haymarket to Inverkeithing and Fife circle. Convert Edinburgh to Fife circle services to electric traction.	5
Option A24.4 Electrify Haymarket to Aberdeen. Convert Edinburgh to Aberdeen services to electric traction. Electrically haul London to Aberdeen services throughout.	5
Option A24.3b Electrify Haymarket to Aberdeen and Fife circle. Convert Edinburgh to Fife circle and Aberdeen services electric traction. Electrically haul London to Aberdeen services throughout.	4
Option A24.5 Electrify Dunblane to Dundee following Glasgow to Dunblane and Edinburgh to Aberdeen. Convert Glasgow to Aberdeen services to electric traction.	4
Option A24.6 Electrify Ladybank to Hilton Junction (Perth) following Edinburgh and Glasgow to Dunblane and Dundee and Haymarket to Aberdeen. Convert Edinburgh to Perth services to electric traction.	3
Option A25.1 Electrify Ladybank to Inverness following Edinburgh and Glasgow to Dunblane and Dundee and Haymarket to Aberdeen. Convert Glasgow and Edinburgh to Inverness services to	5

Appendix 3 Options to address Type A Gaps – Ranking of Options Using the Conversion Ratio	
Option	**Tier**
electric traction. Electrically haul London to Inverness services throughout.	
Option A26.1 Electrify Rutherglen to Coatbridge Junction / Whifflet. Convert Glasgow-Whifflet services to electric traction.	5
Option A26.2 Electrify Midcalder Junction to Holytown via Shotts. Convert Glasgow-Edinburgh via Shotts services to electric traction.	5
Option A26.3 Electrify Corkerhill to Paisley Canal. Convert Glasgow Central to Paisley Canal services to electric traction.	2
Option A26.4 Electrify Cowlairs Junction to Anniesland. Convert Glasgow Queen Street to Anniesland service to electric traction.	5
Option A26.6a Electrify Glasgow Central to East Kilbride. Convert Glasgow Central to East Kilbride service to electric traction.	4
Option A26.7 Electrify Busby Junction to Barrhead / Kilmarnock following Glasgow Central to East Kilbride. Convert Glasgow Central to Kilmarnock service to electric traction.	5
Option A26.6b Electrify Glasgow Central to East Kilbride and Busby Junction to Kilmarnock. Convert Glasgow Central to East Kilbride and Kilmarnock services to electric traction.	5

Appendix 4 – Classification of electrification in-fill options for freight

Appendix 4 – Classification of electrification in-fill options for freight													
Gap	Option	Single track miles electrified	Assumptions	Passenger conversion Ratio Tier	Relative number of freight trains converted	Enabler of reduced mileage for electric freight services	Diversionary routes benefits	Improved maintenance access	Potential environmental benefits	Passenger and freight interaction	Potential performance and capacity benefits	Potential journey time saving	Overall benefits
Gap B5.1 Gap B7.1 Gap B19.10	Option B5.1 Electrify Felixstowe to Ipswich and Haughley Junction to Nuneaton. Also convert Felixstowe to Ipswich and Birmingham to Stansted Airport passenger services to electric traction	302	MML and Nuneaton to Water Orton electrified	5	High	Yes	Yes	High	High	High	High	High	High
Gap B6.1	Option B6.1 Electrify Gospel Oak to Barking, Harringay Park Junction – Harringay Junction and Junction Road Junction to Carlton Road Junction. Also convert Gospel Oak to Barking passenger service to electric traction	27		3	High	Yes	Yes	High	High	High	High	High	High
Gap B6.2 Gap B6.3	Option B6.1 Electrify Ripple Lane sidings and Thameshaven branch	10	Other option 6.1 electrified	-	High	Yes	Yes	Low	High	High	High	High	High
Gap B6.4 Gap B6.5	Option B6.4 Electrify Willesden Acton Branch Junction / South West Sidings to Acton Wells Junction and Acton Wells Junction to Acton West Junction following electrification of the GWML	4	Options 6.6 and 6.7 electrified	-	Medium	Yes	Yes	Medium	Medium	Medium	Medium	Medium	Medium

Appendix 4 – Classification of electrification in-fill options for freight

Gap	Option	Single track miles electrified	Assumptions	Passenger conversion Ratio Tier	Relative number of freight trains converted	Enabler of reduced mileage for electric freight services	Diversionary routes benefits	Improved maintenance access	Potential environmental benefits	Passenger and freight interaction	Potential performance and capacity benefits	Potential journey time saving	Overall benefits
Gap B6.6	Option B6.6 Electrify Old and New Kew Junctions to South Acton Junction with DC electrification	4	Options 6.4 and 6.7 electrified	-	Low	Yes	Yes	High	Low	Low	Medium	Medium	Medium
Gap B6.7	Option B6.7 Electrify Acton Canal Wharf Junction to Cricklewood / Brent Curve Junctions	10	MML and Options 6.4 and 6.6 electrified	-	Medium	Yes	Yes	Medium	Medium	High	High	Medium	Medium
Gap B9.5	Option B9.5 Electrify Tyne Dock branch	2		-	Low	No	No	Low	Low	Low	Low	Medium	Low
Gap B10.6	Option B10.6 Electrify Hare Park Junction to Wakefield Europort	13		-	Medium	No	No	Low	Medium	Low	High	Medium	Medium
Gap B10.7	Option B10.7 Electrify Altofts Junction to Church Fenton	30	North cross Pennine and Options 10.6 and 10.8 electrified	-	Medium	No	Yes	Medium	Medium	Medium	High	Low	Medium
Gap B10.8	Option B10.8 Electrify Altofts to Leeds via Woodlesford + Methley-Whitwood	22	Options 10.6 and 10.7 electrified	-	Low	No	Yes	Low	Low	Low	Low	Medium	Low
Gap B10.9	Option B10.9 Electrify Shaltholme Junction to Milford Junction	31	Options 10.7 and 10.10 electrified	-	Medium	No	Yes	High	Medium	High	High	Low	Medium
Gap B10.10	Option B10.10 Electrify Moorthorpe to Ferrybridge Junction	18	Birmingham to Colton Junction via Leeds and Option 10.7 and 10.9 electrified	-	Medium	No	Yes	High	Medium	High	High	Medium	Medium

Appendix 4 – Classification of electrification in-fill options for freight

Gap	Option	Single track miles electrified	Assumptions	Passenger conversion Ratio Tier	Relative number of freight trains converted	Enabler of reduced mileage for electric freight services	Diversionary routes benefits	Improved maintenance access	Potential environmental benefits	Passenger and freight interaction	Potential performance and capacity benefits	Potential journey time saving	Overall benefits
Gap B11.5	Option B11.5 Electrify Peterborough to Doncaster via Joint Line	170	Option 5.1 electrified	-	High	No	Yes	High	Medium	High	High	High	High
Gap B17.3	Option B17.3a Electrify Nuneaton to Water Orton and Whiteacre to Kingsbury	29	Birmingham to Derby and Option 17.8 electrified	-	High	No	Yes	High	High	High	High	High	High
	Option B17.3b Electrify Nuneaton to Birmingham	49	Option 17.8 electrified	-	High	No	Yes	High	High	High	High	High	High
Gap B17.4	Option B17.4 Electrify Coventry to Nuneaton	12	Birmingham / Coventry to Oxford via Leamington and Reading to Basingstoke electrified	-	High	No	Yes	Medium	High	High	High	High	High
Gap B17.7	Option B17.7 Electrify Walsall to Rugeley Trent Valley. Also convert Birmingham to Rugeley passenger service to electric traction	32		4	Medium	Yes	Yes	High	Medium	High	High	Low	High
Gap B17.8	Option B17.8 Electrify Castle Bromwich Junction and Water Orton West Junction to Walsall / Pleck Junction	28	Option 17.3a electrified	-	High	No	Yes	High	Medium	High	High	High	High

Appendix 4 – Classification of electrification in-fill options for freight

Gap	Option	Single track miles electrified	Assumptions	Passenger conversion Ratio Tier	Relative number of freight trains converted	Enabler of reduced mileage for electric freight services	Diversionary routes benefits	Improved maintenance access	Potential environmental benefits	Passenger and freight interaction	Potential performance and capacity benefits	Potential journey time saving	Overall benefits
Gap B18.1	Option B18.1 Electrify Bletchley to Bedford. Also convert Bletchley to Bedford passenger service to electric traction	34	MML electrified	6	Low	Yes	Yes	Medium	Low	Medium	High M	Low	Medium
Gap B18.1	Option B18.1 Electrify Oxford to Bletchley following Claydon to Bletchley reopening	71		-	Low	No	Yes	Medium	Low	Medium	Medium	Low	Low
Gap B18.2	Option B18.2 Electrify Ditton Yard to Ditton Terminal	2		-	Medium	No	No	No	High	Low	High	Medium	Medium
Gap B19.11	Option B19.11 Electrify Sheet Stores Junction to Stoke on Trent. Also convert Derby to Crewe passenger service to electric traction	86	Option 5.1 electrified	6	Low	No	Yes	Medium	Low	High	High	Medium	Medium
Gap B24.7	Option B24.7 Electrify Edinburgh Suburban lines	18		-	Medium	Yes	Yes	High	Low	Medium	High	Medium	Medium
Gap B24.8	Option B24.8 Electrify Grangemouth branch	5		-	Medium	No	No	Low	Medium	Low	High	High	Medium
Gap B26.5	Option B26.5 Electrify Ardrossan to Hunterston	9		-	Low	No	No	Low	Low	Low	Low	Low	Low
Gap B26.8	Option B26.8 Electrify Glasgow: Shields Junction to High Street Junction	4		-	Low	No	Yes	Low	Low	Low	Low	Low	Low

Appendix 5 Benefits of diversionary schemes

Appendix 5 Benefits of diversionary schemes								
Option		Approx track mileage	Fit with other schemes in strategic options	Existing passenger service which could be converted	Freight use on corridor	Route for which a diversion is provided	Miles of route for which a diversion is provided	Frequency of passenger service on route for which a diversion is provided
C4.5	Bradford South Junction to Thingley Junction via Melksham following GWML and Salisbury to Bathampton Junction	8	No	No	Medium	Reading to Westbury	60	Low
C4.6	Castle Cary to Yeovil Junction following Reading to Plymouth and Basingstoke to Exeter	22	Yes	No	Low	Salisbury to Exeter	39	Low
C9.3	Newcastle to Carlisle	118	Yes	Yes	Medium	Newcastle to Edinburgh	125	Medium
C9.4	Norton South Junction to following Northallerton to Middlesbrough and Stockton to Sunderland	28	Yes	no	High	Northallerton to Ferryhill Junction (second diversionary route)	29	High
C17.2	Oxley Junction to Bushbury Junction	2	Yes	Yes (ECS)	low	Bushbury and Oxley to Wolverhampton	2	High
C17.6	Birmingham Camp Hill line in conjunction with Bromsgrove to Westerleigh Junction	10	Yes	Yes	medium	Birmingham New Street to Kings Norton	4	High
C19.7a	Trent to Trowell via Erewash Valley route following Midland Main Line and Nottingham to Clay Cross Junction	24	No	No	high	Trent to Clay Cross via Derby	28	Medium
C19.7b	Trent to Clay Cross Junction via Erewash Valley route following Midland Main Line	60	Yes	No	high	Trent to Clay Cross via Derby	28	Low
C19.8	Tapton Junction to Masborough Junction following Midland Main Line and Doncaster to Sheffield	30	Yes	No	High	Tapton Junction to Masborough Junction via Sheffield station	15	Low

Appendix 5 Benefits of diversionary schemes

Option		Approx track mileage	Fit with other schemes in strategic options	Existing passenger service which could be converted	Freight use on corridor	Route for which a diversion is provided	Miles of route for which a diversion is provided	Frequency of passenger service on route for which a diversion is provided
C19.9	Corby to Manton Junction following Midland Main Line and Felixstowe to Nuneaton	22	Yes	No	Medium	Kettering to Syston	31	High
C20.11	Ashton Moss / Guide Bridge to Heaton Norris Junction	11	Yes	No	Low	Heaton Norris to Salford Crescent	7	low
C20.12	Philips Park to Ashburys	4	Yes	No	Low	Philips Park to Stalybridge	6	
C20.13	Manchester Victoria to Stalybridge via Manchester following North cross Pennine.	19	Yes	Yes	Low	Ordsall Lane to Stalybridge via Manchester Piccadilly	10	Low
C26.10	Kilmarnock to Barassie	8	Yes	Yes	Low	Glasgow to Barassie	33	Medium

Appendix 6

The schemes for consideration as further options are shown in the table below.

Appendix 6a Further options: Western delivery unit

Appendix 6a Further options: Western delivery unit	
Option	Scheme
B6.4	Willesden Acton Branch and SW Sidings to Acton Wells Junction and Acton Wells Junction to Acton West Junction
B6.7	Acton Canal Wharf Junction to Cricklewood / Brent Curve Junctions (Dudding Hill Line)
A13.3	Swindon to Cheltenham
A13.4	Cross country: Birmingham / Coventry via Leamington to Oxford and Reading to Basingstoke
C17.6	Birmingham Camp Hill line
A13.5b	Cross country: Bromsgrove to Cheltenham and Standish Junction to Westerleigh Junction (Bristol Parkway) and Bristol to Plymouth and Paignton
A13.6	Gloucester to Severn Tunnel Junction
A12.2c	Berks and Hants route: Reading to Cogload Junction
A4.1b	Basingstoke to Exeter

Appendix 6b Further options: Midland delivery unit

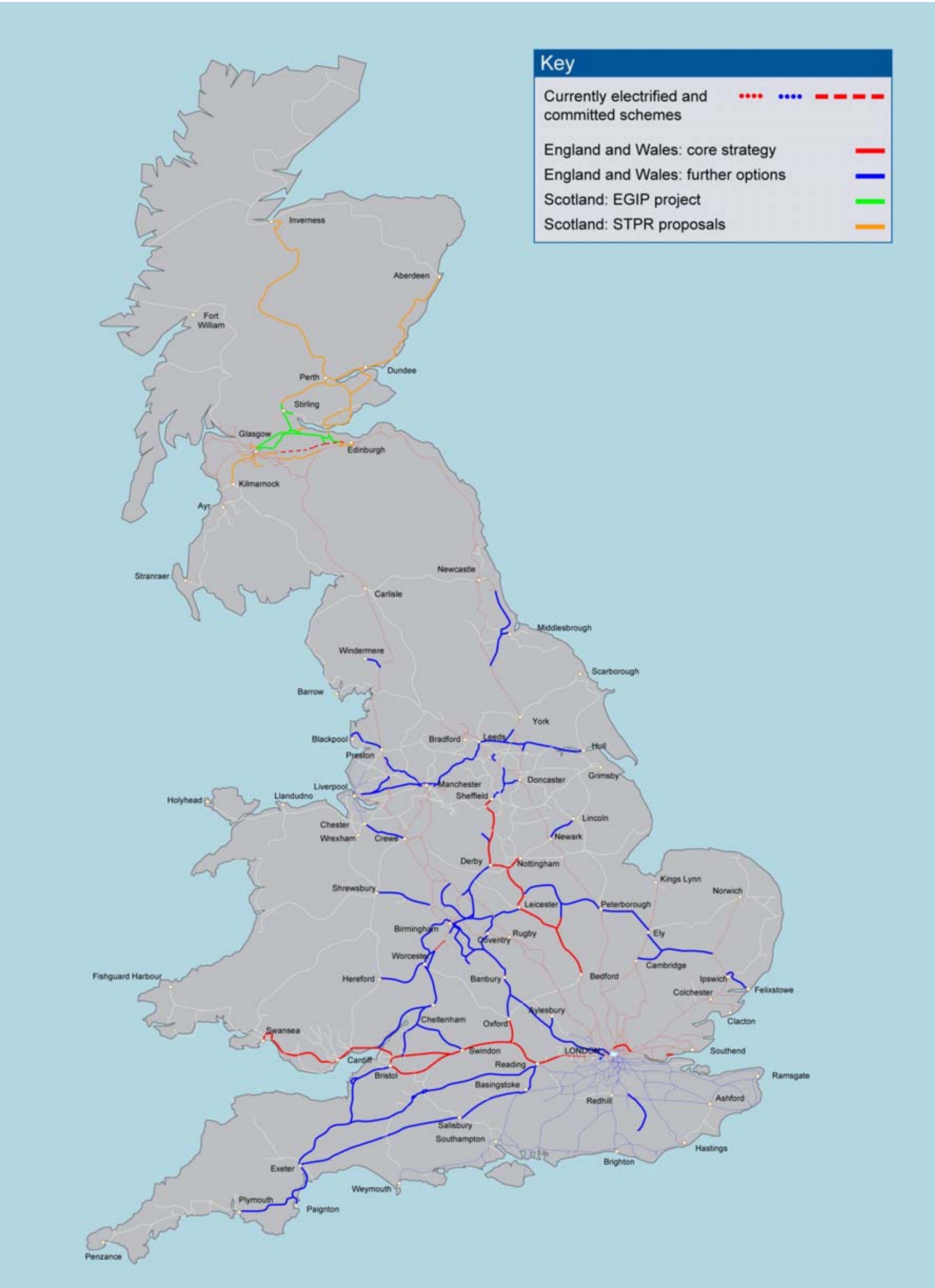
Appendix 6b Further options: Midland delivery unit	
Option	Scheme
A19.3	Ambergate to Matlock
A20.4	Manchester Deansgate to Liverpool (Edge Hill) via Chat Moss route.
B18.2	Ditton yard to terminal
A10.1b	North cross Pennine: Guide Bridge to Leeds, Leeds to Colton Junction and Hull, Northallerton to Middlesbrough and Temple Hirst to Selby following Manchester Deansgate to Liverpool (Edge Hill)
B10.6	Hare Park Junction to Wakefield Europort
A9.2	Thornaby to Sunderland
A22.1	Crewe to Chester
A20.1b	Manchester to Euxton Junction and Preston to Blackpool North
A23.1	Oxenholme to Windermere
C20.13	Manchester Victoria to Stalybridge
A20.5	Huyton to Wigan
A19.2	Cross country: Doncaster to Sheffield, South Kirkby Junction (Moorthorpe) to Swinton, Derby to Birmingham and Wichnor Junction to Lichfield
A11.1	Newark Northgate to Lincoln
A16.1a	Chiltern Lines: Marylebone to Aynho Junction, and Aylesbury via High Wycombe, Hatton to Stratford upon Avon
B17.3a	Nuneaton to Water Orton and Whiteacre to Kingsbury
B17.4	Coventry to Nuneaton
B17.7	Walsall to Rugeley Trent Valley
B17.8	Sutton Park Line: Castle Bromwich Junction and Water Orton West Junction to Walsall / Pleck Junction
D17.5	Wolverhampton to Shrewsbury
A17.1a	Birmingham Snow Hill suburban: Hereford to Bearley Junction via Stourbridge
B5.1	Felixstowe to Ipswich and Haughley Junction to Nuneaton
C19.9	Corby to Manton Junction
A 5.2	Chippenham Junction (Newmarket) to Cambridge

Appendix 6c Further options: DC schemes

Appendix 6c Further options: DC schemes	
Option	Scheme
B6.6	Old and New Kew Junctions to South Acton Junction
A2.1	Uckfield to Hurst Green

Appendix 7

Appendix 7: Core and further options



Appendix 8

Appendix 8: Estimated proportion of passenger tonnage carried on the electrified network (core and further options) by diesel trains