NETWORK
T 07 3235 2095
E David.Collins@qrnational.com.au
W qrnational.com.au

Level 5, 192 Ann Street
Brisbane Qld 4000

GPO Box 456
Brisbane Qld 4001

QR NATIONAL

Mr John Hall
Chief Executive Officer
Queensland Competition Authority
GPO Box 2257
Brisbane QLD 4001

Response to Draft Decision – Electric Traction Services Pricing

Dear John,

QR Network welcomes the opportunity to respond to, and provide comment on, the Queensland Competition Authority's (QCA) draft decision on QR Network's proposed Draft Amending Access Undertaking (DAAU) for Electric Traction Services Pricing.

In considering the attached submission and supporting material, we wish to highlight the broader economic implications of not resolving the uncertainty with respect to investments made pursuant to the regulatory framework. The increase in regulatory risk and uncertainty that such an occurrence would engender could have a broad impact on future investment in Queensland. This would extend not only to regulated infrastructure, but also complementary investments in enabling port and rail infrastructure, which rely on the predictability and certainty of the regulatory regime to underpin funding and commercial commitments. In this respect, it is distinctly possible that the negative economic implications for regional growth and the development of the Queensland resources sector would materially outweigh the value of the electric investments themselves.

QR Network's submission aims to provide further information, analysis and evidence to support our view that electric traction represents the most efficient technology to maximise the value of the Blackwater and Goonyella coal chains. QR Network's submission also seeks to address the QCA's concerns regarding the competitive landscape for electric traction through independent research and analysis.

The submission identifies areas where we believe stakeholders have made factual errors in their submissions and where we consider the QCA should undertake further investigation.

It is not feasible to canvas all matters, or provide all information relevant to this DAAU, in a written submission. QR Network considers that the regulatory outcomes for the DAAU will best be optimized through constructive dialogue and engagement with the QCA and all participants in the Central Queensland Coal Network.

Our submission, and the accompanying expert reports, raise a number of prospective options and issues relevant to the consideration of those options. This list is not exhaustive and we welcome the QCA and other stakeholders to present alternate approaches.

QR Network reiterates its offer to the QCA and supply chain participants to review QR Network's total cost of ownership model and to test any relevant inputs. QR Network also remains open to working with industry participants to develop an independent model if the former approach will not address their concerns.

If you have any questions on this submission please feel free to contact myself or Dean Gannaway, Manager Regulation and Policy on 3235 2055.

Sincerely,

[redacted]

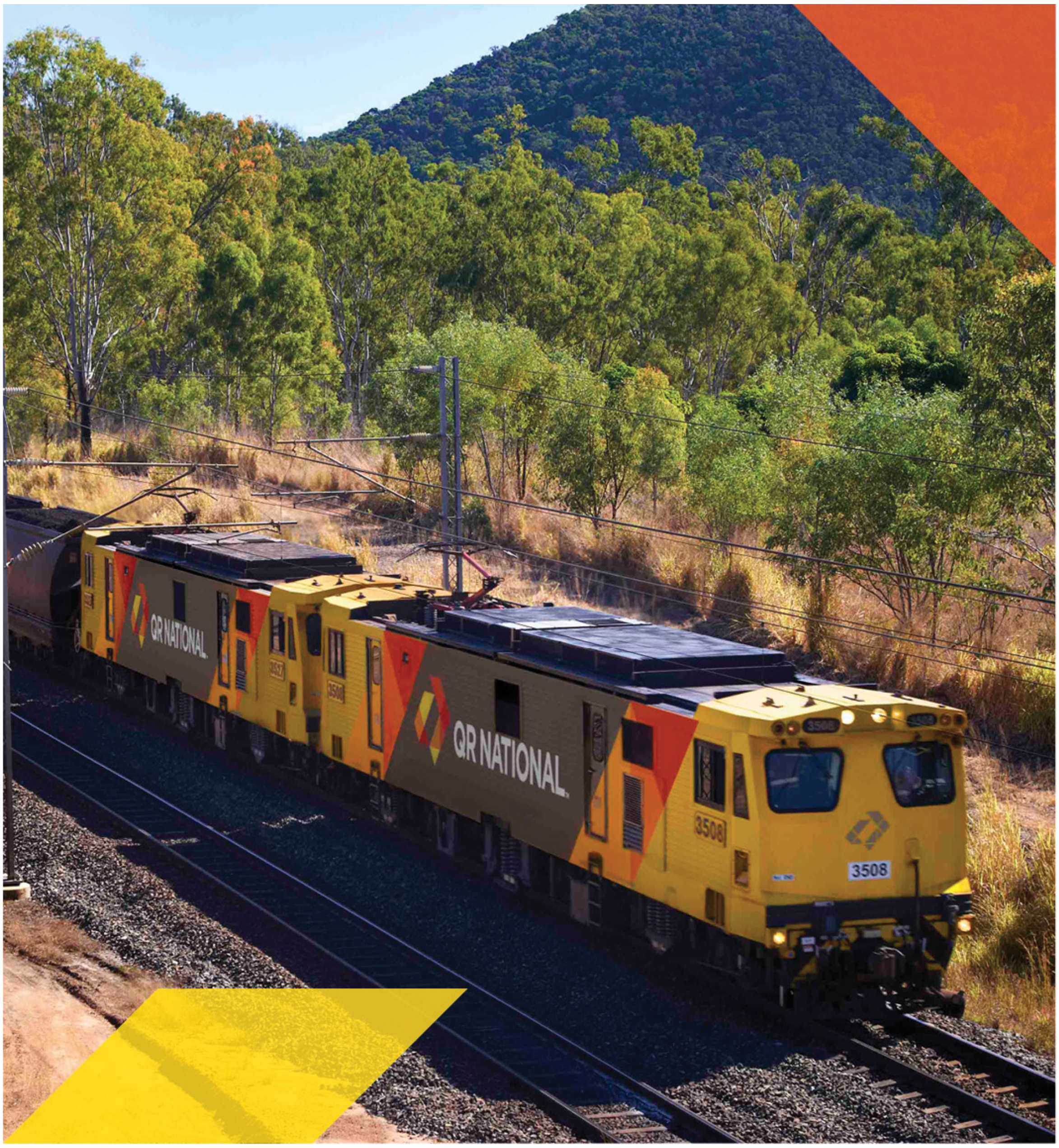
David Collins
Senior Vice President Finance and Regulation
QR Network Pty Ltd

25 September 2012

September 2012

QR National Network

Submission to QCA: Electric Access Draft Amending Access Undertaking



Contents

Executive Summary

A fundamental regulatory pricing problem exists in relation to QR National Network's (QRNN's) electric traction assets, particularly in the Blackwater system. Having made major investments in expanding the capacity of the electric network with customer and QCA endorsement, QRNN now faces the prospect of uncertainty as to the means by which this investment will be recovered, as the regulatory framework encourages access seekers to subsequently bypass this infrastructure and avoid contributing to cost recovery. The 2011 Electric Access Draft Amending Access Undertaking (the DAAU) sought to address this risk by enhancing price signals to promote the use of electric infrastructure. The Draft Decision to reject the DAAU has left this fundamental problem unresolved.

QRNN believes that given the complexity and importance of this issue the consequences of regulatory error are high, not only because it is commercially important to QRNN, but also because it is essential to ensure efficient price signals are in place to promote the efficient development of coal supply chains in Queensland. As this is a critical time of expansion for the Central Queensland coal region, with above rail investment decisions currently being made in relation to haulage of new tonnages in the Blackwater system, it is important to judiciously resolve the issue of pricing of the electric network to ensure these investment decisions are made based on efficient price signals.

A basic premise in the regulation of monopoly infrastructure is that the regulated business can reasonably expect to recover investments that are made to meet the demand of users, and that the regulator will act to mitigate hold-up risks. Legislative and regulatory instruments, such as the customer pre-approval mechanism, have been specifically designed to address this very concern, by giving the regulated business confidence that sunk investments will recovered. Where those mechanisms fail, and a regulated business that complied with the rules faces the risk that the cost of the investment may not be recoverable, the consequence will be manifest underinvestment in the asset or higher prices (to reflect the additional risk premium). Further, the consequences for investment in other supply chain infrastructure, including those that could be subject to economic regulation in the future, such as new coal terminals, should not be understated. In the event regulated assets in Queensland are put at risk, investors in other high fixed costs assets may face materially higher funding costs to compensate. It is therefore submitted that is incumbent on the QCA to fully consider the economic consequences of not maintaining the integrity of its investment framework, and in particular, the prospect that an increase in regulatory risk would undermine investor confidence and certainty in the Queensland regulatory arrangements.

The QCA acknowledged in its Draft Decision that the current price structure for electric traction is flawed in that it sends inefficient price signals – effectively discouraging its use through a higher price in times of underutilisation of installed capacity. As this situation has arisen due to coordination failures in the market (which the regulatory process was intended to overcome), we are seeking the QCA to play a constructive role in helping QRNN and stakeholders to resolve this issue.

QRNN's key concerns with the QCA's Draft Decision are summarised below.

Interpretation of Access Objective in Draft Decision

In interpreting the objective of the access regime the Draft Decision assumes that regulation should optimise below-rail efficiency in isolation from other elements of the supply chain. This approach does not take into account the interaction between the various elements of a highly interdependent supply chain and could have significant adverse implications for the efficiency of coal supply chains in Queensland. This is because a proposal that is lowest-cost or most efficient purely from a below rail perspective may result in higher overall costs to the end user. Such an approach is unlikely to be in the interests of end users of the declared network. It is for this reason that QRNN adopted a 'total cost of ownership' model in assessing what is most efficient as this reflects the best approach from an end user's perspective. Moreover, in other contexts, the QCA has shown that it considers supply chain efficiency matters as central to regulation of the declared network.

This interpretation of efficiency has consequential implications for the way in which the Draft Decision assesses efficiency and competition impacts, as it does not give proper weight to the substantial costs associated with individual operators' decisions to adopt diesel traction.

QRNN is exposed to additional regulatory risk through potential failure to uphold ‘regulatory compact’

The capital expenditure approval process in the Access Undertaking is intended as a means to overcome coordination failures in the supply chain which make it not feasible for investments in all cases to be underpinned by long term contracts with customers. By first obtaining customer and regulator support for the investment, the infrastructure owner should be able to invest with confidence that it will be able to recover the cost of this investment. By allowing operators/customers the ability to avoid paying for the electric infrastructure once built based on this endorsement, the ‘regulatory compact’ embodied by the Access Undertaking customer approval process has not been upheld. QRNN is exposed to significant and costly regulatory risk as a result.

It is not QRNN’s expectation that acceptance of the prudency of scope translates to an obligation to utilise the infrastructure enhancements which are the subject of that endorsement. It is however, our expectation that investment in reliance on that endorsement will be subject to an appropriate and efficient means of cost recovery over the investment horizon relevant to that decision.

Proposals not considered on their merits

In QRNN’s view, the QCA did not give sufficient weight to its legitimate interests as a below rail service provider in its Draft Decision. It would seem to QRNN that the QCA presupposes that the DAAU proposals are intended to benefit its related operator and, as a result, the Draft Decision does not give sufficient weight to QRNN’s legitimate business interests. QRNN believes that the DAAU proposals are consistent with those that a stand-alone network service provider would be expected to adopt – that is, they seek to recover sunk investments in regulated assets in the most efficient way. However, while the QCA has assumed strategic anti-competitive behaviour from QRNN, it has not given sufficient consideration to the prospect of strategic anti-competitive behaviour from a large producer or operator, as the current regulatory framework directly exposes QRNN to the consequence of strategic behaviour which may have the intent of driving up the cost of electric traction.

Concerns with analysis within the Draft Decision

QRNN does not support the QCA’s assessment of the DAAU against the various decision criteria in the Draft Decision. Our specific concerns with the analysis and the conclusions subsequently reached are as follows:

– Impact on competition in the market for locomotives

The Draft Decision adopts a narrow definition of the locomotive supply market and has also claimed that this is an uncompetitive market, particularly with respect to the supply of electric locomotives. A fuller analysis shows that this is a global market which is very competitive, with multiple potential electric locomotive suppliers to the Central Queensland coal region. As a result, we do not agree with the QCA’s conclusions on the impact of the DAAU on competition.

– Impact on competition in the above rail market

The Draft Decision adopts a narrow definition of haulage markets, leading it to overstate impacts on competition of the DAAU. QRNN disagrees with the QCA’s view that above rail haulage in Goonyella and Blackwater are separate markets. Supply side substitution between these two systems is strong. There is considerable scope for deployment of locomotives across interconnected coal systems. Both in the operational environment to a degree but, more significantly, as part of medium term business planning, train operators have the ability to deploy their fleet across their portfolio of haulage contracts throughout the Central Queensland coal network. Taking this broader market definition, it is incorrect to say that the DAAU will have an adverse impact on competition in this market.

– Impact on Pacific National

We believe that the Draft Decision overstates the likely impact of the DAAU on Pacific National. Given that our expectation is that access charges are passed through to end customers and given scope to redeploy diesel locomotives in response to opportunities that arise in a growing market, QRNN considers that the likely adverse impact on Pacific National is negligible.

Further, we do not see sufficient evidence to support the assumption in the Draft Decision that the DAAU will create a competitive advantage for QRNN’s related operator at the point where competition actually occurs – that is, the tendering for a haulage contract. Competition for new haulage contracts will be unimpaired by the DAAU. To the extent the DAAU affects operators under existing contracts, it would be preferable to consider transitional measures to specifically address this rather than allow a commercially unsustainable pricing approach to continue.

– Efficiency of electric compared to diesel

QRNN remains firm in the belief that a total cost of ownership (TCO) approach is the most appropriate perspective from which to assess efficiency of below rail infrastructure. Like any model, the TCO can be criticised on the grounds that its results are sensitive to variability in its inputs. However, many of the criticisms of this model raised by stakeholders are questionable. QRNN urges the QCA to engage with QRNN and other stakeholders constructively in further investigation of this issue.

Way forward

The QCA's Draft Decision to reject the DAAU and effectively persist with the current pricing arrangements which it acknowledges are flawed does not address QRNN's central concerns about efficient use of below rail infrastructure and QRNN's revenue adequacy. Therefore, this submission includes discussion on alternative approaches that may address this issue in a way that does not raise concerns about cross-subsidisation and competition impacts, including the scope to address these issues under the Access Undertaking in its current form.

While rejecting the DAAU, the QCA has acknowledged the problems with the existing pricing arrangements but does not provide any guidance on what may be an acceptable solution. QRNN considers that the Draft Decision could have been further developed in the assessment of the problem and the consideration of reasonable and effective solutions. This is a critically important issue for QRNN, operators, customers and for the future efficient development of Central Queensland coal supply chains more broadly, and it is essential that the Draft Decision facilitates a constructive consultation process in order to develop solutions.

Therefore, QRNN requests that the QCA undertake a further detailed consideration of the DAAU and issue a further Draft Decision which takes into account the new information submitted as part of this process, and, if the QCA is still minded to reject the DAAU, provides guidance on what solutions the QCA consider would be acceptable for dealing with the issues raised in accordance with section 142(3)(b) of the QCA Act. This will allow the opportunity for the QCA to provide constructive input into an industry engagement process which, we believe, provides the best hope of an acceptable resolution.

Submission to QCA: Electric Access Draft Amending Access Undertaking

1 Introduction

QRNN welcomes the opportunity to respond to the QCA's Draft Decision on the December 2011 Electric Access Draft Amending Access Undertaking (DAAU).

QRNN operates and manages the Central Queensland rail network, comprising 2,300km of track across four rail systems – Goonyella, Blackwater, Newlands and Moura. Of these, the Goonyella and Blackwater systems are electrified. QRNN is responding to the QCA's Draft Decision from its perspective as the provider of the declared service. We note that the views of QRNN's related operator, QR National, are reflected in a separate submission to the QCA.

This issue has implication for QRNN and all supply chain participants as, in the absence of changes to the Access Undertaking to change the inefficient pricing signals which incentivise the use of diesel traction, this may result in QR Network deferring the recovery of its investments with the potential for future optimisation of our significant investment in electric infrastructure assets in the Blackwater system. Given the complexity and materiality of this issue we believe that it is also important for the efficient operation and further development of the Blackwater coal supply chain, and indeed the entire Central Queensland coal network, that the resolution of this matter requires consideration of a broader range of issues that were included in the DAAU and addressed in the Draft Decision. This is because efficient price signals are fundamental to achieving the objective of the third party access regime and, in turn, achieving efficient coal supply chains and a competitive Queensland coal industry.

In this submission, we have focussed our discussion on the implications of the QCA's Draft Decision on the Blackwater system, as it is here that the inefficiencies of the current regulatory framework are most clearly apparent. However, we note that this regulatory framework applies equally to the Goonyella system, and submit that there is a risk that the introduction of diesel services on the Goonyella system may in future give rise to the same problems there. Therefore, consideration of how the regulatory framework should address these issues needs to address both the immediate concern of rectifying inefficient price signals in the Blackwater system, as well as the longer term concern of avoiding the emergence of inefficient price signals in the Goonyella system.

The QCA has, in its Draft Decision, acknowledged that the existing approach to setting the electric access tariff is inefficient and unlikely to promote efficient use of the electric network. However, by proposing to reject the DAAU and providing no guidance about how the acknowledged shortcomings of the Access Undertaking can be addressed in a way acceptable to the QCA, the QCA has left QRNN and stakeholders in an ambiguous position with respect to the timing of cost recovery and price expectations necessary to support further complementary investments and has undermined the certainty that is intended to be achieved by the regulatory framework. In summary, QRNN has concerns with the following key aspects of the Draft Decision:

- Having accepted shortcomings in the existing methodology for pricing of electric access, the decision is not constructive in guiding a solution to this issue by proposing amendments to the DAAU, as is required under section 142(3)(b) of the QCA Act. In not providing guidance on a resolution of the issue it means that QRNN can only take a 'trial and error' approach – that is, continue to submit DAAUs with different proposals for changes to pricing for alternate technologies, until a proposal acceptable to the QCA is achieved;
- The QCA suggests full reliance on the operation of the market to select the most efficient traction mode, without recognising that this outcome will only occur if the market is providing efficient price signals and there are no market failures. This is clearly not the case with rail infrastructure, both above and below rail. The Draft Decision does not appear to have proper regard to why, in the absence of changes to the Access Undertaking, market failure is likely to drive the above rail market to select diesel traction, regardless of the relative efficiency of the different traction modes;
- This problem is exacerbated by the Draft Decision's conclusions on efficiency – which is to consider the efficiency of the below rail infrastructure in isolation. This interpretation is inconsistent with the approach that the QCA has adopted since the 2006 Access Undertaking (and which has been further emphasised in the 2010 Access Undertaking) where the QCA has acknowledged the relevance of supply chain efficiency matters to the regulation of the declared below rail network. Indeed, since at least 2005, the QCA has implicitly

accepted that the objective of network regulation is not necessarily the least cost rail infrastructure, but the rail infrastructure that supports the most efficient rail system/supply chain;

- The Draft Decision has the potential to undermine the certainty intended to be achieved by the regulatory framework by not adequately taking into account the implications of bypass of electric assets or of the 'regulatory compact' created by the capital expenditure approval process in the access undertaking;
- The Draft Decision infers that the DAAU was submitted by QRNN to benefit its above rail business. However, the DAAU proposals are not discriminatory between operators – rather, the DAAU seeks to discriminate between forms of technology, where the market for the preferred technology is not closed. QRNN's objectives are squarely aimed at addressing the future prospect of stranding risk for QRNN's electric traction investment – an issue that any independent rail network provider would vigorously pursue. In recommending against the DAAU, the decision has the effect of promoting the interests of one operator against the legitimate business interests of QRNN.

This submission is structured as follows:

- Section 2 – provides QRNN's comments on the QCA's overall approach and in particular elaborates on the key concerns with the Draft Decision that are summarised above;
- Section 3 – identifies QRNN's specific concerns with the robustness of the analysis undertaken by the QCA to support its Draft Decision;
- Section 4 – discusses alternative regulatory options to create signals for the efficient use of QRNN's electric infrastructure issue and to mitigate stranding risk of QRNN's electric infrastructure assets, and suggests the way forward to resolving this issue.

The following attachments also form part of this submission:

- Attachment A: NERA report: "Comment on Aspects of the QCA's Draft Decision Regarding QRN's DAAU (September 2012);
- Attachment B: An overview of current market opportunities and investments; and
- Attachment C: An assessment of incentives for strategic conduct (resubmitted previously confidential attachment to the DAAU); and
- Attachment D: A report by Sapere Research Group: "Cost Recovery Options for Electric Infrastructure".

Also part of this submission is an Appendix (attached) which includes a number of papers referenced in this submission relating to international developments in terms of electrification of railways.

2 Concerns with the QCA's approach

2.1 Need for regulator to provide guidance

In its Draft Decision the QCA has acknowledged that there are shortcomings with the existing regulatory pricing arrangements for electric assets. In particular, it has acknowledged that the average price methodology for setting AT5 is inefficient, creating perverse pricing signals that fail to promote the efficient use of electric infrastructure.[1] Thus, the current approved Blackwater AT5 price represents an error in the regulatory framework. These identified shortcomings in the pricing approach have significant commercial implications for QRNN in terms of asset stranding risk.

Concerns relating to pricing of electric infrastructure and asset stranding risk have been raised with the QCA by QRNN over a number of years. QRNN first raised this issue in its September 2008 submission accompanying the 2009 Draft Access Undertaking (DAU), with its then proposal to amalgamate AT5 for Goonyella and Blackwater rejected by the QCA. The QCA Draft Decision in December 2009 rejected this proposal despite broad support for the pricing proposals, including from Pacific National. The revised DAU given to the QCA in April 2010 reverted to system based AT5 pricing determined on the same fully distributed cost approach (tariff x volume = allowable revenue) applied in other reference tariffs as required by the QCA.

The accompanying supporting documents again highlighted the detrimental impact on efficient price signals that could occur if the AT5 tariff was set at a level that created an incentive to operate diesel traction. QRNN highlighted its concern that it did not have sufficient knowledge of the above rail cost differential between electric and diesel traction to understand whether the proposed reference tariff would have any detrimental effects. It is noted that no stakeholders raised concerns with the level of the AT5 tariff, and this tariff was subsequently approved by the QCA. It is clear from this that all stakeholders – the QCA, industry stakeholders and QRNN – contributed in some way to the regulatory error that QRNN is now seeking to redress.

The issue of prospective underutilisation of electric assets and the need for clear and effective solutions to be found has also been recognised by stakeholders. The QRC has acknowledged that the existing pricing framework provides incentives for coal producers to contract for diesel rather than electric services in Blackwater – a situation which will only worsen in future given the large under-recovery of the Blackwater revenue cap. Moreover, the QRC noted that:[2]

> ….it is reasonable to expect the situation will only worsen before the next regulatory reset. If not addressed within the short-term, this positive feedback loop will only further worsen the problem to the point where there is a real possibility of an asset stranding problem, to which optimisation of the electric assets could be the only effective solution.

In light of this background and having acknowledged these fundamental problems with pricing for electric assets in its July 2012 Draft Decision, we consider the economic regulator has a pivotal role in resolving this issue. In fact, by recommending that QRNN amend the DAAU by effectively deleting all amendments, so that the 2010 Access Undertaking continues to apply unchanged, we consider that the decision does not satisfy the intentions of section 142(3)(b) of the QCA Act by not stating the way in which the Authority considers it appropriate to amend the DAAU.

Consistent with the intent of section 142(3)(b), QRNN considers that the QCA should provide more guidance on an acceptable way to amend the DAAU to address what is an acknowledged concern with the pricing approach for electric assets. In stating how it wants the DAAU amended, the QCA should indicate guiding principles which it believes should apply to any new proposal. As it stands, and in the absence of further guidance from the QCA, QRNN is effectively in a position where it can only seek to resolve this issue by 'trial and error' – that is, continue to submit DAAUs with proposals for changes to electric pricing, until a proposal acceptable to the QCA is achieved. This is clearly not an efficient regulatory process and not consistent with best regulatory practice in terms of providing certainty to infrastructure owners and other market participants about the regulator's likely approach to key issues.

---

1 QCA Draft Decision, QR Network Electric Traction Services Draft Amending Access Undertaking, July 2012, p. 21.

2 Queensland Resources Council, Submission 2010-11 Revenue Cap Adjustment, June 2012

2.2 Leaving the traction decision to the market

A criticism of the DAAU by some stakeholders was that it took a ‘central planning’ approach to the issue of traction choice. The QCA supported this view, stating that QRNN should charge a price that reflects the efficient costs of providing access to electric infrastructure as this would allow the relative efficiency of traction choices to be assessed in the competitive above-rail market.[3]

It is QRNN’s view on reading the decision that the QCA has not considered whether the market is likely to operate in a way that will rationally select the most efficient traction mode. Critical in this is whether the price signals for use of electric infrastructure are efficient in the first place. As noted by NERA (Attachment A), the above and below rail industries have a number of characteristics that reduce the efficiency of competition and market forces in selecting the most efficient traction mode. These market failures include:

- *economies of scale* – with the effect that one traction technology may only be efficient if it has widespread take up. Given that AT5 reflects the average cost of providing this infrastructure, the price (and average cost) are minimised when use is maximised. This means that if electric traction is to be used at all, it will be done most efficiently with maximum utilisation;
- *incentives for strategic conduct* – mine and train operators have an incentive to commercially disadvantage their competitors by not adopting electric traction, as the charge for the remaining users will increase if demand decreases. Without coordinating mechanisms, a user signing a long term contract for electric traction is vulnerable to later decisions by rivals;
- *externalities* – whereby the conduct of one party incurs costs or receives benefits as a result of actions of other parties, where these are not reflected in prices. Network externalities, such as congestion, may occur in network industries such as rail;
- *coordination failure* – these exist between different functions in a vertically integrated supply chain, particularly where decisions made in relation to one element of the supply chain affect another;

These market failures mean that the current (regulated) price for electric infrastructure will not send appropriate price signals to users to drive efficient traction choice, as suggested by the QCA. QRNN submits that the regulatory framework must have regard to these market failures in setting prices.

Moreover, the QCA has acknowledged in the Draft Decision that elements of the access charge are flawed in some respects and unlikely to be sending efficient price signals – namely, that the AT2 capacity multiplier should be updated and the AT5 tariff sending perverse price signals (ie. price currently increases as demand falls).

This issue arises, in part, due to the QCA’s approach of interpreting the QCA Act service declaration as requiring QRNN to provide two separate but substitutable services: access for diesel and electric train services. As customers have the option of bypassing the electric infrastructure, this poses a fundamental problem for a regulated business in terms of cost recovery. Under the pricing structure currently used for electric assets, QRNN can only achieve its revenue adequacy objective by a higher price for electric services. This in turn creates the perverse incentive for users to bypass electric and opt for diesel. In effect, ‘letting the market’ decide as the QCA suggests[4] will not send efficient price signals under current pricing arrangements and will ultimately tend towards a diesel solution. As noted by NERA, the current price mechanisms are likely to encourage users to choose diesel traction more often than is efficient.

As such, regulator ambivalence on this issue by not addressing these price signalling problems will only exacerbate the consequences of market failures. In effect, by making no decision to address these market failures, the systems may tend over time to migrate further towards becoming diesel systems – the only uncertainty then is the time that it will take for this transition to occur.

2.3 What is the efficient below rail infrastructure

---

[3] QCA Draft Decision, QR Network Electric Traction Services Draft Amending Access Undertaking, July 2012, p. 12

[4] QCA Draft Decision, p. ii

QRNN believes that the QCA has adopted a narrow view of efficiency in its interpretation of the objects clause and one moreover that is not consistent with its previous interpretation of this issue. This view of economic efficiency is incompatible with a network industry and has significant adverse implications for the efficiency of highly interdependent supply chains, such as those in the Central Queensland Coal Region. QRNN considers that efficiency of the supply chain is an important matter that is relevant to the overall objective of access to the rail network and not just to consideration of the public interest as stated by the QCA. In this regard, we refer the QCA to NERA's report (Attachment A) which concludes that ignoring the related nature of costs in the supply chain may lead to results that would be inconsistent with those that could be expected from a workably competitive process, and which would therefore be inherently efficient.

The QCA has adopted a view that interpretation of the first limb of the objective of Part 5 must be limited to the declared below rail infrastructure and has equated efficiency to what is 'least cost' for below rail infrastructure.[5] This is an overly narrow interpretation of efficiency. A thorough and complete assessment of the concept of efficiency that is widely accepted would also encompass productive, allocative and dynamic efficiency, assessed from the point of view of end users. This necessarily brings into consideration the efficiency of the trade-offs between different elements of the supply chain and incentives for future innovation. This broader view of efficiency would be more likely to result in an outcome that promotes overall economic welfare than does the QCA's more narrow focus on the efficiency of a single element of the supply chain. In this context it is worth noting that under s. 76(b)(3)(h), when considering whether a service should be declared, the QCA should have regard to the efficient allocation of resources.

It is possible that an investment in infrastructure that is productively efficient may fundamentally undermine allocative or dynamic efficiency. To assess whether an investment is actually welfare-enhancing requires an assessment across all elements of the supply chain. In the context of the Central Queensland coal network, this means that the least cost solution in terms of a single element of the supply chain infrastructure – such as providing the lowest below rail cost – may not provide the least cost, most efficient solution for the supply chain as a whole. This is what is important both from the perspective of end users and from the perspective of the economic welfare of society as a whole. Given this, any assessment of efficiency must necessarily take into account the impact of a proposal on the productive, allocative and dynamic efficiency across all elements of the supply chain.

The QCA's assessment of efficiency in the Draft Decision is also clearly at odds with the approach it has taken on this issue on previous occasions. Indeed, QRNN's 2010 Access Undertaking states that one of the intents of the undertaking is to:[6]

> ….establish principles and processes to guide cooperation with all elements of coal supply chains (in respect of which Access forms a part) to seek to maximise the performance of those supply chains on an annualised basis

There are numerous other examples in the Access Undertaking of where supply chain efficiency considerations have been central to the access obligations imposed on QRNN by the QCA. More broadly, the QCA in the past has clearly moved away from a view that maximising below rail efficiency was the primary consideration from a regulatory perspective. This was a central issue in a joint study between QRNN, QRC and the QCA who appointed Halcrow to assess the current capacity of the Blackwater system in 2005. The agreed Terms of Reference for the consultant's (Halcrow's) study at the time explicitly required above and below rail factors and options to be taken into account in assessing efficiency of QRNN's proposed capital expenditure. Further examples of the QCA accepting the trade-offs and interdependencies inherent in a supply chain as being central to the efficient economic regulation of the declared below rail infrastructure are provided in section 3.3.1.2 of this submission. It is difficult to reconcile the very extensive consideration by the QCA of supply chain matters in the past with its position in the Draft Decision that the central objective of the access regime is the promotion of below rail efficiency alone.

By focusing on this excessively narrow view of efficiency, the QCA has not considered the costs to the rail system (and hence the coal supply chains) overall that are created by individual decisions to operate diesel services, particularly where the operators of those diesel services do not face the full costs imposed on the system as a result of this choice. That is, the QCA is focusing on an interpretation of efficiency that specifically excludes the costs arising from the market failures described above, and in particular one that excludes the costs imposed on

[5] QCA Draft Decision, p. 27

[6] QR Network's 2010 Access Undertaking, October 2010, cl. 2.3

the rail system overall as a result of individual operators making inefficient decisions to use diesel traction on the Blackwater system.

2.4 The regulatory compact

Like an investor, QRNN requires reasonable certainty in order to undertake investments. In the absence of a regulatory framework, this would be achieved through QRNN's investments being underpinned by long term contracts with customers, with appropriate conditions underpinning those investments (eg. take or pay provisions). However, due to time lags in investment between elements of the supply chain and coordination failures between the various parties (both between operators, between existing producers and with future producers of an expansion), attempting to achieve this contractual certainty for common user investments is complex and time consuming and, where there are significant timing differences, contractual certainty may not be possible. This can lead to considerable delays or, ultimately, efficient investment not occurring because sufficient contractual certainty cannot be provided at the time the investment decision is required.

The Coal Rail Infrastructure Master Plan (CRIMP) and associated customer approval process for capex was adopted in the 2006 Access Undertaking to address this issue by providing a longer term planning mechanism and the ability for customers to endorse the scope of a proposed expansion. This capex approval process fed into the reference tariffs which were then reflected in the commercial contracts, and gave QRNN the confidence that it would recover its investment without specifically addressing this in the commercial contracts themselves. This process provided a regulatory response to the coordination failures which may otherwise have resulted in a 'hold up' of efficient investments in below rail infrastructure.

This approval mechanism reflects a 'regulatory compact' in the sense that the regulatory capex approval process acts as a proxy for investment underwriting within commercial contracts, allowing QRNN to invest with an acceptable degree of certainty. The essence of this compact was stated by the QCA at the time:[7]

> In the Authority's view, the process should place obligations on QR to provide detailed information to stakeholders on capacity requirements, infrastructure expansion options and proposed capital expenditure. In return, the process should provide certainty to QR that capital expenditure undertaken in accordance with the plan and supported by stakeholders will be accepted as prudent and efficient by the Authority and not subsequently optimised out.

Asset stranding risk is asymmetric and, unlike the effectively competitive markets in which the WACC is derived, regulated businesses do not have upside revenue potential. That is, there is not an equal probability of return outcomes. Accordingly, the Access Undertaking framework is intended to protect QRNN from stranding risk in all but the most extreme situations. This is consistent with the approach typically used for regulated infrastructure services - the practical issues associated with compensating for asset stranding risk has meant that it is usually addressed through efforts to mitigate the risk rather than to compensate for it.

As a result, while QRNN does retain ultimate asset stranding risk for all of its assets the regulatory framework provides that this will apply in exceptional circumstances only – where total demand for the declared service (the use of rail transport infrastructure for the purpose of operating a train service) is declining to the extent that users cannot afford to pay the resulting access charges.

2.4.1 Possibility of bypass of electric network

The situation for electric assets are anomalous in the sense that, although subject to the declaration (which implies tests relating to monopoly power are satisfied, ie. no effective substitutes), they are in fact able to be bypassed as diesel traction is a substitute for electric traction. This has significant commercial implications for QRNN in a situation where, as at present, a regulatory pricing structure applies that effectively provides an incentive to bypass electric below rail assets.

---

7 QCA, Decision, QR's 2005 Draft Access Undertaking, December 2005, p. 41

The current tariff structure enables an operator that does not wish to run electric trains to avoid contributing to the QCA-determined efficient cost of QRNN's electric infrastructure. This has an adverse impact on the cost competitiveness of electric locomotives relative to diesel locomotives in circumstances where a falling electric utilisation rate contributes to higher average prices for access to the electrical infrastructure. It also increases the risk to QRNN that it could fail to recover the efficient costs of providing access to the electric infrastructure.

In the absence of changes to the Access Undertaking, QRNN may be subject to future asset stranding risk as a result of above rail operators' decisions in terms of traction choice. This is the practical effect of the Draft Decision by enabling the possibility of bypass of the electric assets. In the event this ultimately leads to asset stranding in the future this would be contrary to the intention of this mechanism and the 'regulatory compact' it embodies – even though demand for the declared service is continuing to grow. The potential asset stranding risk in this sense is therefore not related to demand for the declared service – use of rail transport infrastructure for the purpose of operating a train service.

2.4.2 Implications for regulatory approved capex

In its Draft Decision the QCA has highlighted the risks for access seekers and train operators of 'changing the rules' relating to pricing of electric assets. QRNN considers that it is being exposed to the same risk in terms of the QCA's application of the customer approval process for capex. As noted above, this mechanism was intended to provide QRNN with the certainty required to invest by effectively being a proxy for investment underwriting within individual commercial contracts which are not feasible given the coordination failures involved.

Contrary to the intent of the customer approval process, QRNN may be exposed to stranding risk associated with traction choice as access seekers retain the choice of bypassing this infrastructure and not contributing to recovery of this investment, despite customer endorsement through the customer approval mechanism. Customers then retain a free option to use electric traction in Blackwater in future.

QRNN recognises that stakeholders may contend that the Access Undertaking provisions are not intended to protect QRNN from a decline in demand for the services that it offers, that they were not aware that the investments would only be viable if they were required to run electric services and that the appropriate response from QRNN is to reduce the price for access to the electric network to incentivise operators and end users to choose electric traction, and to impair the assets to the extent that this means it can no longer recover the full cost of its investment.

Now that the investment in additional electric capacity in Blackwater is complete (the final new feeder station at Duaringa was energised on 7 September), decisions by individual operators or end users to bypass the electric system through using diesel services will impose additional costs on the rail system – not the least because it will create underutilisation of a high fixed cost investment in electric capacity that the users themselves supported. To the extent that end users have now got the benefit of this investment in additional capacity embedded in the system, they clearly now have a strategic incentive to avoid facing the increase in total system cost associated with their decision to use diesels on the system by arguing that QRNN should instead bear this cost through impairing its assets. However the regulatory framework that has applied since 2001 has placed regulatory constraints on charging for access to electric services which have prevented QRNN from earning a return to compensate for what could be a stranding risk. The QCA must bear in mind this strategic positioning by industry when considering their arguments.

In summary, the consequence of the QCA's combined approach in terms of the customer approval process for capex (which QRNN has relied upon as a proxy for contracts to underpin investments in electric assets) and the pricing of electric assets (i.e. despite customer/QCA approval for investments, allowing customers the option of not contributing towards the cost of this investment) may, in the absence of changes to the Access Undertaking, leave QRNN inappropriately exposed to the future prospect of asset stranding risk.

Should this outcome occur this would represent a failure of the regulatory process, in particular, a failure of the 'regulatory compact' by which regulated assets are not exposed to material stranding risk. The QCA states in its Draft Decision that:[8]

> ….it is difficult to see what material changes could be made that would provide more protection to QR Network and its customers than would be achieved by QR Network adhering to the terms of the 2010 undertaking.

While this statement is reasonable in the context of the rail network itself which is not readily able to be bypassed, experience to date shows that the current regulatory framework has substantial shortcomings in upholding the regulatory compact for QRNN and its customers – with the result of creating a potential stranding risk for QRNN for electric infrastructure.

In this regard, the DAAU proposals sought to address this problem by allowing QRNN to recover the costs of customer/QCA approved investment in electric assets in the most efficient (least distortionary) way. That is, the impacts of a decision by an individual access seeker to adopt a less efficient technology than that which maximises the welfare function and value to the Queensland coal industry is appropriately quarantined to that party.

2.5 QRNN's interests as below rail service provider

QRNN is concerned that the QCA does not appear to have adequately taken into account the type of actions that would be expected of a stand alone below rail service provider in making its determination. This is the relevant benchmark for whether QRNN's proposals are reasonable. Rather, the QCA appears to have wrongly assumed that QRNN's DAAU proposals are designed to benefit its related above rail business and, as a consequence, it has not assessed these proposals on their merits but rather with this assumption in mind. As a result, the QCA has not given sufficient weight to QRNN's legitimate business interests from the perspective of a stand alone access provider.

This approach is apparent in a number of areas of the Draft Decision where the QCA has given greater weight to stakeholder submissions than to QRNN's, without testing whether this judgement is justified on the merits. For example, on the question of whether electric trains are more efficient than diesel trains, the QCA concluded that sufficient doubt had been cast over QRNN's analysis by stakeholder's submissions to not allow it to reach a conclusion on the issue. The QCA did not seek to test or properly investigate the merits of the respective arguments but rather determined the issue against QRNN purely on the basis of the untested arguments of other stakeholders. The QCA adopted a similar approach on the question of whether diesel trains in the Blackwater system provide buffer capacity for the Goonyella system and whether this provides spill-over benefits to Goonyella users..

An apparent key reason for the QCA not accepting QRNN's proposal is its perception that the proposal unfairly differentiates between a related and third party operator. The QCA has correctly stated:

> The pricing principles do not allow pricing practices if they discriminate in favour of a downstream operation (or a related body corporate), except if they are related to cost…. it is not evident how the proposed price amendments in the DAUU are related to cost.

However, the pricing proposed in the DAAU is not discriminatory between operators. It is discriminates between technologies in which the market for the preferred technology is not closed. The practical effect of the Draft Decision is to promote the interests of a competitor, not to promote competition. In rejecting QRNN's pricing proposal for the pricing of feasible electric train services the decision promotes the interests of one operator, at the expense of the legitimate business interests of QRNN.

QRNN is entitled to put proposals to the QCA through the DAAU process to address asset stranding concerns. Contrary to the QCA's assumption that the DAAU was submitted by QRNN to benefit its above rail business, QRNN considers that the DAAU proposal seeks to address real and substantial commercial concerns for the below

---

8 QCA Draft Decision (July 2012), p. 40

rail business, in that the existing regulatory framework entails a potential risk of stranding a significant investment undertaken by QRNN which had the support of its customer base and the endorsement of the QCA.

A specific example of this is the QCA's recommendation to defer consideration of this issue to UT4. The QCA's approach to this issue is concerning in that, despite acknowledging that there is a problem with pricing for electric infrastructure, and despite the fact this issue has been raised with the QCA by QRNN and stakeholders over several years, the QCA appears to prefer to defer resolution of this issue. Given the expected consultation timeframes for UT4 and the impending contractual decisions which will be made over that period it is both appropriate and necessary that such an important and complex issue be given full and reasoned consideration as part of this DAAU.

This issue requires a satisfactory resolution in order for QRNN to properly understand the risks and commercial implications for current and future investments. It is also important to resolve from an industry perspective as the Central Queensland Coal Region is a dynamic and evolving sector, with many parties making long term investment decisions today based on the pricing signals in place. Operators are currently making decisions regarding above rail operations and traction choice for services to the WICET coal terminal. In addition, there is a substantial volume of services to RG Tanna Coal Terminal where existing contracts are close to expiry and decisions on the future traction choice for these services are currently under consideration. Details of the numbers of services that are now being, or are expected to shortly be, commercially tendered are provided in Confidential Attachment B.

Addressing this issue as part of UT4 would mean that these commercial decisions on traction choice will be made before the identified pricing issues are resolved. Consequently, the existing deficiencies in the pricing framework will continue to distort rollingstock investment decisions, and the opportunity for efficient price signalling for related markets at this critical time will be lost. This will substantially exacerbate any transitional issues for operators, potentially to the point where recovery of the electric utilisation within Blackwater to an acceptable level is simply unachievable. For these reasons, QRNN urges the QCA to work constructively with QRNN and industry to reach an outcome which facilitates revenue adequacy and supply chain efficiency.

The QCA's argument that changing regulatory principles or rules is inherently undesirable due to the uncertainty it creates poses the obvious question of when, if a problem with the principles is identified (as it has been), it would be desirable to address them. QRNN submits that where a flawed pricing structure and its consequences have become apparent and have been acknowledged as flawed, it is not unreasonable to request the regulator to seek to address this regulatory design problem. Deferral of a solution to this problem is not an acceptable or commercially sound position for QRNN or other supply chain participants. Having approved the expansion of the electric infrastructure, it is imperative that the QCA address concerns raised by QRNN. Simply refusing to approve the DAAU with no guidance on what alternative approach to address this issue the QCA may consider to be appropriate may simply extend the regulatory process.

3 QRNN response to specific issues in Draft Decision

3.1 Efficiency of electric traction compared to diesel

QRNN submitted in its DAAU proposal that, from a Total Cost of Ownership (TCO) perspective, electric traction is more efficient than diesel. QRNN believes that the rail haulage solution (both above and below rail) that achieves the lowest total cost will reflect the most efficient operation and use of below rail infrastructure, consistent with the intent of the rail access regime. The QCA stated that, based on the information provided, it does not consider that QRNN has made a convincing case that electric traction is superior to diesel. However, QRNN is concerned that the QCA has reached this conclusion based on untested criticisms of the analysis raised by stakeholders.

3.1.1 Validity of Total Cost of Ownership model

Like any model, the TCO can be criticised on the grounds that its results are sensitive to variability in its input. However, QRNN has performed extensive sensitivity testing in the model. This shows that, even across the range of likely outcomes for each element, the result that electric traction will be lower cost than diesel still holds true. Further, QRNN's incremental 'brownfield' analysis is supported by similar independent studies undertaken in the United Kingdom[9], South Africa, China[10], Russia, Mexico and India[11]. These studies are provided in Appendix 1 to this submission.

Stakeholders raised a number of concerns with both the appropriateness of the TCO approach overall and with specific details of QRNN's TCO analysis. These are addressed in more detail below. However, we note that many of the claims by stakeholders regarding the benefits of diesel either reflect improvements that can equally be applied to electric traction, or reflect debates about particular elements where the outcome is within the sensitivity ranges assessed by QRNN.

We refer the QCA to NERA's assessment of QRNN's TCO analysis (Attachment A). NERA notes:

> Overall, we consider QRNN's TCO to be both applicable and broadly appropriate for assessing the relative financial implications of the three traction scenarios. Given that it indicates electric traction has an efficiency advantage over diesel traction of approximately $1 billion, QRNN's TCO analysis provides strong support for the proposition that the prices in the DAAU are consistent with the regulatory objective.

The QCA has indicated that it is reasonable for the operator of a below rail network to understand the economics of its customers' activities in order to better understand future service provision needs and has noted the potential importance of the outcome of any peer review of the TCO analysis in terms of the assessment of the prudency of future capex on overhead electric infrastructure.[12] QRNN welcomes this and would like to respond to individual matters raised by stakeholders in the interests of resolving this issue with stakeholders and the QCA.

Nevertheless, QRNN is concerned that, in terms of the DAAU, the QCA appears to have accepted the criticisms of stakeholders without seeking to test the evidence or conduct its own investigations on the likely impact of these views on the outcome of the TCO analysis. That is, whilst indicating that on the information before it, it is unable to reach a conclusion as to whether electric traction is more efficient than diesel, the QCA has nevertheless relied on the untested criticisms of stakeholders to reject the DAAU proposals on the basis that they cast sufficient doubt on

---

9 Britain's Transport Infrastructure: Rail Electrification, British Department of Transport (United Kingdom), July 2009; Draft Network Utilisation Strategy: Electrification Strategy, Network Rail (United Kingdom), May 2009.

10 Chinese Ministry of Railways, Meeting Minutes, 6 September 2012

11 The Feasibility Study on the Development of Dedicated Freight Corridors for Delhi-Mumbai and Ludhiana-Sonnagar in India (Volume 3), Japan International Cooperation Agency, October 2007.

12 QCA Draft Decision (July 2012), p.12

QRNN's analysis. Detailed responses on specific comments from stakeholders that have been cited by the QCA in this regard are provided below.

We believe that it is the responsibility of the QCA to fully test these claims to ensure it can reach an informed conclusion on whether these criticisms do in fact cast sufficient doubt on QRNN's assessment that maximising electric traction on electrified routes will create the lowest total supply chain cost. This is particularly important as the QCA has relied on its conclusions on this issue throughout the Draft Decision to support its arguments to reject the DAAU.

QRNN would also like to respond to the QCA's comment that QRNN did not provide any additional information in support of its TCO argument in response to a request from the QCA. Following the QCA's request, QRNN offered the QCA the opportunity for detailed consultation and review of the TCO model. QRNN offered to present the model in detail to the QCA, to demonstrate its workings, and to run the model with different input assumptions requested by the QCA in order to satisfy concerns about the sensitivity of the TCO result to changes in assumptions.[13] In addition, QRNN invited the QCA to conduct an audit of the model, subject to preserving confidentiality of the above rail information contained within the model. This approach of engagement with the QCA was considered the most effective way of addressing questions and concerns on the analysis as, given the complexities of the issue, it is not practical to respond to all questions through the public submission process. However, the QCA did not pursue this offer and indicated that its focus was on setting what it considered to be efficient pricing in a theoretical sense.[14] .

3.1.2 Response to stakeholder concerns with TCO analysis

3.1.2.1 Base assumptions

A number of stakeholders have raised the concern that QRNN has relied on QR National above rail data for the purpose of the analysis – both in terms of operational performance data and cost information.[15] In particular, a number of stakeholders submitted that Pacific National's diesel consists will have different operational performance and cost structures, and therefore questioned whether the assessed benefit of electric traction is valid.

In assessing the assumptions to be adopted in the model, it is important that the purpose of the analysis is kept in mind – that is, to assess the relative merits of diesel and electric traction modes. In order for the analysis to produce reliable results, it is critical that at the point of comparison, the analysis takes a consistent approach with respect to factors that are unrelated to traction choice, or which can be applied equally to both traction types given known technology under existing operating paradigms. For example, it would be inappropriate to compare diesel train performance with ECP braking against electric train performance without ECP braking, as this braking technology can be applied with the same benefits to either traction mode. If this assumption is not held constant at the point of comparison, it will not be possible to assess whether the resulting difference in overall TCO is the result of traction choice, or braking technology choice. Similarly, it would be inappropriate to compare Pacific National's diesel train cost structures against QR National's electric train cost structures, as there will be a range of factors impacting on this cost differential apart from traction mode.

In order to ensure that the analysis focuses directly on the different costs associated with choice of traction mode, QRNN has sought to take a consistent approach for the other variables. It has done this by using cost and performance information from QR National for both electric and diesel modes, on the basis that QR National takes a consistent approach to other cost and technology variables across both traction modes. Further, QRNN has the ability to readily source this information from QR National, therefore it is known that these assumptions are realistic and relevant. QRNN recognises that Pacific National has taken different operational and technical choices to QR National, and that it has different cost structures.[16] However, to the extent that these create a competitive benefit for Pacific National compared to QR National, it is still reasonable to expect that Pacific National would apply these

[13] Detailed audit brief presented to the QCA 26 April 2012, followed by regular email and phones correspondence on this issue: the QCA responded that they were not interested in an audit of the model, nor particularly interested in the TCO analysis.

[14] Email correspondence between Dean Gannaway (QRNN) and Leigh Spencer (QCA) dated 19 April 2012 and 26 April 2012 re: meeting to review TCO analysis.

[15] Asciano submission, BMA submission, Anglo submission

[16] PN was offered the opportunity to run their own cost and performance information through QRNN's model on 12 April 2012: PN has not accepted this offer to date.

across both traction modes in assessing the cost differential between diesel and electric traction and, as a result, these different operating and cost assumptions may not materially impact on this cost differential between electric and diesel.

Notwithstanding this, QRNN recognises that the key conclusions of the TCO analysis do need to hold regardless of the identity of the above-rail operator, and for this reason, the analysis includes extensive sensitivity testing of the assumptions within the model. The purpose of this sensitivity testing is to ensure that the different cost and performance outcomes that may be achieved by a different operator, such as Pacific National, are taken into account.

As was the case with the QCA, QRNN sought to engage with industry regarding the TCO model following submission of the DAAU.[17] The purpose of this engagement was to explain the operation of the TCO model. QRNN specifically invited stakeholders to run the model using their own assumptions on the costs and performance of diesel and electric services, in order to assess the impact of these different assumptions on the outcome. This offer was not taken up by any industry stakeholders. Rather, they have submitted to the QCA that potential differences in assumptions mean that the analysis cannot be relied upon, without in any way seeking to inform themselves or the QCA of the impact of these different assumptions on the conclusions of the TCO analysis – which is that maximising the use of electric traction will minimise total cost of the rail services. This leads QRNN to question if there is a true concern about the impact of the different assumptions on the outcome of the analysis, or if the objective is to simply cast doubt on the analysis and cause the QCA to reject the DAAU?

3.1.2.2 Cycle time assumption

QRNN's assumption regarding cycle time differences between diesel and electric consists was raised by numerous stakeholders. The concerns can be grouped into three categories of issues, which are then discussed in turn:

- impact of diesel provisioning requirements;
- materiality of differences in mainline running performance; and
- consistency of assumptions with operational reality.

A number of submissions took the view that diesel provisioning occurs off the below rail network, and therefore had no impact on below rail capacity.[18] They believe that this should not be considered as part of this analysis. QRNN notes these statements are actually incorrect, with diesel provisioning currently occurring on QRNN track in Callemondah. Moreover, QRNN believes that this also shows a misunderstanding of the purpose of the TCO analysis which is to assess the total cost of the rail system under either traction mode, to assess which has the potential to provide a lower total cost. Because electric and diesel traction reflect very different above/below rail cost tradeoffs, it is not possible to assess this using a below rail analysis alone. Therefore, the TCO model explicitly includes all above rail costs in this analysis – the preferred traction mode can only be considered by assessing the sum of above and below rail costs incurred under either mode.

The TCO analysis does not seek to identify what individual party bears the costs of each activity – so therefore whether provisioning occurs on or off the network is not relevant to the TCO analysis. However, if diesel locomotives require additional provisioning time, this means that the costs associated with this need to be reflected in the TCO analysis, otherwise it will not provide a robust comparison of the differences in costs between the two modes. QRNN agrees with Rio Tinto and Anglo that the additional costs associated with diesel provisioning are not likely to be in the form of additional track investment on a discrete basis. The key additional cost is in fact the additional rollingstock investment required as a result of the longer total cycle time for diesel consists.

This then means that the relevant issue for the TCO analysis is not where the provisioning occurs, but what is the appropriate assumption for the increase in cycle time to reflect the additional provisioning requirements of diesel consists. QRNN has assumed that, on average, diesel trains in the Blackwater system will require an additional 1.3 hours for provisioning.

---

[17] Offers for model audit and review, similar to those made to the QCA, were made to members of the Traction Working Group from 12 April 2012, with only QRN Commercial & Marketing accepting to date.

[18] Rio Tinto submission, Peabody submission, Anglo submission

Feedback on the provisioning allowance was mixed. Rio Tinto agreed that a diesel hauled train will nominally require an additional 60-120 minutes for provisioning compared to an electric hauled train.[19] We also note that Asciano did not take issue with this assumed provisioning time.[20] However, Downer has questioned the reasonableness of this assumption given that, at a fill rate of 800 litres/minute, a diesel locomotive should only take just over four minutes to refuel.[21]

QRNN notes that a refuelling time of 4.4 minutes relates to one locomotive only under test/simulated conditions. Fill rates will drop significantly if more than one locomotive consist is being refuelled. There will also be further time associated with pulling into the provisioning facility, queuing for availability of refuelling facility, commencing refuelling, pull-forward to refuel remote locomotives and other provisioning activities. Having said this, QRNN acknowledges that it is likely to be possible to design and build a high performance provisioning facility that is capable of provisioning a diesel consist in less than 1.3 hours.

However, the majority of diesel provisioning on the Blackwater system is currently undertaken at Callemondah yard, which was originally developed to service a much smaller rail network. Callemondah is heavily capacity constrained, and is not laid out in a way that allows for such rapid provisioning and refuelling. To enable diesel trains in the Blackwater system to significantly reduce provisioning time would require substantial investment in upgraded provisioning facilities. While this may well be feasible, this significant investment would need to be included in the TCO analysis as an additional infrastructure cost together with the resulting rollingstock savings associated with the reduced provisioning time.[22] The Southern Bowen Basin (SBB) Supply Chain Operating Assumptions provided to the QCA on 31 August 2011 recognise this issue by noting that trains unloading at WICET are assumed to carryout provisioning and maintenance activities in a manner that does not result in a negative impact on existing operations that utilise Callemondah.

Stakeholders also argued that there was little discernible difference in the mainline running performance of diesel and electric consists. Asciano has supported this position by reference to information on actual performance of Pacific National's diesel trains on the Blackwater system. QRNN is frankly surprised by the poor level of rigour and attribution used by Asciano in its analysis, and considers that the information presented is of no value in assessing whether or not there is a performance difference between diesel and electric consists. In particular:

- Asciano has compared its actual median cycle time for Pacific National diesel consists with QRNN's estimated average cycle times in the TCO model, identifying that Pacific National's performance for diesel trains is similar to the assumed electric performance, and two hours better than the assumed diesel performance in the TCO model. However, Asciano has made no effort to normalise this data for differences in cycle time which will occur due to the different mix of services offered by Pacific National compared to that assumed by QRNN for the system as a whole. The TCO model actually operates on individually constructed cycle times for each train service, however, in order to explain the difference between electric and diesel cycle times, QRNN went to great efforts to develop system averages using like for like comparisons. QRNN sought to assume consistency in all other variables (eg haul distance, loading times, unloading times, required train stoppages, braking technology etc). Asciano notes in its discussion that factors other than traction mode, such as system congestion and planned system shutdowns, also impact on cycle times.[23] Its example of being able to achieve a cycle time of 21 hours where there were no more than three consists operating in the system[24] clearly illustrates this. Given all of these variables, it is hardly surprising that the median raw performance data from services from two mines in the Blackwater system varies from the long term averages assumed in the model for the system overall.
- Asciano has also compared raw performance data of 75 coal haulage services from Bluff to Warren, and sought to use this to demonstrate the efficiency of Pacific National's diesel services compared to electric.
    - First, Asciano has not attempted to ascertain if performance on this section of track is representative of overall mainline operational performance – in particular we note that this section of track does not

[19] Rio Tinto submission, Appendix 2, p4

[20] In its submission, Asciano included detailed commentary regarding why the cycle time of PN's fleet was comparable to QR National's electric fleet. However, on detailed review of this submission, it becomes clear that Asciano is referring to the mainline running time component of total cycle time. Asciano has made no comment regarding the assumed time required for provisioning.

[21] Downer submission

[22] While QRNN has not developed a specific cost estimate of a new refuelling facility in the Blackwater system, we note that PN's recently opened Nebo provisioning facility had an estimated cost of $180m, and QR National's recently upgraded Jilalan provisioning facility had a comparable cost.

[23] Asciano submission, p 21

[24] Asciano noted that this occurred on a day that QR National was not operating trains, therefore, Asciano's current three consists is the maximum number of trains that would have been operating in the system on that day.

include the section from Windah to Westwood which will in future be the critical section driving headway separation of trains; and

    - Second, no attempt has been made to normalise for factors apart from traction type that may have impacted on these times, for example the complex scheduling and system optimisation required to cater for the cascading impact of diesel trains' slower section run times, delays in traversing ruling grades, interaction effects at port and provisioning facilities. Further, the sample size means that little statistical weight can be placed on these results – given that Pacific National operates 3 consists out of a total of 30 consists currently operating in the Blackwater system, it's quite likely that, out of the sample of 75, only 2-4 of the services were Pacific National trains.

- Pacific National specifically highlights the benefits that it believes that it achieves from the use of ECP braking on its diesel trains, which it considers allows it to operate at higher average speeds. ECP braking can be equally applied to electric trains, and would be expected to provide the same benefit for electric trains. Care must be taken in interpreting any raw data comparisons, in order to isolate the differences in train performance that are actually the result of different traction types.

A factor that is particularly difficult to isolate from raw data comparisons is the impact of the Blackwater system's hybrid operating methodology in the actual performance of trains. As QRNN noted in its December submission, where a system is limited to the one traction type, the cycle time of that system will reflect the fundamental operational efficiency of that traction type. However, as the rate of hybrid operations increases, the tendency is for the operating principles to cater to the average mainline running time of the slower traction type.[25] This means that the mainline running time advantage of electric train consists is unlikely to actually be achievable in practice. QRNN's simulation analysis shows that the electric consist can continue to achieve its faster running times where the penetration of the slower diesel consists is less than 20%. However, beyond this, the performance of the faster train quickly degenerates to be equivalent to the slower consist. For example, in the Blackwater system, the current layout of Callemondah means that electric trains need to queue behind diesel trains as they refuel, denying the electric trains the advantage of reduced provisioning time. Given that the Blackwater system is currently operating with approximately 50% diesel consists, the comments by stakeholders that they cannot observe higher performance from the electric trains[26] is not surprising to QRNN.

It was the difficulty in normalising for extraneous factors that led QRNN to choose to use section run times and start/stop times determined through a train performance simulator. The simulated conditions will not necessarily reflect actual raw performance of trains on the network (as discussed above), but the train performance simulator does provide an unbiased analysis of each traction type under consistent conditions. Train simulations consistently show that electric locomotives have faster acceleration and higher speeds on the ruling grades. As shown by Downer, the extent of this performance advantage will depend on the assumed trailing load of the diesel and electric trains.[27]

QRNN submits that, once cycle times have been normalised for all factors other than traction type, electric train consists will have a faster cycle time than diesel due to:

- Increased provisioning requirements for diesel trains, likely to be in excess of 60 minutes, given the need to refuel the locomotives; and
- Ability for electric trains to achieve faster mainline running times, as the higher horsepower of electric trains allows for quicker acceleration and faster operation on ruling grades.

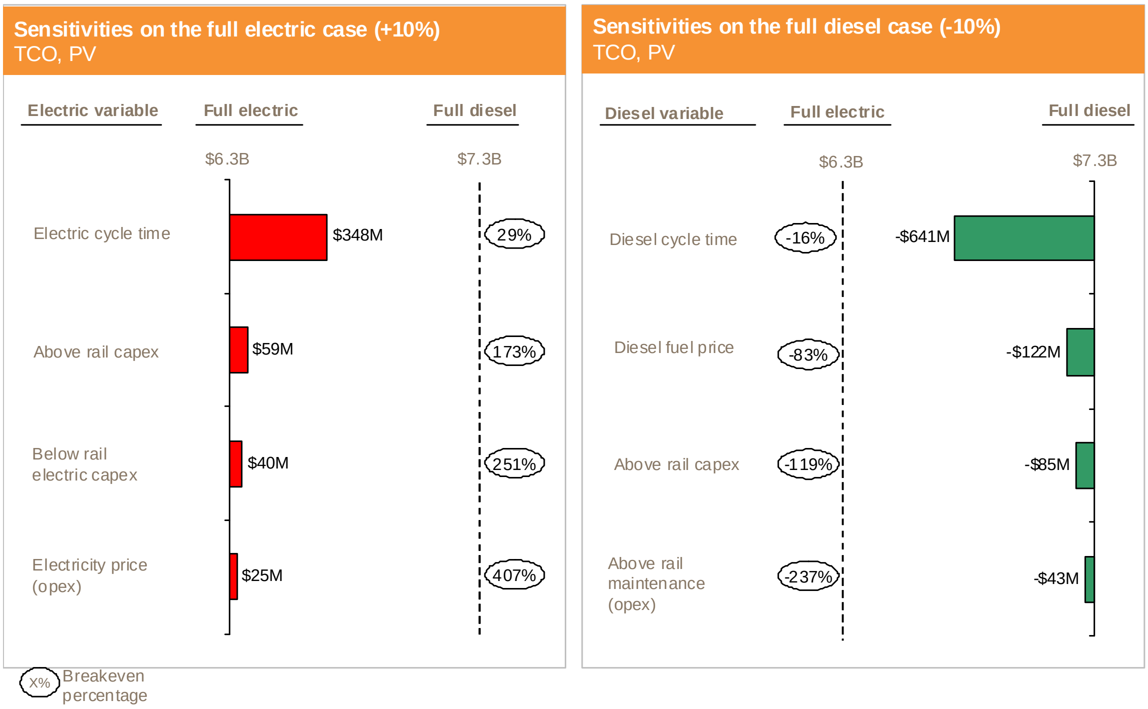
However, QRNN's sensitivity testing of the TCO analysis shows that, even if the cycle time performance of diesel consists were to reduce by 7% to be equal to electric, this would not be sufficient to change the conclusion that maximising electric traction will provide the lowest cost outcome for the rail system. As shown below, a 10% reduction in diesel cycle times (which requires that diesel services then operate with cycle times 3% faster than electrics), will reduce the TCO of the Blackwater system by $641m – which still leaves the TCO of the diesel system significantly higher than the electric. As such, QRNN believes that the QCA cannot rely on these concerns as casting significant doubt on the results of QRNN's TCO analysis.

[25] QRNN submission, p42

[26] BMA, Downer, Peabody, Rio Tinto and Xstrata all made similar comments in their submissions

[27] QRNN's analysis assumed 98 wagon trains for both electric and diesel trains, whereas the Downer simulation assumed 102 wagons for electric trains and 100 wagons for diesel.

Figure 1: Sensitivities between full electric and diesel cases



3.1.2.3 Capacity and infrastructure costs

Some stakeholders, have asserted that electric traction requires greater headways than diesel, and will therefore limit the opportunity for low cost capacity expansions. QRNN considers the analysis used by Rio Tinto to support this view is flawed and based on incorrect information. Rio Tinto has stated that the current 30 minute headway separation in the Blackwater system is driven by electric overhead constraints, and could otherwise be reduced to 25 minutes. This is incorrect, with the 30 minute headway separation actually driven by the remaining single line sections on the Blackwater system mainline, together with the need to match schedules for through running freight trains from the neighbouring Queensland Rail network across the north coast line section. In order to accommodate the additional train services planned to operate to WICET, QRNN will be reducing headways on the Blackwater system to 20 minutes.[28] The QCA would also be well aware that the neighbouring fully electric Goonyella system currently operates with 24 minute headways – both of which provide a clear demonstration that electric trains do not in themselves create any 30 minute headway limit. Headway separation in other electrified heavy haul networks is as low as 10-15 minutes.[29]

Electric traction does not limit allowable headways in the way asserted by Rio Tinto. It is correct that the electric network will place restrictions on the number of loaded electric trains in a feeder section. Prior to the construction of the additional feeder stations in Blackwater, this meant that there were operational constraints on the scheduling of electric trains. However this was not achieved through manipulation of the headway separation (as indicated by Rio Tinto), rather it was achieved through a constraint on the number of electric consists that QR National was permitted to operate in the system, together with operational limitations on how these trains could be scheduled within the system to ensure no individual feeder station became overloaded.

Given that electric traction in and of itself does not create a constraint on headway separation, it follows that improvements to headway separation that can be achieved through the use of ECP braking or other technological improvements such as changed signalling systems can be just as effectively used with electric trains as with diesel.

Rio Tinto is also mistaken in its assumptions regarding the restrictions that the electric network will limit the ability to achieve low cost capacity enhancements. This would only be a risk if the electric network itself was now a

---

28 Southern Bowen Basin Supply Chain System Operating Assumptions

29 Daqin line currently averages 12 minute headway separation, with over 100 consists running per day on an electric-traction only network.

capacity constraint on the system. With the completion of the four new feeder stations in Blackwater, there will be no need for further new mainline feeder stations to be constructed before capacity reaches the 156 mtpa forecast in the TCO analysis. Similarly, in the Goonyella system, once the Wotonga feeder station is complete, there will be no need for future feeder stations on the existing network until capacity reaches the forecast 290 mtpa. There will need to be some in situ upgrade of the existing feeder stations as volumes increase to this level (that is, increasing the diameter of cables, wires, transformers, etc), but these are expected to be able to be done on a more incremental basis, and the costs of this have been factored into the TCO analysis.

The critical factors constraining Blackwater system capacity are in fact the ruling grades, and the resulting requirements for headway separation between trains operating on these sections. These factors are significantly impacted by the operation of trains as electric or diesel. This is readily apparent in the Southern Bowen Basin Supply Chain Operating Assumptions which clearly show in section 3.6.7 the planned variations in section run times associated with the reduction in headway separation to 20 minutes. Following the planned infrastructure enhancements, the most critical section will be the Westwood to Windah section, which shows expected section run times (SRT) of loaded electric and diesel train services of 13 minutes and 23 minutes respectively. The diesel service achieves the required SRT of 20 minutes only through the use of 4x4000 diesel locomotives (which in other circumstances may be considered to be 'overpowering' the diesel train). It is also clear from this that the driver of the required 20 minute train separation on this section is in fact the diesel train, given that the electric train is expected to clear this ruling grade section in 13 minutes. The practical effect is that where a diesel service fails to clear this section in 20 minutes it will sterilise an additional network path.

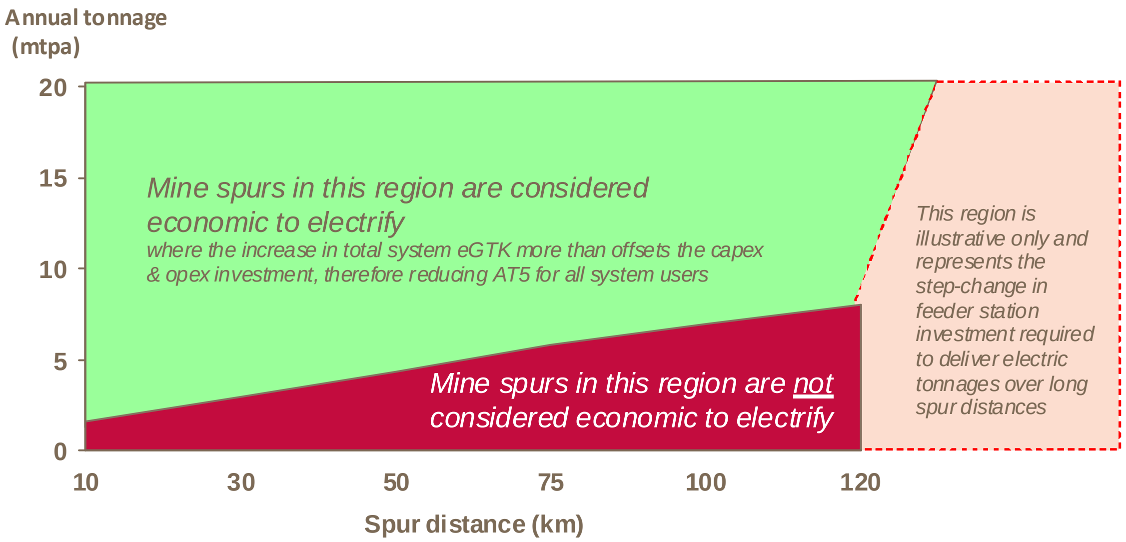
Given that the concerns raised by Rio Tinto and Peabody about the effect of electric traction on the opportunities for headway reduction are based on incorrect assumptions regarding both the factors constraining headways and the cost of future electric traction expansions, QRNN believes that the QCA cannot rely on these concerns as casting significant doubt on the results of QRNN's TCO analysis.

A further concern raised by some stakeholders was that new spurs were likely to be longer than the current norm, and that QRNN had not factored the costs of electrifying long new spurs into its analysis. This reflects a misunderstanding, both of the TCO analysis itself, and also of the extent to which the DAAU requires electrification of new spurs.

In the Blackwater full electrification case, the TCO analysis includes the electrification of the Rolleston spur. The TCO includes both the costs of installing the overhead wiring on the route and, given the forecast volume of traffic and the length of the spur, an additional feeder station. For further system growth (which is not linked to specific mine proposals and is therefore assumed to be broadly distributed across the system), QRNN has included in the TCO analysis an allowance for installation of additional overhead wiring. However, QRNN proposes that electrification of new spurs will actually occur on a case by case basis, depending on the characteristics of the spur in question. There is not an automatic presumption that all spurs must be electrified – rather they will be electrified if economically feasible.

QRNN has undertaken detailed analysis of the likely economics of electrifying new spurs in order to provide stakeholders with an understanding of when this is likely to be feasible. The results of this analysis were presented to the Traction Working Group and are summarised below:

Indicative threshold criteria for feasible electric paths in the Blackwater system[1]



Haul 1: >10mtpa and >50km spur

Haul distance - km	400		
Spur distance - km	100		
Feeder station units	0	1	1
Capex (Growth + Maint.) PV 2014 $m	0	138	138
Opex - PV 2014 $m	0	96	96
Haul electric	No	Yes	Yes
Spur electrified	No	Yes	Yes
Spur electrification in system RAB	No	Yes	No
RAB AT5 Tariff (2014) $/000 GTK	3.05	2.90	2.70
Non RAB Spur AT5 $/000 GTK	0	0	3.10
Total Haul AT5 (2014) $/000 GTK	3.05	2.90	5.73
Delta - from prior option $/000 GTK	0	-0.15	2.83
Economically viable?		**Yes**	**No**

Haul 2: <5mtpa and >50km spur

Haul distance - km	400		
Spur distance - km	100		
Feeder station units	0	1	1
Capex (Growth + Maint.) PV 2014 $m	0	141	141
Opex - PV 2014 $m	0	96	96
Haul electric	No	Yes	Yes
Spur electrified	No	Yes	Yes
Spur electrification in system RAB	No	Yes	No
RAB AT5 Tariff (2014) $/000 GTK	2.90	3.25	2.70
Non RAB Spur AT5 $/000 GTK	0	0	15.62
Total Haul AT5 (2014) $/000 GTK	2.90	3.25	18.32
Delta - from prior option $/000 GTK	0	0.35	15.07
Economically viable?		**No**	**No**

Spur line electrification assumptions:

- *Over head wiring (OHW) infrastructure development capex $0.7m per km*
- *OHW infrastructure maintenance capex $6682 per km per annum*
- *Feeder station infrastructure development capex $41.5m per unit*
- *Feeder station infrastructure maintenance capex $1.1m per unit per annum*
- *Feeder stations connection opex $6m per unit per annum*
- *Tax and Accounting straight line depreciation approach over 30 years with no residual*
- *Non RAB spur infrastructure WACC post tax nominal 10%, CPI 2.5%*

3.1.2.4 Technology

The QCA highlighted that stakeholders raised the concern that QRNN's analysis has ignored technological developments which will improve the efficiency of diesel locomotives.

Xstrata considered that QRNN failed to consider the performance of new diesel technologies and, in particular, their performance against an aging electric fleet. This again reflects a misunderstanding of the assumptions used in the TCO model. QRNN refers to the principle objective of the TCO analysis, being to assess the overall cost differential specifically due to different traction modes. In order to avoid distorting the analysis, QRNN based the all electric and all diesel TCO cost estimates on the current generation electric and diesel locomotives – that is, those currently being purchased in the market by a number of CQCN stakeholders, including QR National, Pacific National and BMA.

Locomotive technology is constantly evolving, with various locomotive producers investing heavily in research and development in order to advance locomotive performance. QRNN notes that Downer has highlighted that it is currently in the process of developing next generation diesel locomotives, which would provide improved efficiency, higher power and increased speed – improvements that it believe could significantly change QRNN's analysis and conclusions. QRNN is aware that Toshiba is also about to release a next generation electric locomotive, which is expected to provide significant improvements in efficiency and reduced maintenance costs.

It is a fact that both electric and diesel locomotives continue to evolve and improve. Many innovations and improvements in locomotive technology can be applied to both electric and diesel locomotives as a large part of the locomotives are basically the same – it is fundamentally the power generation source that varies between them.

QRNN has researched in detail the current and potential improvements in technology for both electric and diesel locomotives and QRNN has concluded that there is at least as much, if not more, potential for technological advances in electric locomotive technology than for diesel.

Contrary to the assertions of the QCA and industry stakeholders – there is intense competition in the supply of electric locomotives. QRNN knows of up to ten international suppliers of electric locomotives. This compares to up five international suppliers of diesel locomotives, who in turn rely on only two known international manufacturers of diesel engines (General Electric and Electro Motive Diesel). As discussed in more detail in the subsequent section on the impact of the DAAU on competition in the locomotive supply market, QRNN considers that the competition in the global heavy haul electric locomotive market is at least as strong as in the diesel locomotive market. As noted by a number of stakeholders, the competitive market is likely to be the greatest driver of improvements in technology - therefore the incentives for improvements in technology are at least as strong in the electric market as they are in the diesel market.

There are approximately ten major suppliers of heavy haul electric locomotives globally (Bombardier, China North Railway, China South Railway, Toshiba, Hitachi Rail, JSC Transmash, Alstom, Seimens, URAL Locomotives, ABB Group) and more than half are actively tendering in markets for narrow gauge electric locomotives. For example, Transnet (South Africa) has recently tendered for 95 heavy haul narrow gauge electric locomotives and has received responses from 5 of the major suppliers mentioned above. Further, the fundamental components used in the manufacture and development of electric locomotives benefit from innovation in the predominantly electrified passenger rail network globally.

QRNN also understands that the scope for future technological developments varies between electric and diesel locomotives. Diesel technology is unavoidably constrained by the fundamental principle of compression. In order to improve the performance once the technical limitations of compression have been reached, the size of the engine itself needs to increase. However, there will always be a physical constraint on the size of an engine that can be inserted into a diesel locomotive. In contrast, research and development in electric motors will be extensive and the rail sector would undoubtedly be able to obtain the spillover benefits from innovation in electric motor design (i.e. wind farm technologies). In addition, the scope for technological developments in electric locomotive technology include the development of more environmentally sustainable and energy efficient technology. The environmental benefits of electric traction are addressed further below in relation to the public interest criterion.

As such, QRNN believes the QCA has insufficient evidence on which to base an expectation that future technological advances in the locomotive market will significantly favour diesel traction over electric traction.

QRNN acknowledges that it has not sought to incorporate the impact of technological advances in locomotive engineering into the TCO analysis. Seeking to estimate the specific improvements that will be achieved is difficult and will be highly contentious. QRNN has taken the simplifying assumption that equivalent technological improvements are likely to be achieved for each traction mode. Technological enhancements will occur that change the operational performance and cost assumptions used in this model, but QRNN assumes that they will affect each traction mode equally, and therefore will not change the TCO differential between the two traction types.

It is a fact that both electric and diesel locomotives continue to evolve and improve. Many innovations and improvements in locomotive technology can be applied equally to both electric and diesel locomotives precisely because the locomotives are, to a large extent, basically the same. However, the different power generation source remains a permanent and fundamental distinction between then. The TCO is focussed on measuring the costs associated with *this* distinction.

3.1.2.5 Variation in energy cost assumptions

Stakeholders have stated that there is significant uncertainty about key input cost assumptions, in particular electricity and diesel price forecasts.[30] QRNN accepts that there is significant uncertainty regarding these input costs, and as such has subjected these input assumptions to a wide range of sensitivity testing. This sensitivity testing shows that the conclusions from the TCO analysis (i.e. that electric traction provides a lower TCO than diesel) are valid across a very wide range of energy cost assumptions. QRNN engaged reputable third parties to provide base forecast electric energy and diesel costs (the forecast costs are included in QRNN's December submission). Compared to the base input assumptions, diesel prices would need to reduce by 83%, or conversely electric prices would need to increase by 407%, in order to equalise the cost of the traction types over the 30 year analysis (refer to the results of the sensitivity analysis shown above). This shows that the conclusions of the analysis are reasonably insensitive to reasonably expected variations in fuel costs over the analysis period.

Further, the significant future benefit of regenerative breaking has not been considered in modelling to date.[31] QRNN believes that this provides significant further upside potential for the energy costs of electric traction.

As a result, QRNN does not consider that uncertainty about future energy costs (both diesel and electric) is a sufficient reason to cast doubt on the conclusions of the TCO analysis.

3.1.2.6 Other input costs

Some stakeholders have criticised the inclusion of Powerlink's break costs in the analysis, as they believe these should not be included in assessing the relative efficiency of electric and diesel traction.[32] QRNN has included these as a cost of moving towards a full diesel system, as they are third party costs that would be required to be paid by QRNN, and will therefore impact on QRNN's profit/loss performance. However, noting the unique nature of these costs, QRNN has clearly identified them in the analysis, and the conclusions that electric traction has a substantially lower TCO than diesel holds true, even if the break costs are not considered in the analysis. Given the transparency of how these costs have been treated, QRNN does not believe that it is valid for the QCA, or other stakeholders, to claim that the inclusion of these costs cast doubt upon the conclusions of the TCO analysis.

3.2 Network benefits of electrification

In its Draft Decision the QCA noted that there may be a range of possible reasons why diesel locomotives were not introduced to the Goonyella system and, consequently, that there is a large element of doubt over QRNN's claims that diesel trains in the Blackwater system provide network benefits by providing buffer capacity for the Goonyella system.

The QCA appears to have misunderstood QRNN's comments regarding the diesel buffer fleet. The key point that QRNN sought to demonstrate is that it is unlikely that the 100% electric utilisation of Goonyella would be sustainable, either historically or into the future, if the Blackwater system were not also electrified.

Within the total electrified network (i.e. across both the Goonyella and Blackwater systems) it is unlikely that 100% of feasible electric paths will be operated with electric trains. As the QCA has rightly pointed out, there are option benefits with diesel trains that electrics do not have. This is primarily due to the greater geographic flexibility of diesel trains which offer opportunities to run elsewhere on the network (beyond Goonyella and Blackwater). This can provide benefits to an operator in various circumstances. Evidence of this is shown by the fact that over the last ten years, QRNN's systems have not run with 100% electrics across the broader electric system – including prior electric capacity constraints emerging on the Blackwater system.

---

30 BMA submission, Anglo submission

31 Studies from Bombardier, China North Railway (CNR) – Datong, Siemens and Toshiba indicate 20-40% energy consumption savings for electric trains utilising regenerative breaking. Further, CNR quoted the Chinese Academy of Rail Science testing that demonstrated the Daqin line (over 400 million tonnes of coal per annum) operating at full energy self-sufficiency when using regenerative breaking.

32 Anglo submission, Peabody submission

This underutilisation will not necessarily present evenly across the electric network. There will be reasons why an operator may prefer to focus its use of diesels in a particular area. QRNN's submission on the DAAU demonstrates that this has been the case in the past. As the QCA has noted, there are a range of possible reasons for this preference relating to the comparative benefit of electric and diesel on particular routes and it is expected that operators will allocate their fleet in the way that is most productively efficient for that operator. As circumstances change, these decisions may too change.

The Queensland Resources Council recognised these implicit benefits in its response to QRNN's proposal to apply a single network AT5 tariff in its response to the September 2008 Draft Access Undertaking:

> QRC understands the merits of the case put forward to QR Network for the combining of the Blackwater and Goonyella electric assets. In particular, it is acknowledged that decisions regarding fleet allocation are made in the interest of the overall network, and that, under the existing approach to AT5 (which has applied during the 2001 and 2006 undertakings), this has delivered a pricing benefit to the Goonyella system at the expense of the Blackwater system.[33]

The QCA has sought detailed evidence of how QRN's fleet deployment strategy over the last 10 years has been part of a clear and sensible strategy which was demonstrably superior to other options.[34] Not only is this applying an incredibly high burden of proof, the QCA itself has argued that this information cannot necessarily be generalised or extrapolated into the future. Given this, the value of this information is limited. In any event, with changes in train technology and the introduction of diesel trains in GAPE, it may well be that operators are just as likely to operate diesel trains in Goonyella as Blackwater in future.

QRNN contends that rail operators will make decisions about investment and deployment of their rollingstock based on optimising the use of their entire fleet – including both electric and diesel traction. Based on historic evidence, QRNN considers that it is likely that this will include operating some diesel services on feasible electric routes. However, the choice of exactly how many diesel services would operate on electric routes would be a decision for each operator to make, based on its perception of the option value of diesel and electric traction at the margin. Again, based on historic evidence, QRNN considered that 90% electric traction offered a fairly conservative view of the likely electric utilisation.

Further, because operators will make decisions about investment and deployment of rollingstock based on optimising the use of their entire fleet, underutilisation of the electric network will not necessarily present evenly across the network. In this environment, pricing component parts of that electric system based on the actual utilisation of that component part will be distorting if it results in a disincentive to run electric trains on a particular component of the network given the high resulting price for that component. Given this, it makes sense to consider utilisation as a "whole of electric system" issue, and not just an issue for a component part of the electrified network.

3.3 Objective of the access regime

The objective of the access regime has two limbs: the efficient operation of, use of, and investment in, the below rail infrastructure; with the effect of promoting effective competition in upstream and downstream markets. Our response to the QCA's assessment of the DAAU against these criteria is set out below.

3.3.1 QCA's interpretation of efficient below rail infrastructure

QRNN believes that the QCA's interpretation of the objective of the access regime is incorrect as it takes a narrow view of efficiency which focuses on the declared below rail infrastructure in isolation from other highly inter-dependent elements of the supply chain. In our view it does not take account of the broader implications for the overall efficiency of the supply chain and the interests of end users. This approach of promoting the most efficient,

---

33 QRC (2008) Submission in response to: QR Network's 2009 Draft Access Undertaking, November, p. 49.

34 QCA Draft Decision, p. 17

lowest cost below rail solution in isolation may in fact result in higher supply chain costs overall. It also limits the concept of efficiency to cost minimisation. It is difficult to see how the QCA could consider this to be an improvement in economic efficiency.

The QCA's focus on below rail efficiency fails to have regard to all the relevant aspects of this concept. The concept of efficiency as contemplated by the QCA Act is widely recognised as having several elements:

- *Productive efficiency* – this is the least cost combination of inputs to produce a given output;
- *Allocative efficiency* – this is when resources are allocated to their most productive use from an economy-wide perspective, maximising overall economic welfare;
- *Dynamic efficiency* – this is about achieving productive and allocative efficiency over the longer term efficiency, and is related to incentives for innovation and longer term technological change.

All of these are relevant to consideration of economic efficiency as contemplated in the objective of the access regime. In the context of a coal supply chain, this means that a proposal that is productively efficient for one element of the supply chain (ie. below rail), but which imposes higher costs or inefficiencies on upstream or downstream markets and increases the overall cost to end users, is unlikely to satisfy the other elements of efficiency and, in consequence, will reduce economic welfare overall. QRNN considers that the QCA's narrow focus on below rail efficiency irrespective of the overall impact on supply chain costs and economic welfare is a mistaken view of the objective of the access regime and is contrary to the achievement of coal supply chain efficiency in Queensland.

3.3.1.1 Interdependencies in the supply chain

It is appropriate to take into account other supply chain factors in considering whether a proposal 'promotes the economically efficient operation of, use of and investment in' below rail infrastructure because of the significant interdependencies and trade-offs that exist between different parts of the supply chain. This was addressed in QRNN's DAAU submission which noted the following trade-offs, or substitution effects, between different supply chain elements:

- electric traction required substantial below-rail investment, which was offset by lower above-rail costs; and
- diesel trains had poorer performance and created congestion on the network, requiring a greater level of installed below-rail track infrastructure.

Another example of substitution effects and trade-offs in the supply chain is the previous lack of investment in stockpile capacity at DBCT and resulting move by DBCT Management and users to shift to a cargo assembly operating mode in Goonyella, as opposed to the previous even railings mode, with reliance on stockpile capacity at the port as a buffer. This move benefited the port and its users by optimising the operation of the port, but it effectively transferred costs to other parts of the supply chain. In particular, QRNN has had to undertake investments to increase below rail capacity in order to be able to conform to this supply chain operating mode imposed by the decisions of other parties.

These examples highlight that adopting a very narrow focus on one element of the supply chain – in this case, the declared below rail infrastructure – is to inappropriately ignore the impacts that decisions taken by one part of the supply chain can have on others. In particular, decisions that may be efficient for one element of the supply chain when considered in isolation can in fact result in higher costs to other parties and potentially also higher supply chain costs overall. For below rail infrastructure, the cheapest below rail solution is not necessarily the most economically efficient. This was noted by NERA (Attachment A):

> Ignoring the related nature of costs in the supply chain may lead to results that would be inconsistent with those that could be expected from a workably competitive process, and which would be inherently inefficient

An analysis which ignores the impact of below rail pricing on the supply chain as a whole cannot produce a proper assessment of whether the below rail tariff structure will promote the efficient *use* of the declared infrastructure (ie. efficient use of this infrastructure in the coal supply chain) or efficient *investment* in the declared infrastructure, having regard to the likely utilisation of different below rail infrastructure in the coal supply chain.

Accordingly, it necessary for the QCA to consider several factors as part of 'public interest' considerations. By not considering the issue of efficiency in the context of the supply chain as a whole, the Draft Decision does not give proper account of the objective which lies at the heart of the regulatory regime, and which must be given weight as a fundamental element in the QCA's decision.

The importance of supply chain interactions to the efficiency of the entire system, including the below rail network, was recognised by Stephen O'Donnell in his 2007 Goonyella Coal Chain Review. This clearly identified coordination failures as being central to the capacity bottlenecks that presented in Goonyella at that time:

> It is recommended that Coal Producers consider future rail haulage contracts with a view to defining the total installed rail supply chain capacity required to move the total tonnage of coal through the system. Penalties for under resourcing of total rail haulage capacity could then be applied as well as minimum take or pay volumes to underpin investment in rolling stock.[35]

Further:[36]

> A coordinated approach to master planning of infrastructure is essential. The situation where investments are being made without concurrent investment in other parts of the supply chain and then additional forecast tonnages are contracted out should never be allowed to happen again. The regulatory frameworks that underpin the governance of the supply chain should support this approach. Implementing the facilitation and coordination roles will be a significant step in moving forward.

3.3.1.2 Inconsistency with QCA's past approach

There are numerous examples in the regulatory history of QRNN where the QCA has adopted an approach which explicitly acknowledges the importance of interdependencies and trade-offs between above and below rail and other supply chain elements and their direct relevance to below rail regulation. These include:

- in 2005, QRNN, industry and the QCA engaged in a process of assessing the then QR Network's capacity expansion planning processes and Goonyella and Blackwater network expansion proposals. The QCA itself prepared the Terms of Reference (TOR) for Halcrow to undertake this work. This TOR clearly show that the QCA then considered trade-offs between above and below rail efficiency as central to considerations of below rail regulation, in particular, the efficient expansion of the network. This is shown in the following excerpts from the TOR:[37]

> "….the consultant is to consider the extent to which QR's capacity analysis and capacity expansion planning processes take into consideration a range of factors. These may include (but are not limited to):
>
> ….
>
> - Cost-benefit analysis of alternative capital expenditure options;
> - Consideration of alternatives to capital expenditure;
> - Efficiency of operating practices (above-rail and below-rail);
> - Below-rail transit times and any other performance-related factors;
> - Consideration of above-rail issues (eg. train consist requirements).
>
> ….
>
> ….the consultant is required to ….undertake appropriate scenario modelling of the systems (using QR's Planimate model) to determine:
>
> ….
>
> - How many train paths are currently available to coal traffic, how many are consumed by other traffics and traffic priorities, and how many (if any) are lost through operational inefficiencies (both above-rail and below-rail);
> - The available options for expanding capacity on each system. These options should not necessarily be limited to below-rail capital projects and should include consideration of operational practices and performance targets, including below-rail transit times;

---

35 Stephen O'Donnell, Goonyella Coal Chain Capacity Review – Second and final Report, 2007, p. 1

36 Stephen O'Donnell, Goonyella Coal Chain Capacity Review – Second and final Report, 2007, p. 7

37 Halcrow, Review of QR Network's Capacity Expansion Planning Processes and Goonyella and Blackwater Network Expansion Proposals, Queensland Competition Authority, February 2005, p. 10-11

….”

- the CRIMP and associated customer approval process for capex included in the Access Undertaking is a mechanism to address coordination failure and provide the information necessary for the coordination of supply chain expansions to help ensure that the most efficient expansion path for the supply chain is taken;
- supply chain governance and efficiency matters in the 2010 Access Undertaking. The QCA accepted as appropriate for inclusion in the Access Undertaking principles and obligations relating to: participation in supply chain planning; reconciliation of QRNN's master plans and any system master plans; input into developing system operating assumptions; and a requirement for aligned contracts to be held before entering into an access agreement. In its decision on the inclusion of supply chain principles in the Access Undertaking, the QCA noted that:[38]

> The Authority was also mindful that a balance must be struck between optimising supply chain efficiency and the legitimate business interests of the service provider.

- the basis of scheduling in the supply chain reflects what is most efficient from a whole of supply chain perspective and not solely what is productively efficient from a below rail point of view. A scheduled or even railings service would reflect a focus on purely below rail efficiency, yet clearly this is not acceptable for end customers or from the point of view of efficient supply chain operations;
- the QCA has required QRNN to coordinate its maintenance activities with other supply chain participants. The effect of this is for QRNN to incur a higher level of maintenance costs than if it were otherwise to disregard supply chain impacts (this is because minimising track possessions requires QRNN to focus its maintenance activities into limited windows, incurring higher crew and equipment costs to achieve the required maintenance outcomes);
- the desirability of contractual alignment of access entitlements across all elements of the supply chain is recognised in the negotiation framework, as QRNN is not required to negotiate with a party that does not have or is unlikely to obtain entry and exit rights to and from the network;
- the ability to depart from pricing limits in setting reference tariffs under the Access Undertaking in circumstances where this will promote efficient investment by either QRNN or another person in the relevant transport supply chain.

Given the above examples of supply chain efficiency being considered by the QCA as highly relevant to the regulation of declared below rail infrastructure, the idea that overall efficiency of the supply chain is outside of consideration of the objective of the access regime and is merely one of many factors to be weighed by QCA in its assessment of public interest is misplaced and inconsistent with QCA regulatory precedent.

In summary, QRNN considers that it is only possible to assess what is an efficient use of and investment in below rail by considering whether this service best meets the needs of users – that is, it facilitates achieving the lowest total cost of the supply chain and not necessarily the lowest below rail cost. This view has been implicitly recognised by the QCA and customers in other contexts.

3.3.1.3 Impact of market based traction choice on efficiency

As QRNN has already explained in Part B of this submission, the existence of market failures mean that users of diesel traction do not bear the full costs that they impose on the rail system as a result of their choice. Under the current Access Undertaking, a decision by one operator to utilise diesel traction on feasible electric services will have the following impacts on operators of electric traction (or their customers) in the system:

- the AT5 charge will increase to reflect the reduced economies of scale for the remaining users of electric traction;
- the introduction of trains with lower performance characteristics will impact on the available utilisation of rollingstock, due to increased system congestion;
- if the diesel penetration in the system is sufficiently high (in excess of 20%), the performance characteristics of the electric fleet will deteriorate to resemble the performance characteristics of the slower trains.

[38] QCA, Final Decision, QR Network's 2010 Draft Access Undertaking, September 2010, p. 185

The full amount of these costs will only become apparent through an analysis that takes into account the costs that are incurred by the total rail system – as is the case with the TCO analysis.

Further, QRNN believes that the QCA should not make a determination that leaves the choice of efficient traction type for the market to decide, without the QCA first having considered the costs that will be imposed on the rail system as a result of different traction choices. This information can then be used to determine what constitutes an efficient price signal to put into the market to encourage the most efficient traction choice.

3.3.1.4 Issue of electrification of spur lines

QRNN disagrees with the QCA's view that the DAAU will promote uneconomic investment in below rail by promoting the electrification of spur lines.[39] The DAAU provisions only apply to "feasible electric services" – that is, the ones where the route is actually electrified. It does not provide an automatic right for QRNN to electrify additional parts of the network and apply these provisions. Future investments remain subject to customer support in the same way as occurs at present. These investments would therefore only occur if there was a successful customer vote in accordance with the undertaking process or a specific customer underwriting the investment. These conditions will only be met if QRNN can demonstrate the economic benefit of electrifying a particular spur. In the event of an unsuccessful customer vote QR Network would still need to demonstrate the prudency of that decision for those assets to be included in the Regulatory Asset Base. The DAAU will not in any way promote electrification of spurs where there is no economic benefit of doing so.

3.3.2 Promotion of competition

Promotion of competition is the second limb of the object clause. QRNN believes that the QCA has adopted an incorrect view of the relevant related markets and, as a consequence, has reached mistaken conclusions in terms of the impact of the DAAU on competition in these markets.

---

[39] QCA Draft Decision (July 2012), p. 27

3.3.2.1 Effective competition

The QCA defines 'effective competition' as requiring both:[40]

- rivalrous market behaviour in all dimensions of the price-product-service package offered to customers; and
- low barriers to entry.

QRNN considers that the QCA's definition of an effectively competitive market sets an inappropriately high threshold. While we agree that a competitive market will involve rivalrous behaviour and the threat of possible market entry, we do not consider that it is necessary for there to be competition in 'all dimensions of the price-product-service' package to be effectively competitive. That is, there does not need to be a range of different price-product-service packages offered, as there can be effective competition between firms offering an identical product. We are particularly concerned that the use of this definition will cause the QCA to seek to create a regulatory framework that encourages rivalrous behaviour even where this causes additional costs to the supply chain as a whole.

In terms of barriers to entry, while higher barriers may tend to reduce competition, it is not necessary to have low barriers to entry for competition to be effective. We refer the QCA to NERA's report which addresses this issue in more detail (Attachment A).

QRNN notes that the NCC takes a different approach to assessing what is effective competition, stating that:

> ….The basic characteristic of effective competition is that no one seller or group of sellers has undue market power. Competition is a dynamic process, generated by market pressure from alternative sources of supply and the desire to keep ahead. In this sense, competition expresses itself as rivalrous market behaviour.[41]

and

> 'Effective competition' refers to the degree of competition required for prices to be driven towards economic costs and for resources to be allocated efficiently at least in the long term.[42]

The effect of the NCC's approach to assessing effective competition places less importance on the dimensions of rivalry, and greater focus on the effect that no one seller or group of sellers has undue market power.

3.3.2.2 Market for locomotive supply

In relation to the locomotive supply market, the QRNN considers that the QCA's analysis of competition in this market is incomplete and inaccurate. QRNN urges the QCA to undertake a more comprehensive investigation than it has apparently done to date in support of its conclusions on this issue.

The QCA has concluded that narrow-gauge heavy-haul diesel and electric locomotives are in the same market for competition analysis. The QCA then identified Siemens as the sole supplier of electric locomotives and Downer EDI Rail and UGL Rail as the known competing suppliers of narrow gauge diesel locomotives. On this basis, the QCA concludes that the market for narrow-gauge heavy-haul locomotives is concentrated. The QCA states that, by providing an incentive for use of electric traction in the Blackwater system, this is likely to reduce the option for operators to use diesel locomotives, with the result that diesel locomotives may no longer be an effective substitute for electric locomotives on the electrified networks. It argues that this in turn could reduce the competitive constraint

---

[40] QCA Draft Decision (July 2012), p. 32

[41] National Competition Council, Declaration of Services, A Guide to Declaration under Part IIIA of the Trade Practices Act 1974 (CTH), August 2009, p. 33

[42] National Competition Council, Declaration of Services, A Guide to Declaration under Part IIIA of the Trade Practices Act 1974 (CTH), August 2009, p.35

faced by the narrow-gauge electric locomotive supplier and hinder technological change by that electric locomotive supplier. The QCA concludes that the DAAU will adversely affect competition in that market.[43]

QRNN agrees that diesel and electric locomotives are effective substitutes and should be considered in the same market for competition analysis. However, there are factual errors in the QCA's findings relating to competition in this market. A more informed assessment of the locomotive supply market would show that it is an internationally competitive market with multiple sellers. Competition assessments are concerned with the number of actual and potential sellers in a market and not the number of manufacturers who have previously 'supplied' goods within a market defined by an overly narrow geographical boundary.

Specifically, the QCA has wrongly identified that there is a single supplier – Siemens – for electric locomotives. The market for the supply of electric locomotives is in fact a global market with up to ten known suppliers of heavy haul electric locomotives: Siemens; China South Railway (CSR); China North Railway (CNR); JSC Transmash; URAL Locomotives; Bombardier; Alstom; Toshiba, Hitachi Rail and ABB Group.

Of these, eight currently supply the Australian market, providing either electric locomotives or electric trains or trams for passenger services. For those currently operating in the passenger market, there is no constraint on them extending their Australian service offering to include their electric locomotives. While at present Siemens has 100% market share in CQCN in supplying electric locomotives, there is clearly the potential for other firms to supply electric locomotives for use in CQCN in competition with Siemens.

In terms of diesel locomotive suppliers, there are five known suppliers of heavy haul locomotives internationally, with four of these represented in the Australian market. Downer has been the dominant provider of diesel locomotives used in the Central Queensland coal network. However, as is the case with electric locomotives, there is clearly the potential for other firms to enter this market. In a competition assessment the relevant information is the number of potential sellers and not the historical number of suppliers.

It is therefore not correct to assume that train operators in CQCN are limited to purchasing locomotives from the existing suppliers. The market for heavy haul locomotives, encompassing both diesel and electric locomotives, is clearly a competitive international market. Both the actual competition and the threat of market entry provide a competitive discipline on suppliers. QRNN notes that the barriers to import locomotives into Australia are the same for all suppliers, with regulatory approvals readily obtained and we understand that international locomotive producers compete strongly with domestic producers.

These suppliers operate within an international market, supplying locomotives to a range of countries on a competitive basis. Electric locomotives are regarded as an effective solution to heavy haul operations where high tractive effort and high traction power is needed. Examples of where electric traction is used internationally for heavy hauls include South Africa, Russia, India and China.[44] Electric traction is dominant for freight throughout Europe[45] and the east coast of the USA is also actively pursuing this option. The demand for locomotives in the Queensland market is only a small component of this international market - we understand that the size of the international market for electric traction is at least as large as diesel, taking into account freight, passenger and heavy haul. As a result, Queensland demand does not drive the extent of competition or innovation in this global market.

In focusing its assessment of suppliers on existing providers of narrow gauge heavy haul locomotives, the QCA is overlooking the low barriers to entry for other locomotive suppliers to supply this product. A more thorough examination of this market and the technological substitution possibilities indicate that it is a broader and more competitive market than indicated by the QCA. For example, it is incorrect to assume that the market for the supply of narrow-gauge locomotives is distinct from the supply of standard gauge locomotives. In reality, the locomotive technology is similar, being based on the same design principles. On the question of gauge, QRNN understands that the process of 'adaption engineering' – ie. modifying production of locomotives from a standard to a narrow gauge – is able to be achieved by any locomotive supplier. The one-off costs of doing this will depend on the re-engineering required to achieve the necessary changes to bogies and chassis size. Similarly, it is incorrect to assume that electric locomotive designs are specific to the electric voltage of the power supply system – again,

[43] QCA Draft Decision (July 2012), p. 33

[44] Vitins, J., Bombardier Transportation, Electric Locomotives for Freight Corridors, January 2007

[45] Bombardier, New electric locomotives for the UK, 20th Annual Rail Freight Group Conference, 29th May 2012

much of the design and technology is the same, and it is simply a matter of adapting elements of the locomotive to suit the design brief. QRNN understands from industry sources that the ability for locomotive suppliers to make such adjustment relatively simply is demonstrated by the fact that in a current tender for 95 heavy haul narrow gauge electric locomotives in South Africa, tenders were received from five international locomotive suppliers. Many of the companies submitting tenders are not traditional narrow gauge product manufacturers.

As would be expected in a competitive market, there are incentives for innovation to meet customer needs and promote the competitiveness of the product. QRNN therefore rejects stakeholders' arguments that technological change is most likely to occur for diesel locomotives and that diesel technologies have greater flexibility. Indeed, the current uncertain environment of rising fossil fuel prices and the introduction of carbon pricing may indicate a more favourable environment for electric traction in the longer term compared to diesel. This is addressed further in section 3.6.

Further, given the level of competition in this market and the fact that it is an international, rather than just a Central Queensland market, it is incorrect to conclude that there will be less innovation in the market should there be greater take up of electric train services in Blackwater. As noted above, the Queensland market reflects only a small proportion of the global locomotive market (for both diesel and electric locomotives) – and is therefore a beneficiary, not a driver, of competition and innovation within the global market.

In light of the above, given that the market for locomotive suppliers is already a competitive international market, it is incorrect to conclude that a change in price relativities between diesel and electric services in the Blackwater system will ease competitive constraints on electric locomotive suppliers and adversely affect competition in locomotive supply in either the Blackwater, Goonyella or any other system in the Central Queensland coal network.

In summary, QRNN considers that the QCA has adopted an inappropriately narrow definition of the market for locomotives, both in terms of its geographic scope and the product dimension of market definition (ie. due to technological substitution possibilities). It has also mistakenly assumed that it is an uncompetitive market with a single supplier, when there are in fact multiple potential suppliers. These characteristics broaden the scope of the market in question and the competitiveness of this market. It also indicates robust incentives exist for innovation. As a result, the QCA has incorrectly concluded that the DAAU will have an adverse impact on competition in the market for the supply of locomotives and that a purchaser of locomotives in the Central Queensland coal region will be worse off as a result of the DAAU.

3.3.2.3 Market for above rail haulage

QRNN does not support the QCA's view that above rail haulage in Blackwater and Goonyella are separate markets for competition analysis. From a mine's perspective (demand side of the market) it may be the case that they have a haulage contract with a particular train operator and an access contract at the particular port that largely serves that supply chain, limiting substitution possibilities across systems (although we note that given the scarcity of port capacity and the economics of coal production, it is increasingly feasible for a mine to run cross system traffic where it is able to obtain the necessary track and port capacity).

However, from a train operator's perspective (supply side of the market) there are very strong substitution possibilities between coal systems. Train operators have a mobile fleet and rollingstock standards are increasingly consistent across the complete Central Queensland coal network allowing them to reallocate locomotives and rollingstock as required to meet customer needs. Moreover, the network is increasingly interconnected, with the development of GAPE and the Surat Basin Rail connecting the Western and Moura systems.

A train operator is likely to have a portfolio of haulage contracts with a number of mines located across different (but potentially interconnected) systems. Both in the operational environment to a degree but, more importantly, over the medium term, train operators have the ability to deploy their fleet across their portfolio of haulage contracts that may span several systems. In a medium term business planning context, any decision to buy new locomotives will take into account the existing fleet and the most appropriate deployment (or redeployment) of this fleet. This indicates a much broader market definition for the above rail haulage market than described by the QCA: for electric services the relevant market should be defined as the electrified network (Goonyella and Blackwater combined); for diesel services, it is the entire CQCN. This broader market definition means that the QCA has reached incorrect conclusions regarding the impact on competition of the DAAU.

QRNN is also concerned that analysis of the impact of the DAAU on competition inappropriately focuses on the current state of the market, and does not consider how this market is likely to evolve over time. For example, the QCA assumes that Pacific National is locked in to diesel traction in the Blackwater system, and makes its competition assessment based on this foundation. There are a range of factors that may change the extent to which Pacific National is "locked in" to diesel traction in Blackwater in the future:

- Pacific National is currently operating off a low volume base in the Blackwater system – Pacific National only operates three diesel trains[46] out of a total of 30 consists that are currently allocated to the Blackwater system between all operators;
- As is shown in Confidential Attachment B, there are significant volumes of coal services that are currently being, or will shortly be, offered for tender. This includes new contracts for services to operate to WICET, as well as significant volumes of existing services to RGTCT that are coming to the end of their contract terms. To the extent that Pacific National is successful in winning contracts in this market, it will need to invest in additional locomotives – there is no constraint on Pacific National purchasing electric locomotives rather than diesel for growth volumes in the Blackwater system;
- Volume buildup for diesel only services is continuing to occur in the GAPE system (with volumes progressively ramping up from 2011-12 to 2015-16 when the full volume commitment is planned to be hauled) and there is the potential for major growth in diesel only services when commitment to the Surat Basin Rail occurs at the end of this year – this will provide significant opportunity to relocate existing diesel consists from the Blackwater system.

Pacific National retains a choice in regard to traction for these substantial growth opportunities, and will presumably respond to the pricing signals created through the regulatory framework in making this decision. In other words, Pacific National is likely to have significant opportunity to change the traction mode used in the Blackwater system and retains the option of choosing electric traction in future, so it is incorrect for the QCA to focus on an expected impact on Pacific National's commercial position based on the assumption that it is locked into diesel traction for its Blackwater operations. Pacific National's submission recognises, in its criticisms of the TCO model, that an operator would respond to price signals over time by changing traction mix:[47]

> ….The model does not allow train operators to react to this cost increase and change the mix of diesel and electric traction over time….
>
> Asciano believes that a more robust model would allow train operators to change their mix of diesel and electric traction at regular intervals in response to the outcomes determined within the model at that time…..

This demonstrates firstly that Pacific National does in fact place a positive value on having the option of using electric traction in future and, secondly, that such changes in fleet deployment would be made in response to price signals.

The QCA should also carefully consider the real commercial impact on Pacific National given it can be expected to pass through access charges to its mine customers and given the potential for it to redeploy diesels as other opportunities arise given the expected growth in the market. The QCA has acknowledged that it is current industry practice under an operator access agreement for access charges to be simply passed on to the end user through the haulage agreement.[48] Asciano also noted in its 2011 Annual Report that, for Pacific National Coal, the structure of coal haulage contracts in Queensland allows it to pass access charges directly through to customers.[49] Given this, a change in a reference tariff for existing haulage contracts is unlikely to result in an erosion of Pacific National's profitability, as suggested by the QCA.[50] The impact is more likely to be felt by Pacific National's mining customers. It is not that this is not a relevant consideration to the DAAU only that it is not relevant to assessment of competition in the above rail market. Therefore, when assessing the impact of this change in reference tariff

---

46 This information can be readily obtained from observations of system operations

47 Asciano, Submission to the QCA on QR Network's DAAU relating to electric traction, 16 April 2012, p. 25

48 QCA, Draft Decision, Proposed Standard Access Agreements, July 2012, p. 21

49 Asciano Ltd, Annual Report, 2011, p. 9

50 QCA, Draft Decision (July 2012), p. 35

arrangements on competition, the more relevant question is whether a change in the price of rail haulage transport for these mines will have an impact in competition in the market for coal supply.

Importantly, QRNN does not consider that the QCA has demonstrated how the DAAU will create a competitive advantage for QR National over Pacific National at the point we anticipate that competition actually occurs – that is, the tendering for a haulage contract. As competition between train operators occurs when a mine seeks a new contract to haul its coal to the port, there is no competition for contracts that are already signed. As such, competition cannot be adversely affected for these contracts. To the extent that the DAAU results in users of Pacific National's existing diesel haulage services paying more and QRN's existing users of electric haulage services paying less, this still does not have an impact on competition for new contracts. Further, the level of access charges does not affect competition between existing train operators – as the reference tariff does not discriminate in any way between operators. In effect, while the DAAU seeks to promote greater use of electric traction, it does not cause a reduction in competition given that it will lead to greater efficiency and the same two operators will compete vigorously for new business (see discussion in NERA report, Attachment A).

The QCA also concludes that the DAAU, by providing incentives for use of electric traction, will reduce the degree of competition between existing rail haulage operators in the Blackwater haulage market by limiting the opportunities for rivalry in all dimensions of the price-product-service package. In response, firstly, traction choice is not eliminated by the DAAU – rather the DAAU seeks to ensure that users of diesel traction pay an access charge that reflects the full costs that this decision imposes on the rail system. Secondly, as discussed above, for effective competition to be achieved, there does not need to be a range of different price-product packages offered to the market. In fact, there can be effective competition between firms offering an identical product. Consequently, the QCA's analysis sets the benchmark for effective competition too high and has therefore overestimated the impact on competition in the haulage market of the DAAU.

Another matter of concern to QRNN is that the QCA has assumed strategic behaviour on the part of QRNN in submitting the DAAU. However, the QCA does not appear to have addressed the possibility of strategic behaviour on the part of non-QR National train operators in the system based on the current regulatory framework. For Pacific National, acting in a way that increases the costs faced by incumbent operator will disadvantage its competitor. In this regard, we note that the QCA appears not to have considered or responded to the (confidential) attachment submitted by QRNN with the DAAU about strategic incentives of Pacific National. QRNN believes that consideration of incentives is central to this issue, particularly as the QCA has placed so much weight on the apparent anti-competitive incentives it has attributed to QRNN, yet has not considered the anti-competitive and strategic incentives faced by other parties. We therefore resubmit that attachment with this submission for consideration by the QCA and all stakeholders (Attachment C).

Overall, QRNN considers that the QCA has focussed its assessment of the impact on competition in the haulage market on the short term impact of the DAAU on Pacific National, rather than considering longer term commercial impacts and opportunities, as well as incentives for strategic behaviour by non-QRNN parties. In effect, the draft decision is based on an assessment of the short term impact on a particular competitor, and not on competition itself. For the reasons outlined above, QRNN considers that the QCA's view in terms of the impact of the DAAU on competition in the above rail market needs to be substantially reconsidered.

Our response to QCA's specific comments in relation to the impact on competition in Blackwater and Goonyella are below.

(a) Blackwater

The QCA concluded that the DAAU would adversely affect the state of actual competition in Blackwater and will discourage future entry. This is on the basis that it thought: the DAAU would reduce the degree of competition between existing operators by 'eliminating' traction choice as a competitive factor; 'changing the rules' would chill future competition by discouraging new entrants; reducing size of the diesel haulage market by discouraging use of diesel; and increase the cost of entering the market with electric services due to a single supplier of electric locomotives.

QRNN has fundamental concerns with this analysis and conclusion for the reasons set out below.

QRNN acknowledges that, to the extent that traction choice is a significant element of competition, the DAAU will reduce the attractiveness of diesel compared to electric traction. However, the issue is whether this element of competition is actually promoting efficient use of and investment in infrastructure. If the existing pricing signals (which strongly encourage the use of diesel traction in competition to electric) are not efficient, then it cannot be assumed that the competition is sufficiently effective to promote efficient decisions on choice of traction. We note that competition in traction choice is not a feature of diesel only systems, and nor is it a significant feature in the Goonyella system, where electric has a significant cost advantage over diesel – these systems all continue to exhibit strong competition between operators. The assumption that above rail competition will suffer if traction choice is not a significant element of competition is therefore inconsistent with demonstrated behaviour in the other CQCN systems where operators compete on the basis of a range of factors, including price, technology and service attributes. It is therefore not clear that the chain of adverse competition impacts identified by the QCA will in fact occur in response to a change in pricing differentials between diesel and electric, and nor has the QCA demonstrated this.

In terms of the QCA's concerns about the effect of 'changing the rules', QRNN acknowledges that there will be a one-off impact on some existing stakeholders (most likely Pacific National's mining customers in the Blackwater system) as a result of the DAAU proposals. However, QRNN does not believe that this argument for rejecting the DAAU stands up to scrutiny, given the following:

- The QCA has acknowledged in its Draft Decision that there is a problem with the current approach to pricing of electric assets. This indicates that the QCA considers that it will be necessary to 'change the rules' in relation to this issue at some point. This begs the question of when would be an acceptable time to finally resolve this issue. For this reason, we have used the legitimate mechanisms under the QCA Act to seek to resolve this issue – namely, submitting a draft amending access undertaking;
- The DAAU proposals apply equally to all operators in both Goonyella and Blackwater. While acknowledging the short term impact on Pacific National's customers given its recent investments in diesel traction for Blackwater services, we would suggest that it is incumbent upon the QCA to adopt a longer term view in its analysis of the impact of the proposal. If necessary, transitional arrangements may be considered to ease any short term impacts on existing participants;
- All stakeholders have been well aware of this issue for many years. QRNN has raised its concerns about asset stranding risk and proposals to address it with the QCA as early as 2008. Industry has been consulted on (and supported) network investment plans with regard to electrification of Blackwater through the CRIMP and customer approval processes since 2006 onwards and was well aware of the stranding risks associated with the investment if electric traction was not subsequently used. QRC has recently acknowledged the shortcomings of the existing pricing framework and noted that they create a risk of stranding of Blackwater electrification assets.[51] In light of this history, it is unrealistic for the QCA to suggest that the change in approach proposed by the DAAU is unanticipated by industry or would effectively discourage new entry;
- QRNN invested in electrification assets in Blackwater in accordance with the rules set out in the access undertaking. Any prospect of being unable to recover the cost of this investment due to the regulatory approved would be contrary to the regulatory compact established by 'the rules' in the Access Undertaking. We are concerned that the QCA appears somewhat ambivalent in its concerns about the consequences of regulatory risk;
- Allowing regulatory arrangements to continue as they are could also have a chilling effect on competition, due to the uncertainty inherent in allowing acknowledged unsustainable pricing arrangements to continue to apply.

Contrary to the QCA's assertions, adjusting the regulatory regime to address clearly identified shortcomings, while ensuring that this does not expose the existing participants to stranding risk (using transitional arrangements if necessary), is likely to engender greater confidence in the effectiveness of the regulatory framework than is currently the case. The key issue for all parties is how to resolve this issue without creating a win/lose situation for existing operators and to enable them to benefit from their existing investments and compete with confidence into the future.

In response to the QCA's argument that the DAAU will reduce the size of the diesel haulage market and make entry of diesel into the market unattractive, we note that a broader view of the network would show that there are many opportunities to manage a fleet across systems. With Surat Basin Railway, Moura, GAPE and Newlands being diesel only, diesel traction remains a significant part of the broader Central Queensland coal haulage market and, as such, a train operator retains considerable scope to deploy diesel trains across the network.

---

51 Queensland Resources Council, Submission 2010-11 Revenue Cap Adjustment, June 2012

QRNN has addressed the issue of the market for locomotive supplies above. In essence, this is a competitive international market and, as such, the pricing proposals in the DAAU are highly unlikely to have an adverse impact on competition in this market and, in turn, are highly unlikely to cause an increase in the price of electric locomotives in the CQCN.

For the reasons outlined above, QRNN disagrees with the QCA's conclusions in regard to the impact of the DAAU on competition in the haulage market in Blackwater.

(a) Goonyella

The QCA concludes that as the DAAU proposes to increase the AT5 tariff for both haulage operators in that system, it is unlikely to affect the pricing terms on which they compete and, therefore, is unlikely to affect competition in the short term. QRNN notes that the DAAU proposal applies equally to both operators in Blackwater as well. The fact that there may be different market impacts of the proposal in Goonyella and Blackwater in the short term reflects the current state of those markets, including past investment and contracting choices of mines and operators. As discussed above in relation to Blackwater, the QCA's analysis takes a very short term focus, which can result in misleading conclusions. The pattern of costs and benefits of the DAAU proposals should be assessed over a longer term and include the full range of impacts on all parties. This would include, in addition to any potential adverse impacts on operators identified by the QCA, the option value that operators have of utilising electric traction in future and the longer terms implications for investment incentives of regulatory pricing arrangements which promote stranding of QRNN's investment in electric assets.

On the question of the supposedly adverse impacts on competition of 'changing the rules', QRNN refers to the arguments set out above in relation to Blackwater. To the extent the QCA has relied on similar arguments to that in Blackwater in reaching its conclusions in relation to Goonyella, QRNN also refers to the arguments above in refuting the QCA's conclusions. Specifically, it is unlikely that the changes to AT5 proposed in the DAAU will affect future competition in the above rail haulage market in Goonyella.

3.4 Interests of owner

The QCA states in the Draft Decision that investments already in the regulated asset base (RAB) should be protected from asset stranding, but goes on to say that the mechanism proposed by QRNN in the DAAU is not an appropriate way to address asset stranding concerns.

Despite this, the QCA has not proposed any mechanisms or guidance on how to address this issue that it would support. QRNN has relied on the customer approval process as the intended mechanism to address coordination failures in the supply chain and to act as a substitute for difficult to coordinate, specific contractual provisions in providing the necessary certainty in which to undertake investments. QRNN has followed this process in relation to its significant investments in electrification assets in Blackwater. In particular, QRNN obtained the full support of the Blackwater customer group for the recent investment in new Blackwater feeder stations and, consequently, regulatory pre-approval of these investments.[52]

We note the comments made in submissions in regard to the 2010 customer vote process, in particular, that QRNN did not provide sufficient information to customers at that time. In this context, the QCA also referred to the fact that $1.1 billion of the $1.4 billion of proposed projects failed to receive the required 60% support from affected customers at the time. QRNN considers that this demonstrates that customers do in fact take this process seriously and will vote against an investment if they do not believe they have sufficient information, whether through information formally provided through the CRIMP process or otherwise, to decide whether they support the investment.

QRNN followed the processes set out in the Access Undertaking in relation to customer vote on investment in increased electric capacity, which includes an opportunity for customers to object if they consider that there is insufficient information. We highlight that the investment was supported by customers, both in relation to the initial vote on the investment in the four substations, and the subsequent vote on the 2009 Master Plan for the

[52] QCA, Regulatory Pre-approval for Coal Master Plan 2008 capacity expansion projects, letter to Mr Lance Hockridge, 23 April 2009. Available at: www.qca.org.au

expenditure on concept and pre-feasibility study for renewing/replacing the Callemondah feeder station[53]. We welcome the QCA's acknowledgement of this fact and, further, its view that it is not appropriate to expose QRNN to the potential of asset stranding risk on the basis of expressions of dissatisfaction with the process after the event.

It is also important to note that under clause 3.2.1(a)(ii) of Schedule A of the Access Undertaking a customer obtains the right to vote if the inclusion of those assets in the regulatory asset base will have an effect on their access charge at any time in the future. Accordingly, customers are aware, as evidenced by the customer vote on the GAPE assets, that they are accepting that they will be required to contribute to the recovery of those investments (regardless of whether they are directly used by access holders).

Further support of the view that customers were well aware of the requirement to recover the cost of electric investments is the fact that submission on the April 2010 Draft Access Undertaking did not raise any material concerns regarding the level of AT5. If this cost recovery, as reflected in the proposed level of AT5 in the DAU, was unexpected by stakeholders, it would be reasonable to expect that this would have been raised with the QCA as a significant issue at the time. The fact that it wasn't supports a view that customers accepted (and expected) that they would contribute to the recovery of the cost of this investment.

In any event, in relation to the investment in electric assets in Blackwater, industry clearly now has an incentive to say that they were not fully informed and that their support for that investment was not in any way intended to be an indication that they would use the asset once built. Now that some participants may choose to run diesel trains, these same users do not want to be the ones that bear the cost of the resulting increase in the total supply chain cost that this imposes. Arguing that QRNN should deal with this issue through asset impairments places the additional supply chain cost of this decision directly onto QRNN. This amounts to a gaming of the regulatory process by industry – by supporting the investment in the customer voting process, they get QRNN to invest in the electric capacity increase. Now that the capability is built, industry seeks to have the cost of the decisions of operators to bypass that asset borne by QRNN, while retaining a free option to revert back to electric traction if the pricing signals change, for example by QRNN impairing its assets.

Due to the long lead times and investment commitments which need to be made with third party suppliers (which the coal industry should be well aware given the substantial power requirements for drag lines and other mine site distribution networks) and the timing of the regulatory pre-approval process itself, the level of information available on the potential cost forecasts for the supply of this services may be at concept level. For example, the September 2008 Draft Access Undertaking noted:

> There is currently significant uncertainty in relation to the likely costs of the connection agreements for the new stations. QR Network is currently undertaking detailed design for additional feeder stations in the CQCR. The costs associated with connecting these feeder stations to the relevant Network Service Provider will not be known with a reasonable degree of certainty until negotiations regarding interface standards and connecting infrastructure (including easements) are sufficiently progressed.[54]

Accordingly, this information is consistent with the information reasonably available to QRNN at the time of the vote and was in the public domain and available to industry prior to the consideration of their vote and acceptance of the investments in December 2009. The Queensland Resources Council noted this uncertainty (with the majority of industry submissions endorsing the QRC paper) by stating:

> QRC accepts that this cost may require an adjustment mechanism if the cost is sufficiently material and sufficiently difficult to estimate for the regulatory period.[55]

QRNN submits that, in the absence of change to the Access Undertaking, it will be the party to bear the adverse commercial consequence of the QCA not applying the regulatory framework consistently, as it faces the risk of future asset stranding of its investment due to allowing operators/customers the option to avoid paying for this and potentially impacting on QRNN's ability to recover cost of these assets (where bypass is a reality).

---

[53] QCA, Regulatory Pre-approval for Coal Master Plan 2009 capacity expansion projects, letter to Michael Carter, 23 April 2010. Available at: http://www.qca.org.au/files/R-2008AUammend-QCA0FinalDec09CustVote-0410.pdf

[54] QR Network (2008) Draft Amending Access Undertaking, Volume 2 – Central Queensland Coal Region Reference Tariffs (p.138) Available at: http://www.qca.org.au/files/R-2009DAU-QR-Vol2Sub-0908.PDF

[55] QRC (2008) Submission in response to: QR Network's 2009 Draft Access Undertaking.

QRNN agrees that the customer approval process has not worked as intended. However, the key issue is not that the capex approval process has failed but rather that future QCA decisions may not be consistent with this mechanism and the ‘regulatory compact’ it embodies. Specifically, the QCA’s rejection of QRNN’s proposals to ensure that the Access Undertaking effectively addresses asset stranding issues in relation to electric assets in Blackwater both in the past and under the present DAAU, and not providing guidance about other workable alternatives or guiding principles to resolve this problem, only serves to increase regulatory risk and uncertainty. This may undermine confidence in investing in regulated assets in Queensland.

The QCA commented that it is difficult to see what material changes could be made that would provide more protection for QRNN and its customers than adhering to the existing Access Undertaking. QRNN believes that the existing access undertaking mechanisms work quite effectively for non-contestable rail infrastructure. However, they do not work effectively for services which users may choose to bypass, as the regulatory framework currently effectively requires QRNN to bear the additional costs imposed on the supply chain as a result of users’ choices to bypass the service. In this situation, it is important to ensure pricing mechanisms are in place that prevents the stranding of assets that are included in the RAB. The proposals in the DAAU sought to achieve this, however QRNN notes that there are other policy approaches which may similarly achieve this outcome.

The QCA has also noted that, given the CRIMP process has failed to provide the intended protections, it may be best to remove this process from the next undertaking, instead relying on more conventional ex-post assessments of prudency. In response, QRNN submits that the CRIMP process and capex approval mechanism in the Access Undertaking is appropriate and can be effective in circumstances where there is no scope for bypass of approved below rail infrastructure and other decisions of the regulator (for example, in relation to pricing for assets approved as prudent under this process) are consistent with the regulatory compact which it embodies. Moreover, the QCA’s suggestion of moving to an ex-post assessment process is unsatisfactory as it does nothing to address the issues that led to the process being included in the Access Undertaking in the first place – being the coordination problems that exist and the need to facilitate investment in the way desired by users. We would also suggest that such an approach has the prospect of sterilising or chilling investment in the declared service, particularly if regulatory certainty is not able to be obtained expeditiously in order to obtain the necessary investment commitments.

While the QCA has accepted that the DAAU will be in the interests of QRNN as owner and operator of the service, it has effectively discounted the impact on QRNN’s legitimate business interests in preference for promoting the short term interests of one operator. QRNN submits that the QCA has therefore not given sufficient weight to QRNN’s legitimate business interests as it has relied on invalid and unproven concerns about the potential impact on Pacific National as a reason to not address a critical business concern for QRNN.

3.5 Interests of access seekers

The QCA has differentiated between the interests of access seekers (who are looking for access) and access holders (who already have access to the service).

In terms of access seekers, these will be either new users of the system (such as those seeking access for WICET), or may be existing users of the system whose haulage and/or access contracts are expiring (eg. existing Blackwater mines). The access seeker may be either the mine or the operators who wish to provide haulage services to the mines. There is presently strong competition between operators to win the business of these end users. Indeed, the tendering process for new haulage contracts reflects the primary point of competition between operators.

However, as previously discussed, QRNN contends that, in its role as an access seeker, Pacific National is not locked in to diesel traction as it would need to procure new locomotive power to provide these additional services. Pacific National retains the choice of electric or diesel locomotives for these services. Pacific National already retains a fleet of electric locomotives, and it is just as readily expandable as is its fleet of diesel locomotives. Therefore, the concerns that the QCA has raised about the impact of the DAAU on access *seekers* who rely on diesel traction is misplaced, as those parties who are seeking access are typically not committed to a particular traction type.

QRNN agrees that it is also necessary to consider the impact on access holders of the DAAU proposals. In particular, it is necessary to consider if the DAAU will impose additional costs on them that they cannot defray and, in particular, if a change in the regulatory framework may result in the stranding of their assets in the future. As noted above, transitional arrangements may be appropriate in this case.

The QCA has stated that it places greater weight on the potentially adverse impact on Pacific National's stranding risk (in terms of its investment to date in diesel locomotives for Blackwater) than it does on the asset standing risk faced by QR National. This is on the basis that the QCA considers QR National invested in electric locomotives under existing, known rules, whereas a change in pricing approach now would reflect a 'change in rules'. QRNN strongly disagrees with the QCA's assessment of this issue. As discussed earlier, we consider that the issue of problems associated with pricing of electric services has been long identified by QRNN in public processes as an issue that needs to be resolved. Pacific National would have been aware of this at the time of its investment and could reasonably have expected that QRNN would seek again to have this issue resolved by the QCA in some way in future. Moreover, in a regulated environment, a range of matters, including pricing structure and methodology, are subject to review and the potential for change at every regulatory reset. The QCA Act also gives access providers the right to submit draft amending access undertakings during the term of an approved access undertaking. Given this, it is unreasonable to suggest that stakeholders such as Pacific National would not be aware of the risks associated with a change in the regulatory approach on this issue at some point in time.

Further, as discussed above, making no change to the pricing approach for electric assets may also have a major 'chilling' effect on investment as it would mean that the regulatory regime is in fact being gamed to undermine previous investment decisions (both above and below rail).

QRNN also believes that the QCA has not adequately investigated the extent of stranding risk actually faced by Pacific National. As discussed above, this is questionable given that access charges are passed through to customers and also given the opportunities to redeploy its diesel fleet across the broader CQCN. However, to the extent that Pacific National itself bears any costs associated with the DAAU, then transitional arrangements should be considered. In this regard, we note that the intention of the DAAU is to influence future investment decisions, not to strand existing investments of any supply chain participant, including Pacific National.

Additionally, we consider that the QCA's analysis of this issue has not attempted to quantify the stranding risk faced by different parties and fails to take account of the relative scale and impact of this stranding risk. According to the QCA's approach, the scale of the impact is not even a consideration. This could lead to the perverse conclusion that a relatively minor impact on one party is given greater weight than a major impact on another. Also, it has not taken account of the fact that the identified asset stranding risk for Pacific National is mitigated by the likelihood of it passing on costs to customers and through flexibility in deploying its fleet of locomotives across the entire Central Queensland coal network. By relying on the 'change in rules' argument to justify its conclusion, the QCA has ignored other highly relevant information that should have formed part of its assessment.

In assessing this issue the QCA did not take into account the incentives and opportunities that the existing regulatory framework provides for gaming and anti-competitive behaviour by new entrants. Customers have an incentive to support QRNN undertaking investments, such as in electric traction, but by having the subsequent choice of not using (and therefore not paying for this investment), they are able to disadvantage competitors by placing the cost recovery burden on other access holders with whom they compete. These producers retain the option of utilising this infrastructure in future, without paying for this benefit. For train operators, new market entrants also have the option of utilising the infrastructure in future. They also have the incentive to elect not to use it in order to strand the assets of its competitor in the above rail market.

QRNN considers that the QCA analysis starts from the assumption that QRNN has strategic intentions, and assesses the DAAU with this prejudgement in mind, but does not have regard to the possibility of any anti-competitive or strategic intentions on the part of other supply chain participants. This not only reflects a potential regulatory bias against QRNN but is also a an uninformed view of the commercial and strategic dynamics of participants in the Central Queensland coal supply chains.

QRNN believes that the decision making has inappropriately focussed on the identity of train operators in its assessment, rather than the impact on competition itself. The DAAU reflects proposals that are consistent with what would be considered reasonable for a stand-alone network service provider. Moreover, they apply equally to train operators in each system, regardless of identity. However, the QCA has not considered the proposals from this perspective, but rather it has assumed strategic behaviour on the part of QRNN to benefit its related above rail operator.

3.6 Public interest

The QCA has assessed a number of matters in its Draft Decision as relevant to the public interest criterion and has rejected QRNN's proposals on each of these grounds. QRNN's response to each of these is below.

3.6.1 Creation of lowest cost supply chains

We consider this factor is integral to the consideration of the efficient use of and investment in below rail infrastructure and should be considered in that context. To consider supply chain efficiency only in the context of one of the many factors to be weighed in consideration of public interest is to fail to give proper and full consideration to a matter that is of central importance to the efficiency of the below rail infrastructure and the entire supply chain. Indeed, as noted by NERA (Attachment A), it is not clear how much weight the QCA is likely to place on a public interest test if it has first determined that a proposal is inconsistent with the objective of the regime. Moreover, this does not appear to be consistent with the QCA's required inclusion of an extensive range of supply chain efficiency matters in the Access Undertaking, the purpose of which is to regulate the declared below rail infrastructure.

QRNN's detailed response to the QCA's assessment of the TCO model is in Section 3 of this submission. In essence, we consider that the QCA has a responsibility to investigate this issue further and test the claims made by various parties before reaching its conclusion to dismiss QRNN's analysis. Much of the QCA's reasons for rejecting the DAAU reflect its view that QRNN has not convinced it of the superior efficiency from a supply chain point of view of electrification. Yet the QCA appears to have accepted various claims about efficiency from stakeholder submissions at face value without a proper investigation. While stating the outcome of this matter is 'inconclusive', the QCA has still relied on this to reject QRNN's proposals.

The QCA has also erred in stating that the DAAU could result in inefficient electrification of spur lines. As discussed above, this conclusion is incorrect as it fails to recognise that the DAAU provisions only apply to feasible electric services – that is, the ones where the route is actually electrified. Future investments remain subject to customer approval.

3.6.2 Commercial and regulatory uncertainty by changing regulatory principles

This issue has been discussed at length in the consideration of the impact of the DAAU on access seekers. As already noted by QRNN, the QCA has not taken into account the uncertainty created by the existing regulatory framework. That is, it is now apparent that investments undertaken in accordance with the customer approval process could potentially being stranded in the future as a result of the QCA's approach. This may also adversely affect future investment decisions, to the detriment of the mining industry and broader Queensland economy.

3.6.3 Environmental impact

While the environmental impacts of one traction choice over another have not been assessed by the QCA, it concludes that it is not evident that the DAAU will result in environmental benefits. This conclusion is presumably based on the view that electric energy production in Queensland is currently highly carbon intensive (as it is heavily dependent on coal fired power stations) and therefore not environmentally preferable to diesel.

Again, this reflects a very short term perspective from the QCA. Electric traction offers environmental benefits as it has a greater potential to reduce its carbon footprint through the use of less carbon-intensive generating methods in future. It also offers a range of non-carbon emission related environmental benefits.

We accept that the carbon price has to an extent internalised the carbon footprint of traction choice, however, it should be recognised that the intention of carbon pricing is to provide a price signal for carbon intensity. Over time, this will tend to provide incentives to shift away from carbon-intensive technologies. There is considerable scope for more energy efficient operation of electric traction in future. The key point is that electric traction may offer greater scope to respond to a carbon pricing signal than diesel due to potential for increasing use of renewables, or other less carbon intensive power sources, in energy generation. This is clearly a key environmental advantage of electric over diesel. Further, as the power generation mix becomes less carbon intensive, the advantage of electric traction compared to diesel in terms of carbon emissions will increase. Given this, rail electrification has a key role to play as a technological response to policies to reduce carbon emissions.

The following are examples of future innovation and energy efficiency potential for electric trains which do not apply for diesel:

- developments at the primary energy source to achieve greater sustainability. This includes the ability to use renewable energy as it is brought into the power network;
- scope for use of energy storage and smart grid controls to lower energy consumption;
- ability to use regenerative breaking. This is the ability to regenerate electric energy while braking by the traction motors working as generators to feed the electric power back to the railway power system through the overhead line. It is estimated that this will allow energy consumption to be reduced by up to 30%, but QRNN notes that in certain circumstances energy consumption can be reduced by significantly greater amounts.[56]

In the UK, rail electrification is regarded as an important part of the Government's carbon strategy.[57] Further, Network Rail regards electrification as having important environmental benefits compared to diesel, particularly given the scope for use of regenerative braking. It reduces the need to transport fuel and is also generally quieter than diesel counterparts.[58]

The importance of increasing the use of clean and renewable energy sources as part of achieving environmental sustainability has also been recognised by private companies. An example of a mining company adopting such a strategy is the announcement by Vale and Pacific Hydro of a renewable energy joint venture in Brazil. This represents an investment of approximately AUD$315 million, with Vale being the sole off-taker of the clean electricity produced by wind farms for a period of 20 years. Vale noted that this was an important step for increasing the use of clean and renewable sources in its energy matrix.[59] This provides an example of a mining company being prepared to take up the option of electric energy over diesel and renewables over fossil fuels, to reduce cost risk (due to fuel price risk) and carbon risk.

The superiority of electric traction over diesel across various attributes, particularly in light of escalating energy costs, is recognised by the UK Rail Safety and Standards Board:[60]

> The energy benefits of the electric railway are well understood. Rail is at its most energy efficient when powered directly by generated electricity delivered to the train by overhead line infrastructure. Electrification also delivers increased reliability, increased capacity, lower carbon emissions and lower capital and operating whole life costs. The following report leads V/TE SIC to the conclusion that, even with uncertainties around supply and expected cost increases, electricity will continue to be the most viable (and green) energy source. This reinforces the industry's view that further electrification is the most critical element of its emerging energy strategy.

As electric locomotives have a greater scope to reduce carbon footprint and improve energy efficiency, electrification will have greater potential to deliver environmental benefits in future. As a result, the potential for future take up of electric locomotives may be greater than diesel. Given this, and in an environment of increasing

56 Refer to results for the Daqin line

57 Department for Transport, Britain's Transport Infrastructure, Rail Electrification, July 2009, p. 8

58 Network Rail, Network RUS: Electrification Strategy, Draft for Consultation, July 2009, p. 32

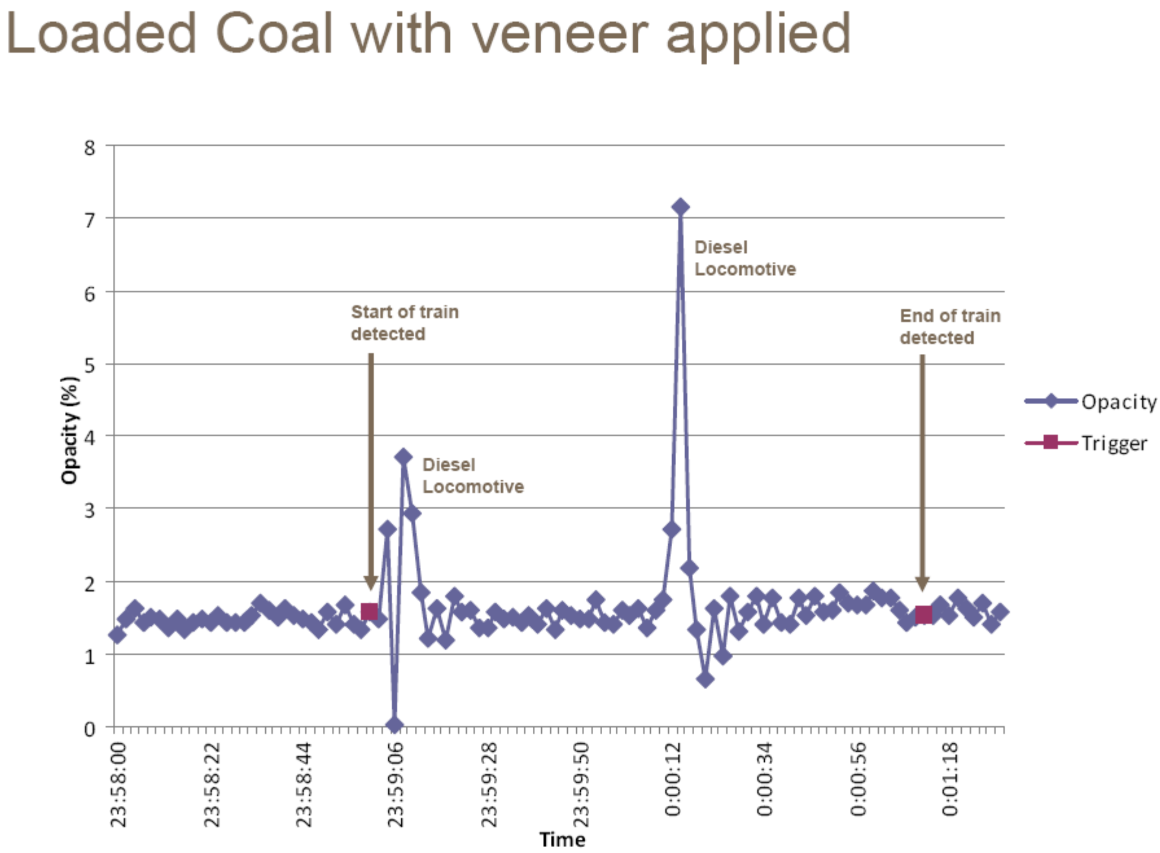
59 Brazil Talk, The Australia Brazil Chamber of Commerce Inc, Volume IV, 2012, p. 24-25

60 Rail Safety and Standards Board (RSSB), Research Programme Engineering, Energy Game Changer, Macro energy risks affecting railway in Great Britain, July 2012.

uncertainty regarding fossil fuel prices, QRNN submits that electric traction provides greater opportunities and incentives for investment in innovation, including those which result in greater ecological sustainability.

There are also other environmental benefits associated with electric traction apart from carbon emissions that the QCA has not considered. These include reduced noise, vibration and exhaust gases. For example, the following graph shows the particle emissions associated with a diesel train services as it passes a dust monitoring station. An increasing number of diesel train services will be operating through local communities which will see a commensurate and avoidable increase in particle emissions.

Figure 2. Diesel particulate emission readings from coal dust monitor.



The QCA's reliance on carbon pricing to effectively dismiss environmental consideration of electric versus diesel traction means that this issue has not been adequately addressed by the regulator. The QCA is obliged under the QCA Act (s. 76(3)(b)) to take into account 'legislation and government policies relating to ecologically sustainable development' in making its determination. QRNN submits that the QCA should more fully consider the range of environmental impacts and benefits associated with electric traction which make it superior to diesel on this issue.

3.7 Pricing principles

The QCA concluded that the DAAU is not consistent with the pricing principles in s. 168A of the QCA Act on the basis that it is not satisfied that the proposed amendments aid efficiency. The QCA also expressed concern that the DAAU compelled train operators to use electric trains and that this was a disproportionate response to the problems with the existing framework.

On the question of the efficiency of electric compared to diesel, QRNN reiterates its response to the issue of the TCO analysis. That is, the interdependencies between above and below rail make an approach that seeks to maximise the efficiency of the total rail component to end customers appropriate. To focus on the below rail elements in isolation will not in fact deliver the most efficient outcome as the 'least cost' below rail solution will not necessarily be the most efficient. We also refer the QCA to our response to the specific comments by stakeholders on the TCO analysis.

In terms of efficient price signalling, the fact remains that under the current pricing arrangements, individual access seekers do not take into account the impact of their investment decisions in terms of traction choice on the efficiency of the whole of the supply chain. This is, in effect, a network externality. This can lead to an inefficient mix of traction in the system. The DAAU seeks to address this by providing a price signal to encourage the use of electric traction, which is more efficient from a supply chain point of view. QRNN rejects the view that this compels operators to use electric traction as customers retain choice. Rather it seeks to provide a tariff structure that promotes efficiency by ensuring that operators take into account the impact of that choice on the costs of the supply chain.

We refer the QCA to NERA's assessment of this issue - namely, the ineffectiveness of relying on prices based on actual costs sending appropriate price signals in the presence of significant market failures (ie. economies of scale, network effects, coordination failure and incentives for strategic conduct).

The QCA refers to the AT2 multiplier element of the reference tariff addressing different performance characteristics. While QRNN agrees that the AT2 tariff component, and the multiplier for different performance characteristics, should be reviewed as part of UT4 to ensure that they provide appropriate signals regarding the long term cost of capacity, these amendments will not address the fundamental pricing problem – namely, that QRNN needs to recover the cost of its investment in below rail electrification assets in a way that provides efficient pricing signals that promote efficient investment in and use of below rail infrastructure (in this case, the electric traction system). A pricing structure that promotes recovery of these costs in the most efficient way possible is a legitimate means of addressing the bypass issue that is consistent with the pricing principles in the QCA Act.

3.7.1 Efficiently pricing for stranding risk

The QCA has stated that the capex approval process and its guarantee not to optimise assets except in defined limited circumstances (i.e. demand has deteriorated to such an extent that regulated prices on an unoptimised asset would result in a further decline in demand price and actual not hypothetical bypass) should be sufficient to address asset stranding risk. QRNN submits that these criteria might now be met in terms of the Blackwater below rail electrification assets not because the investment was not supported by users, nor because the investment was inefficient (in terms of promoting the least cost supply chain) and nor because the overall demand for the declared service is declining. Rather, these criteria may be met because the Access Undertaking enables some participants to choose to bypass the electric assets (recognising that there is a clear incentive for non QR National operators to do so for strategic anti-competitive reasons). Moreover, as has been widely recognised, the WACC does not compensate QRNN for asset stranding risk.

Asset stranding risk is asymmetric in that the distribution of expected returns is skewed, meaning that QRNN faces a downside risk but no commensurate upside risk to compensate for this due to regulatory pricing constraints. Asymmetric risks are unavoidable and cannot be diversified away by the business. There is currently no allowance for asset stranding risk in the WACC. The QCA has in effect acknowledged this fact in its Draft Decision on UT3 when it stated that the CAPM [Capital Asset Pricing Model] does not compensate the firm for asymmetric risk.[61]

An alternative way to compensate a business for stranding risk is via a specific allowance in the cash flows – similar to a self insurance allowance for other risks. However, the practical issue with this approach is that asset stranding risk is very difficult to reliably quantify as it requires an assessment of: (1) the impact on the business if the risk occurred (which could be measured); and (2) the probability that it will occur (which is very difficult to measure and substantiate – particularly when the regulator imposes a very high burden of proof). These practical issues associated with compensating for asset stranding risk has meant that it is usually addressed through efforts to mitigate the risk rather than to compensate for it. This is done via mechanisms such as accelerated depreciation or, as is the case here, customer and regulator pre-approval of the prudency of the investment.

[61] QCA, Draft Decision, QR Network's 2010 DAU – Tariffs and Schedule F, June 2010, p. 48

QRNN accepts that the intent of the regulatory framework established in its Access Undertaking is to mitigate stranding risk, rather than to include compensation for stranding risk in its access charges. However, as discussed above, this regulatory pre-approval process will fail if QRNN is not protected to any meaningful degree from asset stranding risk in relation to electrification assets. QRNN believes that the critical issue then becomes how to set the price for access for different technologies in such a way that it provides efficient signals for use of the alternate technologies, and is also becomes effective in mitigating QRNN's asset stranding risk, as required by the regulatory compact discussed earlier.

3.7.2 Price signals to aid efficiency

While the QCA has acknowledged that the existing AT5 tariff arrangements do not provide an efficient price signal, it has provided little analysis on what matters need to be taken into account to determine how prices should be set to signal efficient utilisation of the electric network.

An efficient price should be reflective of the costs of the individual train service, and not be impacted by the resource allocation decisions of other market participants. In this regard, QRNN considers that a reasonable AT5 price might be commensurate with that which would prevail under the current pricing approach at full utilisation of feasible electric services. However, this price or alternate prices based on marginal or forward looking avoidable costs give rise to the complexities associate with achieving revenue adequacy in the event of asset underutilisation. Therefore, the determination of an efficient price needs to consider a range of factors:

- Potential for regulatory error in setting prices for substitute services;
- Pricing needs to consider the implications of access with existing technologies;
- Efficient pricing discriminates technology and not competitors;
- Ability for multi-part pricing to achieve revenue adequacy;
- Ability for price differentiation to achieve revenue adequacy.

Each of these factors is addressed in the following sections.

3.7.2.1 Potential for regulatory error in setting price for substitute services

The fundamental flaw in the regulatory framework is that QRNN, as the arms length below rail service provider and the QCA as the regulator, are seeking to establish an efficient price which has implications for decisions in a downstream market from which they are both removed. As a consequence, QRNN does not consider it possible to develop a price which is not in some way going to either have a positive or negative impact on decisions made in that downstream market. Arguably, in such cases, a consideration of the declaration criteria in section 76 of the QCA Act or section 44H(4) of the *Competition and Consumer Commission Act 2010* would possibly fail on public interest criteria. The only likely pareto optimal outcome in circumstances where part of the declared service can be bypassed is to either mandate the technical standard or implement other policy options other than open access to achieve the productivity objectives of the National Competition Policy.

This point can be illustrated using the possible pricing scenarios which would likely have prevailed for AT5 had QRNN not undertaken further expansion of the Blackwater overhead power system. QRNN estimates that based on the indicative capacity of the Blackwater system without the additional four feeder stations the value of the electric assets in the regulatory asset base in 2015-16 would be in the order of $160 million. At full capacity this would yield an AT5 rate materially below the diesel equivalent. Now assuming that the QCA's conclusion that expansion was not efficient from the perspective of the supply chain, expansion would not occur and the problems with the resultant price should be readily apparent. It is likely to be substantially below the diesel bypass price and there would a large and unmet demand for electric trains. This raises numerous complexities as to how scarce capacity would be allocated when existing access rights expire or where an access holder is able to secure that capacity and obtains a substantial competitive advantage.

The practical effect of not addressing the pricing of AT5 in the Blackwater system in a way which promotes revenue adequacy for QRNN may very well give rise to this conundrum in the Goonyella system. It is difficult to see how

QRNN could be incentivised to invest in, or whether an Access Seeker could fund, further expansions of the Goonyella coal system if the prospect of asset stranding exists.

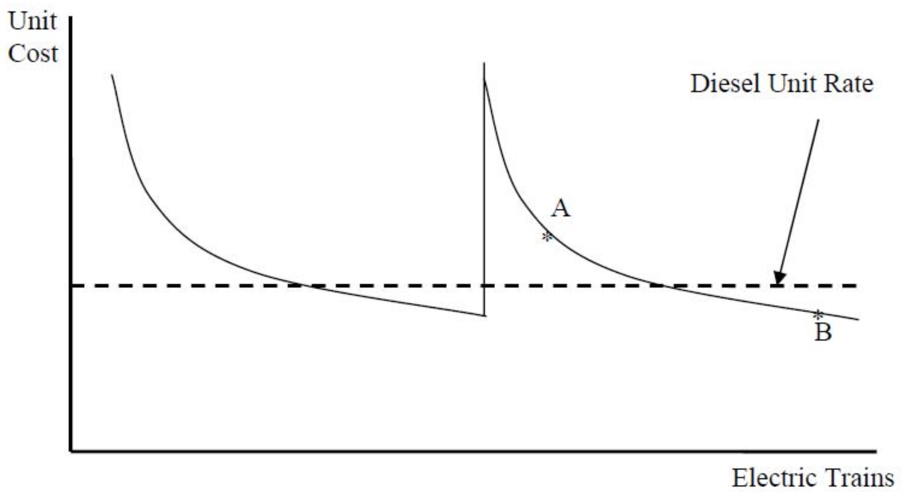
Given the requirements for QRNN to maintain arms length dealings with its related operator it is necessary for the coal industry to assume a greater level of responsibility to manage the information asymmetry that exists between participants in downstream markets and both the service provider and the regulator. Under the provisions of 136A the QCA may issue a notice to the service provider requiring it to amend its voluntary Draft Access Undertaking in the way the Authority considers appropriate, if the service provider does not agree to amend its proposal as specified in the draft decision.

The QCA Draft Decision in December 2009 rejected QRNN's original proposal to establish a common network AT5 price which was included in the DAU lodged with the QCA in September 2008. This is despite support for the pricing proposals by Pacific National, and few concerns being raised by end customers. The revised Draft Access Undertaking given to the QCA in April 2010 reverted to system based AT5 pricing determined on the same fully distributed cost approach applied in other reference tariffs.

The accompanying supporting documents noted QRNN's concern that it did not have sufficient knowledge of the above rail cost differential between electric and diesel traction to understand whether the proposed reference tariff would have any detrimental effects. QRNN's response to the December 2009 submission (p.42) presented this risk in the form of a graph which showed that:

> In the absence of supporting price structures there is an inherent risk that the short term rationale interests of end-users might result in different operator investment decisions in rollingstock. This issue is illustrated in Figure (6.1) below which demonstrates that at low volumes (point A) the unit cost per electric train may not be lower than unit cost for the diesel alternate. This creates a disconnect between the short term commercial interests of the end-user and the long term economic interests of the supply chain in delivering long-term efficient outcomes (point B). There is a strong incentive for the individual user to seek to negotiate for a diesel only service[62]

Figure 6.1: Electric Traction Average Cost Curves



QRNN went further to explicitly state:

> QR Network does not have access to the necessary information to assess the impacts of its proposal on the stranding risk faced by the above-rail operators.

Given this level of information asymmetry, and noting that stakeholder submissions to the DAAU which have demonstrated a clear capacity to assess the efficiency trade-offs between diesel and electric traction choices, QRNN was dependent on stakeholders informing the QCA that the Blackwater AT5 proposed in the revised April

---

62 QRNN (2010) Response to QCA Draft Decision on the 2009 Draft Access Undertaking, February. http://www.qca.org.au/files/R-2009DAU-QRN-SubQR09DAUcvrltrVol1NONPrice-0210.PDF

2010 Draft Access Undertaking would have a detrimental impact on above rail investment choices. As no submissions addressed the materiality of the proposed AT5 reference tariffs, the reference tariffs were approved by the QCA.

It can be seen from this that using this methodology for the development of the AT5 tariff is highly prone to error, in terms of providing an efficient signal for utilisation of the asset, due to information asymmetry on the part of the parties setting the tariff in terms of the consequences for operators.

3.7.2.2 Pricing needs to consider the implications of access with existing technologies

At the commencement of open access regulation under declaration by regulation under Part 5 of the QCA Act both the Blackwater and Goonyella systems were electrified. The introduction of diesel services into these systems introduces operational and capital inefficiencies (not in the least due to the resulting underutilisation of the electric network).

In responding to requests for declaration of its iron ore rail operations in the Pilbara, Rio Tinto raised concerns that the efficiency of its planned driverless train operations would be adversely impaired if there was any intermingling of manned and driverless trains. In responding to this concern the National Competition Council (NCC) noted[63]:

> To the extent that an access seekers use of manned trains imposes additional costs on a service provider these costs could be expected to be included in the relevant access charges (either through appropriate recognition of these costs in commercial negotiations or if needs be through arbitration). In some situations such costs might oblige an access seeker to also use driverless trains.

The circumstances considered in this decision have many parallels to the problem of allowing access seekers a choice of traction technology. The circumstances may be juxtaposed as follows:

- An incumbent operator who commits, or intends to commit significant costs in an integrated train control system (overhead power) prior to the introduction of open access to its facility faces the prospect that an entrant will seek to operate a train service with a substitute signalling technology (diesel traction);
- The entrant's decision erodes the efficiency of the incumbents train operations as it needs to incur additional costs to maintain it own operational efficiency (expand and strengthen the overhead power system to accommodate the entrants proposed train services);
- The total end market demand is met at much greater cost as the combination of the incumbent and the entrants preferred signalling (traction) technology involves underutilisation and inefficient substitution or duplication.

QRNN considers the NCC has correctly identified that it is necessary for the entrant to be subject to the full costs associated with its decision to bypass the predominant technology invested by the service provider prior to the commencement of regulation. It is this intent and purpose which underpins the pricing proposals in the DAAU and not an illusory construct of preferential dealing. This is not to say that the regulatory framework should not support transitioning to alternate and more efficient technologies. Only that the service provider under and open access framework should be reasonably be protected and involved in the decision making to do so.

The introduction of diesel services and the increasing penetration of those services imposes negative cost externalities on the users of the superior and more efficient technology. The primary focus and attention of these externalities has been the potential congestion impacts, which arguably are minimal when an operator adds additional locomotives to achieve or approximate the benchmark performance of the superior technology. The main externality impacts are on the additional costs imposed on the network service provider in meeting the contractual obligations for its binding service obligations to electric access holders.

[63] National Competition Council, Hamersley Railway Application for declaration of a service provided by the Hamersley Railway under Section 44F(1) of the Trade Practices Act 1974, Draft Recommendation, 20 June 2008, General release version, p. 117

QRNN notes that a substantial amount of capital costs have been incurred in expanding the geographical boundaries (electrifying duplications) to also ensure that QRNN could meet its contractual obligations to provide access to electric train services under the specified scheduling rules. In the absence of a customer vote to invest in additional feeder stations to increase electric capacity, power strengthening would also likely have been necessary to address the operational risks and complexities with full duplication of the Blackwater system. This arises because, from an operational perspective, a given electric section might become saturated with electric traction services. Single line sections with passing loops provide a physical constraint on load saturation within a given electrical section. However, as the capacity of the facility is expanded to accommodate the demand of additional train services these physical constraints are removed. While this constraint could have been artificially imposed by not electrifying duplicated sections this would have imposed significant capacity constraints on the system, would have removed the principal operational and capacity benefit of duplication – the removal of crossing delays, and would have resulted in QRNN not being able to meet its contractual service quality obligations to electric access holders.

While conceptually operational constraints could be imposed to restrict the number of electric trains within an electrical section this would provide an unreasonable constraint on an access holder who has invested in an efficient technology and would materially impact its operations. Again, this would be likely to mean that QRNN could not meet its obligations as set out in its access agreement with the access holder.

At a more fundamental level, by not expanding and strengthening the overhead power system to accommodate additional diesel traction services, QRNN would be denying the electric access holder the ability to operate a comparable service and materially affect their ability to compete in the downstream market. This would be directly contradictory with the requirements section 100(2) of the QCA Act which requires:

> In negotiating access agreements, or amendments to access agreements, relating to the service, the access provider must not unfairly differentiate between access seekers in a way that has a material adverse effect on the ability of 1 or more of the access seekers to compete with other access seekers.

Accordingly, QRNN considers that the costs incurred on the electric network (being installation of electric overhead as well as required strengthening of power supply capacity) in order to maintain the service quality provided to electric services in the face of the entry of diesel services should in fact also be charged to the operators of those diesel services.

3.7.2.3 Efficient pricing will discriminate technology, not competitors

An apparent key reason for not accepting QRNN's proposal is its perception that the proposal unfairly differentiates between a related and third party operator. The QCA has correctly stated:

> The pricing principles do not allow pricing practices if they discriminate in favour of a downstream operation (or a related body corporate), except if they are related to cost…. it is not evident how the proposed price amendments in the DAUU are related to cost.

However, the pricing proposed in the DAAU is not discriminatory between operators. It is discriminates between technology in which the market for the preferred technology is not closed.

Importantly, QRNN's proposed DAAU also does base this technological discrimination on cost. It is discriminating on the basis of the investments it has made on the expected combination of Train Services that would operate on relevant parts of rail infrastructure. To the extent an access holder elects to use an alternate technology then it is avoiding making a contribution to the costs that were incurred for the below rail capacity which it is utilising.

The QCA also concludes:

> This DAAU, therefore, runs the risk of reducing the productivity improvements in the above-rail market, with the consequential effect of less efficient use of below-rail infrastructure

The conclusion is internally contradictory. It is not clear to QRNN how even the most ambitious productivity differential between an electric and non-electric train service would overcome the inefficiencies associated with what could amount to a material latent and underutilised capacity in the below rail infrastructure. The Draft Decision therefore supposes that it is inherently beneficial to have underutilisation and inefficient use of below rail infrastructure in order to promote rivalrous behaviour, not between one operator and another, but between manufacturers of different traction technology. Operators are able to engage in rivalrous behaviour and achieve productivity improvements in 'other investments and operations' within the preferred and 'efficient' technological standard.

3.7.2.4 Ability of multi-part pricing to achieve revenue adequacy

QRNN's primary commercial objective is the achievement of revenue adequacy as intended by the first limb of the pricing principles contained in Part 6 of the Access Undertaking. As the QCA notes, first-best pricing of marginal costs will not normally achieve this objective and some form of pricing is necessary to achieve this objective. As noted above a significant issue therefore arises where the access charges are an input cost into a downstream market which also does not price at marginal costs (however, if these costs are passed-through from the downstream market back to upstream market then this issue is materially ameliorated in terms of its effects on dynamic efficiency and competition).

The Draft Decision notes options for achieving this objective may typically require:

- Two part pricing; or
- Price discrimination.

Two part, or multipart pricing is typically associated with seeking to separate those costs, which can be identifiable and attributable, incurred in providing the service such that at least one price component sends a price signal regarding the marginal costs of providing the service. The remainder of the price components will then typically be associated with recovering the balance of the costs in the most efficient and least distorting way. These principles are reflected in the current AT1-4 price structures:

1. AT1 is effectively the marginal cost of usage of the rail infrastructure but only in the sense that it reflects future costs, not current costs;
2. AT2 is the long run incremental train path costs. The combination of these two tariff components are representative of the long run marginal cost;
3. AT3 is a allocated cost recovery tariff which is linear with use; and
4. AT4 is also an allocated cost recovery tariff which seek to impose a distance taper on total costs to replicate what is assumed to be a lower capacity to pay as haulage distance increases.

It is feasible to extract all the costs that are marginal in the long run to the specific electric service and include this in a user based AT5 charge. This would require the development of a form of allocative charge to recover the remainder of the electric network costs in the least distorting way. However, implementing an allocative charge to achieve revenue adequacy presents some issues:

- First, the cost structure of an electrified section is reasonably linear in that it typically involves similar distances and major components. This supports the general linear pricing approach of $ per electric gross kilometres and means that introducing flagfall tariff component for electric services may have unintended and perverse consequences;
- Applying the allocative charge only to electric services would not change the fundamental concern with the existing pricing approach, in that it would continue to distort operators' decisions to invest in electric or diesel traction.

Having regard to these matters we do not consider multi-part pricing to be an effective means of QRNN increasing its revenue adequacy.

QRNN considers it important that the price for a service closely resembles the costs which are relevant to the individual service and not costs associated with meeting the installed capacity for the expected combination of train services. In addition, Ramsey pricing would suggest the capacity to pay a price which exceeds the cost differential between the two traction technologies is constrained and that demand elasticity at that point is close to if not zero.

3.7.2.5 Ability to price differentiate to achieve revenue adequacy

The previous section briefly introduced price differentiation as a means of achieving revenue adequacy in the most efficient way. To the extent that this objective is achievable then the outcome would also achieve revenue adequacy in the least distorting way.

The QCA has acknowledged that the most efficient price is the marginal price. This is the primary intention of incremental pricing. However, as discussed earlier the expansions to the Blackwater feeder stations are also system driven and incremental to all users. This is also consistent with the forward looking cost assumption which underpins the 2010 Access Undertaking definition of incremental costs:

> "**Incremental Costs**" means those costs of providing Access, including capital (renewal and expansion) costs, that would not be incurred (including the cost of bringing expenditure forward in time) if the particular Train Service or combination of Train Services (as appropriate) did not operate, where those costs are assessed as the Efficient Costs and based on the assets reasonably required for the provision of Access;

The definition, quite necessarily, is only concerned with costs which are avoidable. That is those costs 'that would not be incurred if the particular Train Service or combination of Train Services did not operate'. For an electric traction service (or a combination of electric traction services), the only costs which are incremental to the foreseeable demand are energy supply costs, asset renewal and variable maintenance and operating costs (including those costs from a TNSP which change with utilisation <15%).

The 2010 Access Undertaking also defines common costs as:

> "**Common Costs**" means those costs associated with provision of Rail Infrastructure that are not Incremental Costs for any particular Train Service using that Rail Infrastructure

Accordingly a large proportion of the costs associated with the installation and maintenance of the overhead power system are common costs to all users of the relevant section of Rail Infrastructure.

Further the 2010 Access Undertaking defines a cross subsidy as:

> "**Cross Subsidy**" means where the Access Charges payable in respect of one Train Service or combination of Train Services are insufficient to meet:
>
> (i) the Incremental Cost imposed on the Rail Infrastructure by that Train Service or combination of Train Services; and
>
> (ii) in respect of a combination of Train Services, the Common Costs related specifically to sections of Rail Infrastructure that are used solely for the purpose of Train Services within that combination of Train Services,
>
> and the shortfall is contributed to by another Train Service or combination of Train Services;

It is noteworthy that, in order to preclude the possibility of cross subsidy, access charges must meet Incremental Cost, plus the proportion of Common Costs that can be specifically related to sections of Rail Infrastructure used solely for the purpose of electric traction services. However, there are no 'sections of Rail Infrastructure' used solely for the purpose of electric traction services. All sections of Rail Infrastructure that feature overhead power systems are capable of being used by both diesel and electric traction services.

This means that no cross subsidy can arise in a situation where QRNN charges an AT5 reference tariff that is sufficient to meet the Incremental Cost (i.e. the avoidable cost) of electric traction services.

Including the balance of the revenue requirement in an access charge payable by all Train Services operating across the electrified sections it does not fail the cross-subsidy test as these are costs are common costs related specifically to sections of Rail Infrastructure that are used for the purpose of *all* Train Services.

An alternate way of considering this problem (from a cross subsidy standpoint) is price differentiation between diesel and electric train services in the allocation of common costs. For example, recovering the avoidable cost associated with overhead power systems from electric traction services only (but only requiring those services to pay the incremental AT1 and AT2 tariffs and some contribution to common costs) with the balance of the common costs being recovered from diesel services, would still satisfy the cross-subsidy test as the electric traction services are paying their Incremental Costs. No 'revenue shortfall' arises.

The 2010 Access Undertaking permits QRNN to price differentiate on the basis of differences in cost or risk between a particular Train Service type compared to the Reference Train Service. The Reference Train Service for those systems that have been electrified is described as being either an electric or a diesel traction service. The description of this Reference Train Service, and the associated Reference Tariffs, make no allowance for the risk that, due to the distortions created by the pricing of access for diesel versus electric services, QRNN will not achieve revenue adequacy and will face a consequential risk of optimisation of investments that were only recently approved through the regulatory process. This indicates that there are costs and risks, separately attributable to diesel services and electric services, which are not taken into account in the tariffs for the Reference Train Service in the Goonyella and Blackwater systems. On this basis, QRNN believes that it is permitted to price differentiate in the allocation of common costs between diesel and electric services, so as to mitigate those risks and achieve revenue adequacy in accordance with clause 6.3.2.

Such an approach does not violate the pricing limit requiring charges for diesel services to not exceed Stand Alone Costs. The Stand Alone Costs that would be incurred if diesel services were the only services operating includes the whole of the cost of the relevant system, excluding electric traction assets (i.e. the system assets that are used by both diesel and electric services). In this section, we have discussed how these costs might be allocated between diesel and electric services so as to achieve revenue adequacy. However, provided that access charges for diesel services do not exceed the total cost of these system assets, the Stand Alone Cost limit for diesel services will be respected.

This obviously necessitates QRNN and regulator having an appropriate understanding of the above rail cost structures, which returns us to the problem of regulatory error identified earlier in this section.

3.7.3 Effect of excluding assets for pricing purposes

QRNN understands that the QRC considers that, to the extent that efficient pricing (as discussed above) for access to the electric network does not achieve revenue adequacy, the optimisation provisions in Schedule A 1.4 of the Access Undertaking should apply. This states that:

> The QCA will not require the value of assets contained in the Regulatory Asset Base to be reduced unless:
>
> (a) the QCA made its decision to accept the expenditure in the Regulatory Asset Base on the basis of information provided by QR Network that QR Network knew, or should have known, was false or misleading at the time it provided the information;
>
> (b) circumstances arise in the future where demand has deteriorated to such an extent that regulated prices on an unoptimised asset would result in a further decline in demand;
>
> (c) it becomes clear that there is a possibility of actual (not hypothetical) bypass.

In the context of the discussion in the previous section QRNN considers that the RAB which is used to determine the maximum allowable revenue for the combination of Train Services using Rail Infrastructure within the relevant line sections comprises all rail infrastructure within that line section. Accordingly, only where demand for ALL train services for the relevant line section has deteriorated such the prices which have been differentiated to achieve revenue adequacy would result in a further decline in demand.

That is, QRNN should be legitimately entitled to rely on provisions which have been included in the access regime and material investment has been made in reliance of those provisions to price differentiate between diesel and electric traction services before a decision is made to optimise assets under clause 1.4 of Schedule A.

The socialisation of this optimisation risk with the combination of train services for a given line section is commensurate with the risks assumed in the provision of electric traction services. A key driver relied upon by the

QCA in previous regulatory determinations on cost of capital has been the perceived reduction in systematic risk arising from stronger take-or-pay. However, electric traction assets have never been subject to take-or-pay and QRNN doubts the efficacy of doing so. In pricing AT5 the QCA has applied the same cost of capital to these assets and risks that has applied to track assets. This infers the commercial and regulatory risks associated with the provision of the declared service have been considered as common assets with the same risk profile. This is clearly not the case which infers that these risks have been implicitly socialised in previous revenue and price structures. QRNN's application of the optimisation provisions is consistent with this understanding.

In order to have sufficient commercial and regulatory certainty to develop pricing frameworks for UT4 it is necessary that the QCA address the matters in this section to satisfy the requirements of s.142(3) of the QCA Act.

3.7.4 Prices in Competitive Markets

The primary role of regulation is to seek to replicate the pricing which would prevail in effectively competitive markets. This is reflected in s.120 of the QCA Act which requires consideration of the value of the service to the access seeker.

However, in the context of QRNN's services, the QCA has applied the concept of 'financial capital maintenance'. Whereas the pricing principle concepts in the QCA Act relate to economic concepts based on the forward looking costs of providing services, the objective of financial capital maintenance is to avoid the windfall gains or losses to the service provider associated with revaluation of its assets to reflect current replacement costs. This has led to the setting of access charges based on the RAB, which is rolled forward based on general economy wide measures of inflation, rather than reflecting expected changes in the replacement cost of the assets.

As a result, QRNN disagrees with the assumption that the RAB value is commensurate with the stand alone cost definition. The stand alone cost definition reflects the economic concept of the cost of replacing the service potential, whereas the RAB reflects a rolled forward asset value based on a 'line in the sand' established by the initial valuation of those assets. Accordingly, the QCA has incorrectly assumed that the:

> proposal would involve Goonyella electric trains paying more than the stand alone costs of the Goonyella system, as they would be paying for assets in the Blackwater system that they do not use

This conclusion is reached only because the QCA has relied on the current definition of Stand Alone Cost in the 2010 Access Undertaking (which has been linked to the financial capital maintenance concept), and not considered how this varies from a proper and accepted economic and legal application of stand alone costs.

As noted in its submission accompanying the DAAU, QRNN does not consider that the proposed AT5 rate for the Goonyella system would be greater than the stand alone costs, as contemplated by the pricing principles in the QCA Act. We also note that no submissions were made to the QCA which provided any evidence that the tariff would exceed the stand alone cost.

Therefore, while QRNN has explained the network benefits associated with the full electric traction system, and has identified (but not sought to value) benefits that users of the Goonyella system receive from the electrification of the adjoining Blackwater system, QRNN submits that the proposed price for Goonyella users remains within the stand alone cost of providing that network and will not promote inefficient bypass of that electric system. Given the benefit that a network AT5 tariff will have in promoting efficient investment in electric locomotives for use across the entire electric network, QRNN believes that the QCA is able to approve this tariff under clause 6.2.1(b) of the 2010 Access Undertaking, notwithstanding that the access charges for the Goonyella users will exceed the maximum allowable revenue for that system.

4 Regulatory options

Notwithstanding the concerns with the QCA's Draft Decision outlined in the previous sections, QRNN believes that a way forward on this issue needs to be found. The QCA has acknowledged two critical issues:

- the existing method for determining AT5 does not create an efficient price signal for the use of electric infrastructure;
- the QCA does not intend to strand assets where QRNN's investment in those assets has been made with the endorsement of customers and the QCA.

However, to the extent the QCA does proposed to accept the DAAU, then QRNN considers that options to address this issue fundamentally fall into three categories, as discussed below.

4.1 Incentivising the use of electric traction

This approach involves creating a framework that provides an incentive for operators to use electric traction at the level of utilisation required in order that the cost and efficiency benefits of electric traction to be realised.

To date, QRNN has focused on strategies aimed at achieving this outcome - both the DAAU and subsequent parallel discussions with industry about alternate models were based on this approach. This has been favoured because all of QRNN's analysis shows that maximising the use of electric traction will in fact provide the lowest total cost outcome for the coal supply chains. However, if users and the QCA are not prepared to accept an outcome that incentivises all participants to make the most efficient traction choice, then an alternative approach will be required.

4.2 Market choice based on efficient pricing signals

Alternately, a framework can be created that provides efficient market signals for operators and end customers to choose between electric and diesel traction. However, to the extent that this efficient usage charge does not enable QRNN to recover all of its allowable revenue for the electric network (including recovery of the investments that have been endorsed through the regulatory process), the framework would provide for this revenue shortfall to be recovered from all users in the way that will create the least market distortions.

Expert advice obtained by QRNN from Sapere supports this approach. The Sapere report is included in Attachment D.

An efficient signal for the ongoing use of electric traction would be the forward looking incremental cost of electric capacity. We note that this would be very low as the four feeder stations have created substantial spare capacity before further major investment is required. AT5 can be increased above this rate to include the recovery of sunk costs, provided that it does not exceed the "diesel equivalent" cost – beyond this, it would provide an inefficient pricing signal to transfer to diesel traction.

To the extent that pricing actual utilisation at this level results in a revenue shortfall which, if unrecovered, could result in the future stranding of QRNN's electric investment, then this shortfall is to be recovered from all users in the least distorting way. The recommendation by Sapere is that a lump sum charge which is independent of asset usage is likely to be the least distorting approach. However, as noted above, to the extent that overhead power system costs are driven by an increase in total Train Services (rather than an increase in electric Train Services alone) then this may result in diesel services not making an appropriate contribution to maintaining the operational integrity of the network and adversely impacting the train services entitlements of operators of electric train services. As a consequence a lump sum which does not reflect these cost drivers may penalise customers who have elected to use electric trains through a resulting higher cost of Access Rights.

Clearly there are a range of options canvassed by Sapere as to the appropriate allocator for that annuity. In this regard QRNN considers ntk, gtk or distance to be too closely aligned with how costs align to usage. However, they are also most likely to better reflect capacity to pay the access charge that they would have paid if they had operated electric train services.

The critical issue is then at what level to set the AT5 in order to ensure that it provides and efficient signal for traction choice. One option, to address concerns about cost reflectivity and the difficult in precisely defining the "diesel equivalent" cost, is to base the Blackwater AT5 on recovering the full costs of providing the service at the efficient level of utilisation (where the efficient level of utilisation is 90-100% of feasible electric paths). However, whatever option is chosen will be prone to error, as neither QRNN nor the QCA can be confident of having sufficient knowledge of all factors necessary to set a price that will not inadvertently over or under signal either traction mode.

4.3 Commercial strategies to reduce stranding risk

Finally, QRNN could accept the existing approach to setting AT5, noting that this creates a significant commercial risk regarding its recovery of its allowable revenue, and then use alternate provisions in the Access Undertaking to manage this risk in order to avoid asset stranding occurring. These alternate provisions include:

- Price discrimination in the setting of track access charges between electric and diesel services, on the basis that electric services have a lower capacity to contribute to the common costs of the rail network; and/or
- Preferentially allocating capacity on the network to users of electric traction, on the basis that use of below rail capacity by electric services is more commercially advantageous to QRNN, as permitted by the queuing provisions set out in Section 7 of the Access Undertaking.

This reflects the approach that was historically taken in QR's Access Undertakings (when the Central Queensland coal network was managed by QR as part of the entire Queensland rail network) when dealing services where access charges were less than the ceiling price. This framework has been retained in QRNN's 2010 Access Undertaking, and continues to be applied with respect to non-coal train services that pay access charges at a level below the ceiling price.

In the first instance, the pricing principles provide for price discrimination according to the ability of the different train services to contribute to the common costs of the network. This methodology is discussed as part of QRNN's consideration in Section 3.7.2.5 about how efficient prices can be set to comply with the pricing principles. This means that QRNN could set a different AT2-4 price for diesel and electric services, reflecting the lower capacity of electric services to contribute to the common costs of the track network (in order to remain competitive with diesel services).

QRNN's capacity allocation principles also provide for it to allocate capacity to train services that are in its best commercial interest – that is, make the maximum contribution to its common costs. While the Access Undertaking contemplates this discretion being applied in relation to the allocation of capacity to different coal services, this is only on the basis that all coal services pay access charges reflecting full recovery of QRNN's maximum allowable revenue. This means that QRNN is in the same commercial position (i.e. fully recovering its maximum allowable revenue), regardless of who it allocates capacity to.

However, this is clearly not the case if allocating capacity to diesel hauled services results in QRNN not being able to recover the costs it incurs in providing the electric network. QRNN would then be able to preference the allocation of capacity to electric services.

Importantly, QRNN can apply this approach without amendment to the 2010 Access Undertaking.

4.4 Way forward

In this submission, we highlighted our concerns with the QCA's analysis of the DAAU, and have provided further justification and reasoning as to both the efficiency of electric trains and the economic reasonableness of the proposal to require operators of diesel train services to contribute to the recovery of the investment on the grounds that:

- the investments were made in response to direct industry support;
- the regulatory framework provided the necessary commitment that is unable to be commercially obtained or compensated; and
- extensions and capacity augmentations of the overhead power system would have been required in any case to provide additional capacity for diesel services, so that QRNN could continue to meet its access agreement obligations to electric users.

QRNN believes that the proposals submitted by QRNN have no impact on competition in upstream or downstream markets and no evidence has been presented to the QCA to support such a proposition. QRNN does recognise that some commitments have been entered into prior to the submission of the DAAU. To the extent that it can be demonstrated that the DAAU has a material financial impact on party that is not reasonably able to be defrayed or mitigated, then QRNN believes that transitional arrangements can be considered to address that impact.

QRNN also considers that the Draft Decision is fundamentally incomplete as, while rejecting the DAAU, it has acknowledged the problems with the existing pricing arrangements but does not provide any guidance on what may be an acceptable solution. This is a critically important issue for QRNN, operators, customers and for the future efficient development of Central Queensland coal supply chains more broadly, and it is essential that the Draft Decision facilitates a constructive consultation process in order to develop solutions that may be acceptable to all parties.

Therefore, QRNN requests that the QCA issue a further Draft Decision which takes into account the new information submitted as part of this process, and, to the extent that the QCA still intends to reject the DAAU, provides guidance on what solutions the QCA consider would be acceptable for dealing with the issues raised. This will allow the opportunity for the QCA to provide constructive input into an industry engagement process which, we believe, provides the best hope of an acceptable resolution.

Attachment B - Contestable Blackwater tonnages

Resolving the on-going issue of QRNN's recovery of its investment in electric traction assets and the pricing mechanism adopted to achieve may impact on the large volume of tonnages that are currently contestable in the Blackwater system – that is, with contractual arrangements due to expire, and are now being, or are expected to shortly be, commercially tendered. This includes a substantial volume to RG Tanna Coal Terminal where existing contracts are close to expiry and decisions on the future traction choice for these services are currently under consideration. It also includes WICET Stage 1 volumes to be transported via the Blackwater system.

QRNN estimates that services for nearly 50 mtpa on the Blackwater system are either currently being negotiated or expected to be commercially tendered prior to early 2013. This represents approximately 60% of existing Blackwater tonnages. These tonnages that are effectively contestable at this point in time are summarised in the table below.

Blackwater tonnages subject to current negotiations

Customer	Mine	Tonnages (mtpa)
BMA	Existing mines	
Idemitsu	Ensham	
Yancoal	Yarrabee	
Anglo	German Creek	
Sojitz	Minerva	
Xstrata	Rolleston	
Caledon	Cook/Minyango	
Sub-total		**50**
Total Blackwater tonnages		**84**
Contestable tonnages as a proportion of total current Blackwater tonnages		**60%**

The data in the table above clearly shows that a very high proportion of future volumes in Blackwater are likely to be contestable in that they are currently or will shortly be up for negotiation of haulage agreements with above rail operators. This demonstrates that without addressing the below rail electric pricing to ensure that these contract negotiations are conducted on the basis of efficient price signals. This may only further promote further diesel penetration and underutilisation of the overhead power system and that the future pattern of haulage in terms of traction choice in Blackwater will be distorted. The scale of tonnages 'up for grabs' and the high proportion of total Blackwater tonnages they reflect means that this may be a decisive moment for the system - effectively being a 'tipping point' which will determine future traction choice on this system. This may have significant implications for QRNN's future asset stranding risk, for current electric traction customers and for the efficiency of the Blackwater supply chain as a whole.

Attachment C – Copy of Appendix C to QRNN's December 2011 DAAU Submission

Risk of Strategic Competitive Behaviour

1. Background

As noted in the submission, a major potential source of underutilisation of the electric network is the preference by an operator to utilise diesel locomotives rather than electric, due to a private benefit that may be gained by that operator.

An issue of particular concern to QR Network, and its owner QR National, is where there is the ability for a rival operator to utilise the access framework for the purpose of manipulating the costs faced by QR National with the effect of creating a competitive benefit for that rival operator. That is, where the private benefit that the rival operator gains is to increase the cost structure faced by its competitor.

This Appendix C is submitted as a confidential element of QR Network's submission, given the information that it contains regarding QR National's current vulnerability to such a strategic market entry strategy.

2. Strategic market entry causing underutilisation of electric network

Where the difference in the total haulage cost of an electric service and a diesel service is limited, a rival (operator or end user) may adopt an entry strategy designed to increase the cost faced by its competitors. The rival may choose to utilise diesel traction, and be prepared to incur short term pain associated with this choice, in order to force an economic loss on its competitor by reducing the utilisation of the electric network and, as a result, raising the effective price of access to the electric network.

QR National is currently highly vulnerable to such strategic competitive behaviour occurring in the Blackwater system, for the following reasons:

- QR Network's decision to substantially increase the Blackwater system's electric capacity (as strongly supported by end customers) has resulted in a significant increase in the level of AT5 during the 2010 AU.
- In the short term, the current level of AT5 in the Blackwater system (including the revenue cap adjustments associated with underutilisation of the electric network in previous years), combined with the current approach to setting access charges for diesel trains, means that the cost to an end customer of an operator utilising electric trains in the Blackwater system currently exceeds the cost of utilising diesel trains.
- In the longer term, the lowest total rail system cost for the Blackwater system will be achieved by maximising the utilisation of, and further investment in, electric traction. Critically important in achieving this long term cost structure is substantially increasing the number of electric trains operating on the Blackwater system, following commissioning of the additional electric capacity currently being installed.
- However, QR National's rival operator(s) may strategically decide to introduce diesel trains on the Blackwater system as they gain market share.
- This is most likely to be reflected as an inability to increase the number of electric trains operating on the Blackwater system to the sufficient level where electric traction does again provide the lowest cost rail solution for end users.
- In order to remain competitive with the rival operator(s), QR National will need to price its rail haulage services at the market level, which will be the level that reflects the cost of running diesel services.

The costs of this strategy will be borne by QR National (either through its subsidiary, QR Network, being unable to recover the costs of its electric network, or by QR National being unable to recover the costs of its electric fleet), and by the end customers, who will ultimately bear higher rail transport costs than they would do if the most efficient mix of electric and diesel locomotives were used.

There will be little or no harm to the rival operator(s) from this strategy, as it simply results in the market rate for rail haulage services being set based on the cost structure of diesel trains, with the long term higher costs associated with this simply passed through to end customers as higher transport costs.

Figure C.1: Illustrative rail haulage cost curves

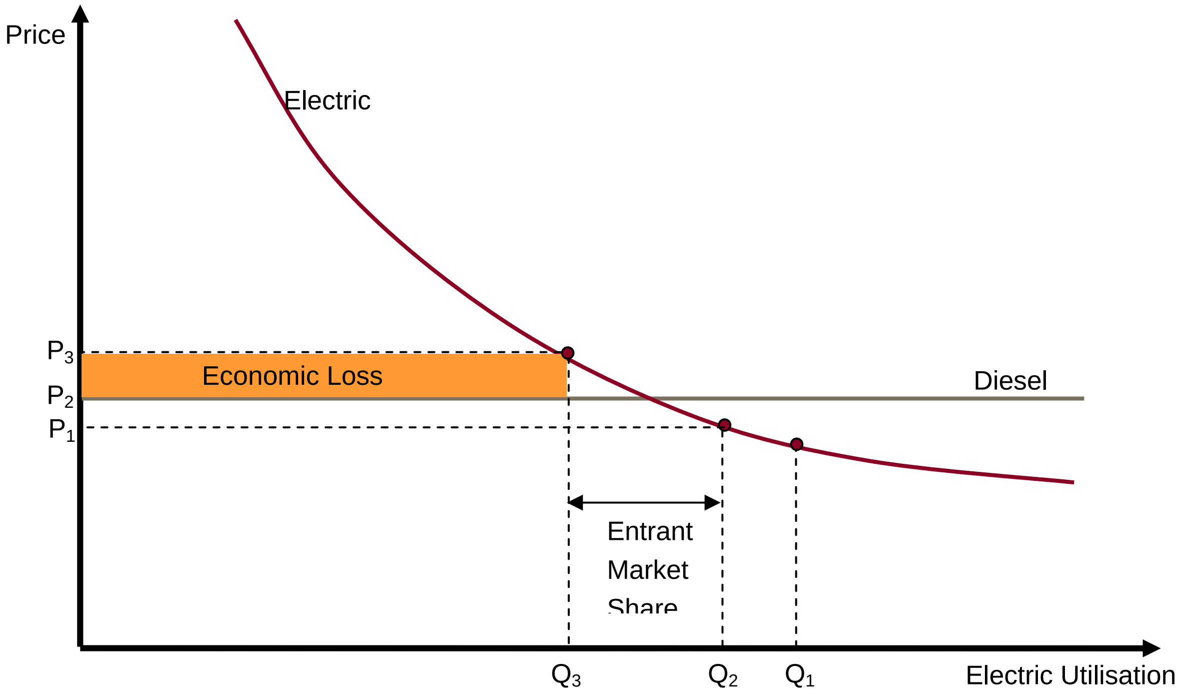


Figure 4 illustrates the operation of this strategy. The long run efficient price occurs at P_1 at service level Q_2 (90% of Q_1). A market entrant with sufficient scale of operation ($Q_2 – Q_3$) can sterilise electric network capacity utilisation and, through the operation of the competitive market, can restrict the price outcomes for electric services to the diesel price of P_2. The impact on existing users of the network who have undertaken investment on the expected long-run price outcome P_1 will be subject to cost structure consistent with the price P_3. As a consequence, these stakeholders would incur an aggregate economic loss as shown in the shaded box.

The ability for the rival operators to enter the market if QR National's rail haulage price exceeds the diesel substitution price provides an effective market constraint against QR National fully recovering its sunk costs in electric traction investment and against the promotion of efficiency in the dependent market. Therefore, an the new entrant is incentivised to adopt an entry strategy which diminishes overall system efficiency in order to provide a competive service offering (on the basis that QR National's cost will increase as a result of QR Network setting the AT5 tariff at a level which enables it to recover the costs of providing the declared service).

QR Network is particularly concerned about the risk of this strategy being used given that it is aware that Pacific National is strongly promoting to end customers the benefits of using diesel locomotives in the electrified Blackwater system.

The ability to implement this strategy with little or no cost to the new entrant is facilitated by the lumpiness of the overhead expansions, where full utilisation of the installed capacity is not feasible following inclusion of the large of incremental costs in the AT5 price structure, and demand lags installed capacity.

3. Proposed solution

QR Network's proposals for amending the 2010 AU will address this concern. Specifically, the introduction of the Electric Utilisation Rebate arrangements will prevent a rival operator from making traction choices with the specific purpose of increasing the costs faced by its competitors.

QR Network considers these proposals are not inconsistent with the matters the QCA is required to consider under s.120(f) of the QCA Act which requires the QCA to have regard to "the direct costs to the access provider of providing access to the service, including any costs of extending the facility, but not costs associated with losses arising from increased competition."

The operation of this clause is intended to address the reduction in monopoly rents an integrated business might otherwise have earned in the absence of competition in the downstream market. QR Network is not seeking to implement the policy positions in this DAAU to preserve monopoly prices in the absence of competition but to ensure that entry, and therefore competition, is based on the long-run efficient costs (and price) of providing the declared service.

NERA
ECONOMIC CONSULTING

Economic Aspects of the QCA's Draft Decision on QRNN's DAAU

QR National Network

25 September 2012

Project Team

Luke Wainscoat, Consultant

Carol Osborne, Senior Consultant

Greg Houston, Director

Ehson Shirazi, Analyst

NERA Economic Consulting
Darling Park Tower 3
201 Sussex Street
Sydney NSW 2000
Tel: 61 2 8864 6500 Fax: 61 2 8864 6549
www.nera.com

Contents

1. Introduction

This report has been prepared by NERA Economic Consulting (NERA) for QR National Network (QRNN) for the purpose of responding to the Queensland Competition Authority's (QCA's) Draft Decision[1] in regard to QRNN's 'Electric Access Draft Amending Access Undertaking' (DAAU).[2]

QRNN has asked us to consider several elements of the Draft Decision, being:

- the economic framework adopted by the QCA;
- the criticisms of QRNN's use of its total cost of ownership (TCO) analysis;
- the proposition that current prices will lead to more efficient outcomes than under the DAAU; and
- the QCA's assessment of the effect of the DAAU on investment incentives and competition in related markets.

The remainder of this report is structured as follows:

- section two provides background material, namely high-level descriptions of the Goonyella and Blackwater railway systems, the coal supply chain, the current access framework and the DAAU;
- section three reviews the economic framework applied by the QCA including its interpretation of the regulatory objective, and the relevance and applicability of QRNN's TCO analysis;
- section four examines the reasons why the DAAU may improve efficiency relative to the current price structure;
- section five assesses the DAAU's likely impact on the incentives to invest in the below-rail electric infrastructure;
- section six examines the DAAU's likely impact on competition in the rail haulage, locomotive supply and other markets; and
- section seven concludes by assessing whether the pricing methodology proposed in the DAAU is consistent with regulatory requirements.

1 QCA, *Draft Decision – QR Network Electric Traction Services Draft Amending Access Undertaking*, July 2012 (hereafter referred to as the 'Draft Decision').

2 QRNN, *QR Network's 2010 Access Undertaking – Draft Amending Access Undertaking for Sustainable Electric Traction Pricing*, December 2011 (hereafter referred to as the 'DAAU').

2. Background

This section establishes the context for the issues we have been asked to consider. It provides a high-level overview of the Goonyella and Blackwater railway systems, the wider coal supply chain, the regulatory framework and the relevant aspects of the DAAU pricing proposal.

2.1. Goonyella and Blackwater systems

The Goonyella and Blackwater railway systems are part of the Central Queensland Coal Network (CQCN). The Goonyella system consists of 924 kilometres of track and links 30 coal mines in the Bowen Basin to two export terminals at the Port of Hay Point (the Dalrymple Bay Coal Terminal and Hay Point Coal Terminal).[3] The Blackwater system consists of 985 kilometres of track and links 14 mines in the Bowen Basin to two export terminals at the Port of Gladstone (the RG Tanna Coal Terminal and Barney Point Coal Terminal).[4] The Blackwater system also serves a number of domestic users, including the Stanwell and Gladstone Power Station, Cement Australia and the Comalco Refinery.[5]

The geographical layouts of the two systems are illustrated in Figure 2.1 below. The Blackwater and Goonyella tracks are linked, allowing trains to move between the two.

The Goonyella and Blackwater systems both have electric traction infrastructure that allows a certain number of electric locomotives to run on them. Much of that infrastructure dates from the 1980s. Diesel trains are also able to run on both systems. Almost all trains that run on the Goonyella system use electric traction whereas, in 2012-13, electric traction will be used in around 77 per cent of trains in Blackwater.[6]

In April 2009, following user support, the QCA pre-approved the scope of a project proposed by QRNN to double the capacity of the electric infrastructure on the Blackwater system by building four electricity feeder stations.[7] These new feeder stations allow almost all trains on the Blackwater system to be run using electric traction.[8] The requirement to distribute power to each section of the electrified system required geographic disbursement of feeder stations. The nature of the electric infrastructure now in place means subsequent capacity expansions can be accommodated by upgrading existing infrastructure.

---

3 QR National website, http://www.qrnational.com.au/networksystems/Pages/GoonyellaSystem.aspx.

4 QR National website, http://www.qrnational.com.au/networksystems/Pages/BlackwaterSystem.aspx.

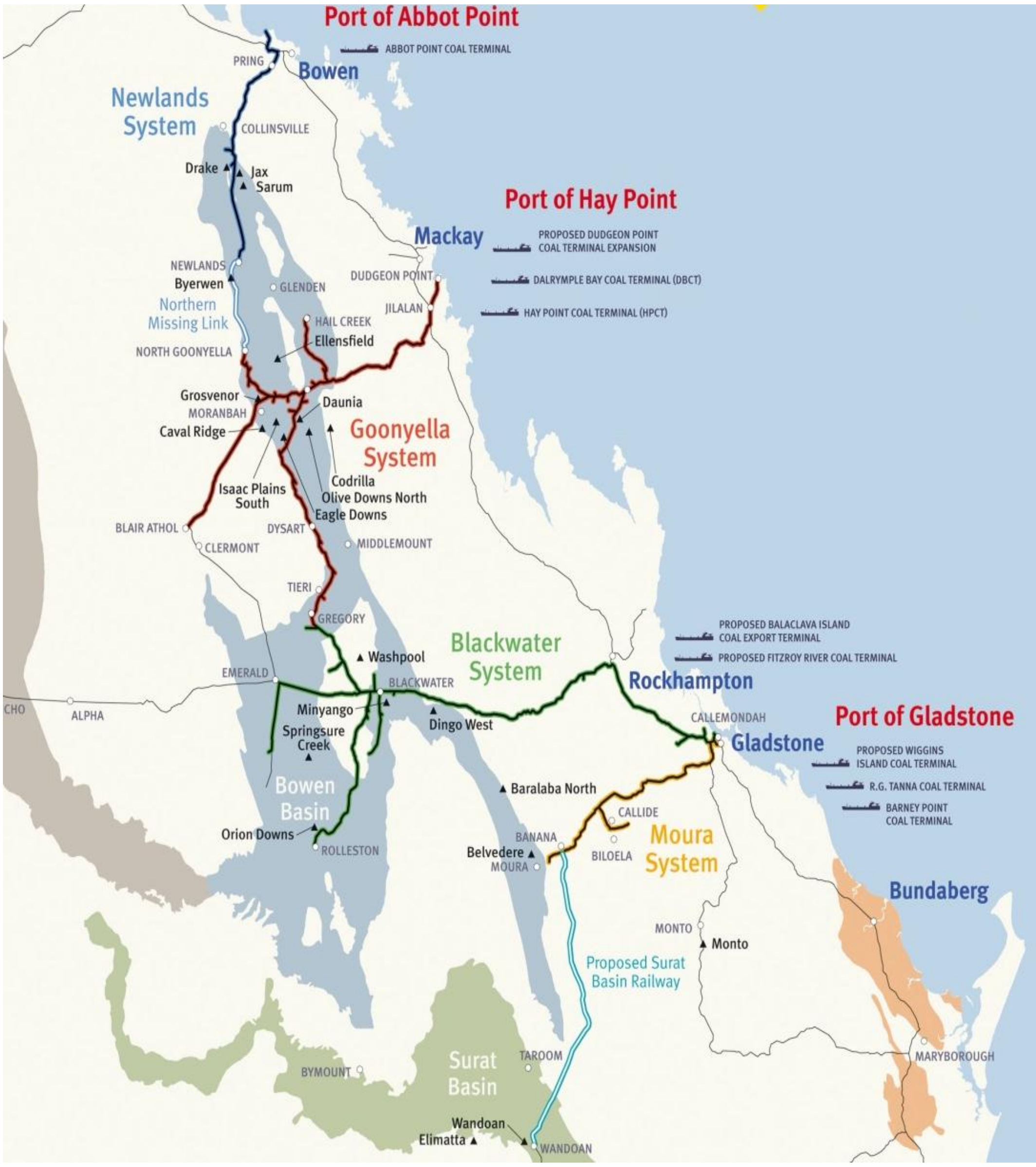
5 *Ibid*.

6 Specifically, in 2012-13, the regulatory volume forecasts for Blackwater assume the percentage of electric trains operating from electrified spurs will represent 77 per cent of forecast train service operations.

7 Draft Decision, p.1.

8 *Ibid*.

Figure 2.1
Map of the central Queensland coal network



2.2. Coal supply chain

The parts of the coal supply chain that are of most relevance to the issues under consideration include:

- **the coal mines** – around a dozen firms operate mines connected to the Blackwater and Goonyella systems, including Xstrata, BHP Billiton Mitsubishi Alliance (BMA) and

Ensham.[9] Each mine has an access point to rail infrastructure, which may be for its sole use or may be shared with nearby mines.

- **the below-rail infrastructure** (the track) – this is owned, managed and maintained by QRNN, and subject to economic regulation of access terms and conditions;
- **the above-rail infrastructure** (rolling stock, locomotives and operations) – two train operators, QR National and Pacific National, currently run trains on the Goonyella and Blackwater systems; and
- **the port infrastructure**.

Mine owners negotiate directly with train operators to haul coal from mine out-loading points to port in-loading points. The form of traction is typically specified within these contracts and the related access charges passed through to the mine owners. Usually the access charges are incorporated into the haulage fees paid by mine owners, but in some cases the mine owner will pay QRNN directly for access.

2.3. Access framework

Charges paid by the access holders for the use of below-rail assets are governed by an undertaking with the QCA and are based on a cost of service, building block methodology. QRNN's revenue requirement is estimated for the relevant pricing period on the basis of the efficient cost of providing the services. The cost components on which such regulatory arrangements depend are:

- the return on capital, which in turn is a function of:
  - the value of the assets used in the provision of services, which changes over time to reflect the recovery of capital from users and any capital expenditure undertaken by the asset owner, net of any assets that have been sold, disposed of, or become redundant in the period; and
  - the rate of return required by a benchmark service provider commensurate with the commercial and regulatory risks involved in delivering the services;
- the return of capital (depreciation);
- the prudent and efficient cost of operating and maintaining the assets; and
- the asset owner's tax liabilities, net of the value of any imputation credits.

Part 5 of the *Queensland Competition Authority Act 1997* (QCA Act) sets out the object and principles for access arrangements and pricing in Queensland. It explains that the QCA may approve a draft access undertaking only if it considers it appropriate to do so having regard to:[10]

---

9 QR National, *Blackwater Coal System*, http://www.qrnational.com.au/OurBusiness/Coal/Blackwater_OCT2011.pdf; QR National, *Goonyella Coal System*, http://www.qrnational.com.au/OurBusiness/Coal/Goonyella_OCT2011.pdf.

10 QCA Act, s. 138.

- the object of Part 5 of the QCA Act (Part 5), namely:[11]

  '[t]o promote the economically efficient operation of, use and investment in, significant infrastructure by which services are provided, with the effect of promoting effective competition in upstream and downstream markets.'

- the legitimate business interests of the owner or operator of the service;
- where the owner and operator of the service are different entities, the legitimate business interests of the operator of the service;
- the public interest, including the public interest in having competition in markets (whether or not in Australia);
- the interests of persons who may seek access to the service, including whether adequate provision has been made for compensation if the rights of users of the service are adversely affected;
- the effect of excluding existing assets for pricing purposes;
- the pricing principles mentioned in section 168A of the QCA Act; and
- any other issues the QCA considers relevant.

2.4. QRNN's DAAU pricing proposal

The price paid by access holders for the use of the electric infrastructure in the Goonyella and Blackwater systems is termed the AT_5.[12] It is charged on the basis of a user's electric gross tonne kilometres (egtk), ie, the total gross weight (in tonnes) of the rollingstock multiplied by the distance (in kilometres) of the electric train service. It seeks to recover the capital, maintenance and operating costs of the electric infrastructure as well as Powerlink's charges to QRNN for the use of its transmission network.[13] There is a separate charge for the electricity consumed by electric locomotives.

At present, the AT_5 is calculated separately for the Goonyella and Blackwater systems by dividing the cost of providing electric traction services on each system by its expected demand for electric traction.[14] There are three main elements to QRNN's proposed changes to the AT_5, ie:[15]

- the introduction of a single AT_5 charge, to be determined on the costs and forecast utilisation of the electric network in Goonyella and Blackwater, taken together;

---

11 QCA Act, s. 69E.

12 Draft Decision, p.1.

13 *Ibid*.

14 *Ibid*.

15 QRNN, *Submission to QCA: Electricity Access Draft Amending Access Undertaking*, December 2011, p.4 (hereafter referred to as the 'QRNN Submission').

- the introduction of an electric utilisation rebate, which would require operators to pay the AT_5 for at least 90 per cent of train services that can be operated with electric trains, irrespective of their traction choice; and
- amendments to restrict annual increases in AT_5 to no more than five per cent, with any unrecovered revenue cap amounts able to be deferred for recovery in later years.

QRNN considers that these proposed changes will provide an increased incentive to use electric trains in Blackwater, and thus increase the efficiency with which the below-rail infrastructure across Blackwater and Goonyella is used.[16]

[16] QRNN Submission, p. 6.

3. The Economic Framework

This section discusses the QCA's interpretation of the objective of Part 5 as well as the relevance and applicability of QRNN's TCO analysis.

3.1. Interpretation of Part 5

The objective of the access arrangements and pricing for QRNN's below-rail infrastructure is set out in Part 5 of the QCA Act. The QCA has deconstructed the objective into two components, ie:[17]

- to promote the economically efficient operation of, use and investment in, significant infrastructure by which services are provided; and
- the effect of promoting effective competition in upstream and downstream markets.

The QCA suggests that these are two 'limbs', both of which must be satisfied in order for it to accept the DAAU.[18] It argues that an assessment of whether the DAAU promotes economic efficiency in relation to the below-rail infrastructure (the first limb), should precede the assessment of whether it promotes effective competition in related markets (the second limb):[19]

> '…the Authority does not agree with QR Network that the primary objective of Part 5 of the QCA Act is purely to promote economically efficient outcomes. In particular, the Authority does not agree with QR Network that the relevant focus of the objects clause is on promoting economic efficiency of the whole of the rail haulage service.
>
> The objects clause specifically refers to promoting efficient investment and use of significant infrastructure; that is, the declared service. QR Network's argument that this should extend to the whole of the rail haulage service is, therefore, not consistent with a proper reading of the objects of Part 5 of the QCA Act.'

The QCA goes on to equate 'efficient' with 'least cost' when it concludes:[20]

> '[t]here is no convincing evidence to show that maximising the use of electric traction will result in lower below-rail costs.'

From an economic perspective, the QCA's interpretation of its task involves two related missteps. First, the QCA has adopted an overly narrow interpretation of efficiency, by limiting the concept to cost minimisation. Second, the QCA has applied its cost minimisation principle to just one functional element of the supply chain.

---

17 Draft Decision, p.23.

18 Draft Decision, p.26.

19 *Ibid*.

20 Draft Decision, p.27.

Decisions made at one level of the supply chain can have significant effects on the resource costs that need to be incurred in operating and investing in other components of the supply chain. For example, the number and efficiency of train paths supplied at the below-rail level will, in part, determine the size and efficiency of the haulage services industry as well as the volume of coal that the mine operators can deliver to customers. This, in turn, will affect the quantity of rail haulage services demanded and the efficiency with which the below-rail infrastructure is used.

Ignoring the related nature of costs incurred at different levels in the supply chain may lead to results that would be inconsistent with those that could be expected from a workably competitive process, and which would be inherently inefficient. For example, under the QCA's interpretation of the objective, any improvement in the quality of below-rail services that involved higher costs at the below-rail level would be deemed to be inconsistent with the objective, even if this reduced the cost of providing above rail services by a greater, offsetting amount. In a workably competitive (albeit hypothetical) market for the provision of below-rail infrastructure, downstream producers would be willing to pay the incremental increase in below-rail charges if it reduced their total costs.

By way of example, the QCA also regulates two distinct components of the Dalrymple Bay Coal Chain, ie, QRNN and the Dalrymple Bay Coal Terminal. Applying the concept of least cost as the measure of efficiency would generate an inherent conflict in the application of regulation where parts of the supply chain are close substitutes. The below-rail network configuration is at least cost when it supports train services that run evenly and uniformly across the weeks and months of a year. In contrast, the coal handling facilities achieve least cost when the port maintains limited stockpile capacity and uses a greater number of train services at peak times. The close substitutes in this example are peaking rail capacity and stockpile capacity. However, adopting a least cost approach to each of the port and rail facilities would be incapable of achieving the full value coal producers attribute to exporting their products.

Put another way, the QCA has adopted an overly narrow interpretation of 'efficiency', which has three elements, ie:

- *allocative* efficiency, which depends on what is produced and for whom, and focuses on whether society's resources are directed to producing those goods and services that are valued most highly;
- *productive* efficiency, which considers how a particular set of goods and services is produced, focusing on cost minimisation; and
- *dynamic* efficiency, which depends on investment decisions and is concerned with the achievement of productive and allocative efficiency over time, particularly in the face of changing technology and consumer tastes.

In the present situation, assessing allocative efficiency involves consideration of the optimal set of services that should be provided at the below-rail level. Assessing productive and dynamic efficiency involves considering whether the specified, optimal below-rail services are provided at least cost and the effect on investment incentives respectively. The QCA has considered productive and dynamic efficiency (which we discuss in section 4), but has overlooked any consideration of allocative efficiency.

The assessments of productive and allocative efficiency are inextricably linked, since the optimal mix of services will depend on both the costs to below-rail providers and the benefits to the users of those services (haulage providers and, ultimately, mining companies). The benefit to users of alternative below-rail services will depend on the implications for their overall costs.[21] All else constant, haulage providers or mining companies will be willing to pay a higher price for services that reduce other costs, such as fuel and maintenance expenses. There is likely to be inherent trade-offs between the costs at different functional levels, since lower above-rail costs may require more expensive below-rail services.

Focusing solely on minimising below-rail costs when there are implications for costs at other functional levels in the supply chain is unlikely to lead to efficiency enhancing decisions. Such a characteristic is not limited to the rail industry. For example, in the communications industry, it may not be efficient to choose copper wire over fibre optic cable to provide internet services simply because the copper wire is cheaper. It is important to take account of the additional value to customers of the higher speed connectivity that comes with fibre optics.

The DAAU will improve the allocative and productive efficiency of the below-rail segment if it leads to QRNN providing, at least cost, those services that result in lower over-all costs for on-rail service users.

We recognise that the QCA has said it would be prepared to take account of the efficiency of the whole of the rail haulage service in a consideration of the public interest but that, because it was not convinced by QRNN's TCO analysis, it has not specifically addressed this matter.[22] However, it is not clear how much weight the QCA is likely to place on a public interest test if it has first determined that a proposal is inconsistent with the object clause.

In contrast, in our opinion, all aspects of efficiency are relevant to the object clause, and it is necessary to form a view as to the implications for allocative and dynamic efficiency of the conduct that the DAAU is likely to encourage (or discourage).

3.2. Total cost of ownership analysis

The objective of the price proposal under the DAAU is to encourage the increased the use of electric traction. Before the implications of the DAAU's proposal for efficiency can be assessed, it is necessary to identify the extent to which the increased use of electric traction is consistent with greater efficiency. This section provides an assessment of the economic framework adopted in the TCO analysis and criticisms made of it.

---

[21] The QCA has previously recognised that the value of the below rail service can be taken into account in setting prices for below rail services and that this value depends upon costs to the above rail firms, stating that: '*The 'value' of the electrical overhead infrastructure will depend on not only the price of diesel, but also the price of electrical energy. The QCA is minded to endorse a pricing arrangement where QR may, for example, set a price for the use of the electrical overhead network on the basis of a formula that includes the price of diesel and the average electricity spot price. Such an approach would minimise the asset stranding risk for QR*.' QCA, *Draft Decision on QR's Draft Undertaking Volume 3 – Reference Tariffs*, December 2000, p.55.

[22] Draft Decision, p.27.

QRNN's TCO analysis provides an assessment of the relative cost of delivering a rail haulage service using electric versus diesel technology. It is therefore an integral component in determining whether the DAAU proposal would improve efficiency.

We concluded in section 3.1 that the QCA has misinterpreted the economic elements of the object of Part 5, and that the assessment of the efficiency of the DAAU pricing proposal should take account of the implication for above and below rail costs. It follows that the QCA should assess the efficiency implications of QRNN's pricing proposal by taking account of the DAAU's impact on both below and above rail costs.

QRNN's TCO analysis explicitly addresses the cost implications of increased use of electric traction across the entire coal supply chain. There are three scenarios in the TCO analysis:

- *Full Electric*, which assumes that only electric trains operate in each system;[23]
- *Full Diesel*, which assumes that only diesel trains operate in each system;[24] and
- *Hybrid*, which assumes a mix of electric and diesel trains operate, based on the current mix of traction type in operation in each system.[25]

Given the question that the TCO addresses, in our opinion, a comparison of the implications on the costs of haulage under each scenario would:

- be undertaken over the life of the relevant assets;
- include defensible assumptions for underlying variables;
- be based on forward-looking cashflows;
- account for future investment requirements at both the below and above rail levels;
- take account of the implications for operating and maintenance costs for below and above rail services, including the costs associated with reliability differences; and
- be discounted by an appropriate rate of return or weighted average cost of capital (WACC).

We consider each of these in turn. First, the financial implications of the various scenarios have been estimated over a 30 year period. If anything, it might be expected that the life of the electricity infrastructure assets could be longer than this. Given that the electric traction scenario resulted in reduced costs, extending the period of analysis beyond this horizon may be expected to further increase the estimated financial benefits of the Full Electric scenario, although we recognise that this effect would be muted by discounting.

---

[23] The transition to full electric utilisation is assumed to occur in 2013, apart for Rolleston and WICET where transition is assumed to occur in 2014. For the Blackwater system, the Full Electric scenario actually reflects 97 per cent electric utilisation as the Minerva spur is not electrified. Finally, it should be noted that a small diesel fleet is still maintained under this scenario to cater for surge capacity requirements.

[24] The transition to full diesel utilisation is assumed to occur in 2013.

[25] This scenario assumes that all mines with electrified spurs will be using electric traction. The starting fleet mix comprises approximately 37 per cent diesel, where all spurs/branches not currently electrified remain so for the duration of the analysis.

Second, we note that QRNN has sought independent information sources where possible for such underlying costs as diesel and electricity prices and total haulage levels, giving credibility to the modelling results.[26]

Third, QRNN has stated that the analysis is based on forward-looking cashflows. This is appropriate for measuring the financial implications of the options and is consistent with financial theory. Notwithstanding this, we note that:

- the analysis is undertaken from 2011 and therefore the Full Electric scenario includes the cost of committed investment, such as the four new Blackwater feeder stations and the Wotonga feeder station, along with uncommitted projects such as Rolleston electrification and power system renewal. The implications of not including the committed feeder station costs (on the basis they are already effectively sunk) would be to reduce further the costs of the Full Electric scenario. However, the inclusion of these already committed costs may be considered informative since access holders are yet to see these costs fully reflected in their prices;[27]
- the inclusion of the Powerlink break costs, which under the Full Diesel scenario will impose a cash cost on QRNN and access seekers, is appropriate; and
- the exclusion of the potential stranding of existing assets under each scenario is appropriate, since this does not have cashflow implications.

Fourth, the TCO analysis incorporates QRNN's expectations as to the investment required at both the below and above rail level under each scenario. Commentators have suggested that QRNN failed to incorporate appropriately the investment that would be required on spur lines should the Blackwater and Goonyella systems become fully electrified.[28] We understand from QRNN that the regulatory process would require any such investment to be cost-effective in its own right before it would be approved. Rather than reduce the benefits of electricity traction, then, such an option would either have a neutral effect or further increase the benefits of electric traction usage.

Fifth, there has been much debate by interested parties regarding the defensibility of the assumed implications for operating and maintenance costs, particularly in regard to the cycle time analysis.[29] Without commenting on the specific assumptions, it must be borne in mind that the objective of this analysis is to assess the relative merits of diesel versus electric traction. Decisions made by train operators regarding their fleet age should not be allowed to cloud this basic premise. To the extent that traction choices inherently allow for different locomotion performance, such variances should be incorporated into the modeling. However,

---

[26] QRNN Submission, p.47.

[27] We understand from QRNN that much of the pre-existing electricity traction infrastructure was almost fully depreciated by the 2011 starting point. Although these costs should not have been included in the TCO analysis, they are relevant to users who are still to pay for the undepreciated component of assets. We understand that Powerlink connection costs associated with pre-existing infrastructure (passed through to access holders within the AT_5 tariff) were included in QRNN's TCO analysis.

[28] Draft Decision, p.9.

[29] Draft Decision, p.13.

if variations between diesel and electric locomotion performance are due to fleet age, and so relevant technical developments in the locomotion industry can eventually be applied to both traction forms, such differences are best left out of the analysis. Although one operator may have a relatively newer fleet at a given point in time, it is impractical to assess how fleet age and associated traction-independent technology choices might change over a thirty year period. We understand from QRNN that its approach has been consistent with this principle, and the criticisms of its cycle-time analysis should be interpreted with this emphasis in mind.

In comparing the operating and maintenance costs of the three scenarios, it is also important to account properly for the relative reliability of diesel versus electric traction. We understand from QRNN that it has included reliability allowances in its TCO modeling and that the assumptions have been based on historic reliability under each system.

Lastly, QRNN's model uses different costs of capital (WACC) assumptions for above and below-rail cashflows. A WACC was used for above-rail that is considered to be commensurate with a commercial return in that market, while QRNN's approved post-tax nominal WACC was used for below-rail cashflows. Whether these WACCs are appropriate for discounting the cashflows associated with a specific component of the CQCN is unclear. However, we would not expect reasonable amendments to the WACCs to significantly alter the estimated cost differences between the three traction scenarios.

Overall, in our opinion QRNN's TCO is both applicable and broadly appropriate for assessing the relative financial implications of the three traction scenarios. Given that it indicates electric traction has an efficiency advantage over diesel traction of approximately $1 billion in net present value terms, QRNN's TCO analysis provides strong support for the proposition that the prices in the DAAU are consistent with the regulatory objective.[30]

[30] QRNN Submission, pp.52-53.

4. Efficiency Assessment

The current pricing mechanism established the AT_5 by dividing the total cost of the electric infrastructure amongst anticipated users of electric traction. The significant consequence of this approach is that the level of the AT_5 is affected by the intensity with which the electrified infrastructure is used. The DAAU proposes to remove the relationship between the AT_5 and the proportion of trains using electric traction by requiring operators to pay the AT_5 for at least 90 per cent of train services that can be operated with electric trains, irrespective of their traction choice. The objective of this revised arrangement is to encourage the increased adoption of electric traction in the Blackwater system, which the TCO analysis suggests would be more efficient.

A number of respondents to the DAAU have characterised QRNN's approach as that of a 'central planner'.[31] For example, Asciano stated that:[32]

> '[i]n terms of conceptual framework the QR Network approach is flawed as it is based on an implicit assumption that outcomes derived by centralised planning are both preferable and more efficient than market outcomes that result from allowing market participants to make their own decisions as how they will invest and operate their capital.'

The QCA explains that it has 'some sympathy with this view'[33] and characterises its own approach as one in which 'market forces' are allowed to operate, stating:[34]

> '…a price that reflects efficient costs of providing access to electric infrastructure will allow the relative efficiency of the traction choices to be assessed in the competitive above-rail market. Market forces will ensure that the traction solution that provides the best result for above-rail operators and their customers will be the one that is selected.'

In our opinion, the characterisation of a framework for analysis as relying on either 'central planning' or 'market forces' is not particularly enlightening. Given that the task at hand involves the assessment by a regulator under a prescribed administrative process, debate over the relative merit of one paradigm over another sheds no light on the essential question as to whether or not the prices proposed under the DAAU meet the regulatory criteria.

For the purposes of setting the AT_5, there are a number of economic characteristics of the coal supply chain that mean the DAAU is likely to improve efficiency, as compared to the outcomes under the current AT_5. These characteristics are:

---

31 See, for example: Asciano, *QR Network Draft Amending Access Undertaking – Electric Traction Services: Asciano Submission to the QCA*, April 2012, p.14; Rio Tinto, *Submission by Rio Tinto Coal Australia to the Queensland Competition Authority: Electric Traction Services*, 16 April 2012, pp.13-14; Downer, *Submission in relation to QR Network's 16 December 2011 Draft Amending Access Undertaking for Sustained Electric Traction Pricing ("Proposed Amendments")*, 9 March 2012, p.2.

32 Asciano, *QR Network Draft Amending Access Undertaking – Electric Traction Services: Asciano Submission to the QCA*, p.12.

33 Draft Decision, p.12.

34 *Ibid*.

- the existence of **economies of scale**, such that the efficiency of either traction technology is likely to be significantly enhanced if it has widespread adoption;
- the existence of **incentives for strategic conduct** by mine and train operators in order to secure financial advantage over rivals;
- the presence of **bypass risk**, which would see the AT_5 rise as electric traction usage falls;
- the existence of **externalities**, whereby the conduct of one party imposes costs or benefits on others; and
- the failure of **coordination** between different functions in a vertically integrated supply chain, particularly in circumstances where decisions made in relation to one functional element have cost or efficiency implications for another.

We consider the implications of each of these in turn.

4.1. Economies of scale

The total cost of running electric trains on the Blackwater system largely consists of access charges for the track, purchasing and maintaining locomotives, wagons, the electric infrastructure (the poles, wires and feeder stations) and the cost of the electricity. Broadly speaking, as the tonnage hauled increases at Blackwater:

- the cost of accessing the track, the number of locomotives, wagons and the amount of electricity required increases in proportion to the tonnage hauled; but
- the total cost of providing the electric infrastructure is largely unchanged.

Since the average cost of running electric traction trains falls as the tonnage hauled on its system increases, it can be said that there are economies of scale in the use of electric traction. It is therefore likely to be cost-effective to maximise the use of the available traction infrastructure.

In contrast, the cost of running diesel-traction locomotives is relatively invariant to total tonnage levels. It is therefore reasonable to assume that the relative cost of traction technologies varies depending on usage patterns, ie:

- at higher levels of diesel traction usage (relative to electric), diesel traction will be cheaper;
- at lower (relative) levels of diesel traction usage, electricity traction will be cheaper; and
- there is a range in which the two traction alternatives have comparable costs.

It follows that at relative usage levels within the range at which the two have comparable costs, decisions to use one versus the other could set off a chain of events with the effect of locking in a specific traction method as the standard for the system.

The TCO analysis shows that costs in the Blackwater system would be minimised if electric traction is maximised. However, under the current regulatory arrangements, traction choice decisions made by reference to average system costs may mean that the usage of electric traction never increases sufficiently for cost savings to be fully realised. At current levels of utilisation, the average cost of electric and diesel traction in Blackwater are similar. It follows that any significant shift towards diesel traction could increase the allocation of the fixed costs of electric traction under the AT_5 to the remaining users of electric traction to such an extent that electric traction is no longer a cost-effective option for those users. Such an outcome would be likely further to reduce the usage of electric traction, creating a cycle of increasing allocations of fixed costs onto a smaller proportion of users. This runs the risk of driving the system towards a diesel standard, even though this would result in higher costs for all users, based on QRNN's TCO analysis.

In this situation, price signals that incentivise users to adopt electric traction are likely to result in overall cost savings. The DAAU proposes to encourage electric traction usage by increasing the price of diesel traction. An alternative would be to reduce the price of electric traction, possibly towards the price that would prevail under efficient usage patterns (ie, high levels of electricity traction usage). However, until usage reached these levels, the latter arrangement would result in a revenue shortfall for QRNN, which would need to be recovered through other tariffs. This would most likely involve an additional charge to all users on the Blackwater, and potentially Goonyella, system. The end result may be a price structure not dis-similar from that proposed under the DAAU, since diesel haulage users would be required to contribute to these costs.

4.2. Strategic behaviour

In general, the form of traction is specified in the contract between the mining companies and the train operators, and access charges are passed through to the miners. Such contracts are typically of ten years' duration and are relatively few in number. Each contract has the potential to significantly affect the price of electric traction services under the existing pricing mechanism.

We understand that a disproportionate number of these contracts are expected to be renegotiated over the next six months. It follows that, absent the changes contemplated in the DAAU, it is conceivable that the use of electric traction may fall below the tipping point at which it becomes relatively unattractive to users. The analysis presented in Figure 4.1 indicates that this tipping point is around 50 per cent utilisation of electric traction.

Importantly, if users were able to coordinate and make a decision that reflected their collective best interests, they would most likely opt for electric traction in Blackwater, since this would minimise their costs. This user conclusion is consistent with the support for the initial decision to invest in electric traction infrastructure, from QRNN's TCO analysis and the relatively low price of electric compared to diesel traction in the Goonyella system at current high levels of electric utilisation.[35]

However, without the ability to coordinate, a mining firm signing a ten year contract committing to the use of electric traction leaves itself vulnerable to the risk of higher than

---

[35] The letter confirming regulatory pre-approval for these assets is: QCA, *Regulatory pre-approval for Coal Master Plan 2008 capacity expansion projects*, April 2009, available at: http://www.qca.org.au/files/R-2008AUammend-QCA0FinalDec08CustVote-0409.pdf.

anticipated costs if other users opt for diesel traction. Furthermore, by not committing to electric traction now, a mining firm is able to avoid the potentially higher short-term costs imposed by the AT_5 tariff, when total tonnage carried by electric traction is lower, and opt into electric traction later once the future AT_5 tariff has fallen. Such an approach effectively allows a miner to 'free-ride' by forcing other users to incur a greater proportion of the capital costs of electric traction in the early years.

These coordination difficulties are exacerbated by the incentives mining firms and train operators may have to increase their rivals' costs. For example, by opting out of electric traction, miners using diesel traction are able to increase the proportion of costs that will be borne by their electricity-using rivals.

Similarly, train operators purchasing electric locomotives for use over a 30 year period leave themselves open to the risk that electric traction may become more expensive and hence less attractive. This prospect is exacerbated by the incentives of train operators to increase their rivals' costs. A train operator may be able to increase the use of diesel trains by purchasing these trains. As a result, mining firms would be more likely to choose diesel traction which may lead to the stranding of electric locomotives.

To summarise, the current price mechanism is likely to encourage self-interested users to choose diesel traction more often than is efficient. The consequence of such decisions is that QRNN is placed at risk of declining utilisation of electric traction infrastructure and of its ability to recover its sunk costs. By removing the link between the price of access to the electric infrastructure and the proportion of trains using it, the DAAU creates an incentive to make more efficient traction choices.

4.3. Risk of inefficient bypass

The analysis presented above highlights that the current AT_5 tariff arrangement is problematic in circumstances when it is possible to 'bypass' the use of electric traction infrastructure, even though it may not be efficient to do so from a system total cost perspective. By avoiding the use of such electric traction infrastructure, diesel haulage users influence the system–wide cost of haulage and, under the existing tariff arrangement, the price of electric haulage. This issue has been recognised by the QCA before where its response was to allow QRNN to set prices such that its bypass risk was reduced:

> '…it is desirable if the use of [the electricity distribution network] is priced so as to remove the incentive for above-rail operators to bypass it. The Authority is also concerned to ensure that it avoids creating an incentive to bypass this infrastructure by requiring QR to levy a use of system charge that makes electricity an unattractive energy source relative to diesel.'[36]

In our opinion, the DAAU is consistent with avoiding precisely the kind of risks to which the QCA has previously referred.

The risk of bypass that has the purpose or effect of avoiding contributions to common infrastructure is the subject of regular attention by regulators. For example, the Commission

[36] QCA, *Draft Decision on QR's Draft Undertaking Volume 3 – Reference Tariffs*, December 2000, p.55.

for Energy Regulation (CER) for the Republic of Ireland recently addressed similar questions in its 29 June 2012 decision on interconnector prices. That decision dealt with the regulatory treatment of the two Bord Gáis Éireann (BGE) owned gas transmission interconnectors (ICs) in the context of new sources of gas coming on-stream that, because of their geographic location, did not need to use these ICs.[37] In effect, the new gas sources will be able to bypass the existing infrastructure when transporting their gas to customers.

Rather than persist with the existing tariff mechanism, which is based on average costs and would therefore see prices rise as usage falls, the CER opted to reform the transmission tariff regime with effect from October 2014. The CER decided to move away from historic cost based tariffs in favour of long run marginal cost (LRMC) based tariffs.

While remaining a cost-based price, LRMC tariffs are forward-looking and depend on the remaining capacity in the system rather than on existing usage levels. LRMC generally increases the closer infrastructure gets to being fully utilised. The use of LRMC pricing is more often seen when infrastructure is nearing its capacity limits and it is desirable to signal to users the effect of their decisions on the need for future investment. However, in the context of the BGE's ICs, capacity is not constrained and the LRMC is anticipated to be very low, and significantly below its historic average cost.

This highlights an intrinsic problem with the use of LRMC pricing, being that it involves assurance that the revenue accruing from such prices will be sufficient to meet the revenues required to finance the assets that are already in place. LRMC-based prices, therefore, often need to be topped up with a supplemental revenue stream.

In the case of the ICs, the CER decided this should take the form of a common charging element, which is to be paid on the basis of the use of any entry point into the gas pipeline network. The cost of using any entry point to the gas pipeline network will in future be comprised of a two-part tariff, ie a single charge based on capacity requirements (gas contracts are based on capacity 'bookings' rather than actual usage) regardless of entry point; and a location-specific charge that reflects the relative (forward-looking) cost of using one entry point (ie, an IC) over another.

The CER determined that such an approach was preferable to either stranding the IC assets or allowing their price to increase as usage falls, which was judged by the CER to be inefficient and damaging to customers and Ireland's energy competitiveness.

If a similar approach were to be applied to QRNN's electric traction tariffs, it would give rise to an arrangement along the following lines:

- a price for electric traction services based on LRMC, which, given the excess capacity on the system, could conceivably be relatively low;
- a price for diesel traction services based on LRMC, which may be higher or lower than that of electric traction depending on its implications for future investment requirements;

---

[37] Commission for Energy Regulation, *The Regulatory Treatment of the BGE Interconnectors and Future Gas Transmission Tariff Regime: Decision Paper*, June 2012.

- given that this would likely leave a proportion of unrecovered required revenue, the relevant amount would need to be raised through other charges; and
- one alternative would be to spread unrecovered costs over all users of the Blackwater (and potentially Goonyella) systems in the form of a 'total usage' tariff.

Such an approach would have the advantage of retaining the difference in LRMC between electric and diesel traction usage. It would therefore establish appropriate incentives for traction choices such that users would opt for electric traction only if the added advantages (in the form of lowering other costs) outweighed any difference, while still allowing QRNN to recover its revenue cap.

However, in practice, this approach may not be significantly different from the pricing proposals under the DAAU since, the lower are the LRMCs, the closer the resulting tariffs would be to those under the DAAU. Furthermore, it is likely to be substantially more difficult to implement since LRMCs can be problematic to estimate.

On this basis, the DAAU can be taken to represent a useful compromise approach, although other means of getting to a similar end-result could be developed.

4.4. Externalities

An externality or transaction spillover occurs when one party incurs costs or receives benefits as a result of the actions of another, and these costs or benefits are not accounted for through prices. Spillovers can affect consumption and production decisions resulting in less efficient outcomes. There are a number of externalities of relevance to the DAAU, ie:

- electric train operators benefit from being able to use their electric trains on a larger railway network since this entails:
  - a lower risk of above-rail asset stranding, there will be a greater opportunity to win further contracts to use electric trains at the end of each contract;
  - greater flexibility in the operation of their fleet;
  - access to a wider set of opportunities to use their assets;
  - greater economies of scale through efficiencies in the operation of electric trains; and
- diesel trains are slower than electric trains and so impose congestion costs on electric traction users.[38]

The current access arrangements for the electric infrastructure, entailing separate prices for the two systems, does not take account of the benefits accruing to electricity traction users from a more extensive electric traction network. We understand that slower trains are charged more for using greater capacity on the railway networks, but this may not fully compensate electric train operators for the congestion costs.

---

[38] QRNN Submission, p.19.

The DAAU proposes to address these externalities by setting a single price for the Goonyella and Blackwater systems, and by increasing the price for diesel traction.

4.5. Coordination failure

In a workably competitive market, an upstream service provider would be unlikely to invest in significant sunk assets without a reasonable expectation that downstream users would require the associated services. An unregulated below-rail firm could be expected to enter into long-term contracts that either guaranteed usage levels or involved payments irrespective of usage.

In the current situation, such contracts would have been very costly to arrange because of the large number of parties (mining companies) with which QRNN would have needed to establish contractual arrangements. Further, QRNN's ability to achieve long-term take or pay arrangements for the new investment would have been constrained by train operators and/or their customers' unwillingness to commit to any form of traction prior to the tendering, negotiation and awarding of haulage contracts.

The existence of such coordination challenges is the underlying rationale for why a regulatory process is in place, not only to secure outcomes similar to those of a workably competitive market, but also to provide QRNN with comfort that it will be able to recover the costs of efficient investments.

However, by ring-fencing the Goonyella and Blackwater electric traction facility costs and requiring that usage-based prices reflect the average cost of service provision at inefficient levels of utilisation, the regulatory arrangements diverge from the risk-sharing arrangements that might be expected in a workably competitive market in two significant respects, ie:

- first, electric traction users are required to bear the costs associated with under-utilisation of the assets, which results from the choices made by other above rail operators; and
- second, QRNN becomes vulnerable to asset stranding in the event that the price of electric traction is increased such that the system tips towards all-diesel usage.

Under such arrangements, there is no reason to believe that usage-based prices derived by reference to average cost at anticipated usage levels will result in the most efficient decisions being made. In contrast, the DAAU is more likely to be more consistent with workably competitive market outcomes that would see users being required to pay for approved, efficient and highly specific investments, regardless of actual usage patterns.

5. Impact of the DAAU on Investment

The impact of the DAAU on investment in below-rail assets is directly relevant to the QCA's assessment since the object of Part 5 includes the:[39]

> 'efficient operation of, use and investment in, significant infrastructure by which services are provided'.

In addition, it is through appropriate investment decisions that dynamic efficiency is achieved, whereby productive and allocative efficiency may be improved over time. Efficient investment in the below-rail infrastructure will be encouraged if QRNN can:

- have confidence in the regulatory process; and
- expect to be compensated for the risks that it incurs when investing.

The section assesses the implications of the DAAU on investment decisions by reference to its effect on each of these factors.

5.1. Confidence in the regulatory process

One of the central objectives of the DAAU is that it will reduce the stranding risk associated with the electric traction infrastructure, while also allowing the total cost of haulage to be reduced. The electric traction assets are at risk of stranding because of the attractiveness of bypass under the current pricing mechanisms. If the use of electric traction falls to too great an extent, it will not be possible for QRNN to recover its investment costs through the AT_5.

This risk of stranding is likely to reduce QRNN's incentive to invest in infrastructure assets in the future. Asciano has argued in its submission to the QCA that this is appropriate, since:[40]

> 'by allowing QR Network to socialise the costs of [the recent investment in the Blackwater electric infrastructure] it sends an inappropriate dynamic efficiency signal to QR Network as QR Network are [sic] then encouraged to build assets without regard as to whether the investment is efficient as they [sic] will be able to recover cost from al [sic] users.'

This observation appears not to have taken account of the fact that QRNN went through a detailed consultation process and received the necessary support of customers prior to undertaking the relevant electric traction investment. This was the Coal Rail Infrastructure Master Plan (the Master Plan) process which was designed to ensure appropriate investment decisions and address uncertainties surrounding the recovery of capital expenditure.[41] The QCA stated at the time that the Master Plan process would address QRNN's 'concern that it is otherwise exposed to the regulatory risk of major investments not subsequently being

---

[39] QCA Act, s. 69E.

[40] Asciano, *QR Network Draft Amending Access Undertaking – Electric Traction Services: Asciano Submission to the QCA*, April 2012, p.17.

[41] QRNN, *Coal Rail Infrastructure Master Plan 2nd Edition*, October 2008, p.17.

approved by the Authority'.[42] In particular one of the objectives was to provide QRNN 'with up-front certainty of inclusion of such additional assets in the Regulatory Asset Base.'[43] In other words the Master Plan process was aimed, in part, at reducing QRNN's investment risk, once such investment was approved by stakeholders.

Asciano states that 'dynamic efficiency requires that the asset should only have been built if it was ex ante efficient'.[44] The investment in the expansion of the electric infrastructure at Blackwater proceeded after a detailed consultation process with stakeholders including potential users of the assets and the QCA. The expansion was consulted upon and explained in the Master Plan published in October 2008.[45] This was followed by a detailed assessment of the costs and benefits of the expansion published in March 2009.[46] The QCA pre-approved the scope of this investment in April 2009 on the basis that it had the necessary customer support and QRNN had complied with the relevant requirements of its access undertaking.[47]

Whilst some stakeholders have criticised the Master Plan process, the QCA has not referred to any evidence that QRNN failed to meet its obligations on the process or provided its customers or the QCA with false or misleading evidence.[48] Thus, the QCA concludes that investments already in the RAB should be protected from asset stranding.

The Master Plan process should provide comfort to QRNN that if it invests in projects that stakeholders approve, it will be able to recover those investment costs. It follows that the regulatory arrangements should now be structured so as to provide QRNN with a high degree of assurance that it will be able to earn the regulatory return on its investment in the electricity traction infrastructure.

The DAAU increases QRNN's likelihood of recovering its investment in the electric infrastructure at Blackwater. The alternative, of persisting with the current tariff setting mechanisms, would at best result in a deferral of the asset recovery reducing profitability and, at worst, significantly increase the risk of future asset stranding. It would amount to the breaching of the implicit contract between QRNN and the QCA regarding the recovery of approved investment expenditure. This would be inconsistent with promoting efficient

---

42 QCA, *Draft Access Undertaking Decision*, December 2005, Preamble p.vi.

43 QRNN, *Coal Rail Infrastructure Master Plan 2nd Edition*, October 2008, p.17.

44 Asciano, *QR Network Draft Amending Access Undertaking – Electric Traction Services: Asciano Submission to the QCA*, April 2012, p.6.

45 QRNN, *Coal Rail Infrastructure Master Plan 2nd Edition*, October 2008.

46 QRNN, *Rationale for Power Systems Upgrade in the Blackwater System – A coal rail infrastructure master plan working paper*, March 2009.

47 QCA, *Regulatory pre-approval for Coal Master Plan 2008 capacity expansion projects*, April 2009, available at: http://www.qca.org.au/files/R-2008AUammend-QCA0FinalDec08CustVote-0409.pdf.

48 Draft Decision, p.40.

investment, since it would reduce the incentive on QRNN to undertake a similarly supported significant investment project in the future.[49]

5.2. Compensation for risks of invesment

Avoiding the stranding of assets, as described above, may not be necessary if QRNN was compensated for stranding risk in other ways, such as:

- by means of an adjustment to the regulated rate of return; and/or
- through an explicit adjustment to the forecast cashflows that underpin its regulated revenue requirement calculation.

QRNN has not been compensated for stranding risk through either of these mechanisms.

The rate of return allowed by the QCA on QRNN's RAB is an estimate of QRNN's WACC. This is the expected cost to QRNN of funding itself through a mix of equity and debt. It takes into account the systematic risks that QRNN faces but involves no allowance for specific risks, such as asset stranding risk. This has been acknowledged by the QCA:

> '[s]ome of the risk reduction measures proposed by QR Network appear to be unrelated to covariance risk (e.g. long term asset stranding) and are, therefore, not normally reflected in WACC estimates.'[50]

Hence, if the rate of return for QRNN was to take account of the asset stranding risk, it would need to be increased. A review of QRNN's access undertakings shows that the asset stranding risk has not been explicitly included in its WACC. Notwithstanding that QRNN has previously proposed an increased WACC to take account of asset standing risk, the QCA rejected this proposal:[51]

> '[w]ith respect to asset stranding risk, the Authority considers that the measures that it is proposing to accept as part of this draft decision, in particular accelerated depreciation for new capital expenditure and the greater ability to seek access conditions (e.g. capital underwriting) for major projects, combined with strong coal demand (in particular in relation to metallurgical coal), and the highly competitive position of Queensland coal producers, means that QR Network's asset stranding risk is minimal.
>
> Accordingly, the Authority does not believe that the previous uplift to the equity beta, from 0.80 to 0.90, can be justified.'[52]

An alternative method for compensating a regulated business for stranding risk is to make an explicit adjustment to the forecast cashflows that underpin the derivation of QRNN's revenue

---

49 While the QCA has stated that it does not intend to strand assets that have been included in the regulatory asset base (RAB), it has not yet proposed a way of amending the AT_5 as it is required to do if it refuses to approve the DAAU. Draft Decision, p.3.

50 QCA, *QR Network 2009 Draft Access Undertaking*, Draft Decision, December 2009, p.11.

51 QCA, *QR Network's 2010 DAU – Tariffs and Schedule F*, Draft Decision, June 2010, p.44.

52 QCA, *QR Network 2009 Draft Access Undertaking*, Draft Decision, December 2009, p.19.

requirement. This involves ensuring that expected revenues are equal to the expected costs (including the risk of asset stranding) of providing the service.

Asset stranding risk is asymmetric in that it may reduce QRNN's revenue but there is no counteracting risk that QRNN's revenue will be higher than expected. Hence, the presence of stranding risk lowers expected cashflows. Consequently, an increase in forecast cashflows, and so the regulatory revenues requirement, is necessary to provide QRNN with a reasonable opportunity of recovering the cost of providing the regulated service.

A review of QRNN's access undertakings shows that the only allowance for asset stranding risk in QRNN's cashflow is the setting of a maximum 20 year asset life in the 2009 access undertaking.[53] This is less than the expected life of some assets and was designed to reduce the risk that assets may be stranded by shortening the period over which invested capital is recovered from users. However, while this adjustment reduces the value of assets at risk of stranding, it does not compensate QRNN for stranding risks associated with un-depreciated assets, such as that facing the electric infrastructure in Blackwater system.

We conclude that the asymmetric risk of asset stranding of the electric infrastructure in Blackwater system has not previously been provided for, either through the WACC or cashflows.

This suggests that the regulatory arrangements governing the recovery of electric traction infrastructure costs should be designed so as to minimise this risk, as described in the previous section. Furthermore, it would be inappropriate now to begin to compensate QRNN for this risk moving forward, rather than accepting the DAAU as the most effective means to eliminate it, since:

- the tariffs through which such risk would be compensated (the AT_5) are at risk of being unrecoverable at the same time as the asset would become stranded;
- the root cause of the bypass risk is the relativity high price of electric traction compared to diesel traction – increasing the price of electric traction would, then, simply increase the risk of stranding; and
- it is in any case more efficient, in terms of reducing the total cost of haulage, to use these assets rather than to allow them to become stranded.

53 QCA, *QR Network 2009 Draft Access Undertaking*, December 2009, p.ii.

6. Promoting Effective Competition

The objective of Part 5 includes the promotion of 'effective competition in upstream and downstream markets'.[54] This section evaluates the QCA's analysis of how the DAAU will affect competition by reference to the following steps for each relevant part of the supply chain:

- define the relevant market, ie, the field of competition including the products and geographic areas that provide a close competitive constraint on the products in question;
- assess the effect of the DAAU on competition between the existing suppliers in the relevant market; and
- assess the effect of the DAAU on barriers to entry and exit in the relevant market.

6.1. Rail haulage

6.1.1. Market definition

The QCA defines separate markets for rail haulage in Blackwater and Goonyella, each with both electric and diesel traction services.[55] This market definition is based on:

- the fact that mine owners usually contract with a specific port and, given the capacity constraints at ports and on the rail system, it is unlikely that a significant number of mine owners would be able to switch between using rail systems in the short run; and
- diesel haulage offers the same service (the transport of coal) that electric haulage does in Blackwater and Goonyella, and so the different traction technologies are close substitutes.

Significantly, the QCA does not consider whether train operators could switch between operating their trains on Blackwater and Goonyella. The connectivity between the two systems makes it possible for train operators to move trains from one system to the other. Competition for a new contract in Goonyella could come from a train operator that presently provides services only in the Blackwater system. For that matter, competition could potentially come from train operators in the rest of the country depending on the availability and compatibility of the trains.

If follows that the market definition may well be wider than that assumed by the QCA, so as to be either:

- that for rail haulage using electric traction in Goonyella and Blackwater;[56] or
- that for diesel and electric rail haulage in the CQCN, and potentially other areas in Australia.[57]

---

[54] QCA Act, s. 69E.

[55] Draft Decision, p.34.

[56] This market definition may arise if the conduct of interest was in Goonyella.

Given these potentially wider definitions of the relevant market, the QCA's analysis may well underestimate the existing competitive constraints on train operators offering rail haulage services.

6.1.2. Competition between existing suppliers

The QCA concludes that the DAAU will reduce the degree of competition between existing rail haulage operators in Blackwater because:[58]

- the DAAU is likely to reduce the choice of traction methods from two to one; and
- the relative increase in the cost of diesel traction will limit the ability of train operators using this form of traction to provide an effective and credible competitive constraint to train operators using electric traction.

Although the DAAU makes it more likely that there will be one predominant form of traction – indeed, that is its very intent – this does not imply a reduction in competition. The service provided is coal haulage. Aside from their different cost structures, it seems unlikely that mine operators would see any distinction between electric or diesel driven traction. As far as they are concerned, there is a single relevant service supplied.

Competition between train operators occurs when a mine owner seeks a new contract for a train operator to haul its coal from a mine to a port. Train operators generally pass on any access charge for the below-rail infrastructure directly to the mining firm. It follows that:

- there is no competition for services that are already under contract, and the DAAU will not affect competition for contracted volumes; and
- as long as all competitors have access to electric locomotives, the level of the access charges will not affect competition for new contracts.

The DAAU is designed to increase the use of electric traction in Blackwater. Both the existing train operators own and run electric trains. The QCA has not presented any reasons why one train operator would gain an advantage over another in providing such services on an on-going basis. A train operator with diesel trains at Blackwater may face a one-off cost of repositioning them elsewhere, but this should not prevent it from competing for new contracts with electric trains on equal terms. The incurring of repositioning costs would only reduce competition from existing suppliers if such costs were to cause an operator to exit entirely; however, we are not aware that this has been suggested by the QCA or any other stakeholder.

6.1.3. Barriers to entry

The QCA claims that the DAAU will increase barriers to entry in Blackwater and Goonyella because:

[57] This market definition may arise if the conduct of interest was in Blackwater.

[58] Draft Decision, p.34.

- the 'DAAU proposes to "change the rules" after a new entrant (Pacific National) has joined, in a way which could take away much of its anticipated profit'.[59] The QCA concludes that potential entrants observing this would be less likely to enter the market as a result;
- accepting the DAAU may provide the signal that QRNN could act to protect its related party;
- the cost of entering the Goonyella market with electric services will be higher since the charge for access to the electric infrastructure will increase in Goonyella;
- the DAAU will make it less attractive to run diesel trains in Goonyella, and thus reduce the likelihood that a firm would enter the Goonyella system with diesel trains; and
- a new entrant would have to use electric traction, which would reduce the number of locomotive suppliers to just one. A new entrant would have very little bargaining power with this supplier, and hence entry would be less attractive than if there were a number of electric and diesel locomotive suppliers to choose from.

We evaluate the first four of these propositions in turn below, while the fifth is examined in the next section.

First, the QCA appears to overstate the risk that accepting the DAAU will create a concern amongst potential entrants that there has been a 'change in the rules' because:

- the proposed change to the AT_5 is not as fundamental a change to the regulatory regime as would be implied by rejecting the DAAU, as discussed in section 5.1; and
- there is no apparent reason to think that a train operator would lose a great deal of 'anticipated profit' from an investment it had made in diesel trains being used in the Blackwater system.

The QCA does not refer to any evidence to suggest that an outcome with greater electric train usage would have been unexpected. Even if a train operator expected diesel trains to be profitable on the Blackwater system but found that they were in fact loss-making, it may be able to earn its expected profit by redeploying these assets on other systems.[60]

Second, it is not relevant for the QCA to make its assessment by reference to how it may or may not affect a related party to QRNN. Rather, the relevant question is whether or not QRNN could be expected to propose a tariff in the form of that put forward in the DAAU if it were not a related party of any train operator. In our opinion, the DAAU would be likely to be proposed by QRNN regardless of its affiliation with any related party since:

- it would best ensure that its risk of asset stranding is minimised, bearing in mind that it has not otherwise been compensated for such risks; and

---

59 Draft Decision, p.35.

60 We understand from QRNN that Pacific National currently uses around 12-16 diesel locomotives in Blackwater. We also understand that these narrow gauge diesel trains could be used in the areas of growth such as GAPE/SBR or other systems such as Mt Isa that use diesel traction.

- it represents the most effective tariff for bringing about the lowest expected cost for the supply chain as a whole, an outcome that is clearly in the long term interests of QRNN, irrespective of any related party interests.

Third, any increase to the cost of electric infrastructure access in Goonyella is likely to be passed on to the mine owners. Its effect on the cost of entry for a train operator is likely to be minimal, if not zero. In our opinion, the QCA is incorrect to claim that such an increase could create a barrier to entry. In any case, to the extent that costs faced by all potential operators can be construed as barriers to entry, the opposite conclusion would hold on the Blackwater system where the greater use of electric infrastructure is likely to cause costs to be lowered.

Fourth, it is not clear why the QCA considers that the cost of entry for a diesel traction supplier in Goonyella is relevant. In addition to being the more expensive alternative, the entry of a diesel traction operator would reduce the efficiency of that network, and so it is not clear why removing this higher-cost possibility would somehow reduce the effectiveness of competition.

Barriers to entry increase with the sunk cost of entry, all else equal. Hence, it is relevant to ask what the sunk costs of entry would be for each form of traction. We understand from QRNN that the cost of entry per consist would be around $19.5m for electric locomotives[61] and $23.4m for diesel.[62] It is difficult to estimate how much of this cost would be sunk. Assuming that the DAAU is accepted, there will be an increasing demand for electric trains on Blackwater and Goonyella in the medium term. We understand from QRNN that there is also expected to be an increasing demand for diesel trains over the medium term. Hence, it is to be expected that these trains could be sold in the secondary market if a train operator exited the market. There does not appear to be any reason why the sunk costs of one form of locomotive would be substantially greater than that of the other.

Finally, it is worth noting that Pacific National began to supply rail haulage services in Goonyella using electric trains in 2009. This suggests that the barriers to entry for a new train operator with electric traction locomotives in the recent past were not insurmountable.

In our opinion, none of the reasons that the QCA cites as causes of increased barriers to entry or of reductions in competition between existing firms in the rail haulage markets stand up to close scrutiny. In contrast, the increased certainty that would be provided through the DAAU is more likely to reduce barriers to entry.

6.2. Locomotive supply

Narrow gauge electric and diesel traction locomotives both run on the Blackwater system, and, on this basis, the QCA concluded that they are substitutes and part of the same market.[63]

---

[61] Based on an estimate from QRNN that the cost of purchasing an electric locomotive is around $6.5m and there are three locomotives per consist.

[62] Based on an estimate from QRNN that the cost of purchasing a diesel locomotive is around $5.85m and there are four locomotives per consist.

[63] Draft Decision, p.33.

The QCA appears to define the geographic market (the geographic area within which there is close competition) as the Goonyella and Blackwater systems. It states that 'the market for narrow-gauge heavy-haul locomotives suitable for use in the Blackwater and Goonyella systems is concentrated'.[64]

The QCA concluded that the DAAU would restrict the choice of locomotive suppliers in Blackwater to only those supplying electric traction, and so it would reduce the competitive constraint faced by the supplier of electric locomotives.[65]

The electric trains used in Blackwater and Goonyella are narrow gauge trains. We understand from QRNN that there are some one-off engineering costs involved in a locomotive supplier adapting its trains for narrow gauges, but that any electric locomotive supplier could make these adjustments and begin supplying narrow gauge trains. Consistent with this, Toshiba offered to develop and supply narrow gauge electric locomotives to Australia in 2009.[66] Furthermore, it is not unusual for a locomotive supplier to alter its locomotives for a particular customer. For example, CNR designed and manufactured 12 locomotives for the Belarus railway,[67] and Bombardier designed and manufactured a new electric locomotive for iron ore mines in northern Sweden.[68] On this information, it seems safe to conclude that all electric train manufacturers will be in the same market.

We understand that electric locomotives are supplied by a number of firms from around the world. For example, Siemens imports locomotives into Australia, and Toshiba has offered to supply electric trains to Australia from Japan.[69] CNR, a Chinese firm, has also recently secured a contract to supply electric freight locomotives to Transnet in South Africa.[70] Furthermore, Toshiba has supplied railway systems from China, Japan and the USA to 20 countries covering each continent.[71] It follows that the market includes global suppliers of electric locomotives.

Siemens is the only current supplier of electric trains to Blackwater and Goonyella.[72] However, there are at least seven suppliers of electric trains globally including Bombadier,

---

64 *Ibid*.

65 *Ibid*.

66 United Group Limited/Toshiba, *Proposal to develop and supply prototype new generation electric locomotive*, April 2009, p.1. We also understand from CNR that it has an agent in Australia: CNR, *Presentation on China CNR Datong Electric Locomotive Co., Ltd.*, slide 22.

67 CNR, *Presentation on China CNR Datong Electric Locomotive Co., Ltd.*, slide 37.

68 Bombardier Transportation, *Electric locomotives in freight corridors*, January 2007, p.2. We also understand that the Bombardier trains under the TRAXX platform have been designed so as to be modular to allow for them to be adapted to different countries.

69 Siemens, *Submission to the QCA*, September 2012, p.2. United Group Limited/Toshiba, *Proposal to develop and supply prototype new generation electric locomotive*, April 2009, p.1.

70 Information on this contract is available at: http://www.chinadaily.com.cn/business/2012-09/11/content_15749048.htm, accessed 18 September 2012.

71 Toshiba, *Railway Systems Business Overview*, September 2012, slide 7.

72 Siemens, *Submission to the QCA*, September 2012, p.1.

Siemens, Alstrom, CNR, CSR, Toshiba/Hitachi and JST Transmash.[73] We understand that five of these major suppliers have recently submitted responses to a tender to provide heavy haul narrow gauge electric locomotives to Transnet in South Africa.[74]

The market for the global supply of electric trains consists of the supply of around 5000 locomotives per year.[75] The Blackwater system has around 80 locomotives running on it, implying that its annual requirement for new locomotives represents a relatively insignificant percentage of the global market.[76] It follows that it is implausible that the choice of locomotive in Blackwater could have a significant adverse effect on competition for the supply of electric locomotives. The QCA appears to have underestimated the existing competitive constraints on the supply of narrow gauge electric locomotives by Siemens. It follows that the QCA has overestimated the loss of the competitive constraint that would result if the suppliers of diesel locomotives did not compete directly with it in Blackwater.

6.3. Other markets

The DAAU may also have an effect on the seaborne coal supply and coal exploration markets since it will lead to a lower total cost to the supply chain. This may allow coal to be profitably explored in more areas of Queensland and for more coal to be supplied to the seaborne market. The DAAU would therefore have a positive effect on competition in these markets.

---

73 *Ibid*.

74 *Ibid*.

75 Toshiba, *Overview of Locomotive Market*, September 2012, p.3.

76 Information from QRNN suggests that there is currently around five diesel train consists and 19 electric train consists on the Blackwater system (excluding Minerva). This amounts to around 20 diesel locomotives and 57 electric locomotives.

7. Conclusion

The current regulatory arrangements are such that it may soon be profit enhancing for individual users to bypass the electric traction infrastructure and use diesel instead of electric traction. The pricing proposal set out in QRNN's DAAU is intended to increase the incentive to use electric traction by:

- reducing the price of electric traction relative to that of diesel traction, especially for users of the Blackwater system;
- removing the link between the traction choices of all users and the prices faced by any individual user; and
- imposing some of the costs of the Blackwater system on Goonyella system users to reflect the spillover benefits to Goonyella users.

The QCA appears to associate lower costs for the below rail function by itself with efficiency. In our opinion, the relevant definition of efficiency encompasses the effect of the DAAU on costs across the whole supply chain. This is because changes in costs beyond the below rail function affect the willingness to pay for one or other type of below rail service (allocative efficiency). QRNN's TCO analysis undertakes this assessment and finds that using electric traction is the most efficient if utilised by the substantial majority of users.

The QCA suggests that prices set by reference to the number of existing electric traction users (as now) are likely to result in more efficient outcomes. There are a number of reasons why such an approach is likely to lead to inefficient utilisation of diesel traction capability, including: economies of scale; the potential for strategic behaviour; the risk of asset bypass; externalities; and coordination failure.

The QCA has previously endorsed the approach of setting prices to ensure that that electric infrastructure is not bypassed, stating that:

> '…it is desirable if the use of [the electricity distribution network] is priced so as to remove the incentive for above-rail operators to bypass it. The Authority is also concerned to ensure that it avoids creating an incentive to bypass this infrastructure by requiring QR to levy a use of system charge that makes electricity an unattractive energy source relative to diesel.'[77]

It is not clear why the QCA no longer appears to support this approach.

The DAAU will also promote efficient investment in the below-rail assets because it will strengthen confidence in relation to the degree of regulatory support for efficient investment decisions.

The improvement in efficiency as a result of the DAAU is likely to promote effective competition in related markets by reducing haulage costs over the longer-term. There is no evidence that the DAAU would adversely affect competition. While any change in tariff structure will inevitably result in certain 'winners' and 'losers', there is no reason to suggest

---

77 QCA, *Draft Decision on QR's Draft Undertaking Volume 3 – Reference Tariffs*, December 2000, p.55.

that the DAAU proposals would be inconsistent with the price structure that would be adopted by a non-affiliated below-rail service provider.

In summary, we conclude that the DAAU is likely to increase the efficiency of prices and is consistent with the object of Part 5.

Report qualifications/assumptions and limiting conditions

This report is for the exclusive use of the NERA Economic Consulting client named herein. There are no third party beneficiaries with respect to this report, and NERA Economic Consulting does not accept any liability to any third party.

Information furnished by others, upon which all or portions of this report are based, is believed to be reliable but has not been independently verified, unless otherwise expressly indicated. Public information and industry and statistical data are from sources we deem to be reliable; however, we make no representation as to the accuracy or completeness of such information. The findings contained in this report may contain predictions based on current data and historical trends. Any such predictions are subject to inherent risks and uncertainties. NERA Economic Consulting accepts no responsibility for actual results or future events.

The opinions expressed in this report are valid only for the purpose stated herein and as of the date of this report. No obligation is assumed to revise this report to reflect changes, events or conditions, which occur subsequent to the date hereof.

All decisions in connection with the implementation or use of advice or recommendations contained in this report are the sole responsibility of the client. This report does not represent investment advice nor does it provide an opinion regarding the fairness of any transaction to any and all parties.

NERA
ECONOMIC CONSULTING

NERA Economic Consulting
Darling Park Tower 3
201 Sussex Street
Sydney NSW 2000
Tel: 61 2 8864 6500 Fax: 61 2 8864 6549
www.nera.com

NERA Australia Pty Ltd, ABN 34 092 959 665

sapere research group

Cost recovery options for electric infrastructure—Discussion Paper to QR Network

Mike Smart

25 September 2012

About the Author

Mike Smart is a director of Sapere Research Group in Sydney. He advises industry leaders in telecommunications, rail, gas, logistics, mining, electricity and aviation. Mike has given expert evidence in the Federal Court of Australia and the Australian Competition Tribunal. He is a member of the Competition and Consumer Committee of the Law Council of Australia and the Economics Society of Australia.

About Sapere Research Group Limited

Sapere Research Group is one of the largest expert consulting firms in Australasia and a leader in provision of independent economic, forensic accounting and public policy services. Sapere provides independent expert testimony, strategic advisory services, data analytics and other advice to Australasia's private sector corporate clients, major law firms, government agencies, and regulatory bodies.

For information on this report please contact:

Name:	Mike Smart
Telephone:	+61 292340210
Mobile:	+61 407246646
Email:	msmart@srgexpert.com

Table of Contents

1 Background

Access prices for the Goonyella and Blackwater systems include two tariff elements that are designed to recover QR Network's costs associated with providing electric traction energy to trains: AT5 and EC. The AT5 element is intended to recover the costs of electric infrastructure on the relevant line sections in those two systems. This infrastructure comprises the overhead wiring that delivers power to electric locomotives via their pantographs, the feeder stations and section huts that deliver power to the overhead wiring in their vicinity, and the custom-built power transmission infrastructure provided under contract to QR Network by Powerlink.

Electrification is relatively mature in the Goonyella system and nearly 100% of trains there use electric traction. In contrast, the capacity enhancements necessary to support greater electric utilisation in Blackwater have been made recently. As a consequence of historic constraints on the availability of electric capacity, utilisation of diesel traction has increased to almost 50% of available paths. Depending on the outcome of current haulage contract negotiations, it is possible that diesel traction's share of Blackwater hauls could increase or decrease in future.

Since 2009, QR Network has made substantial investments in power system upgrades for Blackwater. The QCA has pre-approved these investments for future inclusion in the Regulatory Asset Base following the stipulated customer voting procedure in QR Network's undertaking.

Over approximately the same time frame (from August 2008), Pacific National has entered the above-rail haulage market for Central Queensland coal in competition to QR National. Pacific National decided, in mid 2010, to order a relatively small number diesel locomotives[1], many of which have been or are intended to be used for its Blackwater customers' hauls. Pacific National appears not to have transitioned its Blackwater customers to electric traction (and re-deploy diesel locomotives to non-electrified corridors) following the 2009 pre-approval of the Blackwater power system upgrades and QR Network's consequent commitment to this investment.

---

1 Approximately 12 PN diesel locos versus over 75 QRN diesel locomotives currently in service on the Blackwater system

1.1 The cost recovery problem

These developments have created a potential cost recovery problem for QR Network's recent investments in the Blackwater electric infrastructure. AT5 is the only currently available tariff element with which to recover the investment cost. Diesel train operators have indicated a reluctance to contribute to the maintenance of the overhead power system (AT5) because they do not *currently* use the electric infrastructure. At current levels of diesel penetration in Blackwater, the cost recovery burden on remaining electric traction users is heavy and growing: where a fixed cost is distributed across a potentially increasingly narrow usage base.

I am instructed to assume that the point had already been reached by UT3 where a full cost-recovering level of AT5 would make electric traction uncompetitive with diesel traction. The tipping point in diesel penetration has already been reached. If nothing is done to rectify the situation then electric traction, which has the potential to be the least-cost supply option, could be driven out of the market.

It is important to recognise that this problem has come about through the low utilisation of electric traction in Blackwater in the context of significant capital investment, which has come about through matters of historical mis-pricing of access to the overhead power system and not any fundamental superiority of diesel to electric traction.

1.2 Objections to prior QR Network proposals

QR Network previously proposed the following amendments to the Access Undertaking to recover its recent investments in Blackwater electrification and to remove the pro-diesel bias in pricing:

1. Charge AT5 to diesel train operators in situations where an electric train could have been used;
2. Average the electric infrastructure costs across Goonyella and Blackwater systems so that a single combined AT5 applied to both;
3. Limit single year changes in the AT5 to reduce price volatility.

While the third of these amendments was not strongly criticised, the first two were. The gist of the complaints was as follows.

It was said that forcing diesel train operators to pay for electric traction infrastructure that they do not use necessarily involves a cross-subsidy from diesel train operators to electric train operators. Any cross subsidy could, among other things, create a potentially inefficient bias in the decision about whether to use diesel or electric traction.

It was said that averaging electrical infrastructure costs between the high utilisation, low cost Goonyella system and the lower utilisation, higher cost Blackwater system necessarily involves a cross-subsidy from Goonyella mines to Blackwater mines. As these mines compete against each other in seaborne export coal markets, any cross-subsidy could potentially have anticompetitive effects.

The QCA was not convinced by the arguments that were put forward by QR Network in support of these proposed arrangements.

2 Cost recovery options

2.1 Purpose of this report

QR Network has asked me to consider whether an alternative pricing proposal for the electric infrastructure would address the objections raised against its original proposal. I understand from QR Network that the purpose of this report will be to facilitate constructive engagement between the QCA, QR Network and industry on the way in which asset stranding of the Blackwater assets will be avoided. I note that the QCA has indicated that it does not intend on stranding QR Network's assets.

This proposal is one of several possible approaches to the cost recovery problem. Further, within this proposal, there are several variants, which each lead to somewhat different detailed pricing structures. An assessment as to whether this proposal better meets the requirements of the QCA Act than the original proposal is beyond the scope of this report. In this respect I express no opinion on the economic criticisms made of the first proposal.

The following subsection outlines the proposal. Section 2.2 explains the possible variants within this broad proposal, and section 2.3 briefly notes some of the other possible approaches.

2.2 Suggested approach

In broad terms, the proposal set out here is that a modest AT5 price be applied to the Blackwater system and that the remaining part of QR Network's recent Blackwater electrification investment be recovered from Blackwater mines through a lump sum electric traction availability charge that would be payable whether or not that mine uses electric locomotives. The remainder of this subsection explains the justification for this approach and sets out in more detail how it could be applied.

Appropriate AT5 level

First, the AT5 price must be specified. There are several possible choices, among which the prime candidates are:

1. AT5 = ($mtce_0$+cap_0) / $egtk_0$ —the AT5 that prevailed before the post-2009 investment;
2. current Goonyella AT5;
3. AT5 = ($mtce_0$+cap_0+$mtce_1$+cap_1) / max $egtk_1$ —the AT5 that would be calculated post-2009 if the maximum feasible utilisation of electric traction occurred;
4. AT5 set to make train operators completely indifferent between choice of diesel or electric traction if no locomotive investments are yet sunk;
5. AT5 = long-run marginal cost of the Blackwater electric infrastructure system.

Without wishing at this stage to be definitive, the third and fifth of these options appear to best meet the applicable criteria:

- Cost-reflective;
- Overcomes prior objections by QCA;
- Can be calculated accurately by QR Network.

Option 1 has no regard to the post-April 2009 investment or the business conditions surrounding it. Consequently, it would seem to be too far removed from the present reality to be useful. It is not reflective of current or future costs.

Option 2 has some merit inasmuch as it represents a rate that has some acceptance within a more broadly defined market. However, the use of this benchmark would invite further criticisms of the type levelled at the DAAU proposal. As the purpose of the present proposal is to overcome these objections, option 2 appears unsuitable.

Option 4 has much to recommend it on economic grounds. However, as a practical matter the network owner is unlikely to be in possession of sufficient factual data concerning above-rail economics to calculate this AT5 benchmark accurately. Obviously, an inaccurate calculation would risk distorting the energy source decision.

Option 3 is cost-reflective in that it represents the average cost price that would apply if the Blackwater electric infrastructure system were used to the maximum feasible extent. By pinning this calculation on the maximum feasible utilisation, rather than actual utilisation, the tipping point problems described in section 1.1 are avoided.

Option 5 is the first-best option in an economic sense. It would, in all likelihood, be significantly lower than any of the historic values of AT5 for Blackwater, even pre-April 2009. This may pose a barrier to acceptance by stakeholders as there would be, for example, a stark difference between the AT5 levels on Blackwater (lower) and Goonyella (higher) systems. For this reason Option 3 may be a more practical choice.

Interaction between annuity and Blackwater AT5

It is proposed that a Blackwater AT5 level based on one of the five methods outlined above—of which I argue that option 3 would be the most efficient and practical. The new annuity charge would recover that part of the capital and maintenance costs associated with the new investment that is not recovered through the AT5 tariff element.

The annuity and AT5 level would be determined together, using equation (1) below, to ensure that the combined revenue from these two elements approximately equals QR Network's prudent investment and maintenance costs for the electrical system in Blackwater in present value terms. If the adjustable annuity approach (explained below) were to be taken, then cost recovery would be exact.

QR Network's entitlement to recover investment

The investment in question is QR Network's Blackwater power system upgrade for which QCA pre-approval was received in April 2009. I have been instructed to proceed on the assumption that the intent of the parties (QR Network, QCA and a majority of the Blackwater miners) is that the Blackwater power system assets not be stranded. This assumption implies that QR Network is entitled to recover the prudent and efficient costs of meeting the pre-approved scope.

Blackwater mines on electrified lines benefit from this investment because it provides the option to use electric traction at any time in the future. A mine that currently uses diesel traction also benefits. The option to switch to electric traction gives them more bargaining power with diesel haulage providers.

No Goonyella payment of Blackwater costs

No Goonyella mines would be asked to contribute toward the Blackwater investment cost. This change addresses one of the QCA's objections to the prior QR Network proposals.

I note in passing that to the extent that: (a) some costs might be common between the Goonyella and Blackwater systems or (b) the electrification of the Blackwater system might create a positive externality for Goonyella miners, there would be an economic justification for some payment from Goonyella miners toward the

Blackwater system. An investigation of this possibility lies beyond the scope of this report, which does not rely on either of these points.

Electric traction availability charge

It is proposed that all Blackwater mines pay a contribution toward the capital cost of the 2009 pre-approved Blackwater electric investment, whether they are currently contracted to use diesel or electric traction[2]. This contribution would be called an electric traction availability charge to reflect the true nature of the benefit received by the mines.

Efficient lump-sum basis for charge

Each Blackwater mine's contribution would be determined as a lump sum. The total lump sum across all mines would be determined by applying the formula in equation (1) below. Let the subscript 0 refer to the situation pre-April 2009, and the subscript 1 refer to the situation post-the Blackwater electric investments that were pre-approved in April 2009.

$$\text{Lump sum} = PV\,[\,(opex_0+cap_0+opex_1+cap_1) - (AT5 * egtk_1)\,] \qquad (1)$$

In words, this lump sum represents the present value of the annual opex and capital costs of the electrical infrastructure on the Blackwater system (including old and new investments) less the revenues that would be achieved annually from applying the AT5 price to actual annual electric traction gtk. The opex includes Powerlink connection charges as well as QR Network's own maintenance and operational costs for the electric infrastructure.

A further issue arises because the future egtk is not known at the time the lump sum must be calculated. Here there are two options.

Pure lump sum

First, the future egtk could be guessed on the basis of a value, egtk,* which is observed at the relevant decision time. If this approach were taken, then QR Network would suffer a windfall loss if future egtk < egtk* but would experience a windfall gain if future egtk > egtk*.

---

2 It should be noted that QR Network has, in both the original DAAU and in subsequent correspondence with industry, offered transitional arrangements to access holders with pre-commitments to diesel traction. (where those assets cannot be re-deployed elsewhere).

Clearly, the selection of the egtk* level has the potential to be contentious. If the pure lump sum option is adopted, then the stakes would be high—any miscalculation would be locked in for a long time. One would expect that QR Network's preference would be for a relatively low value, while the preference of miners would be for a high value. If all parties cannot agree on a realistic likely future value, then the pure lump sum approach would probably be unworkable.

Adjustable lump sum

Second, the lump sum or its annuitized version could be adjusted annually to compensate for changes in egtk over time and ensure that QR Network recovers exactly its prudent and efficient investment cost. If this approach were taken, then the "lump sum" would not be a true lump sum. It would be affected by changes in usage over time. The effect of these changes would not necessarily be distorting, since the "lump sum" would increase when electric usage declines and vice versa, so that the sum of AT5 revenue and the adjustable lump sum would be constant.

Lump sum to be annuitised

Rather than paying QR Network the contribution as a lump sum, each mine's contribution would be converted to an annuity. The discount rate would be QR Network's regulatory WACC at the approval date. The term could be relatively long. It would not need to be as short as the regulatory period (as long as the mines' liability to pay it could be established through a binding ruling under the QCA Act). It need not be as short as a coal haulage contract, since the mine's liability to pay it is independent of its haulage arrangements. The main limitation on term is that it should not be so long that some mines might cease operating before the contribution is fully paid.

Several potential allocation methods to mines

The total system lump sum could be allocated among electrified Blackwater mines in several possible ways:

1. In proportion to approved mine output for the reference year;
2. In proportion to the mine's number of eligible votes in the pre-approval process;
3. In proportion to the mine's haulage distance to port across electrified track;
4. In proportion to ntk for the reference year, based on each mine's approved output and distance to port.

It is suggested that the choice among allocation methods be made after a consultation period with customers, mediated by the QCA.

Not a usage charge—minimal distortion to traction energy choice

Importantly, the annuity for each mine would not change as mine output changes and it would not be affected by the mine's decision about whether to use diesel or electric traction.[3] The annuity would therefore not be a usage charge. It would not affect usage decisions and it would not influence the choice between diesel and electric traction. The energy source decision would therefore be made on the basis of relative forward-looking costs.

If the alternative option were adopted and the "lump sum" were adjusted to compensate for changes over time in egtk, then the combination of the adjustable annuity and revenue from the AT5 tariff element would be constant.

Bearing in mind that the total lump sum (or, in this case the combination of the AT5 revenue and the adjustable lump sum) must be allocated among Blackwater mines, the question arises as to whether the allocations are constant over time. In section 2.1, I identified several possible allocation methods. Each of these methods referred to some measure of mine-specific output or usage of the rail network. However, the intention is that the allocations be performed once and for all at a specific reference date based on the snapshot at that date of the relevant output or usage indicator. Therefore, the allocations to specific mines would not change after that date, even though the relevant output or usage indicators might.

The process of adjusting the annuity to ensure electric infrastructure cost recovery over time would create a slight positive bias toward electric traction. This bias would occur because the usage-driven portion of overhead wiring costs(the LRMC) would be, in effect, removed from the energy source cost comparison. The smaller the LRMC as a proportion of total electric infrastructure costs, the smaller the distortion.

Whether the fixed or adjustable lump sum is adopted, the extent of diesel penetration in Blackwater would have virtually no effect on the cost-competitiveness of diesel and electric traction.

2.3 Variants within proposed approach

The foregoing discussion identified three points at which alternative options could be adopted within the overall framework of the proposed approach:

---

3 This is strictly true only if the annuity is based on a pre-determined estimate of egtk1 and not subsequently modified to prevent over and under-recoveries.

1. Method of determining AT5;
2. Whether annuity is fixed at the outset or is adjustable to ensure exact cost recovery; and
3. Alternative methods of allocating the investment cost recovery burden among Blackwater mines.

2.4 Other possible approaches

Obviously, other approaches to the cost recovery problem are available. Without intending to describe any of these in great detail here, one can sketch the broad outlines of some of these alternatives.

The difficulties of cost recovery are amplified by the inconvenient fact that the electric traction infrastructure is declared despite being vulnerable to bypass. It is in fact the bypass risk that prevents cost recovery through high levels of the AT5 tariff. It is arguable that continued regulation of a service is unwarranted where monopoly pricing is prevented by competition. Hypothetically, one approach to the cost-recovery problem for future investments would involve seeking to have the declaration of the electric traction systems of Blackwater and Goonyella revoked.

The focus in this report is on non-usage charges to recover the new investment cost. Among the alternative options, some form of usage charge may be able to be devised. It is fair to say that this topic has not yet been comprehensively examined. However, experience to date suggests the low likelihood that a usage charging system could be found that would simultaneously meet the criticisms set out at the beginning of this paper to (a) avoid cross-subsidy and (b) avoid pricing electric traction out of the market relative to the diesel alternative.

A final type of alternative approach would involve the network operator having the discretion to prioritise trains from which it obtains the greatest financial benefit. In effect, such an approach would balance out higher prices charged to electric trains with higher quality of service for those trains. A more thorough examination of this topic is outside the scope of this report.

3 Economic evaluation of options

3.1 QCA's previously expressed objections

The proposal that is explained in this report avoids the QCA's objections to the prior QR Network proposals in the following way.

Diesel train operators are able to fully pass-through the new Blackwater post-2009 electrical investment annuity to their end-customers, so the operator choice between diesel and electric traction would be based solely on the relative forward-looking marginal costs to them of operating each type of locomotive.

Blackwater mines do pay the annuity, whether they actually use electric traction or not, but they receive the benefit of electrical system availability, which has value to them whether they use electric traction or not. It is possible that the Blackwater mines might object that the amount of the annuity is out of proportion to the benefit that they achieve through electrical availability. However, if that has consistently been their view, one must wonder why they voted in favour of this investment in 2008, and then subsequently elected not to use the asset, thereby creating the need for the annuity.

Goonyella mines do not pay the new Blackwater annuity. There is, in fact, no change to the Goonyella AT5 prices resulting from this proposal.

3.2 Cross-subsidy

Cross-subsidy complaints were raised against QR Network's original proposals by customers and the QCA.

Cross subsidies create an equity problem and an allocative efficiency problem. The equity problem is that some customers (the cross-subsidisers) pay for a benefit that they do not receive. The allocative efficiency problem is that prices do not reflect cost causation. Therefore the price mechanism is prevented from leading economic actors toward employing resources in their highest-valued end use.

I have not been asked to consider whether or not QR Network's original proposal introduced problematic cross-subsidies.

That said, the new proposal, described in this report, cannot be regarded as introducing cross-system-subsidies. Goonyella AT5 prices are unaffected by this proposal. Diesel train operators do not pay the annuity (as it is a pass-through for them). While Blackwater mines do pay the annuity, they receive a benefit from it in the form of the availability of electric train service to their mine. The cost that sits behind the annuity, part of the post April 2009 investment in Blackwater power system upgrades, was *caused* by the majority decision of the Blackwater mines to ask QR Network to proceed with it.

3.3 Lump-sum to recover a portion of post April 2009 investment cost

Another aspect of the new proposal is to charge Blackwater mines an electric availability charge that is expressed as a lump sum. It is well known in economics that lump sum transfers do not distort usage decisions because they are unaffected by usage.

The fact that the lump sum is proposed to be converted to an equivalent annuity does not alter its efficiency properties. The annuity simply reflects extended payment terms for the lump sum. Each mine's liability to pay the lump sum is fixed at the outset, irrespective of their own future decisions on usage or on traction type.

If the adjustable annuity variant of this pricing approach is adopted, then usage would have some effect on the annuity. However, this usage effect would be exactly cancelled by corresponding changes to the AT5 revenue that would move in the opposite direction. In this case, the sum of the adjustable annuity and the AT5 revenue would be independent of usage.

3.4 Distorting the choice of traction energy

Concerns were expressed in the QCA Draft Decision that QR Network's original proposals might inefficiently distort the choices made by miners and haulage providers between diesel and electric traction.

It was said by most submitters that a preferable approach would be to set cost-reflective prices for both diesel and electric locomotive access and let the market determine a preferred traction type based on relative costs as prices evolve in the future.

An apparent attempt by QR Network to pre-determine the outcome of the traction energy debate was considered inappropriate. Some of the bases on which QR Network's preference for electric traction was argued were disputed by submitters.

Of course, allocative efficiency demands that long-run marginal costs,[4] or something approximating them, are used when pricing intermediate inputs such as access services. The problem with using an average cost method to determine AT5 is that as electrical market share diminishes, it becomes increasingly difficult for electric traction to compete with diesel. In other words, a loss of electrical market share can become a self-fulfilling forecast without any inefficiency in investment or operation by the asset owner.

The difficulty with marginal cost pricing for fixed-cost technology such as rail infrastructure is that the owner is forced to make a loss. The first-best solution to such a problem is to charge customers the long-run marginal cost as a usage charge, and to levy a lump sum availability charge to recover the revenue shortfall.

The new proposal closely approximates this ideal. The long-run marginal costs of electric traction, including some parts of the infrastructure maintenance and renewal cost and the electric fuel cost, are paid by electric train operators through the AT5 and EC prices.

The fixed (and sunk) electric infrastructure investment costs are removed from the operator's calculation through the proposed annuity method, payable by a Blackwater mine irrespective of its traction energy choice.

The train operator's forward-looking traction energy choice would then be made by comparing the cost per ntk for diesel locomotive ownership, maintenance and fuel on one hand and the cost per ntk for electric locomotive ownership, maintenance, fuel, and (long-run marginal costs of) electrical traction infrastructure on the other. This comparison is the one that allocative efficiency demands. It avoids the distorting complication of having to take into account the relative market shares of diesel and electric locomotives at various points in time.

---

4 Note that while short-run marginal costs for the electric infrastructure system may be small, the long-run marginal costs include provisions for the eventual renewal of all asset components that either (a) suffer damage from use or (b) were installed to meet growth in demand. Renewals that are independent of usage would not be included.

4 Worked example

The operation of the proposed approach can be illustrated with a worked example. Hypothetical values for the main variables are given in the table below.

	Pre-investment	Post-investment
Sum of annual costs (mtce + cap)	$10 m	$30 m
egtk	10 b	15 b
Max egtk	20 b	25 b
Mine 1 gtk	9 b	9 b
Mine 2 gtk	16 b	16 b

Pre-investment, the AT5 level would be $10 m / 10 b egtk = $1.00 / '000 egtk.

Post-investment, the AT5 level that would be derived under the assumption of maximum feasible electric traction utilisation would be $30 m / 25 b egtk = $1.20 / '000 egtk.

The annuitized lump sum electric traction availability charge would then be determined by equation (1):

Lump sum annuity = annuity(PV [$30 m – ($1.20 / '000 egtk * 15 b egtk)])

Assuming that the same discount rate[5] and term are used, the annuity of a present value of a constant stream of annual payments is simply the constant annual payment. Therefore,

Lump sum annuity = $30 m - $18 m = $12 m.

---

5 That is, excluding any risk premium associated with asset stranding risk, the normal treatment when calculating the weighted average cost of capital for regulated asset owners.

If allocated between mines in proportion to their gtk (irrespective of whether they are electric or diesel gtk), this lump sum annuity would result in annual electric traction availability charges of:

Mine 1 = $12 m * 9 b / (9 b + 16 b) = $4.32 m

Mine 2 = $12 m * 16 b / (9 b + 16 b) = $7.68 m.

Turning to consider how this price structure would impact on a mine's choice between diesel and electric traction, make the following additional numerical assumptions:

	Diesel	Electric
Fuel cost ($ / '000 gtk)	10	3
AT5 ($ / '000 gtk)	0	1.20
Locomotive ownership cost, incl. maintenance ($ / '000 gtk)	30	25
Total cost of locomotive ownership and operation ($ / '000 gtk)	40	29.5

Mine 1's choice between diesel and electric traction would then be based on the following comparison:

Cost diesel = 9 b gtk * $40 / '000 gtk + $4.32 m = $364.32 m

Cost electric = 9 b gtk * $29.5 / '000 gtk + $4.32 m = $269.82 m

Mine 2's choice would be based on the following comparison:

Cost diesel = 16 b gtk * $40 / '000 gtk + $7.68 m = $647.68 m

Cost electric = 16 b gtk * $29.5 / '000 gtk + $7.68 m = $479.68 m

In both cases, electric traction would be preferred, given the superior fuel and ownership cost characteristics of electric locomotives that were assumed in this example. The assumed level of AT5 is small enough so as not to influence the choice that would be indicated by the fuel and ownership cost comparison. The level of the electric traction availability charge does not affect the comparison at all, since it is paid irrespective of the chosen locomotive type.

Turn finally to consider how these results might change under the following assumptions that are in line with the status quo:

- egtk = 5% of gtk (i.e., 95% diesel penetration);
- no electric traction availability charge (lump sum annuity forced to zero).

AT5 would be = $30 m / (5% of 25 b gtk) = $24 / '000 egtk.

Cost diesel = $40 / ' 000 gtk

Cost electric = ($3 + $24 + $25) / ' 000 gtk = $52 / ' 000 gtk

In this scenario, the low penetration of electric traction results in a highly unfavourable relative cost. This type of pricing structure would virtually force the universal adoption of diesel traction over time, and prevent the attainment of the lowest cost supply option (electric traction at high penetration).

What is proposed in this report (namely a competitive AT5 and a lump sum electric traction availability charge) would not mandate the use of electric traction. Rather it would simply provide mines with undistorted pricing signals that would permit the market to solve for the lowest cost supply option.

5 Practical implementation

If the proposed approach were to be adopted, several implementation questions would need to be resolved. First, choices would need to be made on the optional variants within the overall proposal, namely:

1. Method of determining AT5;
2. Whether annuity is fixed at the outset or is adjustable to ensure exact cost recovery; and
3. Alternative methods of allocating the investment cost recovery burden among Blackwater mines.

It would then be necessary to amend the Blackwater AT5 price to reflect these choices.

Most significantly, a new tariff element would need to be introduced to the access pricing structure to accommodate the electric traction availability charge. This charge would be specific to each Blackwater mine and would need to be calculated in line with equation (1) (for the total lump sum annuity), and then allocated among mines according to the chosen rule.

It is necessary to make the electric availability charge part of the reference tariff structure so that above-rail operators can pass it through to the mines. Otherwise it may not be possible for operators to pass through the lump sum annuity directly to the relevant mines.

The long-term nature of the recovery process for these Blackwater power supply system investments implies that the need for recovery will extend over more than one regulatory period. For this reason it is preferable to seek to have this new tariff element in a binding ruling by the QCA, rather than rely on the vaguaries of the undertaking process which involves a review at each reset.

Finally, the question arises as to whether the lump sum annuity idea should also be applied to future electric infrastructure investments in the Goonyella, Moura, or Newlands systems. While this could conceivably be done, there are good reasons to believe that the circumstances giving rise to this cost recovery need for Blackwater are historically unique. These unique features include the first instance in Queensland history of an above-rail competitor to QR, and the unexpected decision of that competitor to eschew electric traction for diesel. In light of these points, it may not be necessary to replicate the lump sum annuity concept for future investments in the other coal systems.

6 Conclusions

A new method of recovering QR Network's electric infrastructure costs is proposed for discussion with industry. Several optional variants to this method were outlined. Among these variants the following option is preferred on economic grounds:

1. AT5 would be set to recover the Blackwater electric infrastructure cost base if electric utilisation were equal to the maximum feasible utilisation;
2. The adjustable annuity option, discussed above, is preferred as it avoids under- or over-recovery of electric system costs by QR Network. While there will be some distortion of pricing signals through the adjustment process, this will be a second-order effect;

Allocation of the lump sum among Blackwater mines does not affect efficiency, as long as the allocations are not so extreme as to affect the viability of some mines.

As efficiency is not affected, the allocation decision should be resolved after a consultative process with stakeholders.

The method was tested against a range of pertinent economic issues and found to be efficiency-enhancing. This method would overcome the cross-subsidy complaints of stakeholders that were raised in response to QR Network's earlier proposals. Some practical implementation issues were briefly addressed.

References

Queensland Competition Authority. Draft Decision: QR Network Electric Traction Services Draft Amending Access Undertaking. July 2012.

Network RUS:
Electrification Strategy

Draft for Consultation

May 2009

Network Rail

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.

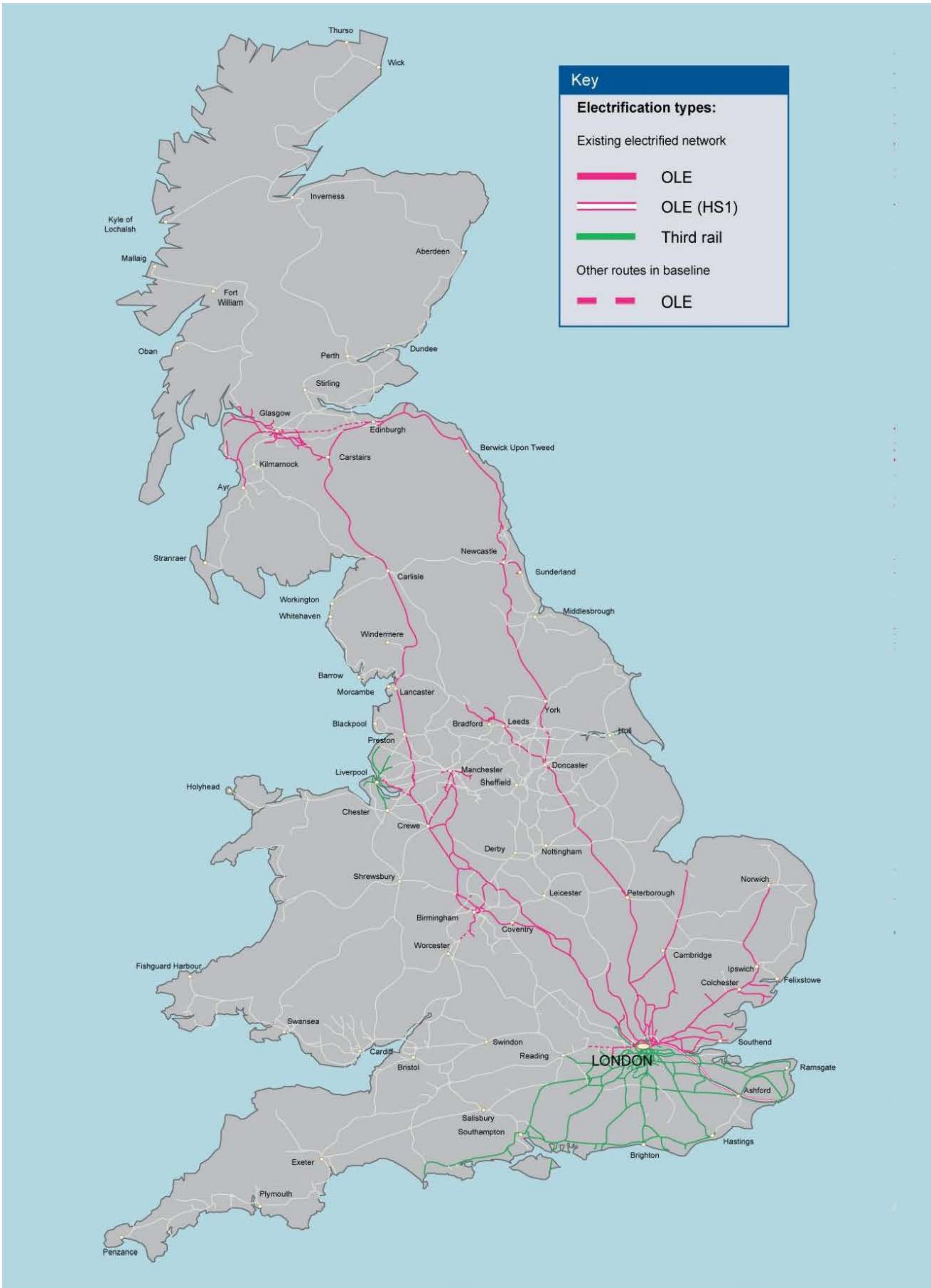
The baselining also assumes that the Great Western Main Line between Airport Junction and Maidenhead will be electrified under the Crossrail project.

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

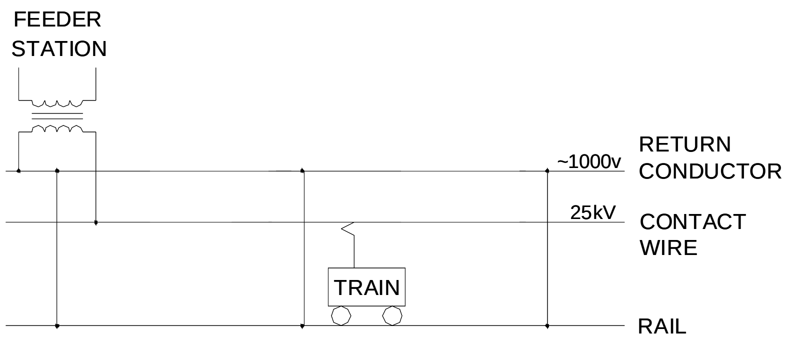
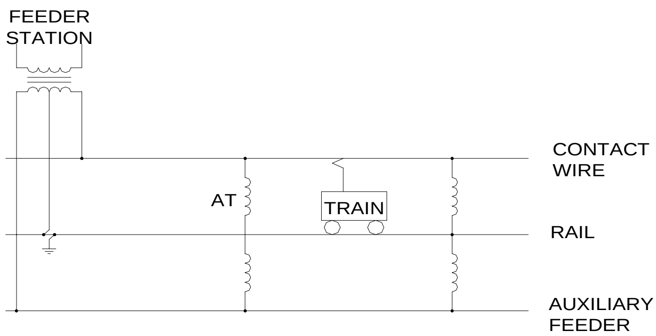


Figure 3.3 Autotransformer System



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.

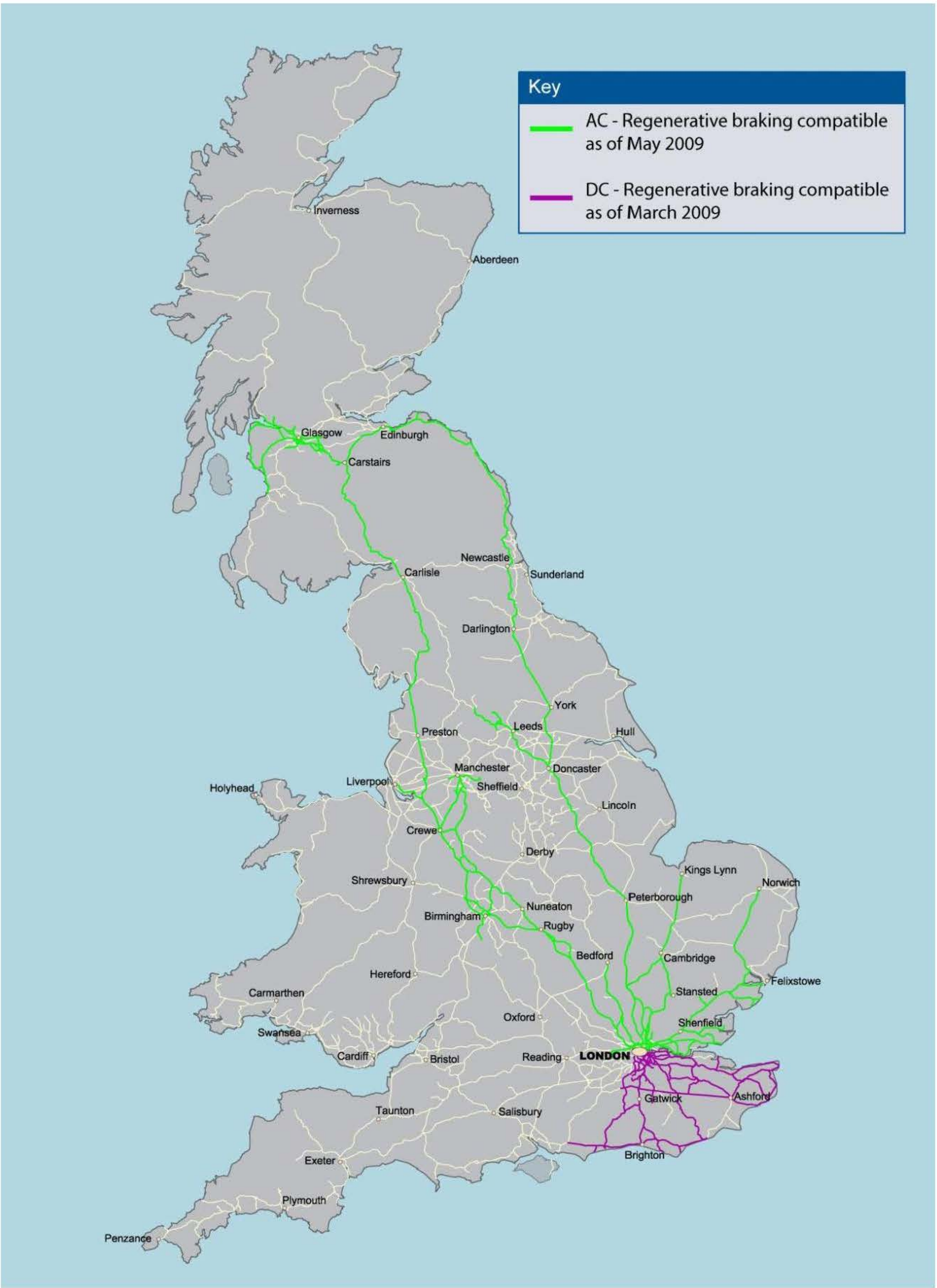
The overhead line system is generally the first choice used for new electrification schemes, with the exception of infill schemes in areas already equipped with the third rail system.

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

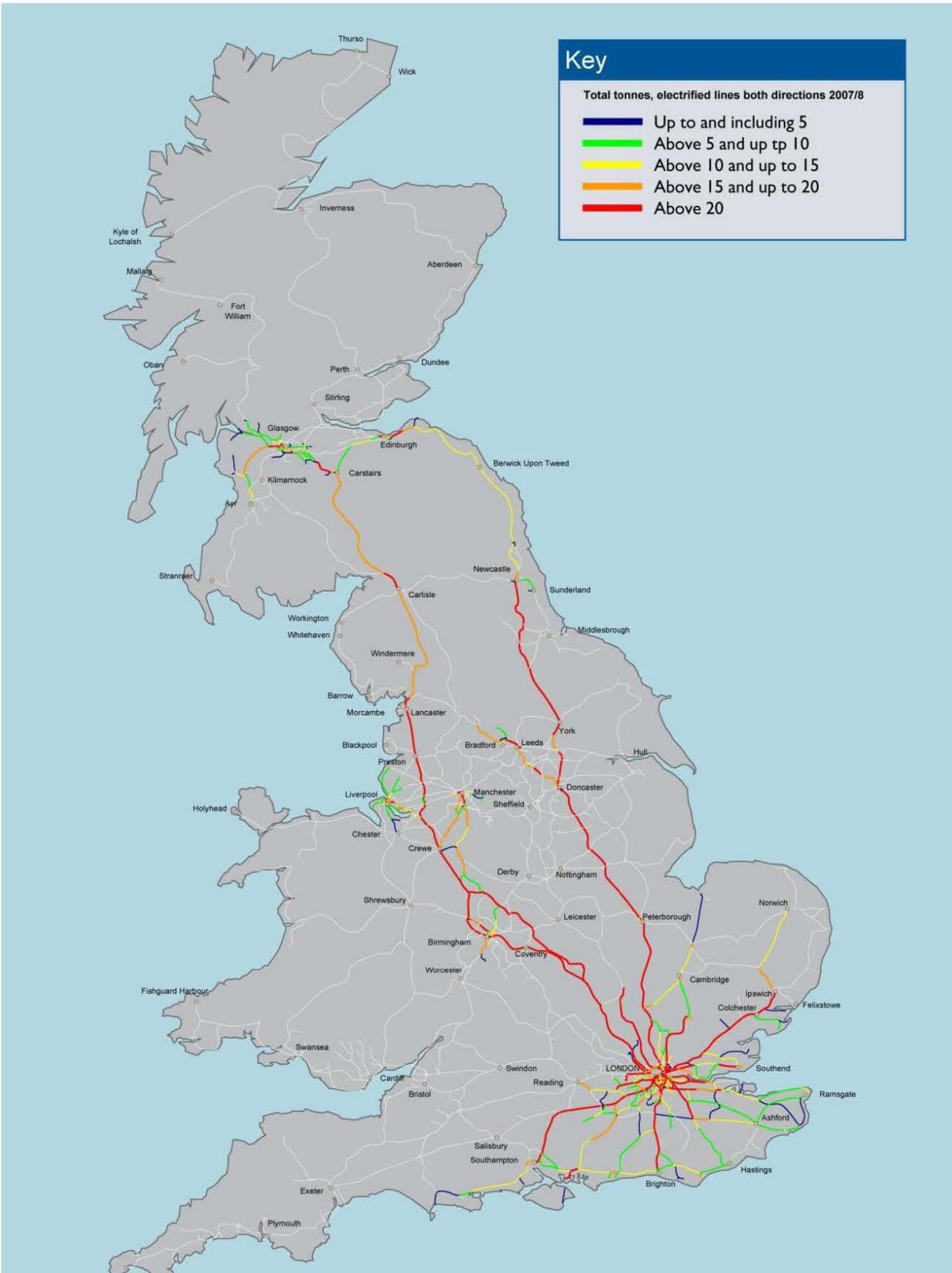
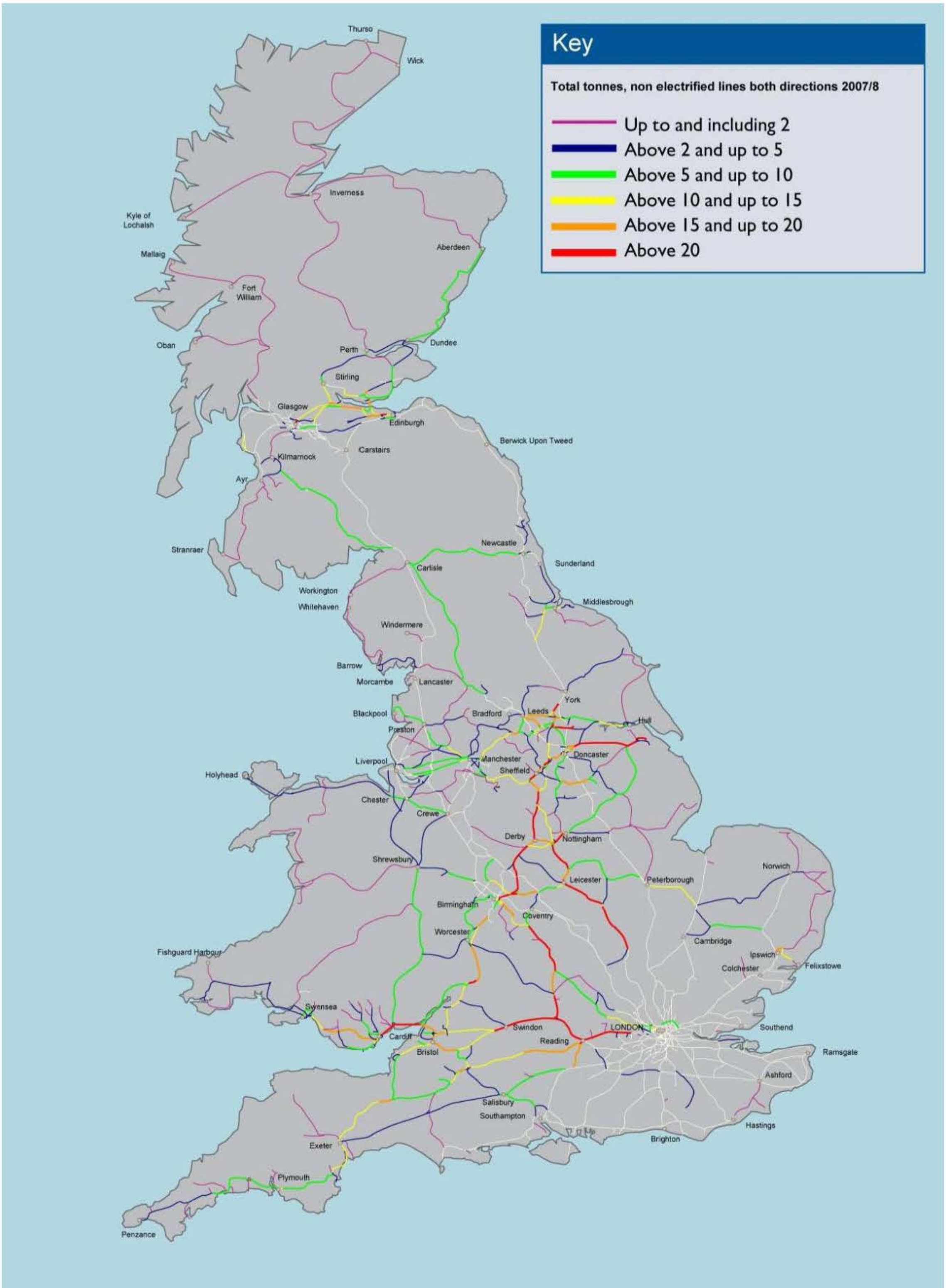


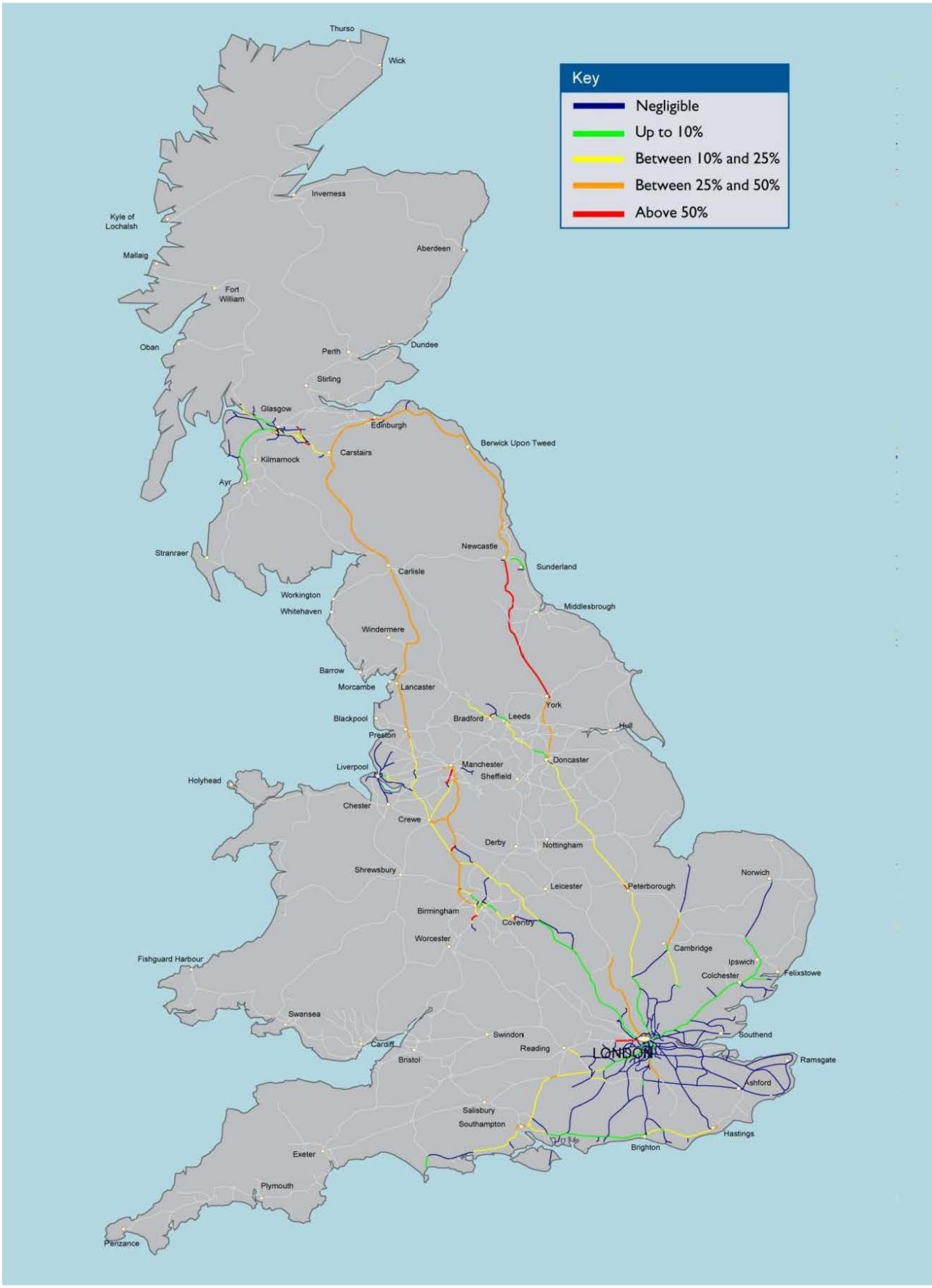
Figure 3.6 Tonnage carried on the unelectrified network 2007/08



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

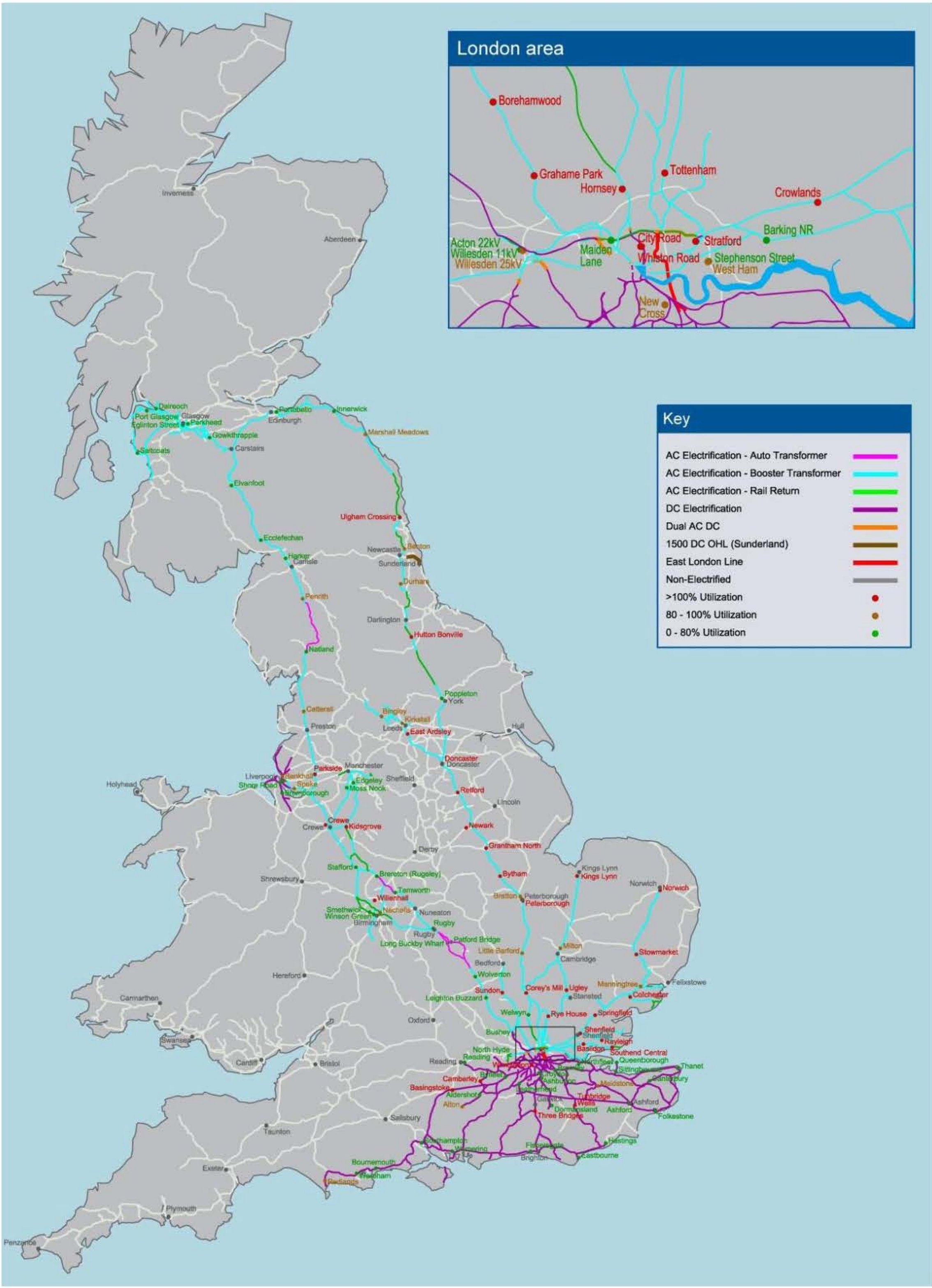


3.3 Power supply on the existing network

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

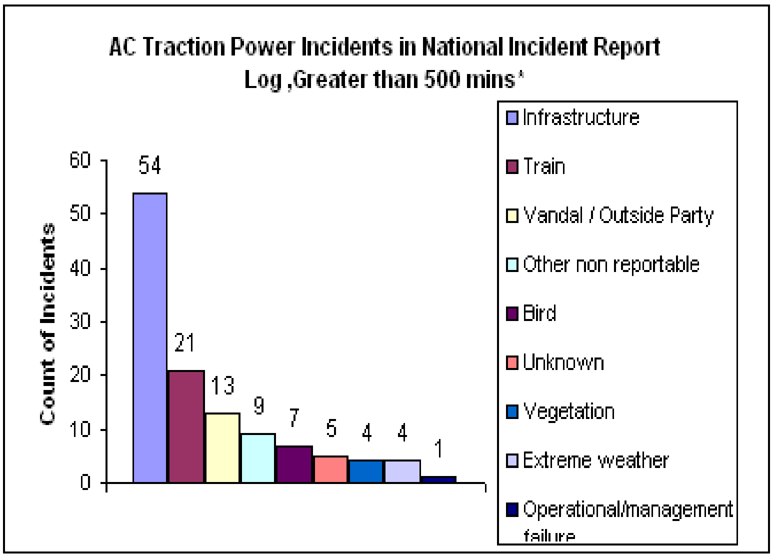
	Typical value for diesel vehicle	Typical value for electric vehicle
Carbon dioxide per vehicle mile	2,100g	1,664g
Source Atkins report T633, 2007 published by RSSB		

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

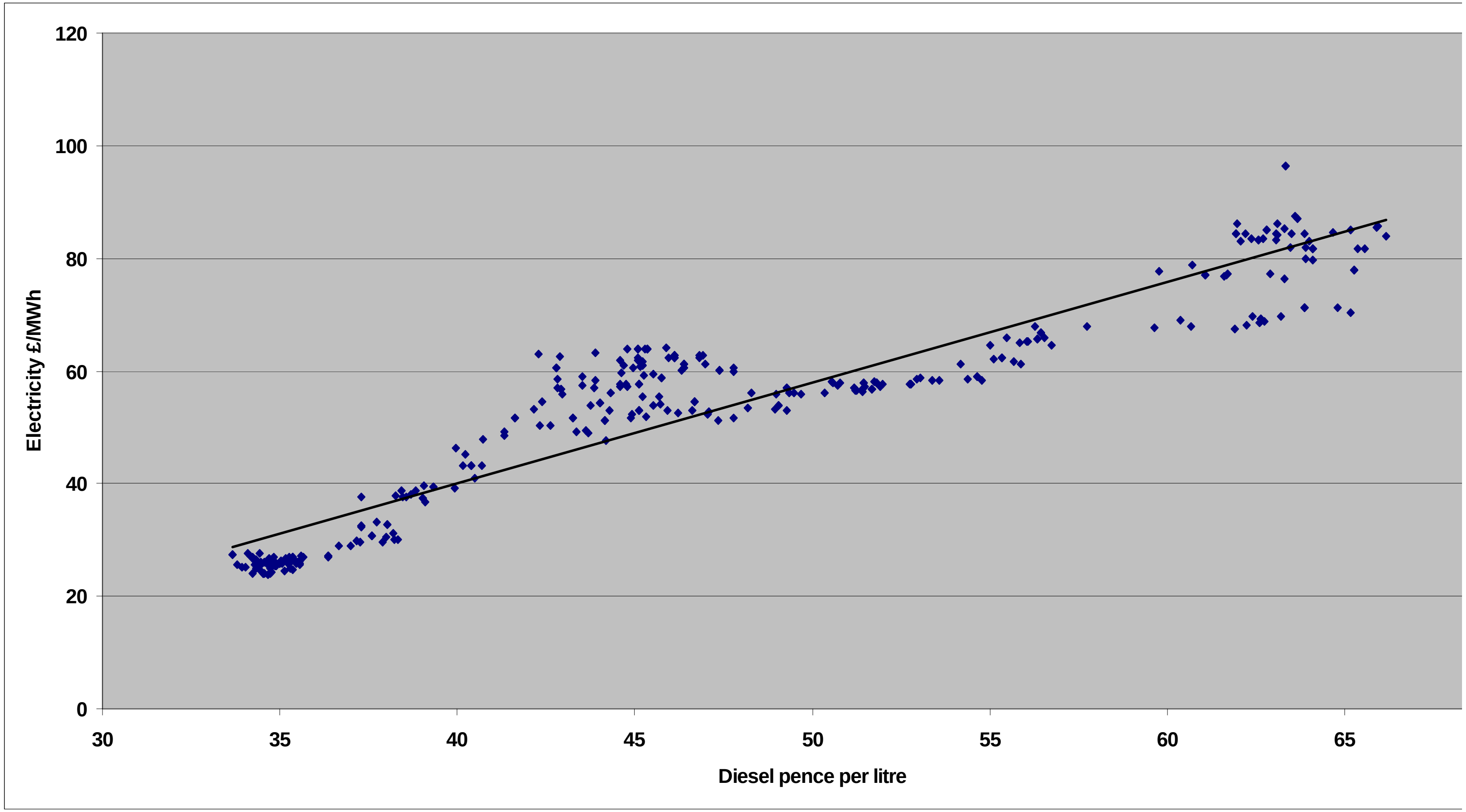
Further electrification has the potential to reduce whole industry costs of operating the railway. The size of the potential savings is directly related to the volumes of traffic which could operate over the converted railway and as such, these savings are greater as the traffic levels grow.

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.

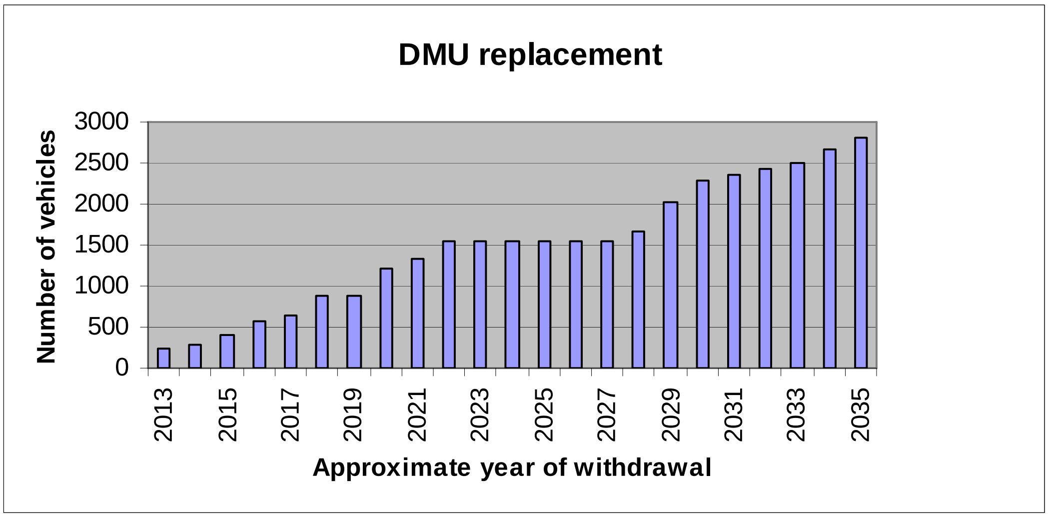
4.3 Passenger rolling stock replacement

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

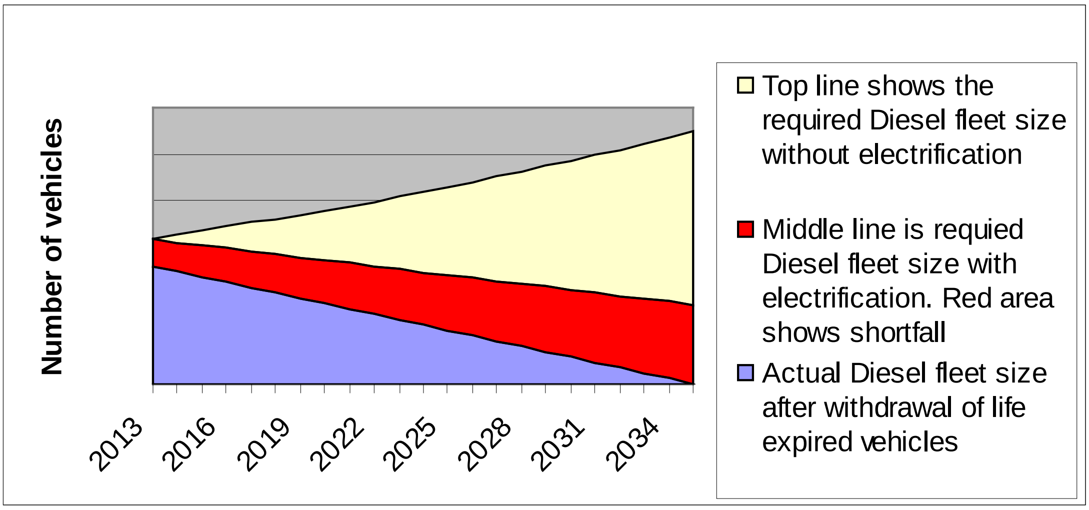


The timing of rolling stock replacement and the procurement of new rolling stock to accommodate growth affects the economic case for further electrification and *vice versa*.

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.

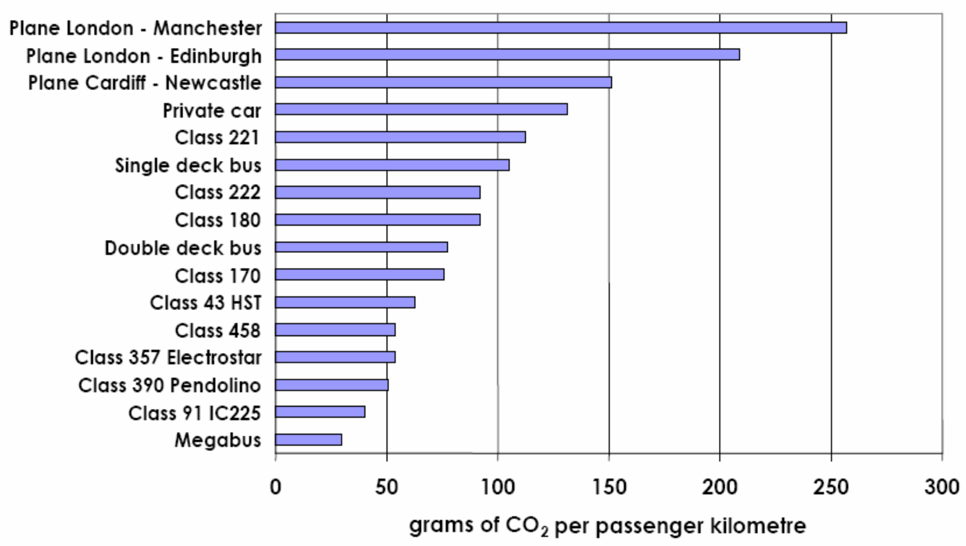
Electrification also reduces the need to transport fuel.

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

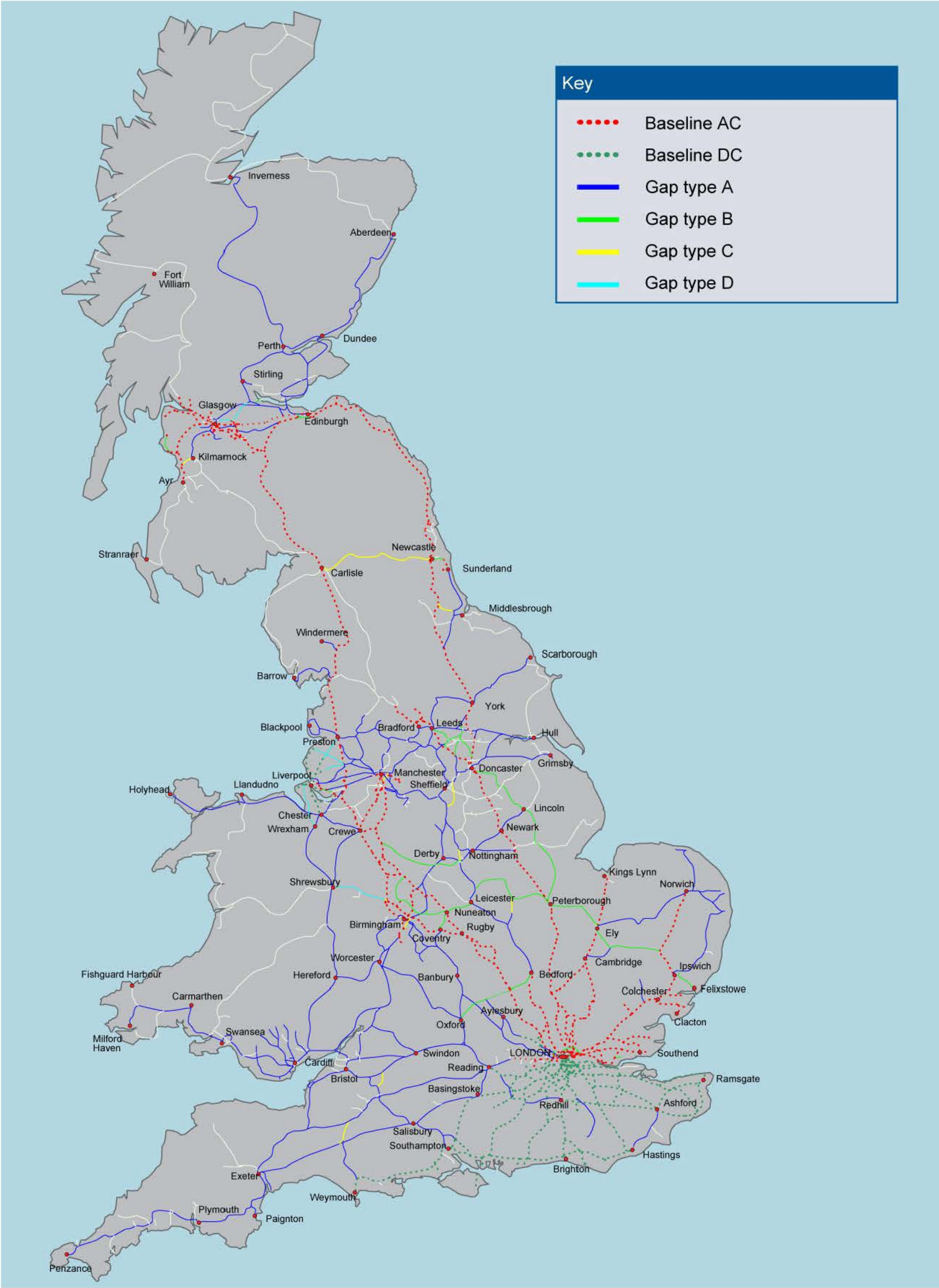


Table 5.1 List of Type A Gaps: Electrification primarily to enable efficient operation of passenger services					
Gap Number	**Gap name**	**Efficient operation of passenger service**	**Efficient operation of freight service**	**Provision of diversionary route**	**New passenger service opportunity**
A1.1	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 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 A11.3	**Thorne Junction (Hatfield and Stainforth) to Cleethorpes**
Option A10.11 Electrify Doncaster to Gilberdyke following Doncaster to Sheffield and Leeds to Hull. Convert Sheffield to Hull service to electric traction.	
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.	
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.	
Gap A10.3	**Leeds to Manchester via Calder Valley**
Option A10.3 Electrify Leeds to Manchester via Calder Valley. Convert Leeds to Manchester via Calder Valley service to electric traction.	
Gap A10.4	**Wakefield Westgate to Thornhill LNW Junction (Mirfield) and Heaton Lodge Junction / Bradley Junction to Milner Royd Junction / Dryclough Junction (Halifax)**
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.	
Gap A11.1	**Newark Northgate to Lincoln**
Option A11.1 Electrify Newark Northgate to Lincoln. Convert projected London to Lincoln service to electric traction.	
Gap A11.4	**Meadowhall to Horbury Junction via Barnsley**
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.	
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.	
Gap A12.1	**Bristol to Plymouth and Paignton**
Gap A12.2	**Reading to Cogload Junction (Taunton)**

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 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 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.	
Option A20.5b Electrify Edge Hill to Wigan following Preston to Blackpool North. Convert Liverpool to Wigan and Blackpool North services to electric traction.	
Gap A20.6	**Manchester South Suburban (Ashburys to New Mills and Rose Hill Marple to Hyde Junction)**
Option A20.6 Electrify Ashburys to New Mills and Rose Hill Marple to Hyde Junction. Convert Manchester South Suburban services to electric traction.	
Gap A20.7	**Manchester to Liverpool (Hunts Cross to Trafford Park)**
Option A20.7 Electrify Manchester to Liverpool (Hunts Cross to Trafford Park.) Convert Manchester to Liverpool via Warrington service to electric traction.	
Gap A20.8	**Kirkham and Wesham to Blackpool South**
Gap A23.2	**Preston to Hall Royd Junction**
Gap A23.4	**Rose Grove to Colne**
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.	
Gap A20.9	**Bolton to Clitheroe**
Option A20.9 Electrify Bolton to Clitheroe following Euxton Junction to Manchester. Convert Manchester to Blackburn and Clitheroe service to electric traction.	
Gap A20.10	**Hazel Grove to Buxton**
Option A20.10 Electrify Hazel Grove to Buxton. Convert Manchester to Buxton service to electric traction.	
Gap A22.1	**Crewe to Chester**
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	
Gap A22.2	**Chester to Acton Grange Junction (Warrington)**

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

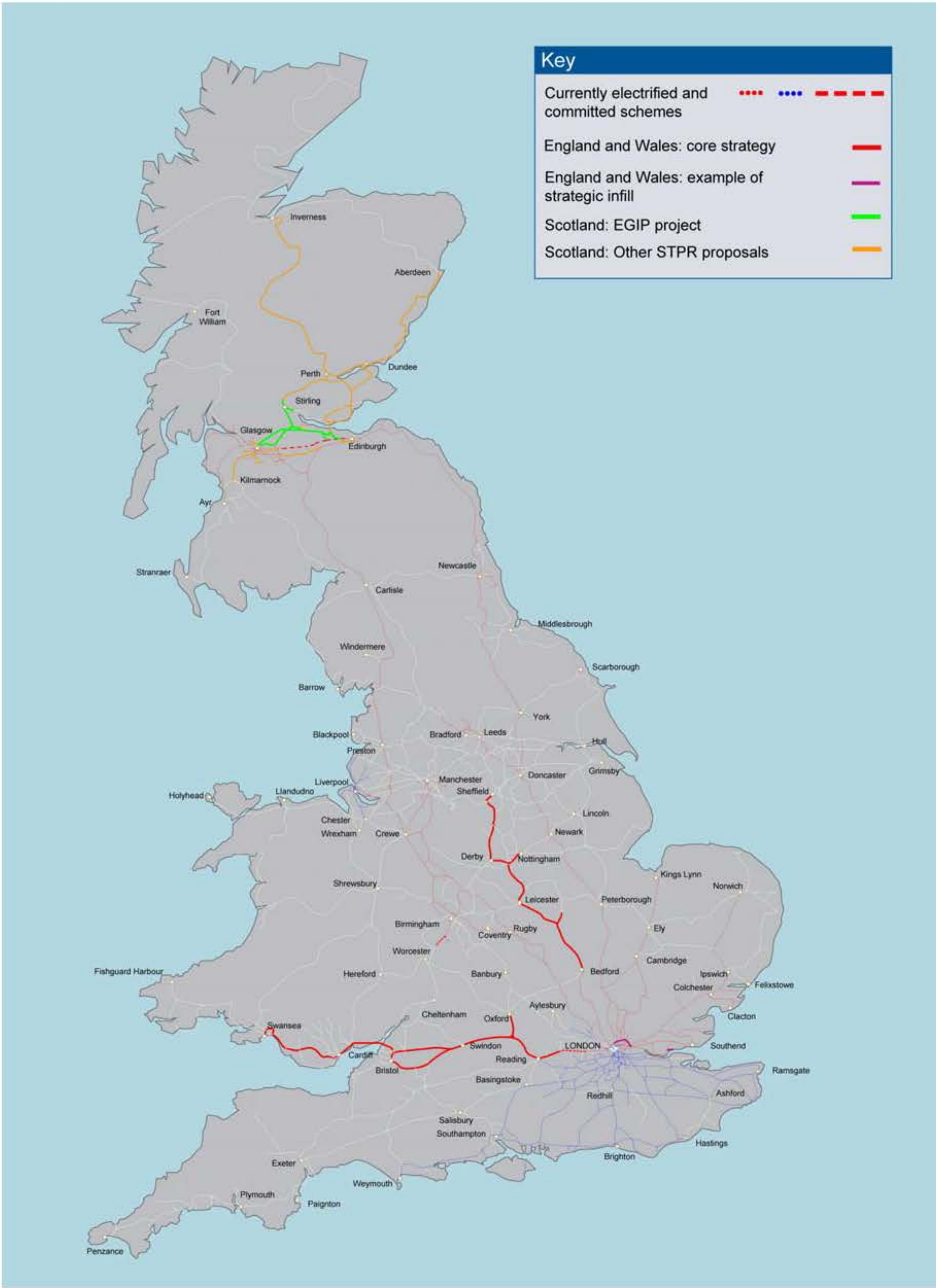


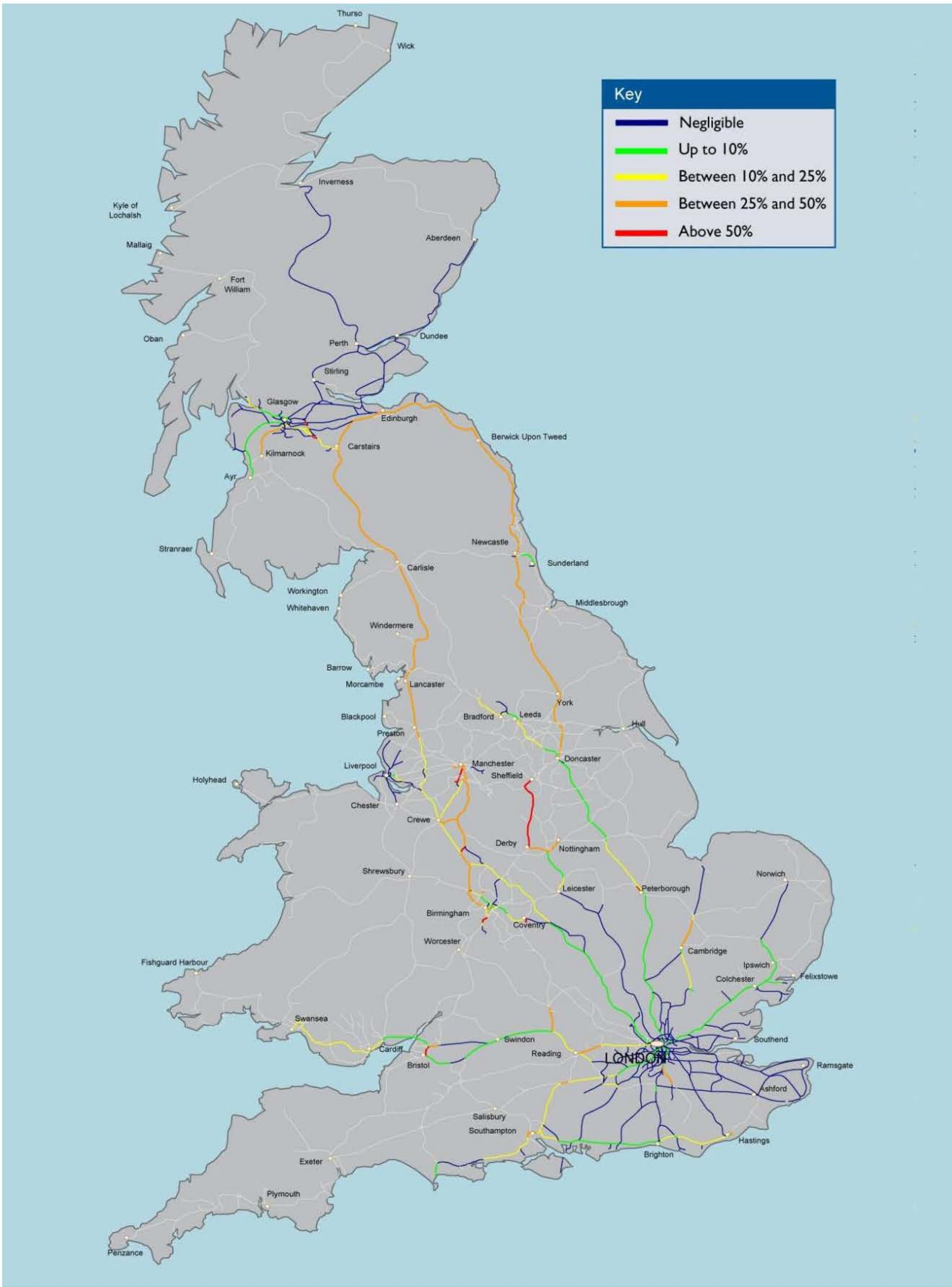
Table 7.5 Reduction in carbon released per year resulting from the strategy	
Option	Reduction in carbon released per annum (tonnes)
England and Wales Core Strategy	20600
EGIP project	2500
STPR proposals	4800

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

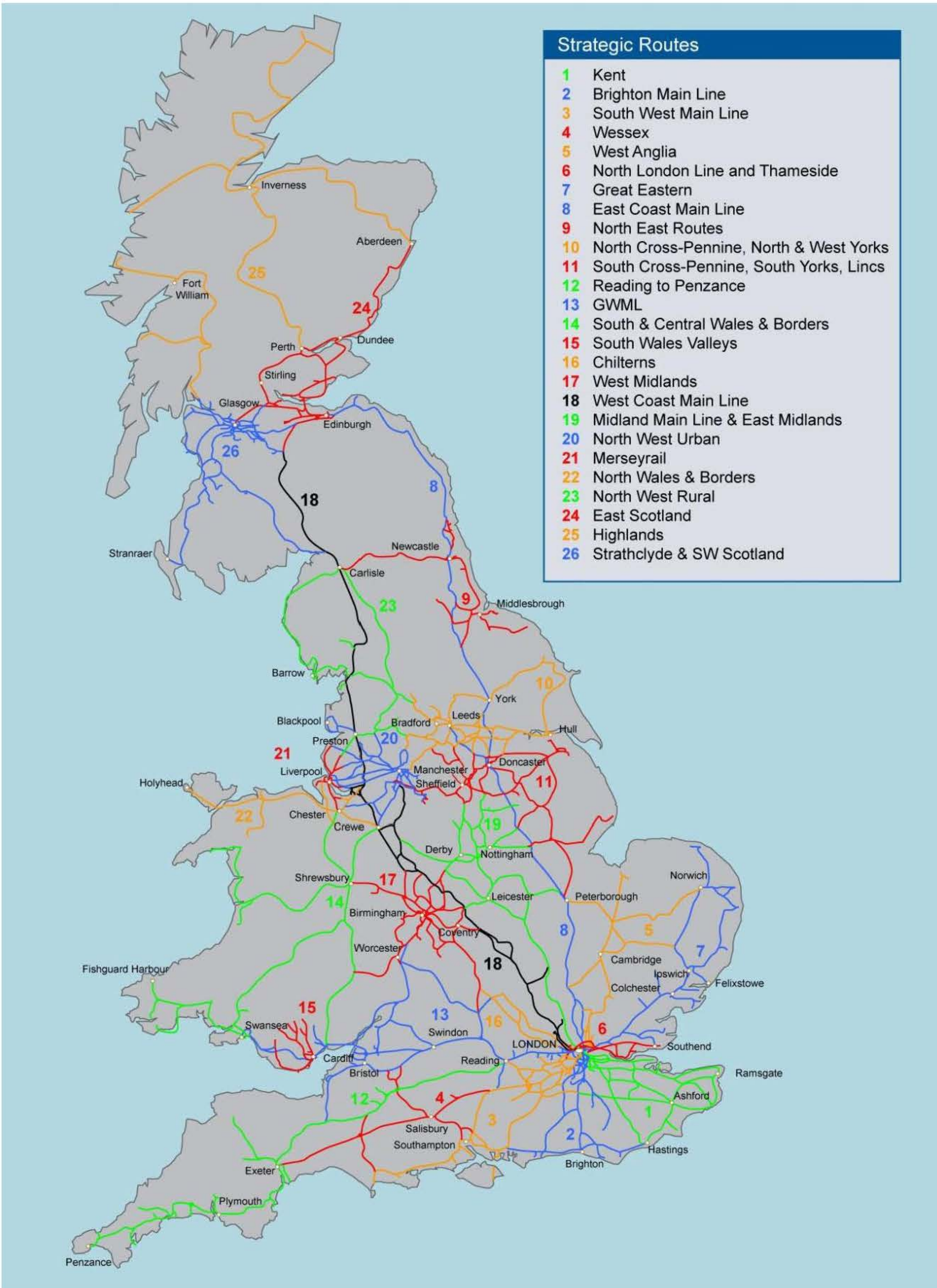
Network RUS Consultation Response
National RUS Manager
Network Rail
Kings Place
4th Floor, Section O
London
N1 9AG

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

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

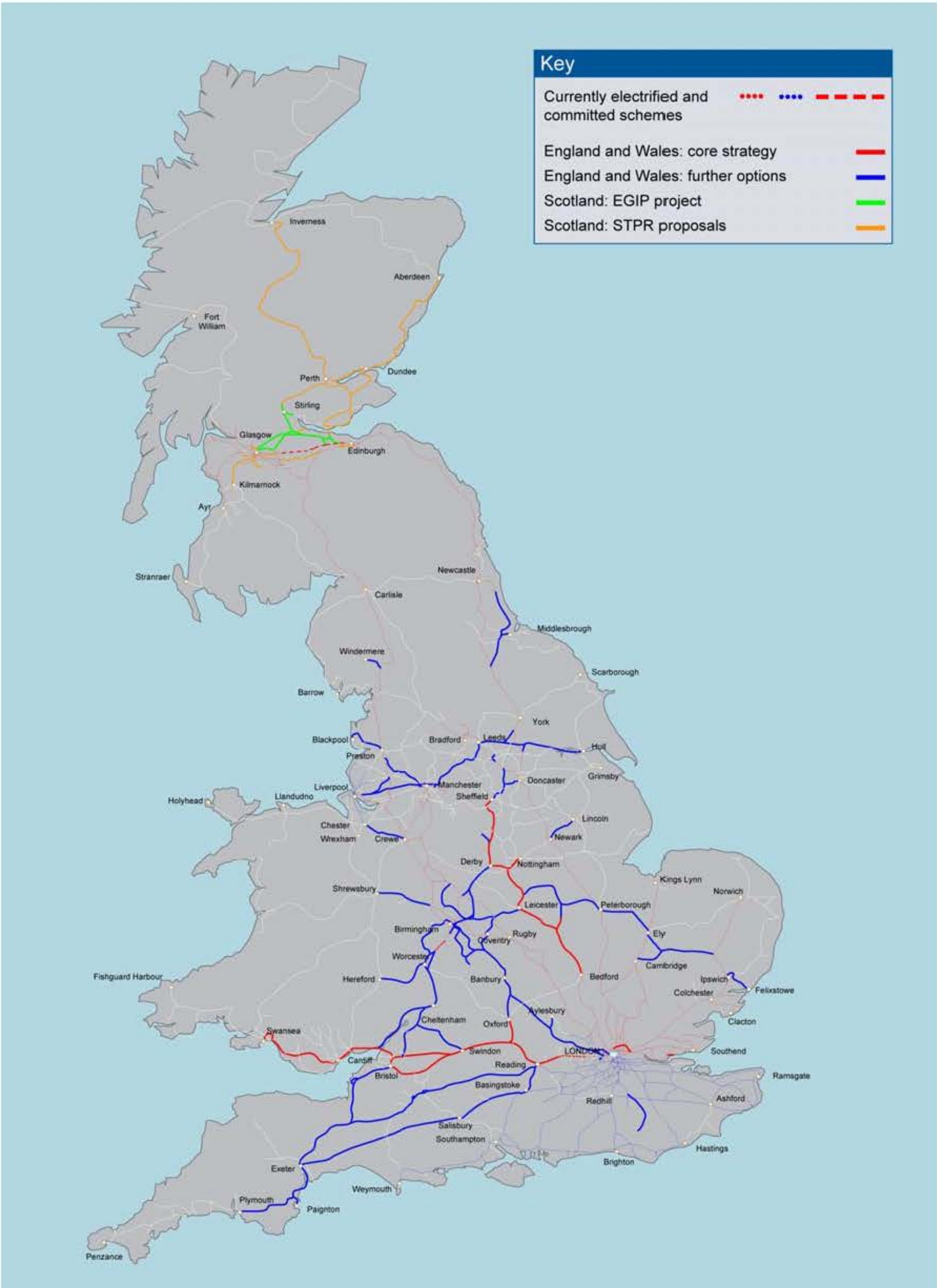
Appendix 6b Further options: Midland delivery unit	
Option	Scheme
A19.3	Ambergate to Matlock
A20.4	Manchester Deansgate to Liverpool (Edge Hill) via Chat Moss route.
B18.2	Ditton yard to terminal
A10.1b	North cross Pennine: Guide Bridge to Leeds, Leeds to Colton Junction and Hull, Northallerton to Middlesbrough 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

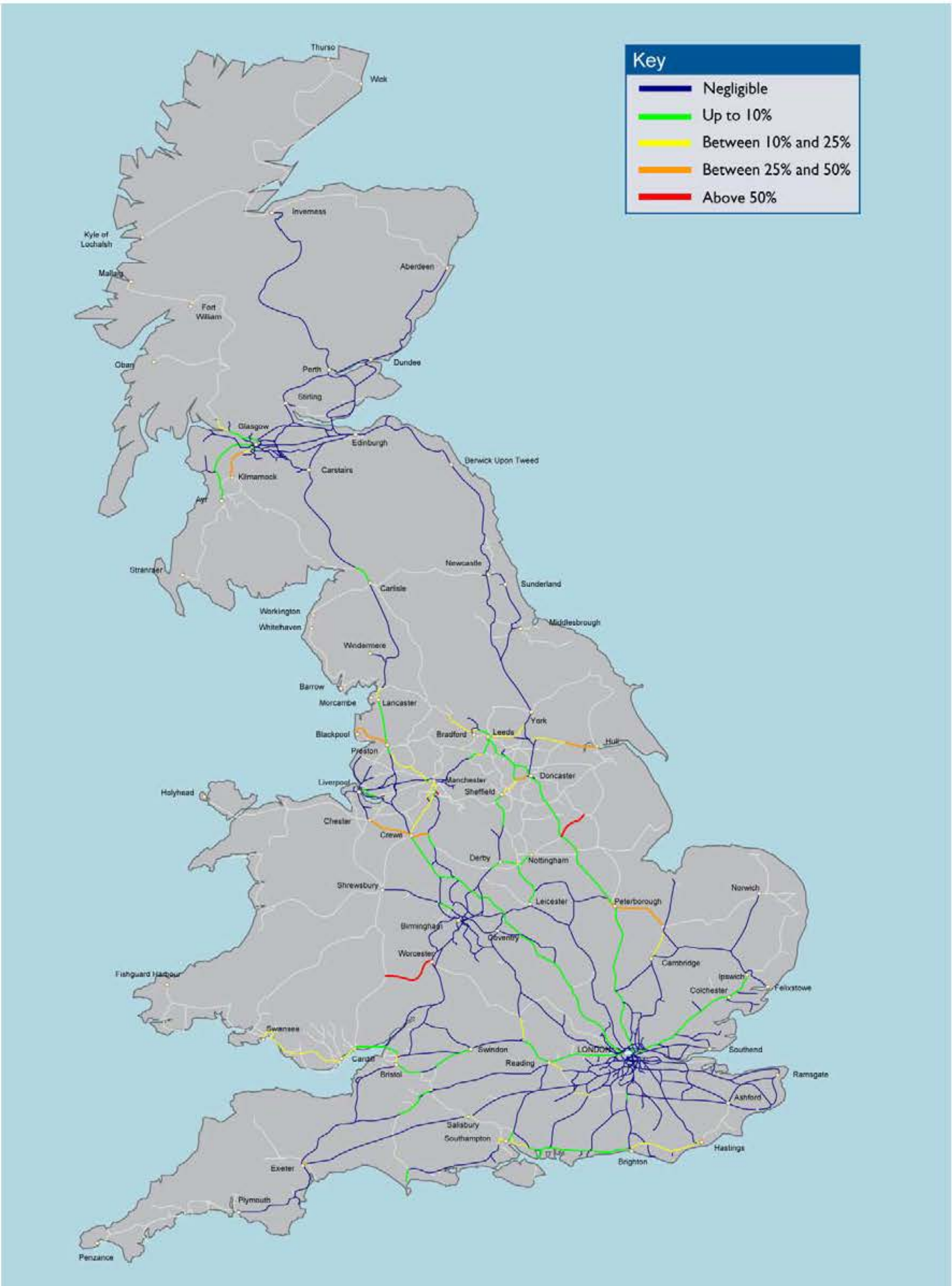
Appendix 7

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



Department for
Transport

Britain's Transport Infrastructure
Rail Electrification



July 2009

Department for Transport

Britain's Transport Infrastructure

Rail Electrification

July 2009

While the Department for Transport (DfT) has made every effort to ensure the information in this document is accurate, DfT does not guarantee the accuracy, completeness or usefulness of that information and it cannot accept liability for any loss or damages of any kind resulting from reliance on the information or guidance this document contains.

DfT has actively considered the needs of blind and partially sighted people in accessing this document. The text will be made available in full on the Department's website in accordance with the W3C's Web Content Accessibility Guidelines. The text may be freely downloaded and translated by individuals or organisations for conversion into other accessible formats. If you have other needs in this regard please contact the Department.

Department for Transport
Great Minster House
76 Marsham Street
London SW1P 4DR
Telephone 020 7944 8300
Website www.dft.gov.uk

© Crown copyright 2009.

Copyright in the typographical arrangement rests with the Crown.

This publication, excluding logos, may be reproduced free of charge in any format or medium for non-commercial research, private study or for internal circulation within an organisation. This is subject to it being reproduced accurately and not used in a misleading context. The copyright source of the material must be acknowledged and the title of the publication specified.

For any other use of this material, apply for a Click-Use Licence at www.opsi.gov.uk/click-use/index.htm, or by e-mail licensing@opsi.x.gsi.gov.uk

To order further copies contact:
DfT Publications
Tel: 0300 123 1102
E-mail: dftinf@capita.co.uk

ISBN 978-1-84864-018-4

A Welsh-language summary of this document is available on request.
Please quote ISBN 978-1-84864-022-1.

Cover photo acknowledgements
Alamy

Printed in Great Britain July 2009
on paper containing at least 75% recycled fibre.

recycle

Contents

Foreword

1. A modern railway system is vital to preparing Britain for the future. The Government has decided to embark on a major £1.1bn programme of rail electrification as an integral part of its rail modernisation[1] and carbon reduction[2] strategies. Work will begin immediately on the electrification of the Great Western Main Line between London, Reading, Oxford, Newbury, Bristol, Cardiff and Swansea, to be completed within eight years. In parallel, planning will begin immediately for the electrification of the line between Liverpool and Manchester, to be completed within four years.

2. The Great Western Main Line is the longest non-electrified intercity route in Britain, of vital national strategic importance to both England and Wales. It also includes heavily used commuter lines into London. Electrification will enable the introduction of a predominantly electric high-speed train fleet. These trains will offer faster journey times, more seats, greater reliability, improved air quality and lower carbon emissions than their diesel equivalents, as well as being cheaper to buy, operate and maintain.

3. The electrification of the line from Liverpool to Manchester will allow the introduction of a fast electric service with a journey time of around 30 minutes, compared to a fastest journey time of around 45 minutes today. It will also enable operation of electric train services from Manchester Airport and Manchester Piccadilly to Glasgow and Edinburgh along the West Coast Main Line. As on Great Western, electrification will enable the introduction of modern electric trains which provide a better service for passengers than the more expensive diesel trains which would otherwise be needed to increase capacity on these key routes.

4. The Great Western electrification project will complement the £16bn construction of Crossrail, which will extend electric train services from Essex and the new east-west tunnel through central London to Slough, Heathrow and Maidenhead on the Great Western Main Line by 2017. With electrification now to be extended to Reading, it would be possible for Crossrail to operate to Reading, rather than Maidenhead, from the outset, and this option will now be considered by the Government and Transport

1 Delivering a Sustainable Railway, July 2007, Department for Transport http://www.dft.gov.uk/about/strategy/whitepapers/whitepapercm7176/hitepapersustainablerailway1.pdf

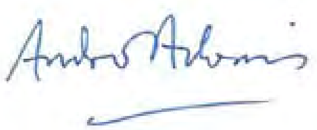
2 Low Carbon Transport: A Greener Future, July 2009, Department for Transport http://www.dft.gov.uk/pgr/sustainable/carbonreduction/

for London. It will also make it easier to improve rail access to Heathrow from the West. Great Western electrification will be integrated with a wider set of enhancements, including the £425m upgrade of Reading station, the installation of in-cab signalling equipment and the introduction of the new Super Express train as the successor to the diesel-powered Intercity 125. The Super Express train will now be predominantly electric powered on the London to Swansea line.

5. Further work is ongoing to assess the detailed costs and benefits of electrification on other routes. The rail industry recently published for consultation its *Network Route Utilisation Strategy: Electrification*[3]. The Government will carefully consider the costs and benefits of wider electrification, with particular reference to the Midland Main Line between London and Derby, Nottingham and Sheffield, as well as the routes between Manchester and Preston, and Liverpool and Preston.

6. As with other rail investments, the cost of electrification will be funded by Network Rail and supported by the Government. Over the medium term this £1.1bn investment in electrification will be self-financing, paying for itself through lower train maintenance, leasing and operating costs. This means that this investment can take place without reducing already planned infrastructure enhancement work.

7. This electrification programme radically affects the requirements for train rolling stock over the next decade. In particular, there will be far less need for diesel trains and a greater requirement for electric trains. The Government will publish a new rolling stock plan in the autumn, taking account of these changed circumstances.



Rt. Hon. Andrew Adonis
Secretary of State for Transport
July 2009

3 Network RUS: Electrification Strategy (Draft for Consultation), May 2009, Network Rail
http://www.networkrail.co.uk/

1 The case for electrification

A railway for the 21st century

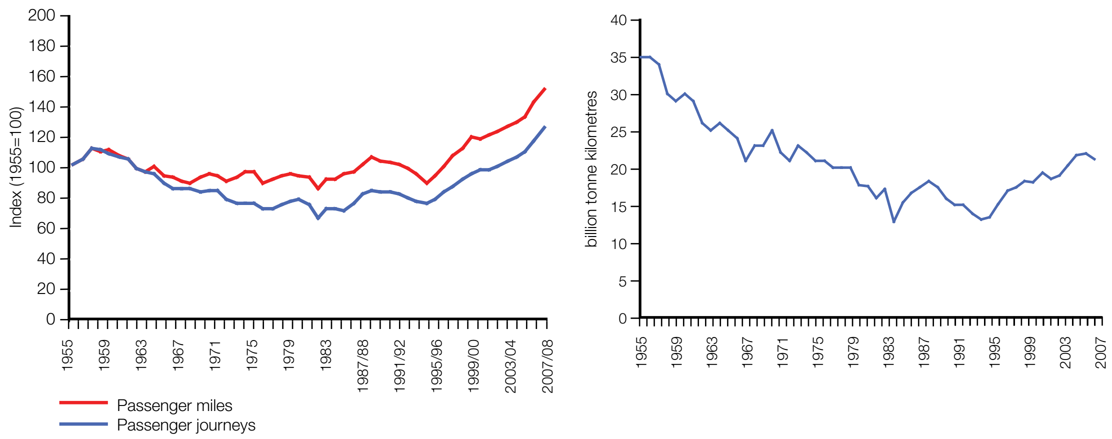
8. The technology powering Britain's railways has changed significantly since the first public railway – the horse-drawn Surrey Iron Railway – opened in 1803. Coal-fired steam trains dominated for more than a century before being overtaken by diesel and electric trains. We now have a network where around 60% of passenger journeys[4] are made on electric trains.

9. The last major electrification on the existing network was that of the East Coast Main Line in the late 1980s. While further routes were considered at the time, investment was constrained and other projects were considered to be a higher priority.

10. Rail privatisation in the 1990s wrought major upheaval in the industry, and the Hatfield accident in 2000 highlighted significant under-investment in basic infrastructure. For most of this decade our railways have focused on making good this backlog and improving the punctuality and reliability of passenger services, backed by huge Government investment (now £4bn a year, up from £2bn in 1997). As a result, performance has reached record levels. We now have a national rail network carrying more passengers than at any time since 1946. Infrastructure modernisation is also advancing, with the completion of major projects including the West Coast Main Line upgrade and High Speed One.

4 Measured by passenger miles.

Figure 1: National rail passenger journeys and miles, and domestic UK goods moved by rail (1955–2007/08)



Source: Transport Statistics Great Britain 2008.

11. The Government is committed to a further programme of modernisation and investment, to meet projected increases in demand, to promote a shift to rail from other modes of transport, and to give Britain world-class infrastructure. The £5.5bn Thameslink project will provide extra capacity and new services to and through London from Bedfordshire, Hertfordshire, Surrey and Sussex. Work has also started on Crossrail, a £16bn project for a new east-west link across London, including a new underground tunnel, which will relieve congestion on the national railway and on the London Underground. And in January 2009 the Government commissioned High Speed Two to evaluate the case for an entirely new high-speed line from London to Scotland, starting with route planning from London to the West Midlands, which is by far the most capacity-constrained section of the West Coast Main Line.

12. Electrification has a central role to play in the next phase of rail modernisation. Electric trains have a number of significant advantages over diesel-powered trains. They have far lower running costs, far lower carbon emissions and offer better environmental performance; they can also increase capacity and reliability, and provide a better passenger experience.

Cutting costs

13. Electric trains are over 35% cheaper to operate than diesels.[5] They require less maintenance and have considerably lower energy costs since electricity is a significantly cheaper fuel than diesel. They are lighter and so do less damage to the track. Although there are additional costs involved in maintaining electrification infrastructure, these are significantly outweighed by the train operating cost savings.

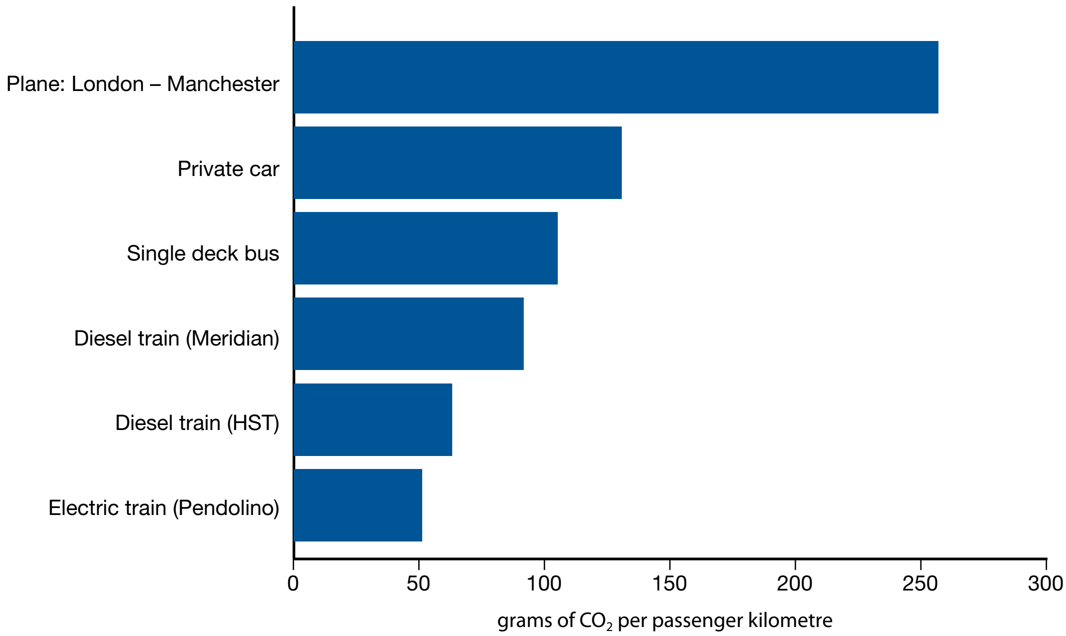
5 Network RUS: Electrification Strategy (Draft for Consultation), May 2009, Network Rail http://www.networkrail.co.uk/.

14. Electric trains are generally cheaper to buy than diesel trains, reflected in lease costs which are typically around 20% lower. This relative advantage is set to increase: engines for diesel trains are likely to become more expensive following the introduction of stricter EU emissions standards from 2012. The engines required by these standards are likely to be heavier, larger and more complicated as a result of the emissions control technology required.

Reducing environmental impacts

15. Rail electrification is an important part of the Department's carbon strategy. Electric trains generally perform better than equivalent diesel vehicles even on the basis of the current electricity generation mix. Typically an electric train emits 20–35% less carbon per passenger mile than a diesel train. This advantage will increase over time as our power generation mix becomes less carbon intensive. Figure 2 compares the relative carbon performance of different modes of transport, assuming average load factors.[6]

Figure 2: Carbon emissions by transport mode



16. The roll-out of regenerative braking enables many electric trains to re-use the energy that would otherwise have been lost when braking, by converting the energy of motion back into electricity. Electric trains have zero emissions at the point of use, which is of particular benefit for air quality in pollution 'hot-spots' such as city centres and mainline stations. Electrification reduces rail's reliance on imported diesel fuel. Electric trains are quieter than diesel trains, and virtually silent when waiting at stations.

6 Traction Energy Metrics by Prof Roger Kemp, 2007, RSSB
www.rssb.co.uk/pdf/reports/research/T618_traction-energy-metrics_final.pdf

Increasing capacity

17. The past decade has seen sustained growth in rail travel. So an ongoing challenge for the railway is to find cost-effective ways of providing more capacity. Electric trains can provide additional carrying capacity compared to a diesel train of the same overall length. Diesel high-speed trains are unable to carry many people in the power cars at either end of the train because of the space taken up by the diesel engines. This is not the case for electric trains.

Improving reliability

18. Experience from around the world shows that a well designed, constructed and maintained electric railway will be more reliable than a diesel railway. This is because the higher reliability of electric trains more than offsets any failures from the additional electrification infrastructure. Industry figures (see Table 1) demonstrate that electric trains have a significant advantage over diesels in terms of how far they travel before a technical problem delays the train. An electric intercity train will travel more than 40% further than an equivalent diesel train before such a failure, and an electric commuter train will travel well over twice as far. This reflects the fact that electric trains are inherently simpler with fewer moving parts to go wrong.

Table 1: Reliability of diesel and electric intercity and commuter trains, expressed as the average distance (miles) between failures which delay the train by at least 5 minutes.[7]

	Diesel	Electric	Improvement factor
Intercity trains	11,800	16,571	1.4
Commuter/regional trains	12,880	30,209	2.3

The passenger experience

19. From a passenger perspective, electric trains offer improved comfort through reduced cabin noise and vibration. Although modern diesel multiple units are better in this respect than older designs, there is still a significant difference. Under-floor diesel engines can need high floors which result in a cramped passenger cabin.

20. Electric trains can offer a higher power to weight ratio than diesels, resulting in better acceleration and reduced journey times.

7 NFRIP Period 9 2008/09 report.

The way forward

21. For all these reasons, the Government has decided to pursue a major programme of rail electrification.

22. Inevitably electrification makes most sense on busier routes where the cost of installing new infrastructure can be offset by large ongoing savings from running electric trains. Network Rail's draft *Network Route Utilisation Strategy: Electrification* was published in May 2009. We have carefully studied Network Rail's proposals, alongside our own detailed analysis. It is this work which has led us to prioritise two routes – Liverpool to Manchester and the Great Western Main Line.

23. Electrification of a key Liverpool to Manchester route will significantly reduce operating costs, cut journey times between the two cities and allow the operation of electric trains from Manchester to Scotland. It will also provide a diversionary route for electric trains on the West Coast Main Line to and from Liverpool and Manchester, reducing disruption and increasing service resilience. Electric train services will be able to operate within four years.

24. The case for electrifying the Great Western Main Line is founded not only on financial efficiencies from running electric trains, but also the potential to integrate electrification with other important projects already planned. The north-south London Thameslink project relies on the purchase of new electric rolling stock with uniform operating characteristics to enable 24 trains per hour to pass in rapid succession through the central London section. A large pool of good-quality existing electric rolling stock will therefore become surplus by 2016. Fully modernised, some of these electric commuter trains can be cost-effectively deployed on commuter services on an electrified Great Western Main Line, as well as on services between Liverpool and Manchester once that route has been electrified, rather than standing idle. The Super Express Programme, which is already underway, will provide the necessary new electric trains for intercity services.

25. In addition to these rolling stock considerations, important infrastructure works are scheduled on the Great Western Main Line itself. Crossrail will provide electrification from London to Maidenhead. Network Rail is currently planning a number of signalling renewal projects, linked to the plan to install in-cab signalling (the European Rail Traffic Management System) on the route. And the £425m Reading Station Area Redevelopment Project is designed to provide additional train capacity to enable better train performance and a reduction in delays.

26. Taking all of these factors into account, our analysis shows that electrifying to Oxford, Newbury, Bristol, Cardiff and Swansea will deliver high value for money. Detailed planning will start straight away. Early works can take place between 2012 and 2014, with the bulk of the construction between 2014 and 2016. Subject to detailed planning work, electric services will be introduced progressively: London to Oxford, Newbury and Bristol by the end of 2016, and London to Swansea by the end of 2017.

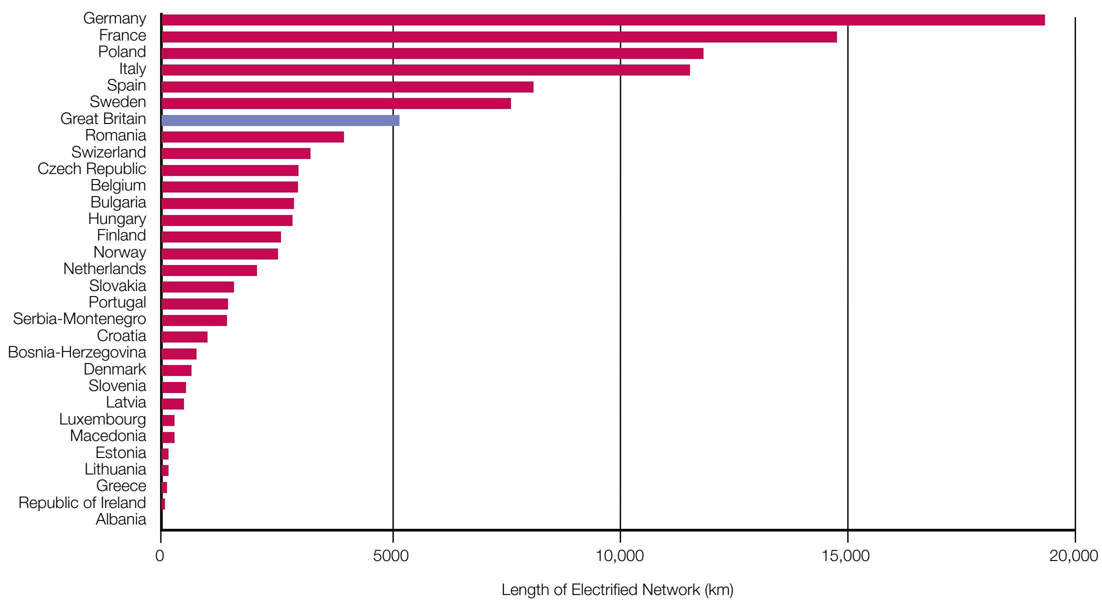
27. This electrification programme radically affects the requirements for rolling stock over the next decade. There will be far less need for diesel trains and a greater requirement for electric trains. In particular, the previously-planned procurement by the Government of new diesel trains has now been superseded. We will accordingly publish a new rolling stock plan in the autumn, taking account of the changed circumstances.

2 Britain's electrified railway today

The European context

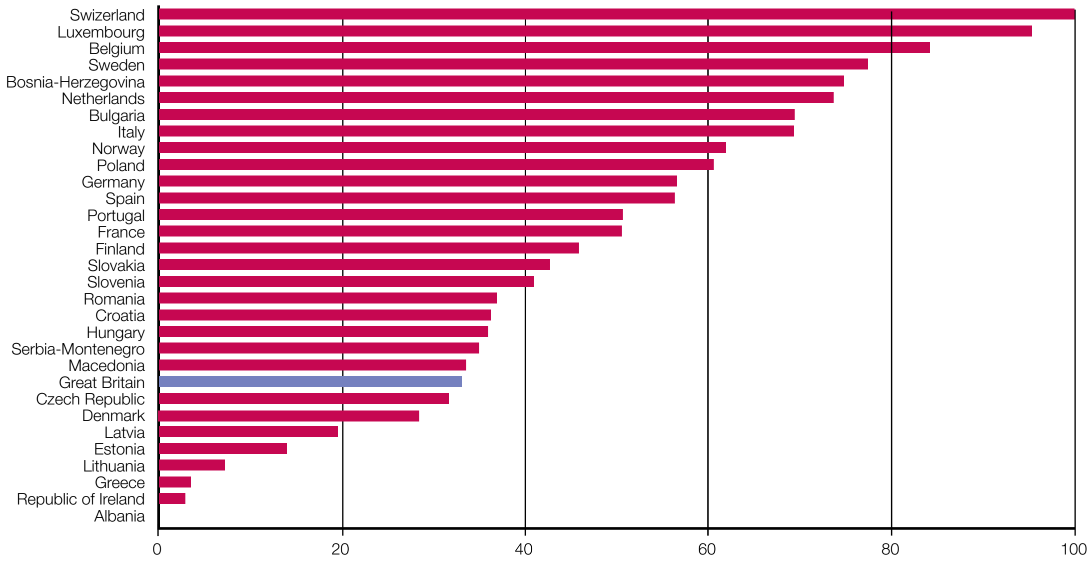
28. Britain significantly under-invested in rail electrification in the post-war decades. Figure 3 shows the total length of the electrified rail network for European countries. Great Britain currently lies in seventh place, far behind Germany, France, Poland and Italy. Moreover, as a proportion of the total network, the electrified network in Britain is far smaller than that of most European countries, as shown in Figure 4.

Figure 3: Length of the electrified rail network (route km) for various European countries



Source: UIC.

Figure 4: Rail electrification in Europe in 2005 showing percentage of network (by route km) which is electrified



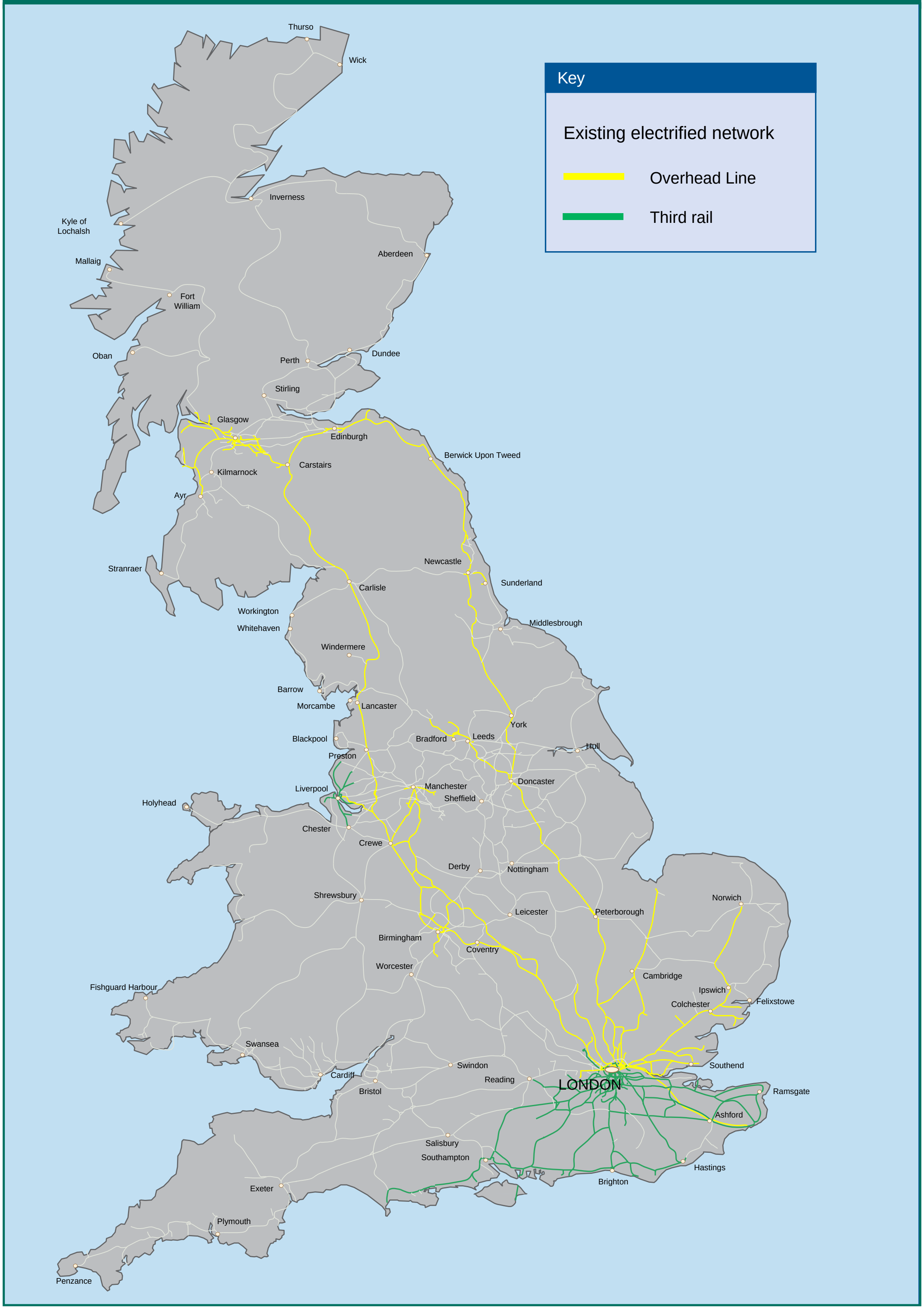
Source: UIC.

Existing GB rail electrification

29. Approximately 33% of the British rail network is currently electrified. Of this, two thirds is equipped with overhead line electrification, while the remainder is mainly 'third rail' electrification. Figure 5 illustrates the extent of the electrified network.

30. 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 much of the London suburban network north of the River Thames, and on parts of the suburban networks of Birmingham, Glasgow, Leeds and Manchester. The route from Newcastle to Sunderland is electrified for Tyne and Wear metro trains, which share the route. Third rail electrification operates on London suburban routes south of the River Thames and on routes between London and the south coast, as well as between Euston and Watford, on parts of the North London Line and on the Merseyrail suburban network.

Figure 5: Existing electrification on Britain's railways



Source: Network Rail.

31. These existing electrified lines serve many of the busiest parts of the network and consequently carry a greater density of traffic than the non-electrified parts of the network.

32. In the period up to 2014, Network Rail is funded to deliver electrification from Barnt Green to Bromsgrove in the West Midlands. The Government has announced that the Great Western Main Line between Airport Junction (near Heathrow Airport) and Maidenhead will be electrified as part of the Crossrail project.

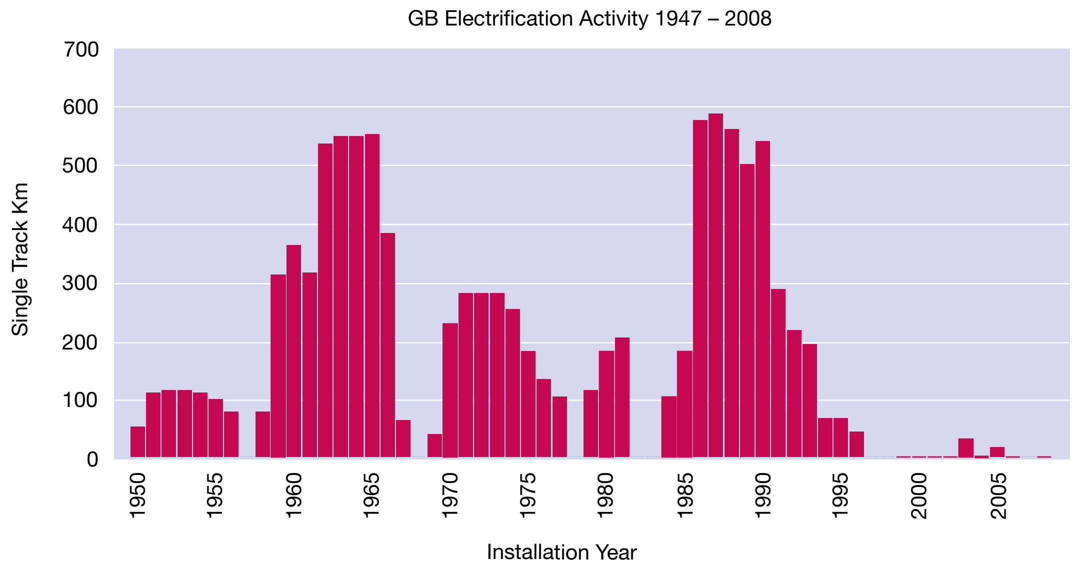
33. There are also plans for further electrification in Scotland. But with certain exceptions, such as safety, rail strategy is a devolved matter in Scotland. The geographical scope of this document is therefore primarily limited to England and Wales, recognising the implications of further rail electrification for cross-border services to Scotland.

Historic electrification

34. The British Transport Commission's seminal 1955 report *Modernisation and Re-Equipment of British Railways* recognised the benefits of electrification, stating: *"In many ways electricity is the ideal, since it meets the requirements of reliability, good acceleration, cleanliness and (where traffic is sufficiently heavy) economy in operation."* As for the costs of electrification, it went on to say that: *"It is not so much a question of whether the nation can afford to undertake the new investment in its railway system here proposed, as whether it can afford not to do so and thereby continue to carry the economic burden of a public transport system that lags far behind the standard of efficiency technically possible."*

35. This followed the successful electrification of the Southern Railway's commuter routes into London in the 1930s. However, only partial electrification, even of the intercity network, took place thereafter (see Figure 6). The routes from London to East Anglia were electrified progressively from the 1950s, the West Coast Main Line from London Euston to Glasgow in the 1960s and 1970s, the southern section of the Midland Main Line from London St Pancras to Bedford in the early 1980s, and the East Coast Main Line from London King's Cross to Edinburgh in the late 1980s. But the majority of the network, including busy intercity routes such as the Great Western Main Line and the Midland Main Line north of Bedford to Sheffield, was neglected.

Figure 6: Number of single track km of electrification delivered in each year since 1947



Source: Network Rail.

36. For the past 15 years, making good the effects of privatisation and clearing the backlog of essential infrastructure work have been the priorities for investment. Now that the essential network infrastructure is in fairly good shape, the Government and Network Rail are addressing the imperative for further electrification. Detailed joint analysis has been underway since the establishment of the National Networks Strategy Group by DfT last October. The completion of the first stage of this work has led the Government to conclude that the Great Western Main Line and the Liverpool to Manchester line should be electrified immediately.

3 The Great Western Main Line

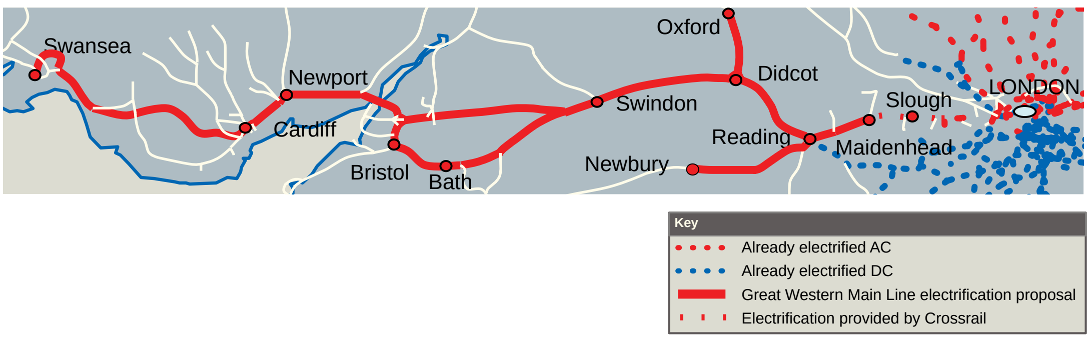
37. The backbone of the Great Western Main Line is Brunel's historic route from London through Reading and Swindon to Bristol, most of it now equipped for high-speed running, and the South Wales main line through the Severn Tunnel and on to Newport, Cardiff and Swansea. These routes provide fast intercity links between the English and Welsh capital cities and the West of England regional capital.

38. The line has seen significant increases in passenger demand, with the Thames Valley and Greater Bristol both being key growth areas. Between 2000 and 2006 there was 20% growth in passenger numbers between the Bristol urban area and London. The 2007 White Paper anticipated significant growth continuing on the route.

The electrified route

39. Electrification will bring important benefits for people making both long and short journeys. From 2016, commuters travelling between London, Slough, Reading, Newbury, Didcot, Oxford, and Swindon and intermediate stations will benefit from the reliability and comfort of electric trains. Figure 7 shows the route proposed for electrification.

Figure 7: The Great Western Main Line between London and Swansea, showing the planned electrified route



Source: Network Rail.

Intercity services

40. The replacement of a whole fleet of trains operating over a route creates an opportunity to reconsider the power source for those trains. Rolling stock fleets tend to last 30 to 40 years, so the replacement of the Intercity 125 High Speed Train (HST) fleet over the next decade creates a 'once in a generation' opportunity to electrify the route at the same time as replacing its rolling stock. The Government has decided to seize the opportunity to bring together the planning for the replacement of the HST fleet with a programme of electrification, rather than embarking on a sub-optimal replacement of the HST with another diesel-only fleet.

41. The proposed fleet for an electrified Great Western Main Line to Swansea will include a proportion of 'bi-mode' trains, so that destinations including Worcester, Gloucester, Cheltenham, Carmarthen and the South West beyond Bristol continue to enjoy through trains while also gaining the benefits of electrification. These bi-mode trains have a diesel generator vehicle at one end and an electric transformer vehicle at the other end. This allows bi-mode trains to operate 'off the wires' to maintain through services and provide diversionary services. They may also assist during the latter part of the construction period by allowing some new trains to be used as they are introduced but before the electrification programme reaches Swansea. Table 2 sets out some potential journey time savings from using Super Express trains compared to the existing HST fleet.

Table 2: Anticipated journey time savings following the introduction of Super Express trains, compared to existing Intercity 125 High Speed Train (HST) services

	Estimated journey time saving to/from London with Super Express trains (minutes)
Reading	4
Oxford	6
Swindon	8
Bristol	12
Cardiff	15
Swansea	19

42. In addition to the journey time savings, it is expected that the introduction of Super Express trains will provide at least 15% extra capacity on intercity services during the morning peak hour, and much more extra capacity across the day and during the evening peak.

Suburban services in the Thames Valley

43. Electrification will enable the current suburban services into London Paddington to be operated by electric trains instead of diesel trains.

44. The Thameslink Project is a major investment in additional capacity linking areas to the north and south of London. In order to operate a high-frequency service of 24 trains per hour in the peak period, a new fleet of around 1,200 vehicles is being procured. These new trains will replace the existing electric trains on the current Thameslink routes from 2013 to 2015.

45. It will then be possible to transfer the current Thameslink four-carriage electric trains onto the Great Western Main Line, replacing the current three-carriage diesel trains. These 100 mph vehicles will be completely modernised, including the installation of air-conditioning, and will offer quieter journeys and additional capacity. It is planned that suburban services between Oxford, Reading and London will be operated with such vehicles from the end of 2016.

46. From 2017, inner suburban services currently running into and out of London Paddington will operate through the new Crossrail tunnel to central London and destinations to the East of London. The Crossrail project will be procuring new rolling stock for these services. Outer suburban services will continue to operate to London Paddington.

47. Existing modern diesel trains that operate the suburban services into London Paddington can then be transferred to provide additional capacity on services in the Bristol area and the South West as well as releasing vehicles that can then be deployed to deliver additional capacity in key Northern cities.

Freight

48. Rail freight operators will be able to take the opportunity to lower costs by using electric locomotives to haul freight trains on the Great Western Main Line where possible.

Crossrail

49. The £16bn Crossrail project involves the construction of a new, cross-London railway connecting Heathrow Airport, the West End, the City and Canary Wharf to areas east and west of the capital. Crossrail will offer high-frequency, convenient and accessible services, with up to 24 trains per hour in the peak period over the core section. It will replace some of the current suburban services into London Paddington as well as some of the existing suburban services into London Liverpool Street. A fleet of around 600 new electric vehicles will be procured to operate these services.

50. The project involves electrifying the Great Western Main Line from Airport Junction (near Heathrow Airport) to Maidenhead. Close co-ordination between the electrification teams and the Crossrail project teams will be necessary to ensure dovetailing with the wider programme of electrification on the Great Western Main Line. This co-ordination could lead to savings in procurement costs and reductions in overall disruption of the railway. The potential savings will be discussed in detail with Transport for London, as co-Sponsor of the Crossrail project, and with Crossrail Limited.

51. Electrification west of Maidenhead also makes it possible to extend Crossrail services through to Reading. This could bring significant benefits, giving Reading and the wider Thames Valley direct rail access to London and the City, while also creating extra capacity in the existing Paddington terminus for longer distance services. The costs and benefits of this option will be considered by the Government and its project partners in Crossrail.

Rail access to Heathrow Airport

52. Heathrow Airport already benefits from an electrified railway link to London, but passengers from the West are required to change trains or use coach links in order to access the airport. A recent study commissioned by local authorities in the Thames Valley identified a potential case for direct rail access to the airport from the West, particularly from Slough, Maidenhead and Reading.

53. One of the constraints identified by the study was the lack of electrification of the Great Western Main Line to support services from Heathrow – which must be electrically operated to use the railway beneath the airport. The commitment now being made to electrification will have a positive impact on the case for Western rail access to Heathrow, and we look forward to the local authorities and BAA taking this into account in their further assessments of airport surface access requirements.

Reading Station Area Redevelopment Project

54. The growth in rail traffic on the Great Western Main Line has meant that, operationally, Reading station has become a serious bottleneck. Trains frequently come to a standstill, waiting before they can enter the station, causing delays to passengers. The Reading Station Area Redevelopment Project is designed to provide additional train capacity for the Great Western Main Line and other routes converging on Reading. These improvements – effectively a doubling in train capacity – will also enable better train performance and a reduction in delays.

55. The project is due to be completed in 2015. Early work has already made passive provision for electrification, with preliminary designs including locations for overhead line equipment and masts. Work will now be undertaken to explore further synergies in order to minimise disruption to passengers and keep down overall costs.

Wales

56. The Government and Network Rail will work closely with the Welsh Assembly Government so that plans for electrification of the Great Western Main Line are co-ordinated with the Welsh Assembly Government's own rail plans.

Super Express Programme

57. The Super Express Programme was launched in 2005 to examine how the current Intercity 125 High-Speed Trains (HSTs), introduced by British Rail between 1976 and 1982, could be replaced. In 2006 and 2007, the rail industry, co-ordinated by the Department for Transport, developed a specification and a deployment strategy for the new trains, which led to the announcement of Agility Trains as preferred bidder earlier this year.

58. In developing the deployment plan, flexibility of power source was a major objective. The Super Express train can operate as a diesel train (self powered), an electric train or a combination of both (bi-mode).

59. The deployment plan for Great Western did not assume any electrification and so was based on using diesel Super Express trains. As these trains have a 30-year life-span, this would have meant the continued use of diesel-only trains on Great Western for the next generation. Electrification of the Great Western Main Line will now enable the Super Express procurement process to focus on electric and bi-mode options for Great Western. The contract with Agility Trains will be conditional upon their delivery of significant savings and expected capacity increases from the deployment of electric and bi-mode trains.

60. Deployment of electric and bi-mode Super Express trains will dramatically reduce the environmental impact of diesel operations within Paddington station and at other major covered stations like Bristol Temple Meads.

Re-signalling

61. Network Rail is currently planning to re-signal sections of the Great Western Main Line linked to the plan to install in-cab signalling, the European Rail Traffic Management System, on the route. This will provide 'immunised signalling' which does not suffer interference from overhead line equipment, and is therefore an essential prerequisite to electrification. The Department anticipates that careful co-ordination of the re-signalling work with the electrification work will minimise any disruption and keep overall costs down.

4 Liverpool – Manchester

62. The route to be electrified is one of three between Liverpool and Manchester. It was the first railway in Britain built with passengers as well as freight traffic explicitly in mind from its inception, and was the scene of early pioneering engineering achievements. George Stephenson met the challenge of building a stable route over Chat Moss, and his steam locomotive "Rocket" triumphed in the Rainhill trials of 1829.

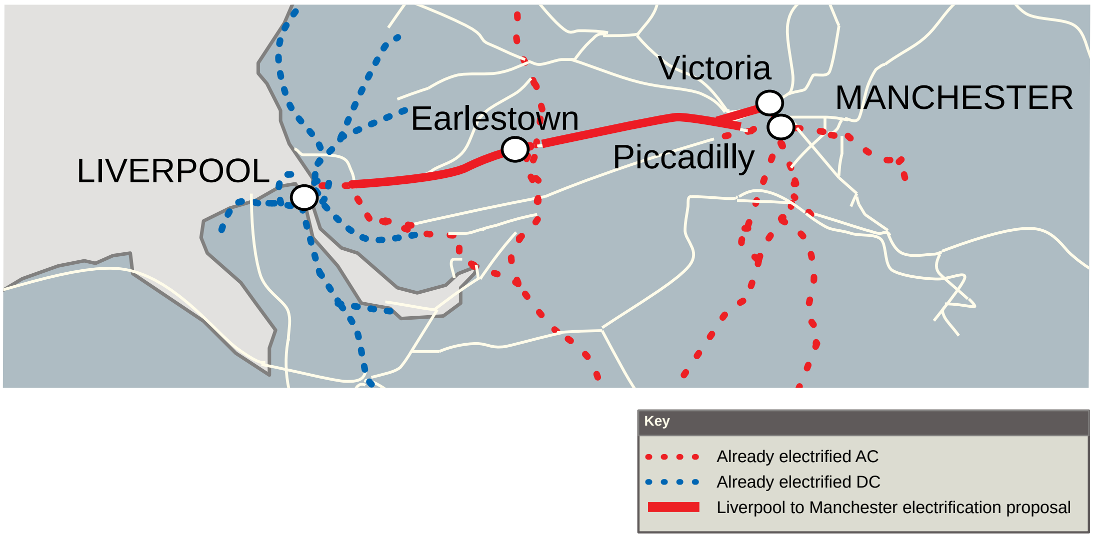
63. The double-track route, 32 miles long, runs from Liverpool Lime Street station to Manchester Victoria station via Huyton and Newton-le-Willows. Four miles of the route, Lime Street to Bootle Branch junction, and between Earlestown East and Newton-le-Willows junctions, is already electrified. The route currently has a maximum permitted speed of 75 mph.

The case for electrification

64. Significant investment on the route is already planned. The maximum line speed will be raised to 90 mph, to achieve a target journey time between Liverpool and Manchester of 30 minutes (compared with 44 minutes today). Signalling renewals are planned in the Huyton and St Helens Junction areas.

65. Electrification will unlock further major benefits, both for intercity and for regional services. In particular, it will enable the Government and the rail industry to make the best use of electric rolling stock.

Figure 8: The Liverpool – Manchester route, showing the planned electrification



Source: Network Rail.

Services between Manchester and Scotland

66. The existing TransPennine Express services between Manchester Airport and Glasgow/Edinburgh are operated by diesel trains, running under the overhead wires for more than 85% of their journey. Completion of the first phase of electrification, between Manchester and Newton-le-Willows, will allow through-train electric operation between Manchester and Scotland via the West Coast main line. This new service will use modern, air-conditioned trains which are currently used on West Coast Main Line services from London Euston. These high-powered, four-carriage electric multiple units have greater capacity than the existing trains, relieving crowding in key sections of the route.

67. Electrification will enable diesel trains to be transferred onto other TransPennine Express routes, delivering much-needed additional capacity with many trains able to operate as six-carriage trains instead of three-carriage trains today.

Regional services

68. Completion of the second phase between Newton-le-Willows and Liverpool will provide a fully electrified route between Liverpool and Manchester. Like the Thames Valley suburban services on the Great Western Main Line, regional services will be operated from 2013 by four-carriage electric trains transferred from the cross-London Thameslink route. These trains will be completely modernised before they are transferred, including the installation of air conditioning.

69. As with the Manchester to Scotland services, these electric trains will provide a better service for passengers compared to the diesel rolling stock which would otherwise have to be ordered to increase capacity and relieve overcrowding on this key regional route.

Freight

70. Electrification of this route will offer electric haulage options for freight. There will be an alternative route to Liverpool docks for electrically-operated freight trains, and better opportunities of electrified access to the proposed freight terminal at Parkside near Newton-le-Willows.

5 Implementation

71. Electrification necessarily involves engineering work on and near the railway. But it is important to minimise disruption to passengers and freight while these works are carried out. Passenger Focus, the statutory body which acts on behalf of passengers, is well placed to ensure that the passenger voice is heard in the planning of major engineering works.

72. Network Rail has developed proposals for an electrification process to minimise disruption. These proposals involve construction techniques which make extensive use of overnight closures of not more than eight hours. The application of modular techniques and the deployment of rapid delivery systems to improve the rate of production will be of key importance. The proposed 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.

73. On the Great Western Main Line, for straightforward stretches of line between major junctions and complex stations Network Rail's work suggests the use of 'factory trains'. This will enable standardisation as far as possible. The factory trains will be flexible units, capable of working individually or in combination, and as such, could play a useful on-going role in the efficient maintenance of the electrified network.

74. For the works necessary to provide clearances for overhead wires there may be some need for more extensive temporary closures for demolition and erection of new structures. But even these can usually be planned to coincide with other works. Close co-ordination with the electricity supply industry will be crucial to ensuring a mutual understanding of expected electrical demand and supply points.

Financing

75. The capital cost of electrifying the Great Western Main Line from London to Swansea is estimated at around £1bn. It is estimated that electrifying the line from Liverpool to Manchester will cost around £100m. As part of implementing the proposals, Network Rail will be seeking the maximum efficiencies in the infrastructure work required.

76. As with other rail investments, the cost of electrification will be funded by Network Rail and supported by the Government. Over the medium term this £1.1bn investment in electrification will be self-financing, paying for itself through lower train maintenance, leasing and operating costs. This means that this investment can take place without reducing already planned infrastructure enhancement work.

6 Next steps

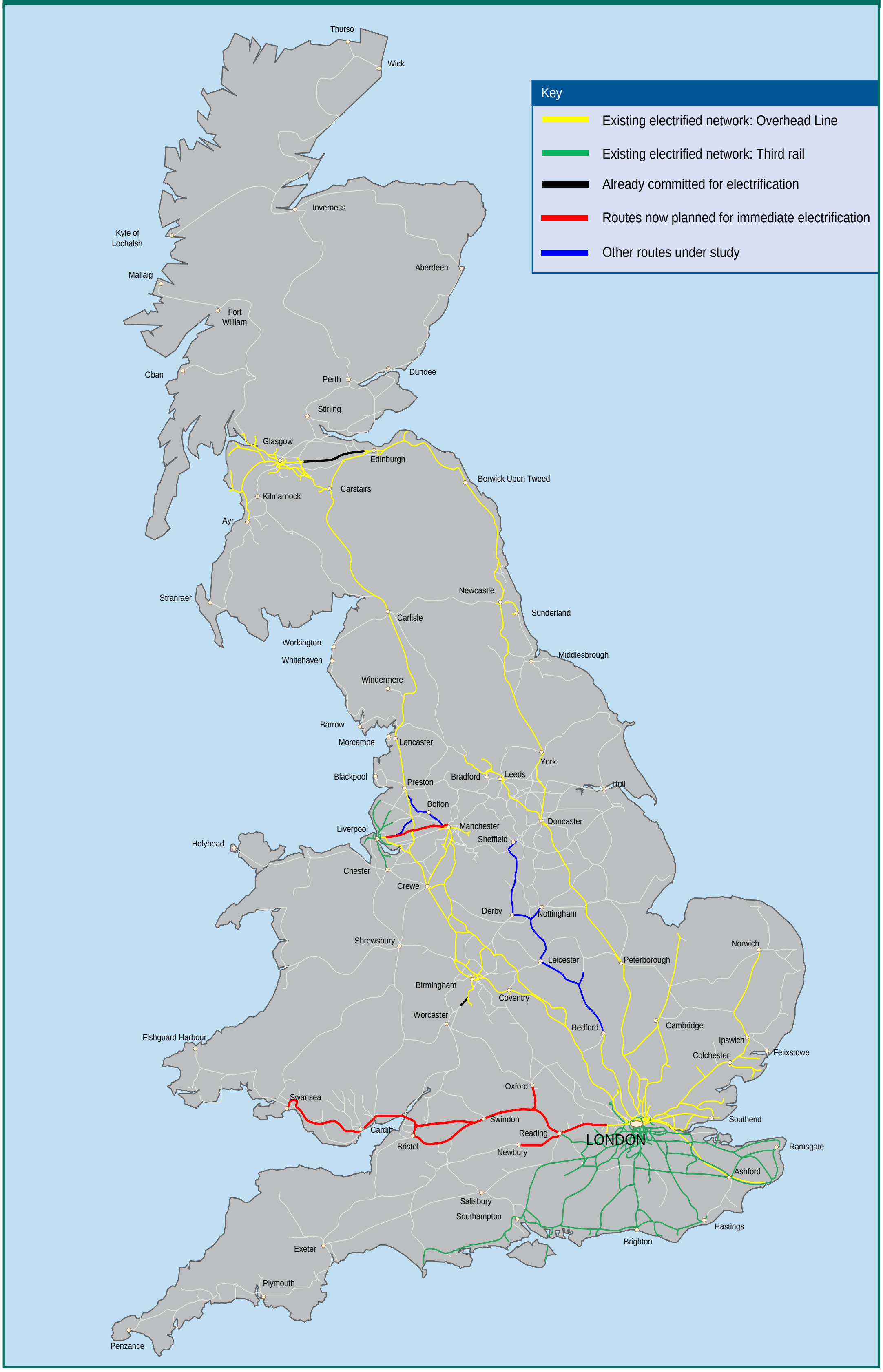
77. Detailed planning to take forward this electrification programme is now underway by Network Rail. It is expected that Liverpool – Manchester electrification will be carried out in two phases, to be completed within four years. On the Great Western Main Line, the programme will be co-ordinated with Crossrail's electrification work to Maidenhead. As planning proceeds, Network Rail plans to start securing resources and ordering items of equipment which have long lead times (such as construction plant). It is currently expected that early works will take place between 2012 and 2014, with the bulk of the construction between 2014 and 2016. Electric services will be introduced progressively: London to Oxford, Newbury and Bristol by the end of 2016, and London to Swansea by the end of 2017.

78. Network Rail recently published for consultation its *Network Route Utilisation Strategy: Electrification*. This draft strategy was the result of work by a cross-industry working group. It concluded that there was a good case for electrification of a number of sections of the network.

79. Reflecting its remit, the study did not consider in any detail several key issues which affect the implementation of any electrification programme. These include the age of existing diesel rolling stock, the availability of electric rolling stock, affordability and phasing of delivery.

80. Further detailed analysis is now ongoing on the other routes identified by Network Rail, and we are looking intensively at the costs and benefits of electrifying the Midland Main Line between London and Derby, Nottingham and Sheffield, as well as the routes between Manchester and Preston, and Liverpool and Preston, as shown in Figure 9. The Department will continue to work with stakeholders to review these schemes.

Figure 9: Electrification on Britain's railways



Source: Network Rail.

ISBN 978-1-84864-018-4

29th July 2007

Mr Michael Roche
Chief Executive
Queensland Resources Council

Mr Bruce Wilson
Director General
Queensland Transport

Dear Mr Roche and Mr Wilson

RE: Goonyella Coal Chain Capacity Review

I am pleased to report that the above review has been completed. This letter gives an overview of the study and summarises the key findings and recommendations. These findings and recommendations have been finalised following the feedback received following the presentation to all stakeholders involved in the supply chain on Friday 6th of July. 2007. Attached to this letter is the detailed supporting information assembled during the study.

Background

The review of the Goonyella Coal Chain was jointly commissioned by the Queensland Government and the Queensland Resources Council representing those Coal Producers that presently make use of the system. The impetus for commissioning the review was the perceived inability of the supply chain to match the rate at which the producers can extract coal and meet their contract tonnages. There was also a lack of clarity on what the projected capacity of the total supply chain will be in future years and what initiatives are required to achieve these future capacities.

The broad objectives of the study were to:

- Identify system constraints (both actual and perceived).
- Have stakeholders agree on realistic throughput targets against contracted throughput.
- Recommend a reporting regime to restore customer confidence.
- Make recommendations focussed on improving:
  - Transparency
  - The capacity of the system to deliver contracted throughput
  - Confidence in capacity forecasts.

The review was conducted by Stephen O'Donnell who was previously the CEO of Pacific National. He has also held senior executive roles in the Queensland mining industry. He was supported by consultants from Partners in Performance, an organisation specialising in business improvement, particularly at the operational level.

During the review, discussions were held with all the major stakeholders in order to obtain an assessment of issues as seen from their perspective and give input on potential solutions. Follow up discussions were held as considered necessary. The discussions involved, but were not limited to, the following groups:

- Senior ministers and officials of the Queensland Government
- The Board and senior management of Queensland Rail
- CEO's and senior executives of the coal producers
- Senior executives associated with the Dalrymple Bay Coal Terminal, Hay Point Services Coal Terminal and the Ports Corporation of Queensland.
- Queensland Competition Authority.

I am pleased to report that the review team received the full co-operation of all stakeholders in gathering of information and in the testing of emerging findings and recommendations.

<u>Initial Perceptions</u>

As discussions with relevant stakeholders proceeded, it became apparent that the current situation had a long and complex history commencing around the time Babcock and Brown (BBI) acquired the lease for the Dalrymple Bay Coal Terminal (DBCT). Many events have occurred which have impacted the capacity of the coal chain. Examples include:

- The decision by the coal producers through the regulatory process during 2004-06 to question the financial details underpinning the proposed price of the port expansion at DBCT; and
- The failure of a stacker reclaimer at DBCT in February 2004.

During this period the export coal market has experienced a sustained increase in demand, in excess of the capacity of the supply chain. Global coal price levels have also markedly increased.

Rail contracts were entered into prior to 2003/04 at a time when cost was the prime requirement of coal producers. These contracts pre-dated the lift in global coal prices. Contracts were structured to minimise the required amount of rolling stock. However, this had the effect of reducing total system capacity due to lack of flexibility in meeting the typical variations that the supply chain experiences.

Export shipments from DBCT have been below port and rail contracted tonnages over the last twelve months, leading to significant concern on the part of coal producers.

There is significant complexity in managing the supply chain from both strategic and operational viewpoints. This complexity is primarily a function of the number of entities directly associated with it. Eight coal producers operating across 13 mines, BBI (long term port leaseholder), DBCT P/L (port operator), QR Network Access

(QRNA), QR National (QRN) responsible for rail haulage. In addition there are regulatory, commercial and shareholder interfaces with the QCA, ACCC, PCQ and the State Government. When the system is underperforming there is ample opportunity to blame other parties, particularly due to the lack of transparency in the provision of some data relating to the performance of the system.

Coal producers have a common interest in maximising the performance of the supply chain but in other arenas they are fierce competitors. There are individual contracts between the port and the coal producers as well as between the rail haulage provider and the coal producers. There is no process to ensure that these contracts reconcile with each other and that they in total add up to the available capacity of the system. When issues arise, given the complexity of the interfaces between the parties, it is usually well beyond the capability of any one party to resolve the point of difference.

Close cooperation and transparency of information are vital ingredients to resolution of issues associated with underperformance of the coal supply chain. **However, there is no person or entity with the authority to pull stakeholders together to obtain an outcome.** Despite the goodwill of all parties to move forward, relationships can become dysfunctional as pressure mounts to do something while individual parties address issues from their own perspective.

Current situation

Many reports have been commissioned and improvement projects commenced. The Hay Point Services operation is in the last stages of an expansion of the port to take it from 38mtpa to 44mtpa. DBCT have commenced expansion work to lift capacity to 68mtpa as the expansion is commissioned in the first quarter of 2008 and have further construction work planned to take capacity to 85mtpa by the end of 2009.

The current bottleneck in the system is lack of rail rolling stock capacity. For example, if there were two more train sets in the Goonyella system, the bottleneck would more obviously be the fact that the two unloading stations at the port cannot cope with demand. **During the planned construction works at DBCT later this year the port will become <u>the</u> bottleneck until early next year when the port's capacity will lift to approximately 68mtpa. Following completion of this work, the bottleneck will return to being lack of rolling stock. QR's plans have yet to be finalised to address this situation.**

This Review's study of the overall supply chain indicates that a business improvement program should be urgently commenced across the entire supply chain, with the initial focus being on Queensland Rail, reflecting the current bottleneck in the supply chain.

A business improvement program focussing on the operation of the rolling stock and interfaces with the coal producers and the ports could liberate another 5mtpa, which would put the rail haulage capacity ahead of DBCT capacity until the port expansion is completed. **This business improvement work could be expected to take about six months to realise these gains.**

<u>Principal recommendations</u>

I have discussed the above analysis with all stakeholders in the Goonyella coal supply chain. I am pleased to report that there is full support from stakeholders for the following recommendations:

- **<u>A central coordination role be created to oversee and if necessary coordinate all activities which span the whole of the supply chain.</u>**

  The position would be a part time role, paid for by the coal producers and be ultimately accountable to them. The individual in the role should preferably be Brisbane based and have had sufficient experience to allow the individual to effectively deal with senior personnel from all the stakeholders (Government, Coal Producers, Queensland Rail and BBI) to get outcomes in the best interest of the supply chain. To support this role, it is considered essential that all parties sign an MoU agreeing to support the role and provide information and resources as required.

  The central coordinator could for example:
  Oversee preparation of master plans to ensure that future capacity is in line with forecasts; facilitate industry consideration of the northern missing link; and oversee short term planning and the establishment of business rules for daily optimisation of system capacity. A co located work group containing resources from the rail provider and DBCT would facilitate optimising the application of resources to service DBCT.

  For the position to be effective two full time resources should support the role. Widening the role of the current DBCT capacity planning consultant should be considered for one of these roles

  I am pleased to report that all stakeholders support this recommendation and good progress has been made in giving effect to this recommendation.

- **<u>QRN to immediately commence a process, including negotiating commercial contracts with users, to purchase additional train sets to allow it to meet projected volumes.</u>**

  This should be actioned as soon as possible as the equipment has a 2 year procurement lead time for delivery of the first additional locomotives to service the expansion plans of the ports. The situation of QRN’s forward contracts also needs to be finalised as approximately 30% of QRN’s business will be off contract in three years’ time.

QRN has commenced a process of consultation with coal producers concerning the commercial terms underpinning the acquisition of additional rolling stock.

- **<u>A business improvement program be commenced across the supply chain, starting immediately with Queensland Rail as this is the current bottleneck.</u>**

  This program should have external resources with expertise in managing programs to achieve gains in operational through put. The program should be externally audited. The starting point for the program should be to focus on improving train cycle times. (Cycle time is total time for a coal train to depart from the train depot, travel to a designated mine, load with coal, travel to the dump station at the port, unload coal, return to the depot, complete any work required on the train and then be available to commence another cycle). Rigorous focus on actual cycle time performance against pre determined standards will start to identify where there are major losses occurring. Each of those areas of loss will then be the focus of an individual improvement program. In this manner, the program identifies the real areas for improvement, quantifies them to determine priority and then gets to work on them. The programs are usually well received by all participants as they work on the real issues at hand and many individuals undergo significant personal development as a result of their involvement (enhanced analytical capability, and leadership capability associated with implementing change).

  QRN has now appointed an external organisation to resource this program which was expected to commence on Monday 23rd of July, 2007.

<u>Other matters</u>

There are issues that the study was requested to examine which could not be adequately addressed in the time frame. For example, an important piece of work that needs to be quickly completed is an assessment of the capacity of the coal supply chain after the completion of the DBCT port expansion to 85mtpa. There is a strong view amongst coal producers that the actual capacity figure may be much lower than 85mtpa when the interface with the rail system is taken into account. This is potentially a serious issue for the producers given that they have contracted port tonnages up to the full 85mtpa.

Given the short time frame for the review and the requirement to interface with all stakeholders, this report should be looked upon as an initial scoping study to quickly identify opportunities to improve the overall performance of the coal supply chain. Progress is being made in implementing the recommendations. As the Business

Improvement Program gains traction, many new insights into opportunities to lift the capacity of the system will be identified.

Supporting information gathered during the review is attached.

Stephen O’Donnell

Goonyella Coal Chain Capacity Review – Second and Final Report

Summary

Action is well underway within QRN working on short term initiatives (Business Improvement Plan) to maximise the utilisation of the existing coal chain assets. A major procurement plan to obtain additional rolling stock to meet projected coal volumes has been announced and QRN are developing contract options to provide the commercial framework to support this investment.

It is recommended that Coal Producers consider future rail haulage contracts with a view to defining the total installed rail supply chain capacity required to move the total tonnage of coal through the system. Penalties for under resourcing of total rail haulage capacity could then be applied as well as minimum take or pay volumes to underpin investment in rolling stock.

The Master Planning process should be clearly defined and preferably facilitated by a representative of the Coal Producers. This is based on the principle that the coal chain infrastructure is there to support the coal industry export markets and any investment is ultimately paid for by the industry. The situation where an element of the supply chain infrastructure is expanded without a full assessment of what additional investment may be required in other parts of the supply chain should not be allowed to happen again. Particularly, when this additional capacity is contracted out and there is no understanding of the economics of up rating the capacity of the whole supply chain to meet the proposed expansion. It should also be stated that this is not a criticism of BBI but more a reflection on the quality of Master Planning processes for the total system at that time.

Further discussions have been held with the coal producers on the scope of the central coordinator. There is full agreement for a facilitation role which would cover the whole supply chain. The primary responsibility of the role would be to identify and then facilitate initiatives on behalf of the system stakeholders. These initiatives are expected to be primarily associated with master planning processes. There are many complex issues (operational, regulatory in nature involving a multitude of stakeholders) associated with the Dalrymple Bay Coal Terminal (DBCT). There is full agreement that a coordination role work across the part of the supply chain associated with DBCT. An MoU to cover the proposed arrangements for the role is in the final stages of preparation.

Agreement on the above is a major step forward for all stakeholders in that it will improve the overall governance of the system and in particular, resource the master planning issues which are critical to future growth in export coal tonnages.

Port Capacity Study

A report was commissioned by Babcock & Brown Infrastructure (BBI) to assess the capacity of the Dalrymple Bay Coal Terminal (DBCT) post the phase one, phase two and phase three expansions. This report (Sandwell Report) was updated on the 3rd July, 2007. Phase 1 completion is expected early 2008 with full completion of works planned around the end of 2008.

A summary of the conclusions from the report concerning the capacity of DBCT are listed on the next page.

Terminal Configuration	**Throughput Capacity**		
	Inloading (Mt/y)	Outloading (Mt/y)	Overall (Mt/y)
Present	59.0	60.0	59.0
Phase 1	87.0	70.0	70.0
Phase 2	94.0	80.0	80.0
Phase 3	94.5	89.0	89.0

This report which is based on detailed modelling of processes within DBCT makes assumptions about the how the rail system will interface and interact with the port. It is strongly recommended that a joint approach between coal producers, QRNA, rail haulage operators and the port is taken with a view to determining the system capacity based a detailed assessment of how all the elements interact, rather than the current approach, which has a very detailed analysis of the port supported by more general assumptions for the rest of the system.

Design Rail Haulage Capacity

Assuming there are no rail infrastructure bottlenecks, the capacity of the rail haulage system will be ultimately set by the unload stations. The number of trains required is a function of the unload station cycle time (train unloading time + minimum inter train gap), total train turnaround time (overall cycle time for a run and additional dwell time – e.g. for crew changes or provisioning) and the number of planned coal train paths (CTP's) on the network.

In appendix 1, there are charts summarising the interaction between train paths, number of trains, train turnaround times and train unloading times. The most important message from the charts is that as the unload station capacity is reached, adding additional trains will not increase system capacity. However, reaching maximum unload station capacity requires that trains are presented evenly throughout the day and in the correct sequence to the unload stations. In order to ensure unload station utilisation is maximised, additional capacity estimated to be of the order of 10% over and above the theoretical design figure would be required. However the utilisation, as stated earlier will be lower for these additional rail assets.

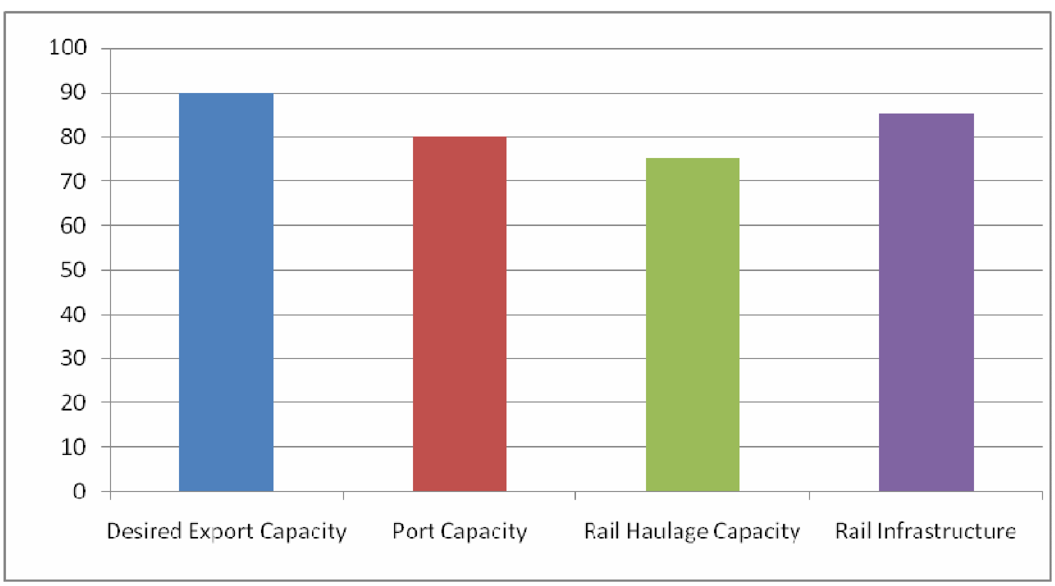
It is recommended that Sandwell or similar group, study the whole DBCT coal chain or at least review the analysis of the major elements to confirm consistency in the key assumptions used by parties. It is believed that both BBI and QRNA would support such a proposal. This would be a big step forward in resolving the issue of DBCT capacity and its relationship to the rest of the supply chain. Sandwell also have a live rail model which, at first sight, would be very useful in determining infrastructure bottlenecks and assisting in short term planning.

Daily meetings to determine root cause analysis should be initiated between DBCT, QRN and QRNA. The supply chain is complex and many of the variances as they present themselves are manifestations of more deep seated issues, some of which may have occurred earlier in time. This process would yield much better insights into how to maximise performance as well as improve cross organisational understanding (assuming the will is there to do so). It is recommended that for the first twelve weeks this daily meeting is attended by senior members of the respective organisations. This will serve two purposes: establish the necessary priority to the organisation and secondly educate leadership in what some of the issues really are within the total supply chain. A process such as this would, for instance, establish to what extent the new yard configuration at DBCT will alleviate congestion around the two ports (Appendix 2). After an initial period, a review should be held to determine the future format going forward and if it should be extended to consider other aspects of the operation of the coal chain.

Rail Haulage Contracts

As long as the desired export volume exceeds the capacity of the port and rail system, some capacity allocation system will have to prevail for at least the next 3 years until the completion of the Jilalan upgrade and the commissioning of sufficient rolling stock to meet demand. In the simplest form this can be through a pure turn of arrival process or mechanisms such as the present Queue Management System (QMS) which focuses exclusively on the rationing of port contracts.

Capacity of Elements of the Coal Supply Chain (example only)



In the situation where the export capacity is constrained, individual rail contracts will have little relevance other than the rate to be charged. The volume railed will be set by QMS and there will always be fertile ground to argue who is actually to blame for the shortfall in export volumes. Of primary concern to the Coal Producers should be a requirement to assess the total installed rail haulage capacity, rather than just the capacity allocated to their contract. If this rail haulage capacity is above the capacity of the other elements in the supply chain, then the Producers should have confidence it will be railed. Consideration should be given to penalties in the rail haulage contract where a supplier's total installed capacity falls below a pre determined figure. This capacity figure should also include an allowance for buffer capacity to ensure the agreed tonnages can be met. A proposal such as this can only work if all producers accept this principle, as the system cannot be easily managed to differentiate one type of contractual arrangement versus another. Neither BBI nor QRNA have any volume risk in their revenue model. The volume risk issue for the above rail operators can be addressed through 'take or pay' arrangements whereby the Producers carry the volume risk associated with Production issues. By the same token, above rail operators should carry the volume risk associated with their own performance (this would provide focus on mitigating the risk through operational excellence rather than pricing in the risk).

<u>Business Improvement Program (BIP)</u>

The BIP has been in place within QR over 12 weeks and is well established and starting to realise gains. A weekly review has monitored the program and improvements have been grouped in the following categories.

- Organisation structure – identifying the positions required to supervise and manage the operations as well as those for the performance of operational work.
- Reasons for train payload losses and initiatives to improve lift payload.
- Program to up rate the maximum train capacity.
- Monitoring of network speed restrictions and having timelines in place for the speedy removal of these.
- Increasing the range of route knowledge across train drivers to improve flexibility
- Improving locomotive asset utilisation.
- Rolling stock maintenance performance, timely response to work orders and reduction of back log.

QR management are committed to the program and it is well resourced. Although it is at an early stage many of the initiatives have a positive trend line. This will have a significant benefit for QR as it will increase the utilisation of the existing assets as well as for the coal producers who are starting to see much more focus on the operations. Over the next few months the program should broaden out to cover the interfaces between the producers (load point performance) and the coal terminals (train interaction with the unload stations).

<u>Contract Renewal</u>

A new supply chain-focused contracting framework is in the process of being developed by Queensland Rail. The proposed framework includes a number of key issues and business requirements that were raised during the first stage of consultation with DBCT customers and BBI DBCT.

The new contracting framework being developed details the requirements of each supply chain party in supplying capacity to the chain to lift the desired tonnage.

The new contract framework (from QRN's perspective) is expected to require:-

- The support of all stakeholders and customers to renew during 2008 any current rail contracts prior to their existing expiry date;
- Key changes to the current and future rail and port undertakings to provide a more flexible business operating environment; and
- A new "cause and effect" reporting process to be implemented to correctly, identify, through one trusted source, performance achievement or not of each party in the supply chain.

A more extensive range of consultation is now planned to seek comments on their draft contract and specifically on the new concepts. This will commence in late October. After this, QRN state that any new contract will then be tailored to meet the specific business needs of each customer.

<u>Locomotive Procurement Program</u>

Delivery has now commenced of the production run of 60 electric locomotives ordered in 2005. Three prototypes of these locomotives were delivered into the Goonyella system earlier this year.

Delivery of a further 20 electric locomotives ordered in early 2006 ex Germany, will occur during late 2008 and 2009. A site inspection of the build program was conducted by QR in September 2007, with a permanent QR representative to be located on site during production.

A further 25 electric locomotives are now on order for 2009/10 and 2010/11 delivery for the Goonyella system, following receipt of approval from QR's Shareholding Ministers.

In addition to these locomotives for the Goonyella system, QR also is commencing delivery of 15 new diesel locomotives for the other systems, with a further 15 on order for 2009/10 and 2010/11 delivery. These locomotives are for additional coal volumes on the Blackwater, Moura, Newlands and Northern Missing Link systems.

510 x 106 tonne wagons have been approved for construction, with a further 1190 currently requested from an overall build requirement for all systems. These wagons will be constructed to complement the delivery of the locomotives.

Upgrade of the Jilalan yard to support both the additional Goonyella train operations and maintenance requirements is also required. Design work has progressed with requests for investment approvals occurring later this year for a late 2009 commissioning. This upgrade is considered essential to allow the coal chain to operate at the desired capacity. Every action should be taken to expedite completion of this work which is expected to be completed twelve to eighteen months after the final phase of the port expansion.

Coordination Role

Following further consultation, primarily with the coal producers, there is full agreement for a facilitation role which identifies and progresses initiatives on behalf of all stakeholders in the Goonyella supply chain. The elements of the Goonyella system associated with DBCT are more complex. This is primarily a function of the number of stakeholders and complex regulatory environment. A more intensive coordination approach is required across this part of the system. These positions could be filled by one individual or two depending on background and availability of candidates.

Key accountabilities for the facilitation role are:

1. Facilitation of Master Planning processes across the whole system. In particular, address the question of rail infrastructure requirements to operate DBCT at 89.0Mt/y and how the proposed Northern Missing Link interacts with any investment decisions to upgrade rail infrastructure to DBCT. Assist in the development of an approach to ensure that any future plans to lift capacity consider the operating and capital costs across the whole supply chain with a view to preparing an optimum solution.
2. Facilitation of special projects as nominated by the Stakeholder CEO's.

Key accountabilities for the coordination role are:

1. Optimising the throughput of the current supply chain. This would be achieved through facilitating processes such as the proposed 'root cause' analysis. A review of all the different meetings, their charters, make up and a clear definition of how they all fit together in governing the supply chain would be beneficial. Identification of governance processes that lead to coordinated management of resources across the supply chain, whilst at the same time respecting the individual commercial arrangements of stakeholders would also be of benefit.

2. Reviewing and recommending commercial frameworks to better align the interests of system stakeholders to help ensure that the necessary commercial drivers are in place to provide the required assets to maximise the supply chain throughput.

As stated earlier the supply chain is there to support the coal industry. With a clear direction fully supported by the whole of the industry it will move forward to meet its stated goal of having 'best practice operations' throughout coal producer and supplier operations suppling export markets.

Conclusion

The coal supply chain is a complex system. Not only from an operational aspect with the different stakeholders but also considering the different commercial agendas of the stakeholders and the different regulatory frameworks. In the only short term, the business improvement program improvement is the only initiative which can be undertaken to lift export volumes from the existing rail assets. An independently led approach managing the DBCT supply chain on a daily basis (short term planning and day of operations oversight) would also be beneficial not so much in lifting export volumes but in facilitating the interaction of the stakeholders.

In the medium term plans are well underway to purchase additional rolling stock and develop a new contracting framework to better align the interests of stakeholders in the supply chain and ensure export volumes are maximised from the supply chain.

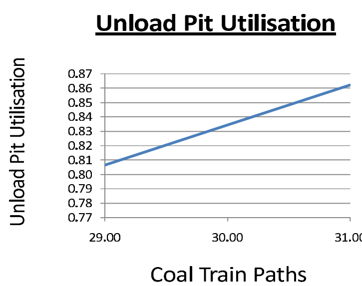
A coordinated approach to master planning of infrastructure is essential. The situation where investments are being made without concurrent investment in other parts of the supply chain and then additional forecast tonnages are contracted out should never be allowed to happen again. The regulatory frameworks that underpin the governance of the supply chain should support this approach. Implementing the facilitation and coordination roles will be a significant step in moving forward.

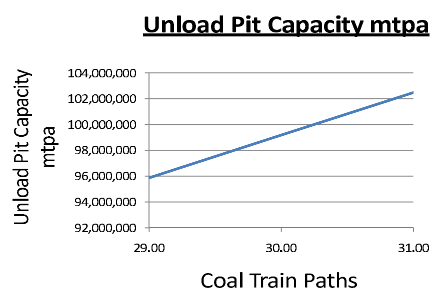
I would like to thank all parties who have provided information and assistance during this study.

Stephen O'Donnell

Appendix 1 – Supporting Rail System Information

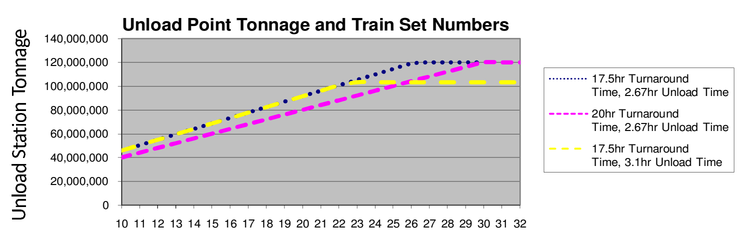
The system is presently designed to operate with a total of 30 coal train paths (CTP's) a day to both ports. The charts below translate this into unload pit utilisation and nominal capacity. For a system operating with limited train storage capacity ahead of the unload pits and limited ability to handle out of sequence trains, the utilisation is approaching the maximum that could be realistically expected.



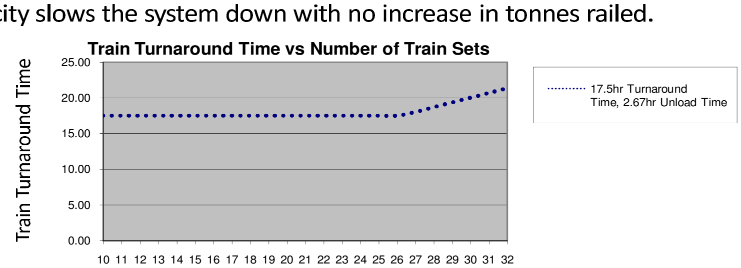


The charts below demonstrate the impact of train turnaround time, unloading time and train numbers on unload station capacity.

Unload station turnaround time sets the maximum number of train consists – beyond full utilisation there in no gain in adding additional train consists.

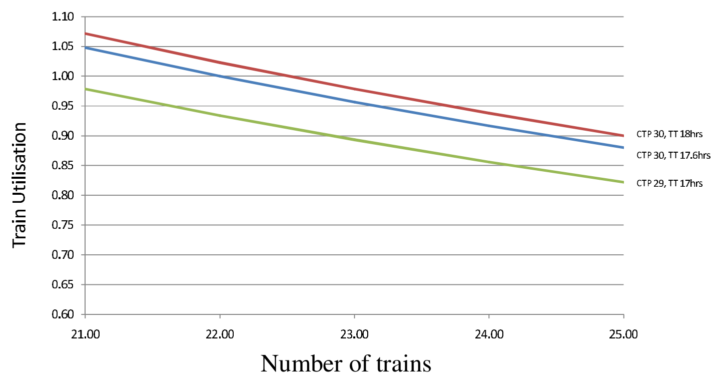


Increasing the number of train consists beyond the unload station capacity slows the system down with no increase in tonnes railed.



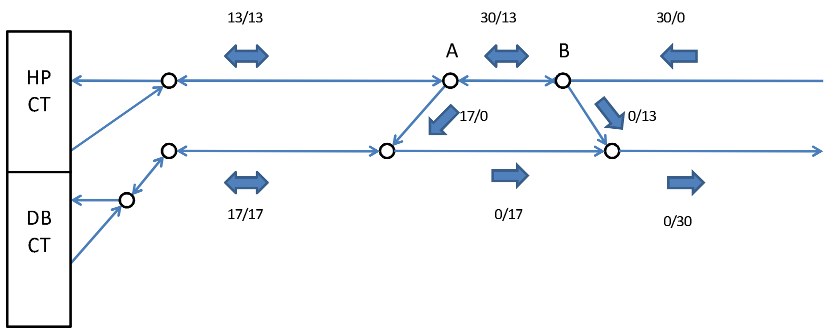
This chart shows the utilisation of train sets for a given system design (Coal train paths, train turnaround times). Demonstrates that 24 train sets are required to achieve target conditions (CTP 30, train T/T of 17.6hrs) with a utilisation of approximately 92%.

- Weighted average cycle time is 16.4hrs (Jilalan/load point/unload point/Jilalan)
- Additional time is required for train examinations, provisioning, driver changes etc.
  - This approximately 1hr 10mins, design train turnaround is 17.6hrs

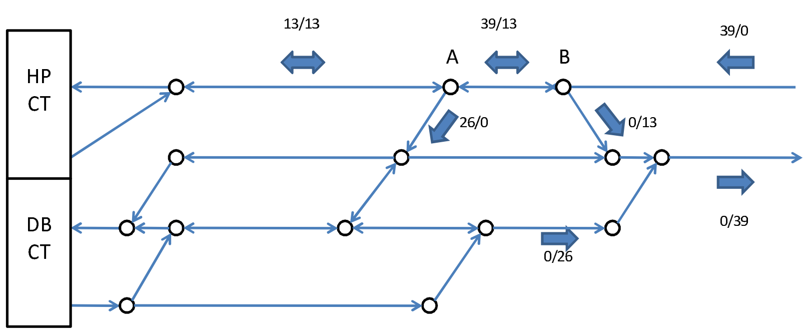


Appendix 2 – Infrastructure Example

Present Port/Rail Connection



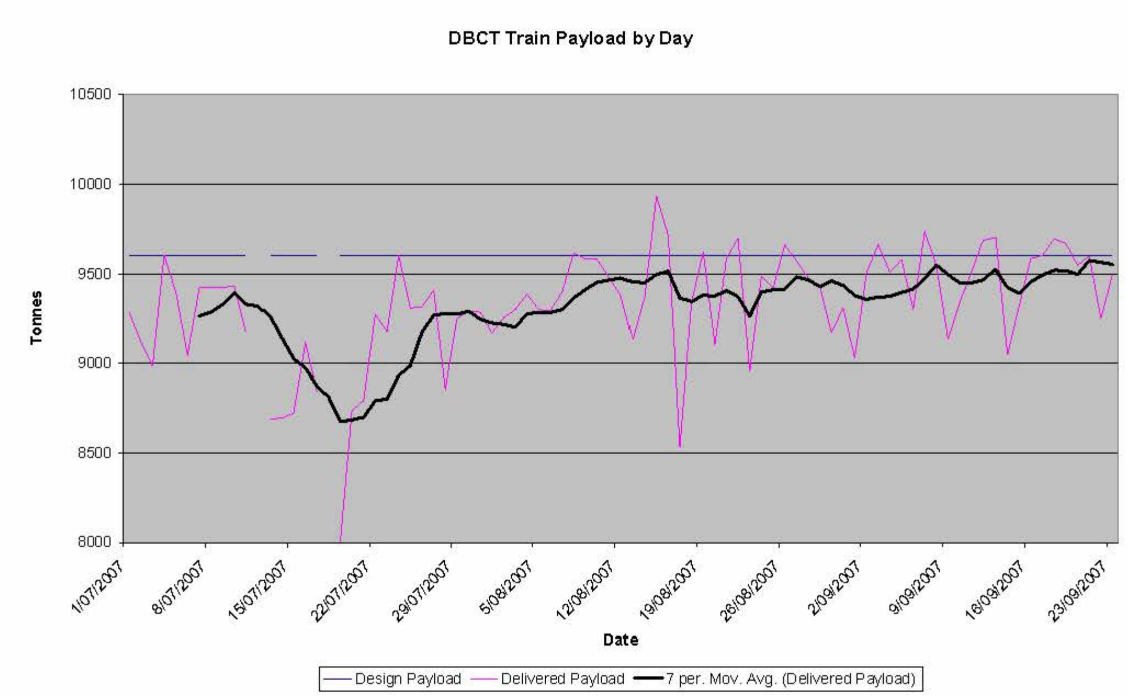
Proposed Port/Rail Connection

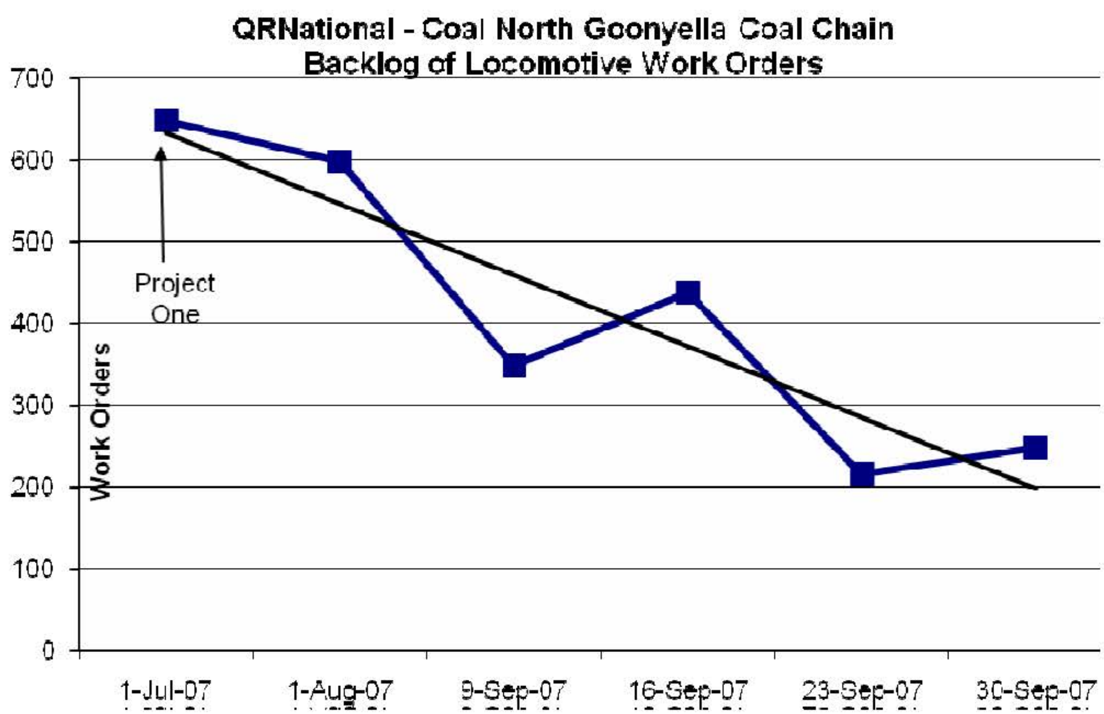


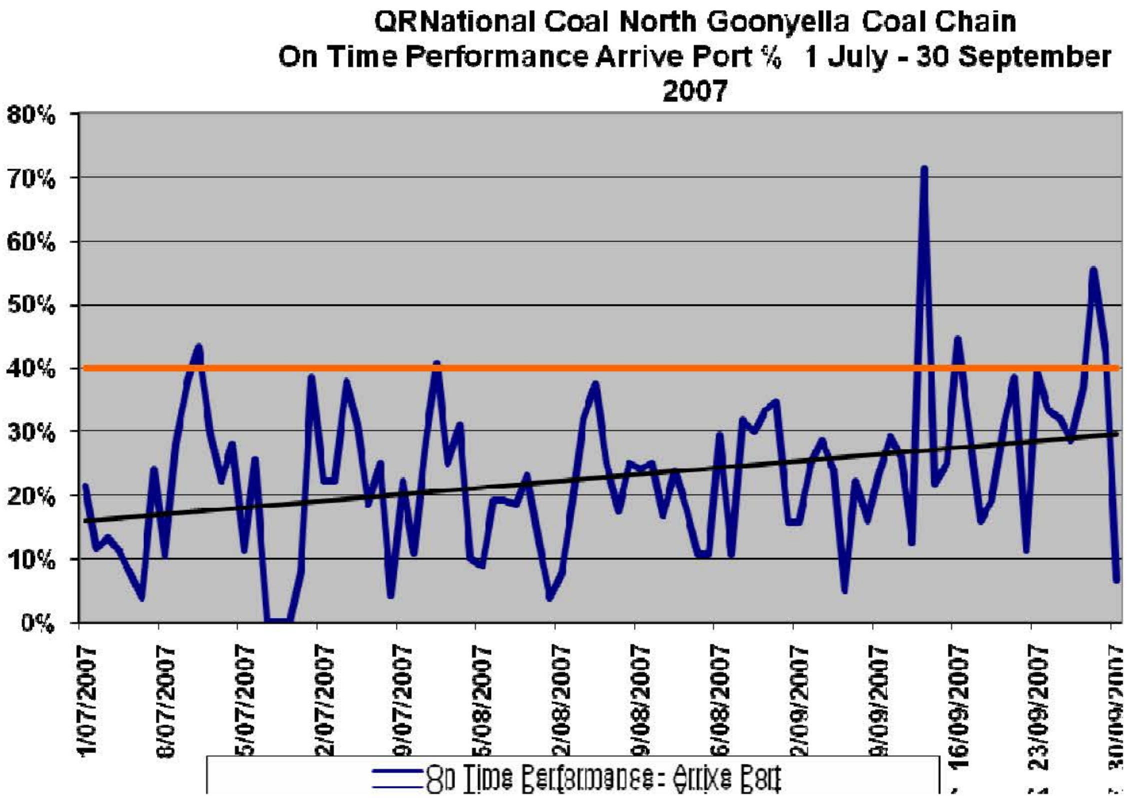
These charts show the current and proposed rail infrastructure feeding the two ports. Data above each arrow indicates the daily up and down train movements. Every two hours a train from Hay Point has to cross incoming trains into DBCT. There are two more crossover points between the port and Jilalan Yard.

Appendix 3 - Business Improvement Program

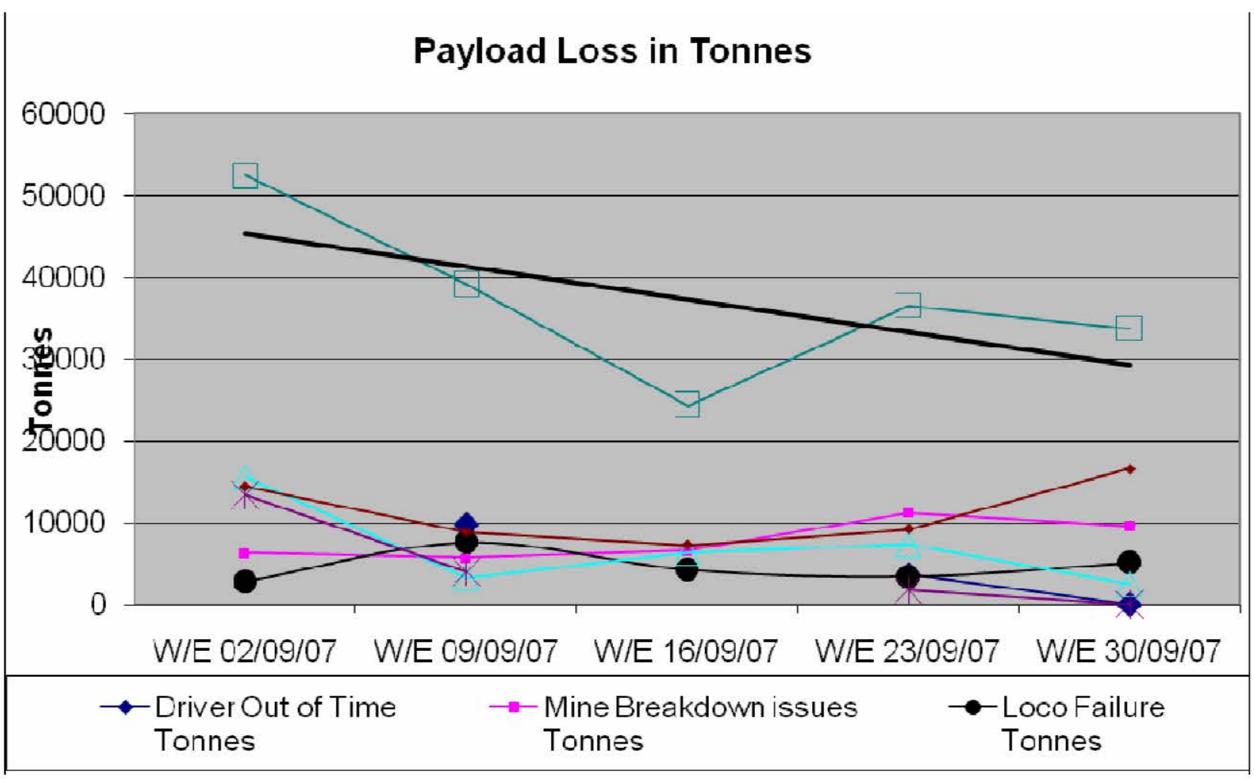
A selection of charts from the BIP currently underway in QRN.







QRNational Coal North Goonyella Coal Chain
On Time Performance Arrive Port % 1 July - 30 September 2007
80%
70%
60%
50%
40%
30%
20%
10%
0%
1/07/2007
8/07/2007
5/07/2007
2/07/2007
9/07/2007
5/08/2007
2/08/2007
9/08/2007
6/08/2007
2/09/2007
9/09/2007
16/09/2007
23/09/2007
30/09/2007
On Time Performance - Arrive Port



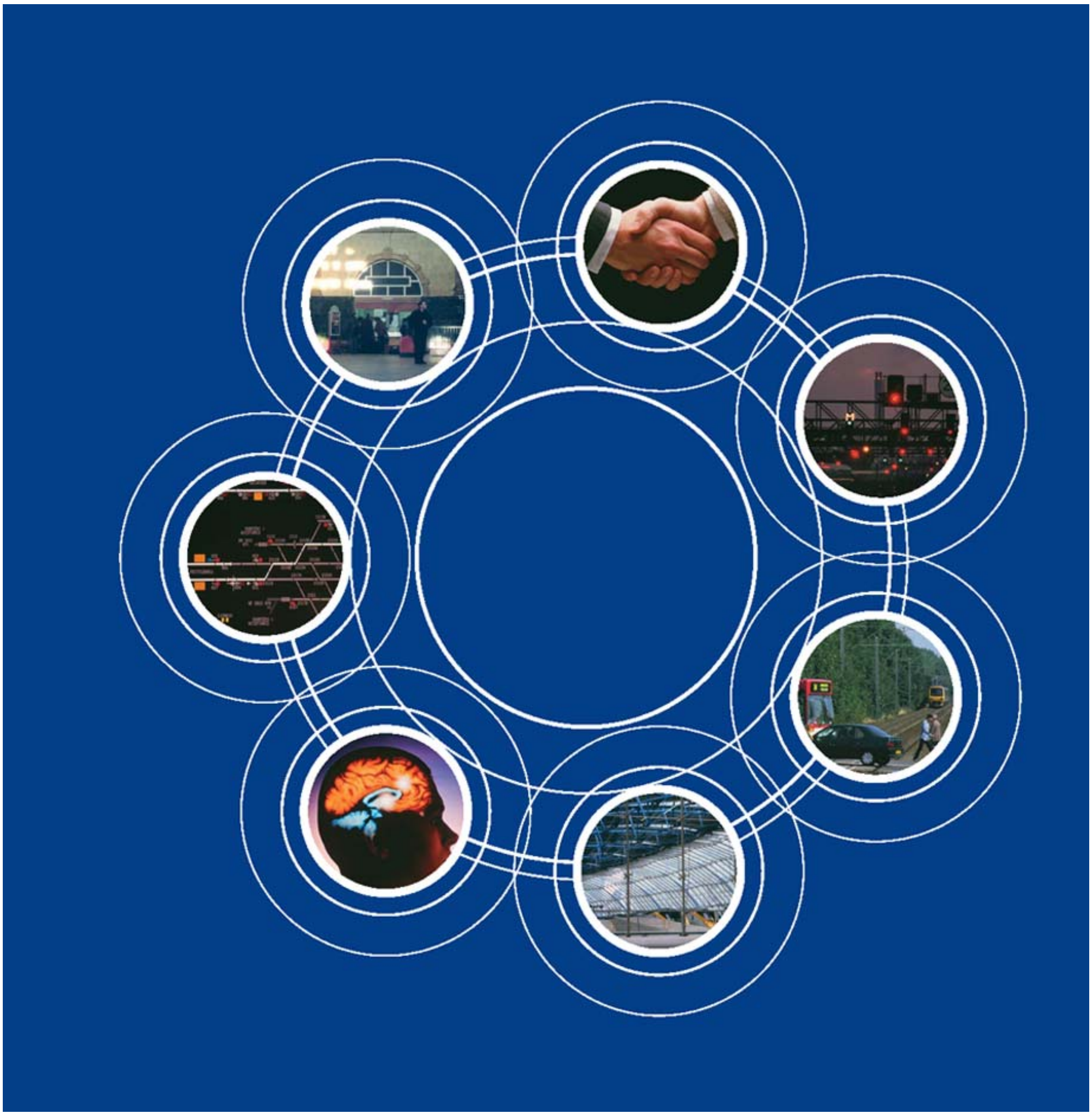
Payload Loss in Tonnes
Tonnes
60000
50000
40000
30000
20000
10000
0
W/E 02/09/07
W/E 09/09/07
W/E 16/09/07
W/E 23/09/07
W/E 30/09/07
Driver Out of Time Tonnes
Mine Breakdown issues Tonnes
Loco Failure Tonnes

Research Programme

Engineering

Energy Game Changer

Macro energy risks affecting the railway in Great Britain



Copyright

© RAIL SAFETY AND STANDARDS BOARD LTD. 2012 ALL RIGHTS RESERVED

This publication may be reproduced free of charge for research, private study or for internal circulation within an organisation. This is subject to it being reproduced and referenced accurately and not being used in a misleading context. The material must be acknowledged as the copyright of Rail Safety and Standards Board and the title of the publication specified accordingly. For any other use of the material please apply to RSSB's Head of Research and Development for permission. Any additional queries can be directed to enquirydesk@rssb.co.uk. This publication can be accessed via the RSSB website: www.rssb.co.uk.

Written by:
Vaibhav Puri
RSSB

Published July 2012

Macro energy risks affecting the railway in Great Britain

Foreword

The Vehicle/Train Energy Systems Interface Committee (V/TE SIC) is a cross industry group which helps deliver the energy aspects of the Rail Technical Strategy (RTS) as directed by the industry's Technical Strategy Leadership Group (TSLG). As part of this role the V/TE SIC also looks at cost effective and efficient ways to manage energy use.

The report that follows was commissioned by TSLG to inform the energy agenda for the RTS by presenting an impartial view of the full breadth of macro level energy issues. It is a knowledge search/literature review which brings together the key points from over 130 sources.

As the industry lead on energy issues, V/TE SIC offers some high level conclusions based on the evidence gathered.

The energy challenge

The supply and security of UK energy is likely to undergo major change over the coming years. Increasing demand for oil (along with the 'Peak Oil' phenomenon), will drive energy costs to much higher levels than today leading to significant capital expenditure in upgrading the national grid and in new power generation. That expenditure is forecast is expected to exceed £100bn by 2020.

Existing power stations soon to be decommissioned will be replaced in part by less predictable sources such as wind, reducing electricity generating capacity margins at peak times. As a result of the generating mix change, we can expect to see significantly higher and more volatile electricity prices.

As the largest single UK consumer of electricity (about 1% of the market) these changes will have a major impact on the railway. Whilst there are things that rail can do to reduce this impact (e.g: through increasingly efficient use of energy, raising the amount of energy recovered through regenerative braking and reducing electrical losses) we can expect the industry's energy cost to rise substantially over the coming years.

Rail's response

The energy benefits of the electric railway are well understood. Rail is at its most energy efficient when powered directly by generated electricity delivered to the train by overhead line infrastructure. Electrification also delivers increased reliability, increased capacity, lower carbon emissions and lower capital and operating whole life costs. The following report leads V/TE SIC to the conclusion that, even with uncertainties around supply and expected cost increases, electricity will continue to be the most viable (and green) energy source. This reinforces the industry's view that further electrification is the most critical element of its emerging energy strategy.

Currently, new electrification schemes are expensive to install. So there is a pressing need to reduce the cost of electrification through more efficient delivery methods, use of new materials and technologies, standardisation, economies of scale and a rolling programme of work. V/TE SIC asserts that, whatever the solution, it must be robust, scalable and able to accommodate future growth in demand from rail transport.

Given the state of current and near future energy storage technology the V/TE SIC does not support the general concept of 'Discontinuous Electrification' which involves not wiring through short sections (bridges, complex junctions etc.) such that the train coasts or uses an alternative energy source to traverse the gap. Research work of the SIC shows that this is both uneconomical (on a 'whole life' basis), and imports significant operational risk.

There will, however, be many parts of the rail network that will not be electrified in the foreseeable future because of cost and/or the economic business case. These routes will continue to rely on ‘self-powered’ trains. In the short-term this means conventional diesel trains but may, over time, extend to hybrid or bi-mode designs.

High density energy storage suitable for use on trains still requires a huge amount of development and testing, practical vehicle operating range being but one issue. Here it is recommended that the rail industry keep a close watching brief on the HGV and large-bus markets where the power demands of circa 350kW per vehicle are comparable with that of a rail vehicle. Road sector developments can then be applied to rail from a position of greater certainty of cost, maintenance and performance risks associated with these new technologies.

Tony Mercado

Chair of V/TE SIC

Summary of key findings

Background and context

The rail industry is a major consumer of energy, traction alone consumes about 670 million litres of diesel and 3,000GWh of electricity a year. The annual expenditure on traction energy is over £500 million[1]. The industry represents one of the biggest single customers of electricity consuming around 1% of the UK's supply (or 2.6% if all railway types, rail premises etc are included). In considering the shape of the of the 30-year Rail Technical Strategy, the Technical Strategy Leadership Group (TSLG) has identified energy use as one of the five key 'game changer' issues that the industry will face. To support the industry, a full understanding of the risks and uncertainties it is likely to face in the next 20 years (2030), was needed. This would in turn inform discussion and policy related to energy issues.

Scope of work

An extensive literature review was carried out to identify and assess the existing knowledge on macro energy risks and the potential implications for the GB railways. This report, through the knowledge gathered, aims to provide the context for the debates and discussions around energy and GB rail's energy future. The review does not seek to tell the rail industry what it needs to do, but rather present an unbiased, dispassionate view of the full breadth of macro level issues.

The literature search reviewed over 130 relevant sources[2]; these included key reports, as well as discussions where possible, with various government, commercial, international and research bodies.

The report mainly examined electricity and diesel as the main energy contributors for the railway, but also examined the prospects of alternative sources for the 2030 time horizon. It examined the availability of raw materials that underpin electricity generation such as coal, gas, nuclear fuel, etc, as well as the plans to meet future transmission and distribution challenges.

It explored key questions and issues that are often raised in discussions around future energy security to understand if existing literature and information addresses them adequately.

1 Technical Strategy Leadership Group website http://www.futurerailway.org/Pages/EnergyStrategy.aspx

2 See Section 4 for the full list.

This includes future electricity and diesel price projections, and the impact on the rail industry operating costs.

It also examined the prospects of renewable energy generation which is the cornerstone of current government plans and policies, and thereby allowing the reader to examine the possibility of government plans coming to fruition, as well as the associated challenges if they did.

The report explored the potential for energy efficiency measures and efforts in mitigating the risks and opportunities identified here. Finally, it identifies areas which may require further work and assessment to provide a fuller picture of the impact on the rail industry and its response options.

General findings

All energy sources will have challenges and risks associated with them in the future. At a macro level these issues are heavily dependent on national government intervention / steer with limited potential for GB rail to influence them directly. It is important to recognise that there is a significant political dimension to energy security which will play the overriding role in shaping the future. Despite the uncertainties there are opportunities for the industry to respond through greater energy efficiency; flexibility through a diverse mix of energy sources; micro-generation opportunities; and by playing an active part in matching demand and available supply through energy storage and smart grids.

The literature review considered security risks in terms of availability, affordability, accessibility, and sustainability of the energy required by GB railways now and in the future[3]. The next few sections provide an overview of findings from these four perspectives.

Availability: Electricity is the preferred long-term energy source though it has some short- to mid-term availability risks

Most government bodies indicate that electricity availability is not a significant risk, with options available in the future to adjust supply to changing demand requirements. However, there is a high risk that capacity margins will be very small in certain years

3 See Section 2 for a fuller explanation of the four terms.

between 2019 and 2025 as new renewable and nuclear plants are phased in[4]. There are suggestions that electricity availability is not a risk as long as most sectors continue their drive for greater energy efficiency, government reacts well ahead in time to ensure adequate capacity[5], and the intermittent nature of renewable dependant electricity supply capacity is addressed. However, these are significant challenges to overcome; therefore electricity availability has to be considered a moderate to high risk for the railways especially 10-15 years from now onwards. It is important to note that longer-term prospects beyond 2030 are considered more stable as renewables become an integral part of the grid. Electricity availability constraints are due to planned closures and retirements, and the transition planning to greater renewable dependence to replace that capacity. There is flexibility available to the government of the day to incentivise prolonging the lives of plants, applying for derogations, etc to ensure that shortages in the interim are avoided. However in the longer-term, the current plans suggest that additional capacity will be available and should accommodate the expected demand growth[6].

Projections for the future (2030) electricity mix point towards 40% reliance on renewables - mainly wind energy (30GW, 33-35%), while Gas (Combined Cycle Gas Turbines - CCGT) will become the main generation type (45%). Nuclear will contribute approximately 7GW (6-7%)[7]. Dependency on coal will be reduced significantly through plant retirements and decommissioning. It is important to recognise that raw materials underpinning electricity generation such as coal and uranium are not indefinite and their availability is not as unlimited as often assumed[8]. Prospects for gas availability are very good, and UK is considered to have a very resilient and robust position in terms of gas availability. The literature also suggests that in terms of potential for wind energy, the projected generation capacities (2030) can be catered for by the UK[9]. However, wind and nuclear energy have significant other challenges and issues to overcome before this future is realised, and a greater reliance on wind energy has associated risks and

4 See Section 6.3 for more details.
5 See Sections 6.3, 6.4 and 6.5 for more details.
6 See Section 6.5 for more details.
7 See Section 6.3 for more details.
8 See Sections 5.4, 5.6, 5.6 for more details.
9 See Section 6.7 for more details.

issues with intermittency and volatility. These are discussed further in the accessibility section.

Diesel's future availability is much more downbeat with supply shocks due to Peak oil and geo-politics likely to constrain supply. Diesel fuel availability is going to be significantly affected as per the peak oil phenomenon[10] which is likely to drive prices up. However, dampening demand due to slow economic growth and/or fuel switching to greener options may balance the supply demand dynamic and ensure that prices rise more gradually. An alternative view from the anti peak oil school claims that high prices will bring forward investment in exploration, discovery and generation thereby meeting demand[11]. However, reports from UKERC[12] and IEA suggest that even if the prices were high enough to justify increased extraction, it would be likely to simply delay peak oil, and lead to an even sharper fall in production (and higher prices) later. Diesel availability in the long-term remains a high risk, as well as its sustainability, which is likely to lead to more emissions based taxation and levies. For the report's horizon of 2030, fossil fuels will still play an active part in providing energy for transport, although the increasing supply constraints and growing demand from countries like China and India is going to have an adverse impact on the price.

The long-term prospects for alternative sources such as hydrogen fuel cell look promising but they are unlikely to be a significant factor for the railways until 2030, although developments in these areas should be monitored[13].

Energy storage solutions can provide benefits in some circumstances and are likely to become a big factor with greater reliance of renewables with volatile supply conditions. Their feasibility and commercial viability are their biggest challenge[14]. Research suggests that battery cost projections show a downward trend especially with greater use as well improvement in performance such as energy and power densities and lifecycles, thereby making them much more commercially viable

10 See Section 6.8 for more details.
11 What Goes Up Must Come Down? - An Economic Analysis of Peak Oil (Boyce, 2009).
12 Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production (UKERC, 2009).
13 See section 5.11 for more details.
14 See section 5.9 for more details.

and affordable in the future[15]. However, the future availability and escalating cost of rare earth metals and Lithium which are used in these batteries and key electronic components is a real risk, although the recycling potential and with industries slowly reducing their dependence on them, suggest that this risk could be addressed.

Affordability: Energy prices will rise significantly and become more volatile

Growing global demand, Peak Oil, and the increased cost of extraction will push oil prices up and increase price volatility (with a potential supply shock before 2020). While for electricity, by 2020 the £100 billion+ investment in new bulk generating capacity and associated grid connections (double the investment rate of the last decade) will drive higher electricity prices.

The reduction in spare generating capacity (coal and nuclear decommissioning could lead to supply shortages) and increased reliance on supply from renewable sources which are greener but more variable in terms of availability, could exacerbate the peak / off-peak differential. The highest peak (daily + seasonal) tariff could be significantly higher than the lowest off-peak tariff. Generally the rail industry energy costs (traction) are likely to nearly double (from £500 million to £1 billion) in real terms by 2030, which strengthens the case for initiatives aimed at greater energy efficiency.

It is expected that both electricity and diesel fuel prices will increase considerably in real terms, thereby impacting affordability[16]. However, electricity prices in the mid-term (until 2030) are projected to rise far more dramatically relative to the increases in diesel price in various scenario conditions provided by DECC[17] (average of 84% increase in electricity prices compared to only 8% increase in diesel price across six scenarios).

However, despite the relative rate of price increase described above, the relative efficiency of diesel vs. electric equipment (ie electric vehicles being far more efficient than diesel vehicles) will significantly impact the relative costs for the two energy sources

15 See section 5.9 for more details.
16 See section 6.9 for more details.
17 DECC energy retail price projections (DECC, 2011).

for the railways. Therefore, despite the greater relative increase in electricity prices compared to gas oil (which will also rise but far less dramatically in the short-/mid-term) highlighted, in the six projected scenarios, diesel costs will still be on average 13% more expensive than electricity in terms of cost of fuel per vehicle km by 2030.

It is also important to recognise that over a longer timescale (>20 years) it is likely that the increased electricity costs will stabilise, while diesel costs are likely to carry on increasing. Therefore, despite the mid-term price rises, electricity will still be the more reliable and greener long-term energy source for the railways. Also, despite electricity costs rising more quickly than diesel, the relative efficiency advantage that electricity offers today have the potential to offset some of the price hike, if the industry moves towards more efficient electrification systems (eg DC to AC). However, it is also true that fossil fuels (diesel) are likely to still play a significant part in an electric future. An ongoing challenge for GB rail would be to ensure they are as efficient, and as low carbon as possible.

Accessibility: Wind energy will contribute to significant mid-term risks if not addressed

Despite being adequately available, both wind and nuclear energy generation come with challenges associated with social acceptance of such the schemes, especially if they are large scale and across the country. Wind will contribute a significantly bigger chunk of the capacity in 2030 than nuclear, but its potential intermittency requires implementation of mechanisms and ways to store/manage excess energy when it is generated (but adequate demand is not there) and deliver/distribute that stored energy when the demand is there (but adequate supply is not there). Research suggests that this supply and demand mismatch does occur, and if nearly 30% of the supply will come from wind power, the need to manage this mismatch becomes critical as it would lead to significant wastage of energy when demand is not there, or significant shortfalls when demand is there[18].

18 See Section 6.6 for more details.

The current constraints (physical, technical and commercial) on large scale storage mean that this is a huge risk in terms of supply of electricity in the future. One of the responses requires large scale take up of electric cars which in turn help manage the supply/demand imbalance through smart charging and providing some energy back to the grid if supply suddenly drops. However, this response means a greater electricity use (which in turn itself fuels potential availability risk), although supply becomes more robust. This intermittence also has an impact on price volatility, and research suggests that variability could cause a differential of five times or more between prices at different times of the day or year. Again, it is important to recognise that these issues will be part of the transition to these renewable energy sources, and it is expected that they will be addressed once renewables become an integral part of the electricity supply in the long-term.

Sustainability: Emissions polices, taxation, levies, etc will drive energy prices and choice

Current plans and the future generation mix are aimed to reducing UK's carbon emissions and meeting its stated obligations. Electricity is the greener source of energy, with environmental commitments and government / EU policies[19] incentivising low carbon, low emissions energy sources more and more the generating mix will move away from fossil fuels.

Research shows that current carbon pricing is unlikely to be a major factor in the economics of fuel choice for the end user. However, ethical and political considerations (both for government and the end user) as well as commitments given in national and international frameworks are likely to push toward greater consideration (and taxation) of carbon emissions. It is also important to note that traction energy only accounts for 63% of rail's carbon emissions, which means that stations, depots and train control systems are also key contributors to energy use and

19 The European Commission (EC) Directive on the promotion of the use of energy from renewable sources (Directive 2009/28/EC, known as the Renewable Energy Directive or RED) requires that by 2020, 20% of the European Community's gross final consumption of energy should come from renewable sources, and 15% of each Member State's transport energy consumption should be from renewable sources.

related emissions[20]. Non-traction energy will face similar rises in energy prices, with an additional levy for many rail industry organisations through the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme.

The impact on the railways

Rail industry traction energy costs are likely to rise from £500m, to £800m (in today's prices) by the end of CP5. Adding non-traction energy (for powering stations, depots, signalling etc) could push the industry's annual energy bill to over £1bn over the same period.

Energy currently accounts for a relatively small proportion of the industry's costs (4-5% today). However, as energy prices rise and post-RVfM[21] savings are made elsewhere, energy costs will become a greater slice (perhaps 19%) of a smaller cost pie. The significance of the cost rises could be even bigger for individual TOCs where the current energy cost contribution of around 10% could potentially rise to 39% so is likely to significantly impact industry competitiveness and profitability[22]. It is inevitable that energy costs will rise, and finding savings is an important objective for the railways. This will increase the importance, and strengthen the case for energy saving initiatives.

Greater peak/off-peak variation (which could be as much as five times) will exaggerate the cost impact on rail as peak rail traction demand tends to coincide with peak electricity demand across the grid. The cost rises projected are average prices and do not show the implications of the peak/off peak variability, which could mean that the impact on the railway costs could be significantly more than reported here. The costs escalation combined with the peak/off-peak variation in price will have a significant impact on operators unless they can mitigate this through hedging/longer-term supply contracts. The 'electrification' of the road vehicle sector will make road more competitive by allowing it to access cheaper off-peak energy.

20 RSSB R&D project T913: Whole life carbon footprint of the rail industry http://www.rssb.co.uk/sitecollectiondocuments/pdf/reports/research/T913_rpt_final.pdf

21 Rail Value for Money review http://www.rail-reg.gov.uk/server/show/ConWebDoc.10401

22 See Sections 6.1 and 6.2 for more details.

What can the railways do?

The response options for the railways can be categorized as where the railway is not in control and is affected by policies and directions set elsewhere, and where the industry is more in control such as greater effort towards energy efficiency.

The railways generally tend to have long-term contracts with its electricity suppliers (via Network Rail) which are very favourable compared to general costs and terms of electricity supply. However, it is worth noting that the railway is treated as any other household customer, ie there is no extra legal or contractual protection or commitment to supply electricity to the railway. In the event of a shortage it is as prone to the 'lights going out' as any general household (unless it is a national emergency - war, etc). The rail industry should be lobbying and influencing the relevant bodies and government to ensure that the railways is provided greater protection as a critical public service, if a supply shortage becomes imminent.

It is important to note that the railways are the transport mode which can make most efficient use of electricity, directly down the wire. Putting this through vectors such as batteries or Hydrogen fuel cells destroys this advantage by lowering capacity and efficiency. Despite the efficiency advantage rail enjoys over other modes, there are significant opportunities for rail to increase its efficiency even more, by reducing losses and managing energy more intelligently. Conversion of the DC network to a more energy efficient AC system would result in a significant reduction of up to 25%[23] in energy costs. Rail's peak demand may be reduced (peak lopping) through energy storage, self generation and - in the longer-term - intelligent traffic management. Storing energy to help balance the grid and provide security is likely to carry significant financial incentives and cost savings for the railway.

However, rough analysis in the report also shows that energy efficiency measures have the potential to offset the energy cost rises[24]. The analysis also highlights the scale of the challenge facing the industry but also shows that with significant effort these

23 Emerging findings of RSSB research project T950 - Investigating the economics of the 3rd rail DC system compared to other electrification systems http://www.rssb.co.uk/RESEARCH/Lists/DispForm_Custom.aspx?ID=965

24 See Section 6.10 for more details.

challenges can be met. Ensuring availability and affordability of supply (through self generation, energy efficiency and protecting against the peak / off-peak energy price /availability disparity) should be a cornerstone of a robust energy strategy for GB rail.

While there are risks to future electricity availability, electricity will offer a more secure, low carbon (through government's decarbonisation targets), long-term energy solution for rail. However, even if a major electrification programme is taken forward, large parts of the network will still require self-powered trains for the foreseeable future. The industry will therefore need to continue to find ways of improving the efficiency of the existing diesel fleet while exploring alternatives that are as sustainable and low carbon as possible.

Storing energy to help matching demand and available supply (arbitrage - store low cost energy for peak consumption) is likely to carry significant financial incentives and cost savings for the railways, and provide security. Microgeneration could also aid in offsetting peak energy prices and providing greater security.

Energy risk mitigations are likely to require significant strategic planning and commitment. Rail's long lead times / asset lives mean decisions about how the industry responds to these challenges will need to be taken in the very short-term. It is important that GB rail is prepared to meet the significant energy challenges in the not-too-distant future.

The remainder of this report provides the evidence base, with external references, from which this summary is derived. The reader is invited to review that evidence and consider the impacts and options for rail.

Table of Contents

Macro energy risks affecting the railway in Great Britain

1 Background

The rail industry is a major consumer of energy, using about 670 million litres of diesel and 3,000 GWh of electricity a year for traction purposes. The annual expenditure on traction energy is over £500 million. In considering the shape of the 30-year Rail Technical Strategy the Technical Strategy Leadership Group (TSLG) has identified energy as one of the five key 'game changer' issues that the industry has to face.

This report reviews existing knowledge on macro level energy risk and the potential implications for GB railways over a 20 year time horizon (2030). Its purpose is to ensure discussion, decisions and policies related to energy issues are carried out with a full understanding of the risks and uncertainties in terms of its energy security. This report provides a consolidated view of the literature reviewed and a summary of the findings.

This document provides a summary, including headlines, key points for discussion and questions for further exploration. Access to the list of knowledge sources identified and analysed as part of this work, including a graphical representation of the macro (national and global) factors affecting energy risks to the GB rail that have been looked at can be found in the bibliography, which is available on request.

2 Energy security – what does it entail?

In 1985, the International Energy Agency (IEA) defined energy security simply as:

> *'An adequate supply of energy at reasonable cost'*

This is increasingly seen as not holistic enough. In Government's ambition to move to a low carbon economy energy supplies that come with high greenhouse gas emissions are not considered secure due to climate change impacts in the longer term. The European Commission's (EC) definition of energy security is:

> *'Energy supply security must be geared to ensuring the proper functioning of the economy, the uninterrupted physical availability at a price which is affordable, while respecting environmental concerns'.*

Based on this, the extent to which the current energy supply for the railway sector is 'not secure' can be analysed by examining the risks to availability, affordability, accessibility, and sustainability of energy needs for the GB railways, where:

- **Availability** is defined by enough energy supply potential to support the current and future energy needs of the railways to match the expected demand for the railways in the future.
- **Affordability** is defined by the level of energy costs which can be reasonably borne without endangering the commercial competitiveness of the railways vs. other modes of transport, as well as, the commercial competiveness of the organisations that operate the GB railways.
- **Accessibility** is defined by availability of enough energy on demand to ensure that the railways can meet its ongoing operating obligations to its customers on a day to day basis.
- **Sustainability** is defined by a railways energy mix which would allows it to meet its environmental, legal and social obligations and objectives.

This review of the literature identified key issues based on these four perspectives of energy security.

3 Potential energy futures for the railways

The analysis and review of the literature highlights that all energy sources have challenges and risks associated with them and their security is heavily dependent on national government interventions.

With no silver bullet to future energy risks, the need to be more energy efficient and exercise more control and self reliance in energy matters is paramount for the railways under all circumstances. Electricity, diesel and other sources, all face potential availability and affordability risks and complete reliance on any one source increases those risks.

The nature of risks is different for the two main current energy sources (electricity and diesel).

Risk to electricity availability comes from:

- Greener policies focussing on renewable energy sources, coupled with decommissioning and retirement of current generators.

- Greater reliance on electricity by other transport modes (partly compensated for by efficiency gains in electricity use).

Diesel risk comes from:

- Peak oil and geopolitics.
- Contributions to emissions.
- Its fuel efficiency.

The general message from the literature is that future energy needs at the point of use will be met by electricity but due to the significant challenges and some risks to electricity supply, fossil fuels may need to play a part in aiding the transition. The risks associated with this most likely future require consideration of mitigating measures such as:

- Energy storage technologies and other solutions such as Smart Grid to aid balancing of the grid.
- Hybrid technologies to ensure that there is flexibility of fuel usage to counter availability and affordability issues.
- Microgeneration.
- The role of fossil fuels in a greener future for the railways (can they help?).
- Assessment of key operational tradeoffs GB railways would be willing to make if energy availability is under major threat in the future.

The review of the literature has highlighted three basic alternative scenarios and associated risks. These have been put forward to spark discussions within GB rail on how future macro level energy risks may impact the railways and what considerations need further assessment to ensure that the GB rail policies are robust in the face of a potentially uncertain future.

These are not meant to be exhaustive or detailed scenarios or predictions of the future, but are only illustrative to help explore how the key issues and trends highlighted in the report can be used to assess the challenges and robustness of existing energy policies and strategies.

These scenarios could be explored in greater detail in future work, which would need to consider rail specific factors on top of the macro factors explored in this report. The report is highlighting these scenarios to invite debate on how the railway industry is going to mitigate the risks highlighted in the report (through smart grid, DC to AC conversion, etc) if such a future were to exist. The futures are not predictions. Some mitigations might be common across all scenarios (such as greater energy efficiency) but more important in some than others. While others, may be specific to a scenario.

3.1 Scenario 1: Status quo (with no hybrids, separate diesel and electric fleets)

3.1.1 Risks, issues and opportunities

- Potentially parallel risk of electricity shortfalls plus peak oil (and other disruptions) causing rapid increases in energy costs. The likelihood of this happening at the same time might be low to moderate.
- Potential for electric or diesel vehicles to be rendered useless in the short term if either energy source is inaccessible or prohibitively expensive.
- Emissions targets will be much harder to achieve.

3.2 Scenario 2: Greater electrification with hybrid fleets (still depending on fossil fuels to allow for flexibility and security of supply)

3.2.1 Risks, issues and opportunities

- Hybrid trains will allow the ability to adjust fuel source as needed to optimise costs.
- May need trains to be able to be totally powered by either energy source, in case the other is unavailable or very expensive.
- Improved efficiency of diesel hybrids trains providing significantly lower fuel costs than electric vehicles.

3.3 Scenario 3: Greater electrification with electric only fleet (limited dependence of fossil fuels)

3.3.1 Risks, issues and opportunities

- Greater overall efficiency in terms of consumption value due to greater electric traction efficiency.
- Will be prone to risks of electricity supply and price rises.
- A potential future dependency on renewables in the generation mix may require a significant grid supply demand balancing. The railway would benefit from SMART GRID and other solutions such as the ability to store energy (eg line side batteries, battery powered trains, large scale central energy storage). Storage will allow the railways to make best use of intermittent demand variations and store power at cheaper times and redistribute under conditions when available supply is low. This could be incentivised, thereby reducing energy costs in the long run, but it would require significant capital investment and careful planning.
- Risks of very high battery costs and issues with battery availability.
- Emissions targets easier to achieve.
- Changes/upgrades to rail electricity infrastructure for more efficient systems, and reduced losses.
- The remainder of this report discusses in greater detail some of the key challenges, issues and risks which underpin the highlighted scenarios and invite the reader to examine the evidence presented to form a view on the opportunities and threats that emerge for the GB rail industry.

4 Key sources of literature underpinning the work

This review assessed data and information from various government, commercial, international and research bodies. This included discussions with Department of Energy and Climate Change (DECC), Department for Transport (DfT), Network Rail, RSSB, and the Ministry of Defence (MoD). A full list and description of sources and specific literature is available from RSSB. The key sources below illustrate the range of perspectives covered.

4.1 UK Government

- **Department of Energy and Climate change (DECC)** before October 2008 part of the Department for Business, Enterprise and Regulatory Reform (BERR), and the Department for Environment, Food and Rural Affairs (Defra)
- **Department for Business, Innovation and Skills (BIS)**, formerly Department for Trade and Industry (DTI)
- Department for Transport (DfT)
- Department for Environment, Food and Rural Affairs (Defra)
- Ministry of Defence (MoD)
- Office of the Gas and Electricity Markets (Ofgem)
- House of Commons Committee on Climate Change (CCC)
- HM Treasury
- Infrastructure UK
- HM Revenue and Customs (HMRC)

4.2 International agencies

- International Energy Agency (IEA)
- International Atomic Energy Agency (IAEA)
- The Atlantic Council of the United States (ACUS)
- United States Department of Energy
- United States Geological Society
- Organisation for Economic Co-operation and Development (OECD)
- European Commission (EC)
- Sustainable Development Commission (SDC)
- United Nations Environment Programme (UNEP)

4.3 Commercial

- **Consultancies:** RedPoint, Pöyry, PriceWaterhouseCoopers (PWC), McKinsey, Parsons Brinkerhoff, NERA Economic Consulting, DeltaRail, Interfleet, Transport Research Laboratory (TRL), Lloyd's Register Rail, Global Insight, Best Foot Forward, etc
- **Energy:** National Grid, Shell, BP, British Energy, EON, EDF, British Gas, etc
- **Other:** HSBC - the world in 2050, BBC, The Economist, The Telegraph, Goldman Sachs, etc

4.4 Other groups

- Technology Strategy Board (TSB)
- UK Energy Research Centre (UKERC)
- UK Industry Taskforce on Peak Oil and Energy Security (ITPOES)
- Electricity Networks Strategy Group (ENSG)
- UK Petroleum Industry Association (UKPIA)
- Renewable Energy Foundation (REF)
- The Carbon Trust

4.5 Railway specific

- Office of Rail Regulation (ORR)
- Network Rail (NR)
- Association of Train Operating Companies (ATOC)
- RSSB

5 Headlines based on the review of the literature

5.1 Availability of electricity and diesel

Most government bodies (DECC, Ofgem, etc) indicate that **electricity availability** is not a significant risk, with options available in the future to adjust supply to changing demand requirements. However, there is a high risk that capacity margins will be very small in certain years between 2019 and 2025 as new renewable and nuclear plants are phased in. In some scenarios (ie periods when the output from wind farms is near zero due to lack of wind – and history shows that it does occur when energy needs are high) the capacity margins could fall below zero from 2019 onwards[25]. In addition, current projections do not explicitly explain how any significant shift to electric road vehicles will be catered for. Greater energy efficiency generally from households, and transport as well as improved efficiency in generation, transmission and distribution will assist in addressing some of these risks but it may be that greater generation capacity (over and above currently planned) may also be required. This means that electricity availability is not a risk as long as most sectors continue their drive for greater energy efficiency, government reacts well ahead in time to ensure adequate capacity, and the intermittent nature of renewable dependant electricity supply capacity is addressed. However, with these significant challenges lying ahead, the security of electricity supply has to be considered a moderate to high risk for the railways especially 10-15 years from now onwards. This position should be reviewed and revised as the planned mitigations to these challenges start to come to fruition.

Diesel fuel availability is going to be significantly affected as per the peak oil phenomenon which is likely to drive prices up. However, dampening demand due to slow economic growth and/or fuel switching to greener options may balance the supply demand dynamic and ensure that prices rise gradually. An alternative view from the anti peak oil school claims that high prices will bring forward investment in exploration, discovery and generation thereby meeting demand[26]. Reports from UKERC[27] and IEA suggest that if the prices were high enough to justify increased extraction, it would be likely to simply delay peak oil, and lead to an even sharper fall in production (and higher prices) later. Diesel availability in the long term remains a high risk, as well as its sustainability, which is likely to lead to more emissions based taxation and levies.

Impact and timescales for **peak oil** remain uncertain but UKERC figures suggest that the timing of the global peak for conventional oil production is relatively insensitive to the assumed size of the global resource. For a wide range of assumptions about the

25 *Electricity Market Reform - options for ensuring electricity security of supply and promoting investment in low-carbon generation* (DECC, 2010).

26 *What Goes Up Must Come Down? - An Economic Analysis of Peak Oil* (Boyce, 2009)

27 *Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production* (UKERC, 2009).

global Ultimate Recoverable Resource (URR), ie oil economically extractable over all time, the date of peak production can be estimated to lie between 2009 (ie it has already happened) and 2031. Current evidence analysis suggests that a peak of conventional oil production before 2030 appears likely and there is a significant risk of a peak before 2020.

Research suggests that maintaining current rates of **oil production,** translates to approximately 3 million barrels per day (mb/d) being supplied by new capacity (extra capacity is needed to compensate for the declining rates of production from existing fields). This is equivalent to a new Saudi Arabia (in terms of rates of production) coming on stream every three years, which is highly unlikely. Oil production capacity is relatively inflexible in the short term (to about 2016) because the projects providing supply on these timescales are already under way[28].

The rail industry currently uses **Gas oil**[29] diesel which is taxed significantly lower than the type **Diesel Engine Road Vehicles (DERV)**[30] making it nearly 50% cheaper. Gas oil is similar to DERV as such (there may be differences in Cetane values, and sulphur and bio-fuel contents), and is often dyed red and contains chemical markers in accordance to customs and excise requirements, to prevent its use as a fuel in road vehicles. **Note that from this point onwards, all references to diesel refer to gas oil rather than road diesel (DERV) unless otherwise stated.**

5.2 Electricity and diesel prices

It is expected that both **electricity and diesel fuel prices** will increase considerably in real terms, thereby impacting affordability. However, electricity prices will rise far more dramatically relative to the increases in diesel price in various scenario conditions provided by DECC[31] (84% average increase compared to only 8% increase in diesel).

Despite the relative rate of price increase described above, the relative efficiency of diesel vs. electric equipment (ie electric vehicles being far more efficient than diesel vehicles) will significantly impact the relative costs for the two energy sources

28 Global Oil Depletion - An assessment of the evidence for a near-term peak in global oil production (UKERC, 2009) and The Oil Crunch: A wake-up call for the UK economy (UK Industry Taskforce on Peak Oil & Energy Security, 2010).
29 BS 2869 : Class A2 - British standard for non-road mobile diesel.
30 BS EN 590 - British/European standard for road diesel.
31 DECC energy retail price projections (DECC, 2011).

for the railways. Therefore despite the greater relative increase in electricity prices compared to gas oil (which will also rise but less dramatically in the short-mid term) highlighted, **in most projected scenarios on average diesel costs will still be around 13% more expensive than electricity in terms cost of fuel per vehicle km by 2030**. Please note that although speculating beyond 15-20 year time horizon of specific energy price figures is futile. Most of the literature acknowledges that electricity prices are likely to stabilise in the long term, as the use of renewable sources increases leading to greater economies of scale, more innovation, a maturing supply chain, and ever improving management practices and technologies. On the other hand, diesel's long term forecasts are much more downbeat in terms of availability and diesel price is very likely to carry on increasing (even more so due to greater political interventions to meet emissions obligations). **So the longer term prospects make electricity the preferred future way to use energy despite the short to mid term price hikes and issues.**

It is also important to note that **fuel duty** is the biggest contributor to diesel retail prices. Current rates for DERV are 58 pence/litre (40% of the cost), while for gas oil used by the railways it is only 11 pence/litre (20% of the cost). It is likely that any significant increase or decrease in fuel duty will affect diesel competiveness. At the moment fuel duty rises are based on the rate of inflation, ie Retail Prices Index changes, and whilst no indication on future trends exists, this could be used to incentivise greener fuels or stabilise the price of diesel to buffer short/mid term price hikes. Also note that VAT is applied.

A sudden hike could also be experienced in oil commodity prices due to disruptions in supply (eg geopolitical issues in the Middle East) and/or post peak oil disruption is more severe than expected. It is important to note that electricity prices could rise at an increased rate in the short term if, for example the shift to electric road vehicles happens more rapidly than expected. It can be argued that the **level of control on price variations** for electricity is greater than that for diesel due to international factors around supply. The counter argument is that oil is far more heavily taxed and taxation could be controlled by the national government to smooth short term peaks - and oil is also easier to store. Though there has been little evidence of the UK government reducing tax in order control prices (recently tax increase were delayed but not reduced). Also future dependence on gas based power plants could also be subject to tracking oil price changes, while greater reliance on renewables counter balances this risk but exposes us to greater variability due to intermittent nature of the renewable power supply, although this is more within UK's control. It is also important to acknowledge that another option open to the government of the day would be 'price control regulation' to protect the consumers from disproportionately high price hikes by the market which may ease some of the impact.

Increased fuel prices may impact the **competitiveness of railways as an affordable mode of transport as well as the profitability of the companies operating in the industry**. However there is a need to acknowledge that this potential predicted increase in electricity and diesel prices is likely to impact other modes of transport as well, so the relative impact may not necessarily be negative. **The increased energy costs will definitely improve the business case for greater energy efficiency interventions and efforts in that direction.**

5.3 Future electricity generation mix

Projections for the **future (2030) electricity mix** point towards 40% reliance on renewables - mainly wind energy (30GW, 33-35%), while Gas (Combined Cycle Gas Turbines - CCGT) will become the main generation type (45%). Nuclear will contribute approximately 7GW (6-7%). Dependency on coal will be reduced significantly through plant retirements and decommissioning. Nuclear dependency will also decline in the immediate future due to retirements but will then increase as new builds are phased in. Please note that a CCGT is nearly twice as efficient, and has significantly lower carbon emissions than coal fired plants[32].

5.4 Availability of gas supplies

Gas supplies (the primary fuel for electricity generation in 2030) are considered by some to be secure in supporting future energy requirements with unconventional reserves such as those found in shale providing prospects for further growth in supply. However, the difficulty in recovering and transporting gas from these sources, as well as criticism on the carbon footprint in its extraction/refinement may detract from their appeal[33].

32 *Electricity Market Reform - options for ensuring electricity security of supply and promoting investment in low-carbon generation* (DECC, 2010).

33 BBC reports: Shale gas moratorium in UK urged by Tyndall Centre http://www.bbc.co.uk/news/science-environment-12190810, Shale gas drilling contaminates drinking waterhttp://www.bbc.co.uk/news/science-environment-13333473 , Shale gas 'worse than coal' for climate http://www.bbc.co.uk/news/science-environment-13053040 ,

Nevertheless, global natural gas reserves should be able to accommodate increasing global demand to 2030 and beyond. Currently, 22 commercial gas storage projects are planned, which could quadruple GB's gas storage capacity by around 2020. The UK's gas market was tested in the winter of 2009/10 when prolonged cold spells led to unprecedented levels of demand while a major external supplier in Norway experienced technical difficulties. Supplies continued to meet demand and the system demonstrated its resilience. High annual demand projections can be met up to 2020 and beyond, by existing import capacity and projected supply from indigenous resources. 2020 peak demand can also be met by capacity that is existing or under construction. After 2020, planned infrastructure would provide sufficient capacity to supply the highest peak demand scenarios, even if only a minority of the planned projects succeeded in coming to market. Ofgem's Project Discovery Consultation Document (2010) models the risk of a combination of a very severe winter with a serious interruption to gas supplies from either mainland Europe or other international markets. DECC has analysed gas supplies and consider the probability of high risk events to be very low, deeming UK's gas market to be resilient for 2020 and beyond. According to the IEA increasing supply and demand for gas could set off a golden age of gas, with projections that gas demand will outstrip coal by 2030 and get close to demand for oil by 2035. It also suggests that ample supplies, robust emerging markets and uncertainty about nuclear power all point to a prominent role for gas in the global energy mix.[34]

5.5 Availability of nuclear fuel

Nuclear raw material[35] global reserves are considered adequate to support future energy needs. Ocean based uranium reserves are considered to be an area of huge untapped potential several magnitudes bigger than land reserves, though with significant challenges of mining and extraction, not to mention safety. The IAEA and OECD estimate that uranium reserves will last for approximately 85 years based on the level of nuclear electricity generation forecasted (although this figure does not include the potential ocean based resources)**.** However, a nuclear power plant takes around 5-10 years to build and commission and has a lifespan of around 30-40 years. So potentially the nuclear raw

34 http://www.iea.org/press/pressdetail.asp?PRESS_REL_ID=415, http://www.bbc.co.uk/news/business-13677732

35 *The role of nuclear power in a low carbon UK economy* (DTI, 2007).

material reserves are not endless and some even suggest that over reliance on nuclear energy will only shift the issue to a nuclear energy shortage crisis. The SDC and the IEA agree that world uranium resources are more than adequate to supply the expected expansion of nuclear power. There are however significant safety and public acceptance issues especially in light of recent events in Japan[36], as well as significant challenges of nuclear waste disposal, and planning and decommissioning[37] costs. The potential of nuclear power is discussed in greater detail in Section 6.

5.6 Availability of coal

Focussing on more conventional sources of energy, reports suggest that **coal supplies** (often thought to be limitless) could last around 60 years given current consumption rates and growth predictions. Professor McKay[38] demonstrates this through the following calculations for worldwide coal reserves:

> *In 2006, the coal consumption rate was 6.3Gt per year. Comparing this with reserves of 1600 Gt of coal, people often say 'there's 250 years of coal left'. But if we assume 'business as usual' implies a growing consumption, we get a different answer. If the growth rate of coal consumption were to continue at 2% per year (which gives a reasonable fit to the data from 1930 to 2000), then all the coal would be gone in 2096. If the growth rate is 3.4% per year (the growth rate over the last decade), the end of business-as-usual is coming before 2072. Not 250 years, but 60!*

In terms of **the role of coal in future energy needs,** the EC[39] expects that, even though the end of fossil fuel usage may be more visible in 2030–2050, coal will remain an integral part of meeting energy needs throughout the 21st century. Increasing emphasis on limiting greenhouse gas emissions must force aggressive deployment of **clean coal technologies** such as carbon capture if coal is not to diminish as a significant energy source in the latter half of the century. The downside of carbon capture is that it is likely to be powered by the same coal fired plants thus reducing the amount of power supplied to the

36 Fukushima Nuclear Accident, March 2011.

37 The nuclear decommissioning authority had an annual budget of £2 billion for 25 years, and a National Audit Office (NAO) assessment in 2008 put the figure for the total cost of decommissioning at £73 billion http://news.bbc.co.uk/1/hi/uk/7215688.stm

38 For more details see *Sustainable Energy — without the hot air* (McKay, 2008).

39 *Coal of the future - supply prospects for thermal coal by 2030-2050* (EC, 2007).

customer – there is a price to pay for carbon capture's green credentials. Some research suggests that these technologies will not be mature enough to become commercially operational in the next 10-20 years.

5.7 Wind power and associated issues

The **short term and long term intermittent nature of renewables (especially wind)** as a key supply of electricity raises major issues in balancing the grid. With current policies leading to a significant future dependence on wind energy, the need to store energy is critical to the grid functioning effectively. The two apparent options for this are pumped storage (which has constraints associated with sites and scale, etc[40]), and battery based storage by users (where devices such as electric cars interact more intelligently with the grid thereby aiding in balancing it). The rail industry may need to explore how it could contribute in this area to ensure a balanced supply when needed. There is also likely to be a significant differential in daytime tariffs (although no prediction for 2030 are available, the highest price could conceivably be 4 times more expensive than the lowest which is twice as much as today [41]). This could have an adverse impact on rail given that peak rail traction demand tends to coincide with peak electricity demand across the grid. The monthly and yearly variations of the price of electricity could also become extremely spiky, going from very low to extremely high (analysis done by Poyry in 2009 suggests that it could fluctuate from short periods of negative prices to short periods of as high as £8/kWh in 2030, which is 33 times DECC's highest scenario price of £0.24/kWh in 2030)[42]. Some of the variability could be mitigated by the government and energy suppliers themselves as it would be in their interest to reduce such volatility but if suppliers do it (invest in large scale energy storage) then they are likely to pass costs down to consumers. Also, with greater nationwide adaptation to potential volatile prices and volatility, the peak to off-peak differential could be addressed more naturally ie people charging batteries or storing or using low cost energy through smart appliances or change in behaviours to avoid peak prices. It is also possible that load shedding becomes more attractive to

40 *Sustainable Energy — without the hot air* (McKay, 2008).

41 Current variability is already around double ie peak price is nearly double than off-peak, so assuming the gap widens to twice as much (lower off-peak and even higher at peak) this could potentially go up to 4 times or even more.

42 Impact of intermittency: How wind variability could change the shape of British and Irish electricity markets (Poyry, 2009)

users to avoid high costs at times of peak demands. It is important to note that the railway is unlikely to have this luxury of being able to change its energy use during peak durations.

5.8 Transmission

The **GB transmission grid**[43] consists of around 25,000 kilometres of high voltage overhead lines (the national grid) and 800,000 kilometres of overhead lines and underground cables (the regional distribution networks). In July 2008, the government published its consultation on its UK Renewable Energy Strategy. Following which, the Electricity Networks Strategy Group (ENSG)[44] requested the three GB transmission license holders develop electricity generation and demand scenarios aligned to the EU target of 15% renewable energy for the UK by 2020. The three license holders were supported by an ENSG Industry Working Group for this. These scenarios examined and evaluated a range of potential electricity transmission network constraints and solutions. The ENSG work assessed eight possible network configurations with different reinforcement packages. The reinforcement was justified if:

T + OUT < O + L

Where:

T = capital cost of the Transmission Reinforcement

OUT = cost of the Outages needed to accommodate the reinforcement construction

O = Constraints costs saved (discounted over a 15-year horizon)

L = Transmission Losses costs saved.

Most of the reinforcements identified had a healthy cost benefit outcome in different conditions, thereby highlighting that there are several options available to address the increased reliance on renewables adequately in terms of transmission. No reinforcement was without technical challenges but none of the

43 The electric grid delivers electricity from points of generation to consumers, and the electricity delivery network functions via two primary systems: the transmission system and the distribution system. The transmission system delivers electricity from power plants to distribution substations over long distances and high voltage, while the distribution system delivers electricity from distribution substations to consumers. The difference between these grids is normally the voltage. Transmission grid voltages are normally 275 KV and above in England and Wales; (132 KV in Scotland and offshore), while the Distribution network voltage levels are normally 11 KV, 33 KV, 66 KV and 132 KV (except for offshore wind and Scotland).

44 ENSG is a cross industry group jointly chaired by the DECC and Ofgem.

issues were considered insurmountable. Recent (2011) statements from the government indicate the need for over £100 billion investment in generation and transmission alone[45]. This means twice as much investment in energy infrastructure in this decade as was achieved in the last decade[46].

5.9 Battery power and associated opportunities and constraints

DfT recently commissioned a report by TRL, Lloyd's Register Rail, and University of Birmingham[47] that investigated the feasibility of **battery powered trains**. It found that a larger battery (around 8 tonnes) exchanged at depots between peaks in service demands, could deliver an operational range of nearly 1000km without the need to exchange batteries at stations. A high level/ basic economic assessment of this approach was also carried out by comparing the annual costs of a battery-powered train with a Diesel Multiple Unit (DMU) running on similar routes. The comparison showed that the DMU would be cheaper to operate, but if the price of diesel (gas oil) rose to approximately £0.80 per litre[48], the DMU and battery-powered train would achieve operational cost parity[49]. To put this in context, the analysis of the DECC projections show that diesel (gas oil) prices could rise to £0.80 per litre (£0.83 per litre by 2023 in the high price scenario) but in only one of its scenarios (*note these are not predictions but long term trends so they do not reflect short term variations, and are in 2010 price*s *ie ignore inflation*).

A detailed examination of the case is beyond the scope of this work but it is important to highlight that the projected electricity

45 DECC's analysis shows that around £75 billion could be needed in new electricity generation capacity, and Ofgem's 'Project Discovery' estimated that around an additional £35 billion of investment is needed for electricity transmission and distribution. *See Planning our electric future: a White Paper for secure, affordable and low- carbon electricity* (DECC electricity market reform white paper, 2011) for more details.

46 See http://www.decc.gov.uk/en/content/cms/news/pn2011_053/pn2011_053.aspx for more details

47 *Battery-Powered Trains: Feasibility Study for Battery Energy Storage and Propulsion on Trains* (TRL, LLR University of Birmingham, 2010).

48 The reporting is referring to the cost of gas oil (currently at around £0.70 per litre), which is nearly 50% cheaper than DERV (currently around £1.40 per litre).

49 Note detailed examination (technical or economic) of this work is beyond the scope of this work. However it is worth pointing out that the cost comparison included a number of assumptions and caveats not least that the power unit in the battery-powered train, a flywheel or super capacitor, would not require replacing or servicing. In reality replacement/service would be required, so the report recommends a more complex and robust economic assessment is needed to address this assumption and extend the analysis to include capital costs.

costs look likely to severely hamper the economic case put forward. However, it is possible that the economic benefits of aiding grid balancing, as well as future improvement in batteries (reduced costs, size, etc)[50] could counter balance these issues to some degree. There has also been significant work done by RSSB on assessing the capabilities of batteries, capacitors and flywheels on the railways[51].

Specialty metals, such as lithium (found in South America) and indium, and **rare earth elements** (REE), such as neodymium, are required for production of many green-technology products, including photovoltaics (solar panels), batteries for hybrid engines, LED lights, fuel cells, wind turbines, energy efficient lighting systems, etc. They exist in nature in relatively small quantities and often in discreet geographical locations[52]. Mobile phones, MP3 payers, as well as radar and missile systems are among the multitude of high-tech products that require small but indispensable amounts of seventeen REE. China controls up to 97 percent of global REE production which totalled 124,000 tonnes in 2009, according to experts. REE have the benefit of lower toxicity over lithium cadmium batteries, and is extensively used in hybrid batteries, for example, a single Toyota Prius battery contains over 30 pounds of the REE lanthanum. In recent years, exports of rare earth metal have been dramatically cut back, resulting in prices rocketing for elements such as lanthanum (Lanthanum oxide is used in rechargeable batteries and cracking catalysts and costs, at the time of writing, $60.80 per pound up from $8.12 per pound in June 2010), cerium, praseodymium and neodymium (key ingredient in super strong permanent magnets used in electric motors and generators. It has quadrupled in price last year). Further reductions in export may come in the future. China is also planning to consolidate the number of REE producers to just 20 by 2015, thus concentrating market power on the supply side[53]. This coupled with the

50 *Americas: Clean Energy: Energy Storage* (Goldman Sachs, 2010) shows the future trajectory of reducing battery costs. Also see S. Gerssen-Gondelach and A. Faaji. *Performance of batteries on short and longer term*. Journal of Power Sources. 2012; Also see report prepared for the Climate Action Directorate General of the European commission published in April 2011, *Assessments of electric vehicle and battery technology*

51 T779 *Energy storage systems for railway applications* http://www.rssb.co.uk/RESEARCH/Lists/DispForm_Custom.aspx?ID=374 .

52 *Rare Earth Elements—Critical Resources for High Technology* (United States Geological Society, 2002) and *China's Rare Earth Elements Industry: What Can the West Learn?* (Hurst, 2010).

53 *China's Rare Earth Elements Industry: What Can the West Learn?* (Hurst, 2010).

increased demand for electronic goods requiring REEs is likely to significantly impact prices and availability in the future.

Yet despite concern over scarcity and high prices, only around one per cent of these crucial high-tech metals are recycled. The rest are discarded at the end of a product's life. Unless future end-of-life recycling rates are dramatically increased these critical, specialty REEs could become ‘essentially unavailable for use in modern technology’, warn experts. These are among the findings of a new report entitled **Metals Recycling Rates** issued by the International Panel for Sustainable Resource Management hosted by the UN Environment Programme (UNEP). Assessing the full extent of the impact of these elements on batteries, wind and solar power is beyond the scope of this work but the general issues raised highlight a significant risk and also an opportunity to address it through increased recycling[54]. Also, some companies have made a significant effort to not rely on REEs by not using permanent magnet motors such as the Tesla Roadster an electric sports car, Mini-e (BMW), and AC Propulsions (electric vehicle technology pioneers). Toyota is currently developing a neodymium free electric motor for its hybrid cars using asynchronous motors[55]. So alternatives to overcome the supply constraints due to heavy reliance on REEs already exist.

5.10 Environmental and carbon policies

Electricity is likely to be a greener source of energy, with environmental commitments and government / EU policies[56] incentivising low carbon, low emissions energy sources more and will lead to more of the generating moving away from fossil fuels. That said, it should be noted that carbon price projections based on the Emissions Trading Scheme (ETS)[57] show the price could

54 *Metal stocks in society – scientific synthesis* (UNEP, 2010). Also see P. Gruber at el. *Global lithium availability A constraint for electric vehicles?* Yale University. 2011; and L. Gaines and P. Nelson. *Lithium-ion batteries: examining material demand and recycling issues*. Argonne National Laboratory, Argonne, Illinois. 2010

55 Difference engine – Nikola Tesla’s revenge, The Economist Technology Quarterly, 4 June 2011

56 The European Commission (EC) Directive on the promotion of the use of energy from renewable sources (Directive 2009/28/EC, known as the Renewable Energy Directive or RED) requires that by 2020, 20% of the European Community’s gross final consumption of energy should come from renewable sources, and 15% of each Member State’s transport energy consumption should be from renewable sources.

57 The EU ETS operates by the allocation and trading of greenhouse gas emissions allowances throughout the EU - one allowance represents one tonne of carbon dioxide equivalent. An overall limit, or 'cap', is set by Member State's Governments on the total amount of emissions allowed from all the installations covered by the scheme. The allowances are then distributed to the installations in the scheme. At the end of each year, operators are required to ensure they have enough allowances to cover their installation's emissions. They have the flexibility to buy additional allowances (on top of their free allocation), or to sell any surplus allowances generated from reducing their emissions.

even rise to £200/t of CO_2 by 2030 (taking the highest projected cost extreme of the non traded, traded and social cost of carbon emissions)[58]. Future emissions from electricity are projected to be 100g/kWh, equating to 0.02 pence/kWh compared to electricity price projection of 19.5 pence/kWh (DECC's central scenario 2030, in 2010 prices). This shows that current carbon pricing is unlikely to be a major factor in the economics of fuel choice for the end user.

However, ethical and political considerations (both for government and the end user) as well as commitments given in national and international frameworks are likely to push toward greater consideration (and taxation) of carbon emissions. According to the IEA, energy related carbon emissions reached record levels in 2010, which means emissions rose again mainly due to India and China's contribution[59]. This means that the pressure to reduce emissions is likely to become greater. Note that ETS applies to electricity and large scale energy generation but does not include individual fuel use (ie diesel trains and cars) as the related emissions are not tradable. However, some gas oil suppliers do offer carbon neutral supply by charging the buyer extra for the equivalent carbon emissions.

The **Climate Change Levy (CCL)** is part of a range of measures designed to help the UK meet its legally binding commitment to reduce greenhouse gas emissions. It is chargeable on the industrial and commercial supply of taxable commodities for lighting, heating and power. It applies in the following sectors of business: industry, commerce, agriculture, public administration, and other services. The levy applies to most energy users, with the notable exceptions of those in the domestic, charities and transport sectors. All revenue raised through the levy is recycled back to business through a 0.3% cut in employers' national insurance contributions (introduced at the same time as the levy), and supports the development of energy efficient and low carbon technologies. At the time of writing, electricity CCL is 0.485 pence/kWh. From 2012 to 2013 it will be 0.509 pence/kWh[60]. This represents 5% of the current electricity price and is therefore a significant contributor to the cost.

58 http://www.decc.gov.uk/en/content/cms/emissions/valuation/valuation.aspx
59 http://www.bbc.co.uk/news/science-environment-13595174
60 HM Revenue and Customs (2011)

There is no indication on future trends for the levy; but may be used to incentivise greener fuels, and could well be extended to include public transportation thereby impacting electricity prices for the railways. The CCL is also likely to become a factor if the railway decides to generate its own electricity in the future.

It is also important to note that traction energy only accounts for 63% of rail's carbon emissions, which means that stations, depots and train control systems are also key contributors to energy use and related emissions[61]. Non-traction energy will face similar rises in energy prices, with an additional levy for many rail industry organisations through the **Carbon Reduction Commitment (CRC)** Energy Efficiency Scheme.

5.11 Other energy alternatives

Hydrogen and fuel cells[62] are related but discrete technologies which offer the potential for low, and ultimately zero, CO_2 emissions and increased energy security. Hydrogen is an energy carrier, like electricity, which requires a source of primary energy to make it. Hydrogen can be produced from a number of different ways including fossil fuels such as coal or natural gas, renewable energy such as wind, hydro and biomass, or nuclear. Hydrogen can be converted to electricity and heat using modified internal combustion engines, gas turbines or fuel cells. Fuel cells convert hydrogen or a hydrogen-rich gas into electricity and heat by an electrochemical process which results in water (or steam) being the only emission.

It is worth noting that there are various types of fuel cells and not all of them use hydrogen as a fuel. Fuel cell technology has applications for stationary power generation, combined heat and power – distributed energy and heat [63]or microgeneration[64], portable power and transport (as a replacement for the internal combustion engine). According to DECC, these technologies are currently being demonstrated, but they will have to overcome

61 RSSB R&D project T913: Whole life carbon footprint of the rail industry http://www.rssb.co.uk/sitecollectiondocuments/pdf/reports/research/T913_rpt_final.pdf

62 See Review and assessment of hydrogen propelled railway vehicles (Roberts et al, 2010);
Well-to-wheel analysis for electric, diesel and hydrogen traction for railways (Roberts et al, 2012);
Analysis of a fuel cell hybrid commuter railway vehicle (Roberts et al, 2010);
Fuel cell-hybrid shunt locomotive: Largest fuel cell land vehicle (Miller et al, 2010) for an overview of application of hydrogen fuel cells in the railways. Detailed discussion in this area is beyond the scope of this work.

63 http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/distributed_en_heat/distributed_en_heat.aspx

64 http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/explained/microgen/microgen.aspx

significant techno-economic barriers in order to displace the incumbent technologies. The timing of commercialisation will depend on the application. Niche applications such as portable and remote power are expected to be first. Once a carbon friendly solution to the manufacture of hydrogen is found, stationary power and, then finally, transport applications may follow. So for the next 10-15 years, prospects of this technology replacing incumbents in the railways are not high, but there may be longer term applications.

Work has also been done by RSSB in this area – R&D project T531 *Feasibility study into the use of hydrogen fuel,* a project completed in 2005 concluded that **hydrogen fuel technology** is unlikely to become part of the mainstream, commercial transport energy mix until **at least** 2020. However, current prospects by 2030 are very poor due to the carbon intensity of hydrogen production, and other supply and distribution constraints. If and when it does the first applications are likely to be in road vehicles so rail applications are not on the horizon until 2030 (*note this date is not a milestone date associated with hydrogen use. It only reflects the scope of this report's assessment*). Further efforts to test its feasibility were made via RSSB R&D project T722 *Hydrogen fuel cell trial*. Feasibility studies were conducted on fitting a hydrogen fuel cell to a diesel HST for auxiliary power supply, and fitting a polymer electrolyte membrane fuel cell to a passenger vehicle for traction power on non-electrified branch lines. This work was done to assess the practical risks associated with doing a hydrogen fuel cell trial. It demonstrated that a hydrogen fuel cell trial remains a practical means of informing the rail industry of the operating implications of the technology, allowing the industry to intelligently specify future rolling stock and energy/infrastructure requirements.

However, the costs of staging such trials are significant, and it was concluded that now is not the right time to undertake them. In the meantime, it has been recommended that fuel cell technology and associated gas storage technology improvements should continue to be monitored, together with changes in funding and availability of donor rolling stock.

DECC allocated a total indicative budget of £7.2m in 2009 for capital funding for a **Fuel Cells and Hydrogen Demonstration programme**, with the support of the Technology Strategy Board (TSB). Three hydrogen and fuel cell projects and one carbon abatement Technology project from the October 2006 call for proposals are currently underway, with DECC support totalling £5.9m[65]. The programme will cover transport and stationary market applications and enable full scale demonstrations for projects that have already successfully undertaken R&D, prototyping and small scale demonstration.

The UK also participates in the European Hydrogen and Fuel Cell Technology Platform, and the European Commission's Fuel Cells and Hydrogen Joint Technology Initiative. The UK is also a member of the International Partnership for the Hydrogen Economy and the IEA's Hydrogen Implementing Agreement. Clearly fuel cells and Hydrogen are clearly seen as a key to long term energy requirements, but prospects till 2030 (in terms of large scale use) remain poor mainly due to the supply and infrastructure constraints and challenges.

RSSB R&D project T721 *Review of potential rail vehicle fuels and 'energy carriers'* considered the potential of more radical and long term solutions for energy such as **biogas, methanol, ammonia, battery technology and flywheels**. The project concluded that the alternative fuels comparison clearly emphasises the benefits of liquid fuels to rail operations; they are a high-density energy source, offer convenient refuelling and minimal impact on train weight. **Low sulphur/sulphur free diesel and bio-diesel scored significantly higher than other options to replace the diesel currently used by the railways.** Unfortunately the reduced combustion efficiency of bio-diesels drive commercial considerations in the opposite direction[66]. First generation bio-diesel is available in the short-term, while other alternatives will demand significant development delaying availability to the medium to long term. Another RSSB R&D project T697 *Investigation into the use of bio-diesel fuel on Britain's railways*[67]

65 The projects include The London Bus Services Ltd Hydrogen Project, Penner Road Fuel Cell CHP Demonstration, Demonstration of an oxyfuel combustion system, etc. For more details see http://www.decc.gov.uk/en/content/cms/what_we_do/lc_uk/innovation/historic/hydrogen_fuel/hydrogen_fuel.aspx

66 Biodiesels are mono-alkyl esters containing approximately 10% oxygen by weight. The oxygen improves combustion efficiency, but it takes up space in the blend and therefore slightly increases the apparent fuel consumption rate observed while operating an engine with biodiesel. Kaplan et al (2006) compared sunflower oil biodiesel and diesel fuels at full and partial loads and at different engine speeds in a 2.5 kW engine. The loss of torque and power ranged between 5% and 10%.

67 http://www.rssb.co.uk/RESEARCH/Lists/DispForm_Custom.aspx?ID=365

investigated the impact of using bio-fuel in the diesel engines of locomotives and DMUs.

The EC Directive 2009/30/EC requires that from 1st January 2011 onwards, all gas oil marketed must contain no more than 10 milligrams of sulphur per kilogram of fuel (virtually ‘sulphur free’). This fuel is needed by cleaner engines fitted in new off-road equipment which **will be made to meet stringent new EU emission standards. In railway vehicles the introduction of sulphur free gas oil is one year later (1st January 2012)**[68]. This is likely to add around 2 pence per litre to the price of diesel currently used by the railways.

RSSB has already done some work on the use of sulphur-free diesel fuel on Britain’s railways: R&D project T536 *Investigation into the use of sulphur-free diesel fuel on Britain’s railways (2007)*). The aim of this research was to trial the use of Sulphur Free Diesel (SFD) in order to understand the advantages and disadvantages. The project conducted engine test bed trials on a representative sample of engines, followed by service trials on specific engines on trains.

The results of these two projects (T536 and T697) have enabled the rail industry to assess the implications of the wider introduction of SFD fuel with increased confidence. No major negatives were encountered.

6 Detailed discussions on key issues

This section further discusses in greater detail some of the key concerns and opinions around future energy risks. Each sub section heading has been put forward as a key hypothesis, and evidence from the knowledge search is used to critically assess it.

6.1 Impact of energy security at a national level on the railways

Before the macro factors are explored, it is important to assess the railways size and relative energy consumption compared to other national and regional consumers. This will provide the context of level of risk exposure the railways face. The two primary sources of energy for the railways are electricity and diesel fuel. Diesel (gas oil) fuel is used for about 40% of passenger kilometers and most of freight tonne kilometers, whilst

68 DfT’s guidance on Fuel Quality Directive: http://www.dft.gov.uk/pgr/roads/environment/fuel-quality-directive/pdf/fuelquality.pdf

electricity is used to power the remainder (about 60% of passenger km).

This work has not examined the prospects for bio-diesel as significant work on that front is being conducted elsewhere. RSSB R&D project T697 *Investigation into the use of bio-diesel fuel on Britain's railways*[69] assessed the impact of bio-diesel in the diesel engines or railway locomotives and diesel multiple units of Great Britain, and has conducted service trials on South West Trains and First Great Western.

There is also significant work being commissioned by the DfT in his area which would provide more specific information on bio-fuels[70]. More generally, there are significant issues with increased production and use of biofuels, and this can be understood through the 'Gallagher Review' published in 2008 which explores the indirect effects of biofuel production[71]. However, the need to comply with **EC Renewable Energy Directive** means that research continues to explore different diesel bio-fuel blends for engine performance and environment friendliness.

The railway as a sector, consumes around 2.6% of the total UK electricity supply (includes all rail premises and all railway types, ie over-ground and under-ground), with traction demanding the greatest portion[72], and consumption will increase with greater electrification of the rail network. The risk exposure of the railway to security of supply issues has to be assessed with proportionality in this context. The railways tend to have long term contracts with its electricity suppliers (via Network Rail) which are very favourable compared to general costs and terms of electricity supply. However, it is worth noting that the railway is treated as

69 RSSB R&D project T697 research brief http://www.rssb.co.uk/SiteCollectionDocuments/pdf/reports/research/T697_rb_final.pdf

70 http://www.dft.gov.uk/pgr/roads/environment/renewable-fuels/biofuels/ and http://www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/res/res.aspx

71 The Gallagher Review concluded that projected increased global demand for biofuels did carry significant risks that required urgent mitigation. It found that, whilst there was probably sufficient land for food, feed and biofuels, current policies did not ensure that additional production occurred in appropriate areas. As a result, the displacement of existing agricultural production was likely to lead to reductions in biodiversity and possibly increases in overall greenhouse gas emissions. It also found that biofuels would contribute to rising prices for some commodities that would adversely affect the poorest, but that the scale of these effects was complex and uncertain to model. To access the full report go to http://www.renewablefuelsagency.gov.uk/sites/renewablefuelsagency.gov.uk/files/_documents/Report_of_the_Gallagher_review.pdf

72 DECC statistics – *Energy consumption in the UK - Overall consumption data (DECC, 2010).*

any other household customer, ie there is no extra legal or contractual protection or commitment to supply electricity to the railway. In the event of a shortage it is as prone to the 'lights going out' as any general household (unless it is a national emergency).

The rail industry should be lobbying and influencing the relevant bodies and government to ensure that the railways is provided greater protection as a critical public service, if a supply shortage becomes eminent. Also, the current electricity contract is very favourable for the industry which has buffered it despite recent hikes. However, future contracts are unlikely to be in such favourable terms. The UK railway's consumption of oil (petroleum, diesel, etc) is 1.3% of all transport fossil fuel consumption. Transport is 83% of all oil use; rail is responsible for around 1.1% of all oil used. Road transport is 49% of total oil consumption which (based on 2009 figures) stands at 40,704,000 tonnes of oil equivalent per year[73]. This equates to approximately 53GW[74]. Transport volumes in OECD European countries are expected to remain relatively constant according to IEA projected scenarios.

6.2 Energy as a contributor to the cost of the railways

According to the 2011 rail value for money study[75], the rail industry costs for 2009/10 were around £12.7bn. The rail energy costs are estimated between £500 and £600 million (traction), which means they are approximately 4% of the total costs of the railways. The value for money study recommended a potential 30% reduction in rail industry costs. Assuming that this target also applies to energy costs then the range and the changing potential contribution from energy savings to the overall cost reduction (based on rough calculations) can be seen in Table 1.

73 DECC statistics - *Energy consumption in the UK – Transport data tables* (DECC, 2010).
74 The tonnes of oil equivalent per year was converted to electric equivalent energy (GWh) per year, which was then spread over the year to arrive at the power capacity (GW) at any time, which is a measure of the rate of energy flow to assess if enough generation capacity would be available to support any energy requirement.
75 Realising the Potential of GB Rail: Final Independent Report of the Rail Value for Money Study (ORR, 2011)

Table 1 - Traction energy cost contribution to annual industry operational costs and the cost saving challenge

Assumptions	Total rail industry cost	% contributed by traction energy costs	% reduction target for traction energy costs	% size of prize due to reduction in rail industry costs through traction energy
1. Current cost assumptions	£12.7bn	4% (£0.5bn)	30%	30% of 4% = **1.2%**
2. Doubling of energy costs	£13.2bn	7.5% (£1bn)	30%	30% of 8% = **2.3%**
3. 30% savings on all other costs excluding traction energy AND doubling of energy costs	£9.54bn[a]	10.5% (£1bn)	30%	30% of 11% = **3.2%**
4. 30% savings on all other costs excluding energy AND traction energy costs reach £2bn (costs are 4 times more) due to significantly higher peak prices caused due greater demand from other sectors and intermittent renewables powering the national grid	£10.54bn b	19%(£2bn)	30% The potential for savings could be much higher due to savings through smart grid, intelligent storage, or more secure energy contracts, etc to leverage the lowest prices	30% of 19% = **5.7%** Assuming the advantage from using lower electricity prices, energy security and incentives of balancing the grid could increase the savings to 60% making the size of the prize 60% of 19% = 10.4% This excludes any greater energy security or emissions benefits, or investment cost needed to realise these benefits.

a. If the proportion of all other costs reduces by 30% while the traction energy costs increases to £2 billion, then the all other industry costs would be [(14.2 – 2) x 70%] = £8.54 billion and the total industry costs would be £8.54 billion + £2 billion (energy) = £10.54 billion

b. If the proportion of all other costs reduces by 30% while the traction energy costs increases to £2 billion, then the all other industry costs would be [(14.2 - 2) x 70%] = £8.54 billion and the total industry costs would be £8.54 billion + £2 billion (energy) = £10.54 billion.

Opinions may vary on what is a realistic energy efficiency target, and which of the scenarios discussed above are a more likely projection of future traction costs and potential savings, but the rough calculations above do highlight that energy costs and economics could become a much bigger factor than it is now in impacting the affordability of the railways both as a sector and a competing mode of transport. **Considering that there are also non-traction energy costs, then as total energy costs become a larger percentage of rail industry's operational costs, the increased value of a unit of energy saved will significantly strengthen the economic case of current and new energy efficiency improvements.** Other modes (such as road) will also be affected by increases in energy prices, however if they are much better placed than rail to take advantage of variable energy prices then they could steal a march on GB rail.

If a single TOC is examined (see Table 2), and assuming 4% of a TOC's costs are on energy[76] then the picture looks even more challenging. With TOC profits at just 3% the impact of energy cost rises will make energy a crucial factor in business survivability and competiveness in the future.

Table 2 - Energy cost contribution to annual TOC costs and the cost saving challenge

Assumptions	% contributed by energy costs per year	% reduction target for energy costs per year	% size of prize due to reduction in TOC costs through energy per year
1. Current cost assumptions	4%	30%	30% of 4% = **1.2%**
2. Doubling of energy costs	8%	30%	30% of 8% = **2.4%**
3. 30% savings on all other costs excluding energy AND doubling of energy costs	11%	30%	30% of 11% = 3.3%

76 ATOC- rail fares in 2012 online guide.

Table 2 - Energy cost contribution to annual TOC costs and the cost saving challenge

Assumptions	% contributed by energy costs per year	% reduction target for energy costs per year	% size of prize due to reduction in TOC costs through energy per year
4. 30% savings on all other costs excluding energy AND energy costs are 4 times more (based on the £2bn industry assumption) due to significantly higher peak prices caused due greater demand from other sectors and intermittent renewables powering the national grid	19%	30% (The potential for savings could be much higher by taking advantage of the lowest electricity prices)	30% of 19% = 5.7% If we assume that the advantage from using lower electricity prices, greater energy security and financial incentives of balancing the grid could increase the savings to 60% then the size of the prize could be 60% of 19% = 11.4% This excludes any greater energy security and emissions benefits, or investment cost needed to realise these benefits.

Over and above the costs, the potential lack of availability, and accessibility of energy would also have a detrimental impact on the railways. Therefore, ensuring the availability and accessibility of energy to the railways and mitigating for potential rising costs could become a significant risk factor to GB rail, making energy efficiency and energy reliability paramount strategic objectives.

6.3 The generating capacity will reduce significantly due to decommissioning

It is important to understand the generation capacity constraints and risks which may impact the availability of electricity to the rail industry. One of the key uncertainties is associated with how the planned losses in generation capacity due to planned retirements and closures[77] will be replaced and its potential impact on the availability of electricity in the future. It is also important to assess the credibility of the replacement options, as well as the related challenges and operational implications. This and the next few sections explore these issues.

Currently available information points to significant generator retirements amounting to a loss of nearly 40GW, or 45% of current capacity by 2030. Most of the retirements are coal, gas, oil and nuclear power plants. Recovering this loss of capacity, while meeting increasing demand, represents a critical risk for security of electricity supply.

Most of this loss is meant to be compensated by wind (on shore and offshore), nuclear and gas as shown by Figure 1.

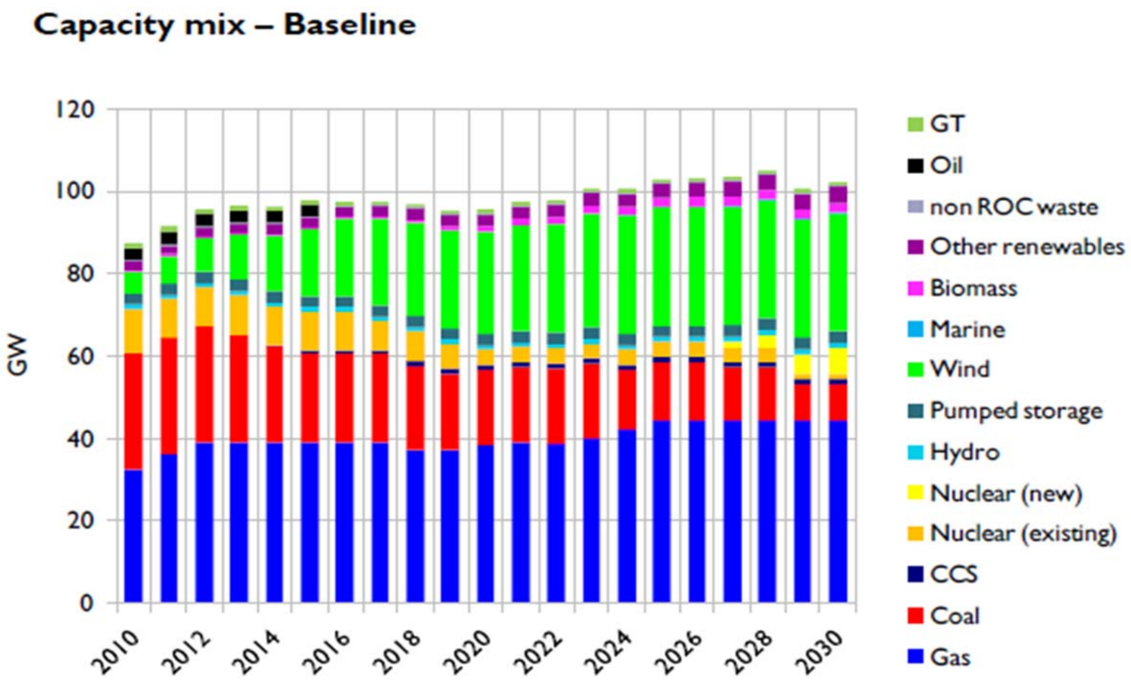


Figure 1 - DECC's baseline projections for the future electricity mix (2010)

According to DECC's modelling (base line scenario), the transition in terms of replacement planning means that the capacity margins (de-rated supply capacity[78] vs. demand) in

77 There is an important difference between retirements and closures. Closures are scheduled for regulatory reasons (predominantly coal, oil and nuclear plant) for example as a result of generators opting out of the Large Combustion Plant Directive (LCPD). In the absence of a major policy change (never to be ruled out) these closures will happen. While retirements are largely due to plant economics (predominantly CCGT gas plants) ie after a certain lifetime, significant further investment is required to extend the life of a plant. These retirements are surrounded by some uncertainty and these plants could be incentivised to stay open during period of transition or a gap which has a supply shortfall as renewables are planned in. See http://www.timera-energy.com/uk-power/the-uk-generation-capacity-crunch-in-numbers/ for more details.

78 De-rated capacity margins are supply/demand margins based on the power plants operating at lower than maximum capacity to ensure reliable functioning ie the practical load they would normally operate at rather than at full capacity.

some years might be 'too close for comfort' (0-5%)! The reduction in capacity margins are shown in Figure 2.

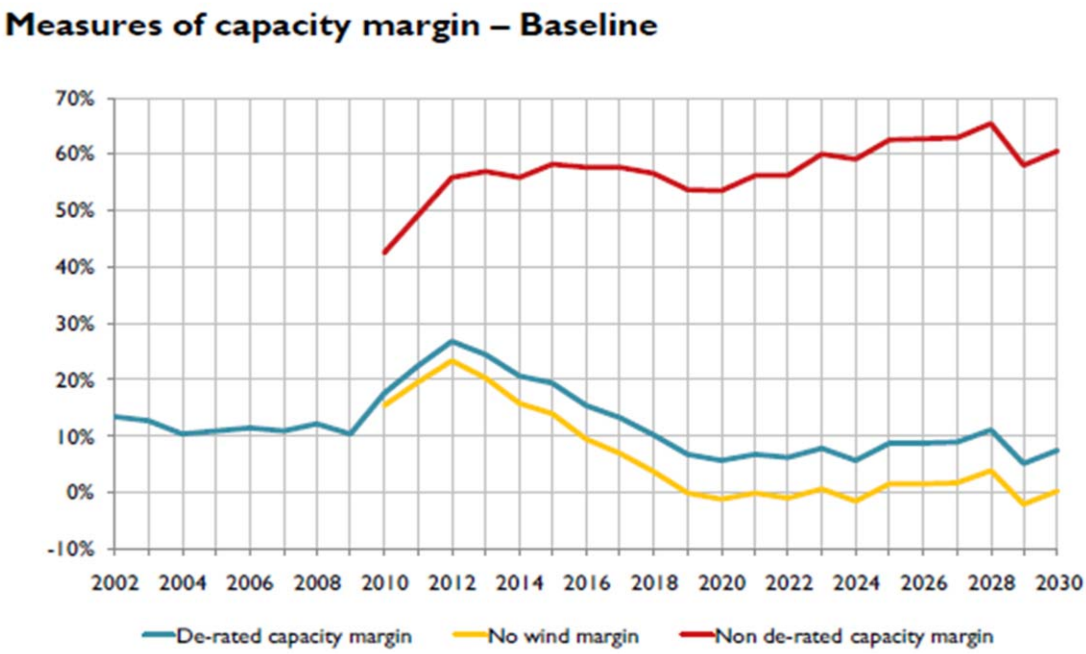


Figure 2 - DECC's baseline scenario's projected capacity margins

DECC's baseline scenario does not account for issues such as financial resources, planning, and supply chain constraints, which could further exacerbate the risk of new wind and nuclear plants being available in time. Traditionally, investment in CCGT has been on the back of expectations of baseload running (full efficiency), but due to the increasing proportion of intermittent renewables on the system, CCGT may only be operating at mid-merit levels. Work commissioned by Ofgem (Project Discovery, 2010) suggested that under current arrangements, revenues may not rise high enough for CCGT to justify operating at mid levels thus increasing the security-of-supply risk further.

Despite these risks existing, if significant threat to security of supply is evident then there are several options available to delay the decommissioning and retirements until the renewables and nuclear can be reliably activated. These options include applications for derogations, asset life extension and incentives to ensure that adequate supply capacity will be available.

Also baseline scenario has not taken into account the potential of a European super-grid, or potential exports and inter-connectedness with other parts of Europe which may be better placed to deliver renewable energy or store energy. International co-operation could be the key ensuring efficient use of energy resources in the future.

Also the baseline assumes very conservative Demand Side Response (DSR)[79] - only 1% of total capacity of self generation which may increase if risk to immediate supply was high. The Global Insight report for DTI and Ofgem in 2005 analysed the DSR in a 1 in 10 years extreme winter scenario testing the capacity of energy intensive industries to respond to energy prices increases. Their analysis noted that the contractual arrangements restrict significant DSR and in rare scenarios some industries can cope with coal providing the back up fuel for generators. The availability and price of coal would also be a factor in DSR. They also noted that DSR becomes likely when price goes up by 15% or more.

The Global Insight report tested the following three hypothetical electricity and gas price scenarios: £100/MWh and 100pence/therm; £200/MWh and 200pence/therm; and £500/MWh and 500pence/therm. They found that DSR would reduce power consumption between 2.3% to 3.8% of national electricity demand, and between 2.3% to 2.7% of national gas demand. This could improve capacity margins if severe sudden shortages are encountered. These results point to a larger response than DECC's energy model's baseline scenario. DECC acknowledge that their DSR assumption in the baseline scenario is conservative and is likely to increase if supply security is affected. Energy contracts that allow for more flexibility of response will also help increase that capacity. Discussions with government organisations such as DECC indicate that Government is more likely to intervene than allow a shortfall in supply thus ensuring the transition to new generators is managed adequately.

DECC's projections suggest that the risk of unserved energy (a statistical measure of a supply demand deficit) appear very low

79 Demand side response is about switching to back up fuels, self generation, and/or reduction in energy consuming activity when energy prices are too high or other factors require a response to ensure an individual entity's (person, organisation or sector) supply security is maintained. The 'responsive' (able to switch or generate own energy quickly) energy intensive sectors are the following five: chemicals, glass, paper, iron & steel, and heavy food. These sectors account for over 90% of industrial DSR.

over the next few years, but rise after 2016. By 2020, expected average energy unserved reaches 5.8 GWh, and the probability of at least one brown out in the year exceeds 20%. A brown out is defined here as a drop in voltage for some customers but without necessarily a full outage. Average energy unserved is a statistical measure, in some years there may be minimal supply shortages but in others the shortages could be far greater[80].

Figure 3 shows DECC's projections of the level or unserved energy as well as the probability of a brown out from 2010 to 2030.

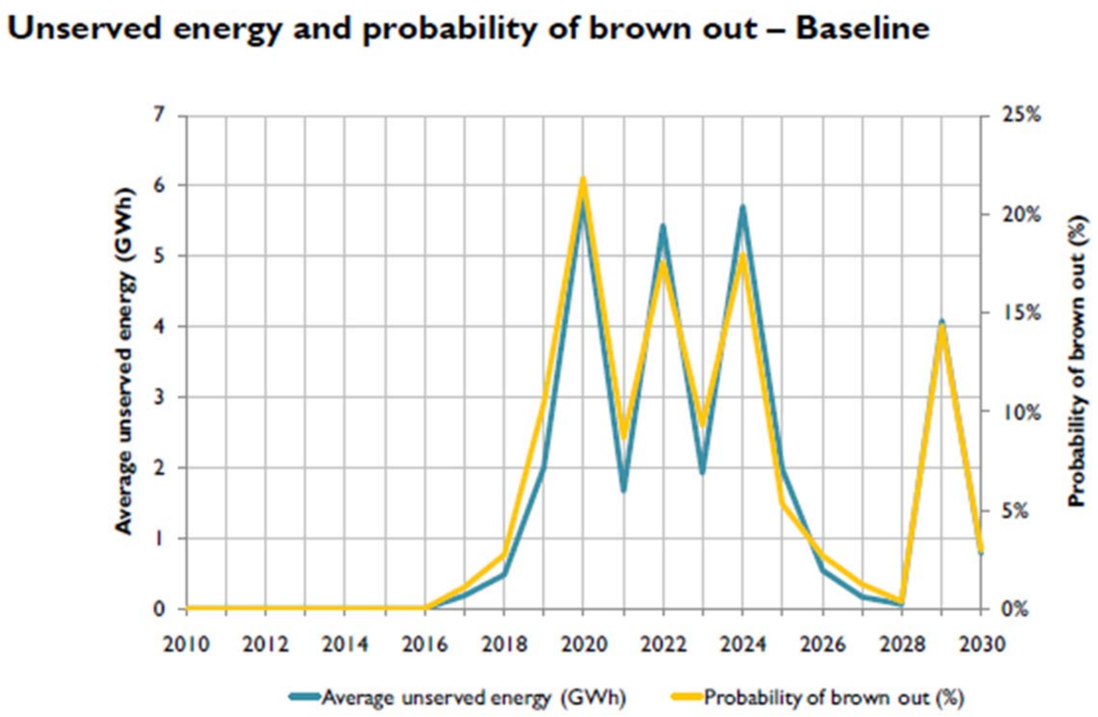


Figure 3 - DECC's estimates of unserved energy and probability of brownout up to 2030

These levels of unserved energy are considerably greater than anything experienced in recent history, and exceed annual losses due to outages on the transmission system.

However, in the context of outages experienced on the distribution networks, the figure is relatively modest. For example,

80 Electricity Market Reform - options for ensuring electricity security of supply and pro moting investment in low-carbon generation (DECC, 2010).

averaged across the whole system the 5.8 GWh of unserved energy would be equivalent to around 8.7 minutes of lost supply annually for all customers. This compares to an average of approximately 75 customer minutes lost through power distribution failures in the year.

This comparison shows that the risk of distribution failures is a significantly bigger problem than security for supply.

6.4 Supply capacity lost may not be replaced

Despite the nearly 40GW of lost capacity, this will be more than offset by nearly 55GW of new capacity planned between now and 2030. According to DECC's projections and other government plans, nearly 20-30% increase in supply capacity is projected for electricity generation and supply.

Figure 4 shows the new build rates projected by DECC in its baseline scenario.

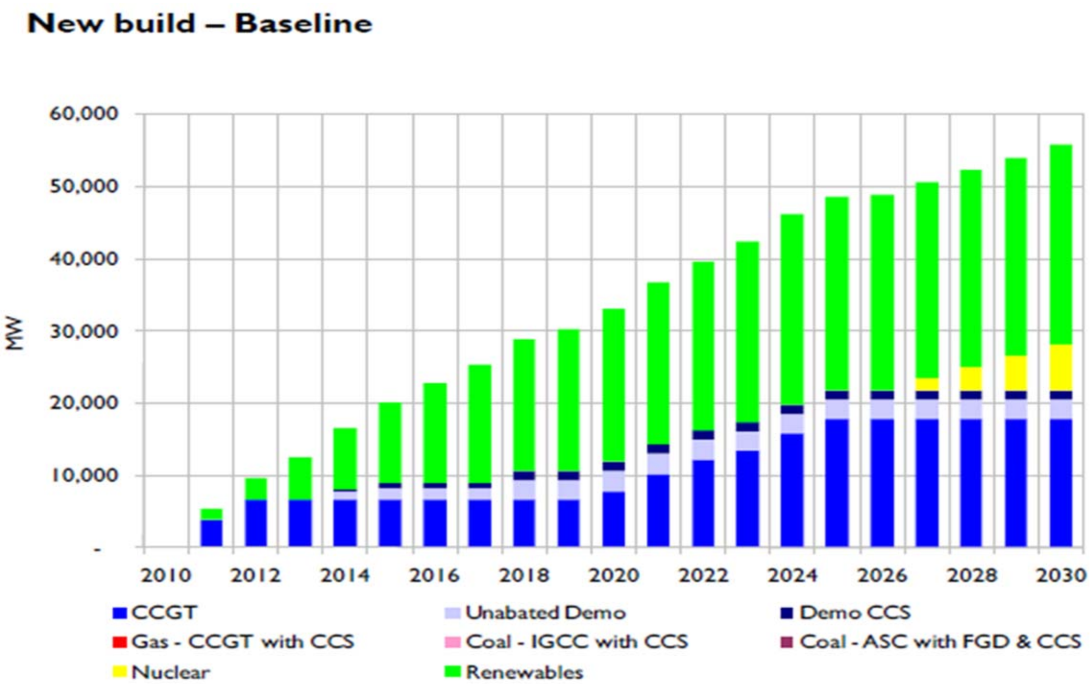


Figure 4 - New build rate projects in DECC's baseline scenario

6.5 Supply will be outstripped by demand

Several demand projections for energy / electricity consumption have been made by DECC and the National Grid. Projections and scenarios describing the potential world in the distant future (2050) have also been developed by consultancies (eg PWC), commercial bodies (eg HSBC), energy firms (eg Shell, BP), and International and research agencies like IEA, OECD, EU, and UKERC. All of them point towards an increased reliance of energy, especially electricity - due to its increased efficiency and sustainability. The increased demand for energy generally is mainly driven by:

- Increasing population
- Economic growth

Increased demand for electricity specifically (in conjunction with the factors above) will be driven by:

- Switching to electricity (eg road transport)
- Expansion of systems already reliant on electricity (eg electrified railways)

In addition to increased generation capacity, supply will be enhanced by:

- Greater energy efficiency at the point of use (ie less energy to do more)
- Greater energy efficiency in transmission, distribution and generation
- Micro-generation
- Smarter, more sophisticated balancing of demand and supply

DECC's baseline scenario is characterised by 'business as usual'; current policies and initiatives leading to reduction in carbon intensity of around 50% through 35% renewable energy generation by 2030. Demand projections according this and National Grid's National Electricity Transmission System Seven Year Statement (NETS SYS) have been examined.

The National Grid assesses demand under several scenarios. One scenario of particular interest is the high growth scenario in which GDP expands at an average of 1.7% between 2010 and 2015 in conjunction with slower efficiency improvement. This is broadly aligned with DECC projections to 2017 showing total annual capacity to balance demand between 60-65 GW; electricity demand increasing by 1.3% per annum. A rough linear projection might indicate a 20-30% increase in electricity demand by 2030, counter balanced by the 20-30% increase in capacity projected by DECC's base case (also for 2030). Other studies done by IEA show OECD Europe's (includes the UK) primary energy demand growing by only 5% between 2007 and 2050.

These projections / scenarios do not explicitly account for a dramatic switch from oil to electricity. The current energy requirement for road transport needs is estimated to be around 53GW (electricity equivalent to gas based energy needs). Assuming that only 60% of road vehicles were to shift to electric, out of which 50% were hybrids (requiring 50% power through electricity) while 50% were full electric vehicles (100% electricity). Then this would equate to a shift of [*(30% x 50%)* + *(30% x 100%)*] x 53GW = 45% x 53GW = **23.85GW** from oil to electricity. But oil based engines are very inefficient (around 30%) compared to electric vehicles (85%), ie a 55% efficiency difference. This means 23.85GW of oil equivalent power requirements could be achieved by (100% - 55%) = 45% of 23.85GW = **10.73GW** in electric energy. However electricity generation and transmission may suffer losses of around 60%. This means a generation capacity of around (10.73/0.40) =**27GW** approx. might be required. To put this in context: (i) The UK's projected national capacity in 2030 is around 100GW so 27GW is not a small number (27% additional capacity); (ii) The derated capacity margin upper limit (best case) for the UK as per DECC projections and data from the recent past has been 10%, so a 27% shift would leave a 17% shortfall.

However, the switch from oil to electricity is unlikely to happen suddenly. The automotive industry and government are likely to coordinate to ensure balancing of energy supply needs - even so the likely rate of transition is difficult to forecast. A slow shift would allow the market and government to react to address the increase in demand. A rapid shift could create short term supply shortfalls.

6.6 Over reliance on wind energy could be risky

The need to balance the grid will be one of the main challenges when greater reliance on renewables is pursued. Recently in the US (Pacific Northwest), the Federal Power Agency has been forced to push wind turbines off the grid to compensate for the very high power being generated and supplied by its dams! This was due to high flooding caused by too much snow melting and causing river surges[81]. The loss of energy and revenues due to such basic ways to balance the grid could be very high, and in an increasingly energy starved world almost criminal.

However, the fluctuation potential from wind itself is neatly described by Professor David Mackay in his book *Sustainable energy - without hot air*. Irish wind power has an overall generating capacity of 745MW. On 11 February 2007, output fell steadily from 415MW at midnight to 79MW at 4am, a slew rate (rate at which power supply rises or falls) of 84MW per hour (for 4 hours). If, as per current plans, British wind power is scaled up to capacity of 30GW (so that it delivers 10GW on average), and if we assume a similar worst case scenario as Ireland happening at a similar scale in Britain *(Britain may be more robust due to a wider distribution of wind power locations than Ireland but the example is examining a worst case scenario)*, we can expect to have occasional slew rates of:

84MW/h × (33000MW / 745MW) = 3700MW/h (or 3.7GW/h)

There would be two options to balance this:

1 Find extra supply at a rate of 3.7GW per hour (*just less than four 1GW capacity nuclear power stations going from no power to full power, which we know is highly impractical and improbable),* or
2 Turn down our demand at a rate of 3.7GW per hour. To put this in context, every morning British demand climbs by about 13GW between 6.30am and 8.30am - that's a slew rate of 6.5GW per hour. So power engineers already cope with slew rates bigger than 4GW per hour on the national grid every day.

Long-term lulls in wind lasting two or three days (known to happen several times a year) pose a very different type of problem. If we have 30GW of wind turbines delivering an average power of 10GW per hour then the amount of energy we must either store up in advance (or do without) during a worst case scenario of a five-day lull is = 10GW × (5 × 24 h) = 1200GWh. There are two ways to get through lulls, either we can:

81 *Tilting at Windmills,* The Economist, 18 June 2011.

1 Supplement with stored energy, or
2 We need to have a way of reducing demand during the entire lull - or a mix of the two.

Solutions of the first type could use stored energy from a variety of sources, eg coal, biomass and waste incinerators. All these could help (of course they would be costly) but could not address a slew range of 10-30GW. Another solution could be hydroelectric energy but Britain does not have a large enough capacity to cope with this variation in demand. Possibly the best potential solution is pumped storage (currently only 3.1% of total capacity)[82]. However to meet these levels of demand, significantly more pumped storage sites like the one in Dinorwig in Snowdonia will be required (at least 12, according to Prof. Mackay).

Within the second type of solutions there are smart chargers for electric vehicles. Electric cars could be plugged in to smart chargers, at home or at work, which would be aware both of the value of electricity and of the car user's requirements (eg 'my car must be fully charged by 7am on Monday morning'). The charger would sensibly satisfy the user's requirements by rapidly drawing electricity whenever the wind blows, and switching off when the wind drops, or when other forms of demand increase.

According to Professor McKay, if 30 million electric vehicles were willing, in times of national electricity shortage, to run their chargers in reverse and put power back into the grid, then, at 2 kW per vehicle, we'd have a potential power source of 60GW. Even if only one third of the vehicles were connected and available at one time, they'd still amount to a potential source of 20GW of power. If each of those vehicles made an emergency donation of 2 kWh of energy – corresponding to perhaps 20% of its battery's energy-storage capacity – then the total energy provided by the fleet would be 20GWh – twice as much as the energy in the Dinorwig pumped storage facility.

There is potential of a third option which is getting storage support and input from abroad with greater interconnectedness with the rest of Europe, but such solutions are also likely to carry a significant cost to the UK. Denmark effectively pays to use other

82 Pumped storage systems use cheap electricity to move water from a downhill lake to an uphill lake; then regenerate electricity when it's needed, using turbines just like hydroelectric power. Britain has four pumped storage facilities, which can store 30GWh between them. They are typically used to store excess electricity at night, then return it during the day, especially at moments of peak demand (MacKay, 2008).

countries' hydroelectric facilities as storage facilities. Almost all of Denmark's wind power is exported to its European neighbours, some of whom have hydroelectric power, which they can turn down to balance things out. The saved hydroelectric power is then sold back to the Danes (at a higher price) during the next period of low wind and high demand. Overall, Danish wind is contributing useful energy, and the system as a whole has considerable security thanks to the capacity of the hydro system. To be able to export all its excess wind power in the style of Denmark, Britain (assuming 33GW of wind capacity) would need something like a 10GW connection to Norway, 8GW to Sweden, and 1GW to Iceland. However this makes the UK significantly dependant on other countries and implementing this inter-connectedness is a great challenge in itself.

According to the London mayor's office (2011), there are currently more than 2,000 electric vehicles on London's roads, with a city-wide charge-point network of 150 outlets set up to serve their owners. Users just need to park their vehicles in designated bays on streets and in car parks, swiping their membership cards to activate the power, then leave them to charge at the branded points. A further 1,150 charge points will be rolled out under the 'Source' scheme by 2013, giving London more of the outlets than petrol stations[83]. However, this only represents a small proportion of the UK road vehicles, and in order to balance the grid, a significantly larger and more ambitious push towards electric vehicles will be required. This would require significant investment and nationwide change.

These smart chargers would provide a useful service in balancing to the grid, a service which could be rewarded financially. This could be even more robust if interchangeable batteries were used which could be swapped at fuel stations for fully charged ones. Fuel stations could charge them at appropriate times, generating profits while helping to balance the grid. Household energy use could also contribute to balancing supply – eg passive energy consumption (ie appliances plugged in but not in use) presents a significant opportunity contributing around 8% to electricity consumption.

83 http://www.metro.co.uk/tech/864613-electric-car-charging-scheme-launched-in-london

6.7 New nuclear and wind power may never see the light

Construction of nuclear power stations involves very long lead times, requires major capital investment as well as consultation with multiple stakeholders. To proceed in a competitive market, investors have to be confident that regulatory requirements are clear, and that decision making will be efficient (it took Sizewell B six years to secure planning consent, costing £30 million in the 1980s) without hindrance through stakeholder opposition (particularly during set up phases).

Build rates for nuclear power are more affected by business cases (investor confidence in return on investment) and the availability of suitable sites, than specific technical limitations. The draft National Policy Statement for Nuclear Power, the consultation period for which closed in February 2010, used the strategic siting assessment to identify 10 potentially suitable sites for new nuclear power stations by 2025. Following government reforms to planning, applications will be decided within a year in most circumstances.

Even though no new nuclear plants have been opened since 1995, EDF which now owns British Energy, has indicated an intention to invest in up to four new plants - the first to be operational by 2018. RWE and E.ON have formed a joint venture, Horizon Nuclear Power, with similar plans. Also, a consortium of Iberdrola, GDF SUEZ and Scottish and Southern Energy has announced that their joint venture company, NuGeneration, is aiming to develop up to 3.6GW of new nuclear capacity.

Nevertheless extraction of uranium and supply of nuclear energy has significant risks and challenges including the ongoing issue of public acceptability especially in light recent events in Japan[84]. On 30 May 2011, Germany announced a reversal of policy that will see all the country's nuclear power plants phased out by 2022[85]. The decision makes Germany the biggest industrial power to announce plans to give up nuclear energy. The official commission set up by the German government to review the issue[86] reckons that electricity use can be cut by 10% in the next decade through more efficient machinery and buildings. The intention is also to increase the share of wind energy to compensate for the shortfalls. It is important to note that Germany

84 http://www.bbc.co.uk/news/world-europe-12741547 and http://www.bbc.co.uk/news/science-environment-13699055

85 http://www.bbc.co.uk/news/world-europe-13592208

86 http://www.bbc.co.uk/news/world-europe-13257804

relied on nuclear power for 23% of its energy, while the projected UK share by 2030 is only 6-7% so the risk exposure to nuclear energy issues is much lower in the UK. Other countries such as Italy and Switzerland are also reviewing their position on nuclear power with low current public and political support for greater reliance on nuclear[87]. However, there are no signs from the UK government that their position on nuclear energy is changing, while France has plans for nuclear power expansion despite Fukushima[88].

Table 3 below shows the status of on-shore wind energy generation projects for UK as of May 2010. The average approval rate across all sizes of project 2004-09 was 69%.

Table 3 - On-shore schemes numbers, planning status and capacity (DECC, 2010)

Onshore status	Schemes	Capacity (GW)
Operational	301	3.6
Under construction	37	1.3
Approved but not built	159	3.3
In planning process	282	7.6

Based on work done by Enviros Consulting Group in 2005, the practical annual capacity for on-shore wind will vary between 28GW to 31GW by 2020. While DECC estimates point to off-shore wind capacity of around 44GW (see Table 4).

Table 4 - Off-shore schemes numbers, planning status and capacity (DECC, 2010)

Onshore status	Schemes	Capacity (GW)
Operational	14	1.0
Under construction	4	1.5
Approved but not built	6	2.6
In planning process (includes anticipated applications not yet submitted	32	43.7

In the 2007, the Government announced a review (the Transmission Access Review) led by Ofgem and BERR (now DECC) to

87 http://www.bbc.co.uk/news/world-europe-13732050
88 http://www.bbc.co.uk/news/world-europe-13595455

examine the technical, commercial and regulatory framework for the delivery of new transmission infrastructure and management of the grid to ensure that they remain fit for purpose as the proportion of renewable generation on the system grows. The final report (2008) contains actions designed to allow faster connection of some renewable generation in the short-term and steps to improve the speed of connections for renewables and expansion of grid capacity in the long-term, so there are plans in place to ensure the robustness of the grid with large scale renewable reliance.

6.8 Peak oil will severely impact the availability and affordability of oil

The concept of the peaking of world oil production follows from the fact that the output of an individual oil field rises after discovery, reaches a peak, and then declines. Oil fields have lifetimes typically measured in decades, and peak production often occurs roughly a decade or so after discovery under normal circumstances. It is important to recognise that **oil production *peaking* is not 'running out'.** Peaking is the maximum **oil production rate**, which typically occurs after roughly half of the recoverable oil in an oil field has been extracted[89].

Oil supply is determined by a complex and interdependent mix of 'above-ground' and 'below-ground' factors. There are two main opposing schools of thought on this issue. The first group claims that physical depletion will have the dominant influence on future oil supply, while the second emphasises that the effects of depletion can be mitigated by investment and new technology. A concern for both is whether relevant organisations will have the incentives and/or ability to justify investment in either scenario. Most studies examined indicate that peak oil is a real risk to future oil supply and will have a direct implication on the cost of diesel.

According to the IEA, there will be a near-term 'supply crunch' owing to the potential cancellation and/or delay of many upstream investment projects. There is a growing consensus that the age of cheap oil is coming to an end. Key issues include the production profile of individual fields, the concentration of resources in a small number of large fields, and the early discovery and exploitation of large fields (the easy oil has already been found). The uneven distribution of conventional oil resources between different sizes of field is increasingly well understood. Although

89 For more details on peak oil, see DECC's call for evidence- *Prospects for crude oil supply and demand (June 2011)* http://www.decc.gov.uk/en/content/cms/meeting_energy/int_energy/global_oil/cfe_crude_oil/cfe_crude_oil.aspx

there are around 70,000 oil fields in the world, approximately 25 fields account for one quarter of the global production of crude oil, 100 fields account for half of production and up to 500 fields account for two-thirds of cumulative discoveries. Most of these 'giant' fields are relatively old, many are well past their peak of production, most of the rest will begin to decline within the next decade or so and few new giant fields are expected to be found.

Estimates of the recoverable resources of individual fields are commonly observed to grow over time as a result of improved geological knowledge, better technology, changes in economic conditions and revisions to initially conservative estimates of recoverable reserves. This process appears to have added more to global reserves over the past decade than the discovery of new fields and it seems likely to continue to do so in the future. Reserves and production should not be confused.

Estimates of reserves are but one factor used in estimating future oil production from a given oil field. Other factors include production history, local geology, available technology, oil prices, etc. An oil field can have large estimated reserves, but if a well-managed field is beyond maximum production, the remaining reserves can only be produced at a diminishing rate. Sometimes decline can be slowed, but a return to peak production is impossible.

The oil industry must continually invest to replace the decline in production from existing fields. The average rate of decline from fields that are past their peak of production is at least 6.5% per year globally, while the corresponding rate of decline from all currently-producing fields is at least 4% per year. If we assumed that this ongoing reduction/shortfall has to be compensated by an increase in reserves and/or new fields discoveries, it translates to approximately 3 million barrels per day (mb/d) of new capacity to be added each year, simply to maintain production at current levels.

On the other hand, Prof. Boyce in his paper in 2009[90], replaces the Bell curve with a conventional stock market chart to track the rise and fall of oil discoveries, as influenced by price incentives. Expressed in five-year averages, new oil discoveries peaked in 1952 at 25 billion barrels; then fell to 18 billion. They peaked again

90 Boyce, R, J (2009) *What Goes Up Must Come Down?* An Economic Analysis of Peak Oil

in 1970 at 55 billion barrels; then fell to 25 billion. They peaked yet again in 1990 at 80 billion barrels; then fell to 20 billion. And they peaked once more in 2007 at 85 billion barrels; falling since to 45 billion. In this same period, proven reserves increased to 1.4 trillion barrels. The explanation reflects classic economic theory.

When incentives exist, the industry produces lots of discoveries – enhanced by technological innovation. These discoveries produce a decline in profits and prices, lowering the incentives for exploration. The subsequent shortages restore incentives. The process repeats itself in 'a multiplicity of peaks'. *Peak oil*- he says - *is one-dimensional and mechanical. It omits human behaviour and human choice. It is mere extrapolation from arbitrarily selected statistics … Thus it rests upon an assumption that people don't make decisions – don't make choices*.

According to Prof. Boyce, if you insist on a Bell curve for oil, you must logically use a Bell curve for peak aluminium, iron ore, and cement! Yet the per-capita consumption of 80 minerals increased throughout the 20th century even as prices for almost all of them fell. With oil (similar to minerals), technological advances, driven by price incentives, produce the paradox of rising production at falling costs. The exploitation of methane gas and shale gas will take place in the same way.

Prof. Boyce is not suggesting that oil may never run out, or that a peak will not be reached (there will be multiple peaks). The argument is that declines will be counter balanced by incentives and technological improvements. Even according to peak oil supporters (see Hirsch for the Atlantic council, 2005), oil peaking represents a liquid fuels problem, not an 'energy crisis' in the sense that term has often been used.

Peak oil however, irrespective of what school of thought one belongs to, will lead to increased prices which will have an implication on greater incentive to find and extract more oil. That is likely to happen after the fact; it is insensitive to changes in rates of production and very optimistic estimates of reserves.

According to UKERC (2009), contemporary estimates of the global Ultimate Recoverable Resource (URR) for conventional oil fall within the range **2000-4300 Billion barrels (Gb)**, while the corresponding estimates of the quantity of remaining recoverable resources fall within the range **870 to 3170 Gb**. In other words, the highest estimate of remaining recoverable resources is four times larger than the lowest estimate.

A study conducted by Kaufmann and Shiers (2008)[91] shows the sensitivity results using assumptions for the global URR ranging from 2000 Gb to 4500 Gb. If we take it to be 2500 Gb, the model gives peak production in 2009 at a level of 30 Gb/year (82 mb/d). If, on the other hand we take it to be 4500 Gb, it gives peak production in 2032 at a level of 42 Gb/year (115 mb/d). Hence, with this model, we see a 125% increase in the size of the URR (or a 260% increase in the size of the remaining resource) and a delay in the date of peak production by only 23 years.

Put another way, increasing the global URR by one billion barrels delays the date of peak production by only 4.7 days. To delay the date of peak production by one year would require the addition of some 78 billion barrels to the global URR. This is two and half times greater than 2007 global production and almost seven times greater than global discoveries in that year. To put this in perspective, the discovery of resources nearly equivalent to those of the entire United States would delay the global peak by less than four years. This analysis also shows that the timing of the global peak for conventional oil production is relatively insensitive to assumptions about the size of the global resource.

Kaufmann and Shiers (2008) also show that for a production rate for any given value of URR, changing the initial growth and decline rates of production has relatively little effect on the date of the peak. Their results imply that to delay the peak in global oil production beyond 2030 would require a combination of a large URR (eg at least 3000 Gb), slow rates of production increase prior to the peak and/or a relatively steep post-peak decline rate. Only three out of 64 possible scenarios they assessed, gave a peak after 2040 and these require all three assumptions to hold. They also imply that later peaks will lead to a faster rate of decline which might be a bigger problem anyway.

The analysis mentioned above does not consider lower rates demand growth due to recessions, etc. However this most recent recession has led to the cancellation of many projects which could lead to near-term supply constraints (IEA, 2009). So the risks from peak oil remain high.

91 Kaufmann, R. K. and L. D. Shiers. (2008). *Alternatives to conventional crude oil: When ,how quickly, and market driven*. Ecological Economics, **67**:3, pp. 405-11

Some responses in DECC's recent (June 2011) call for evidence on the prospects of crude oil supply and demand, anticipate that China, as a planned economy, will develop its transport sector in such a structured way that electric vehicles will become the predominant mode of transport, bypassing the combustion engine era that developed countries experienced, and hence lower the oil intensity of China's growth (counter arguments show that 80-90% of the oil demand will come from china and India).

By contrast, OECD oil demand growth is expected to be small, if not negative in the long-term. Population growth is also cited by a range of respondents as a major driver behind oil demand in developing countries. Some respondents, mostly with an economics/business background also believed that the demand for oil would be limited by prices, in that once prices reach a certain level, the economy will go into recession and demand will decrease. The specific price level that would cause this was not discussed.

In addition to this, the geopolitical risks to supply of oil are well known and there is a plethora of documentation and information in the public domain. Figure 5 from the US Department of Energy highlights the level of lost gross output in million barrels per day due to disruptive events. The lost output ranges from 1.5 to 5.6 million barrels a day; 270 million to nearly a billion barrels over a six month period. It is important to note that these disruptions tend not be long term and only cause a short supply constraint. They are relatively small compared to total global reserves of oil. However, greater dependency on oil does expose the GB railways to short term supply constraints and price hikes.

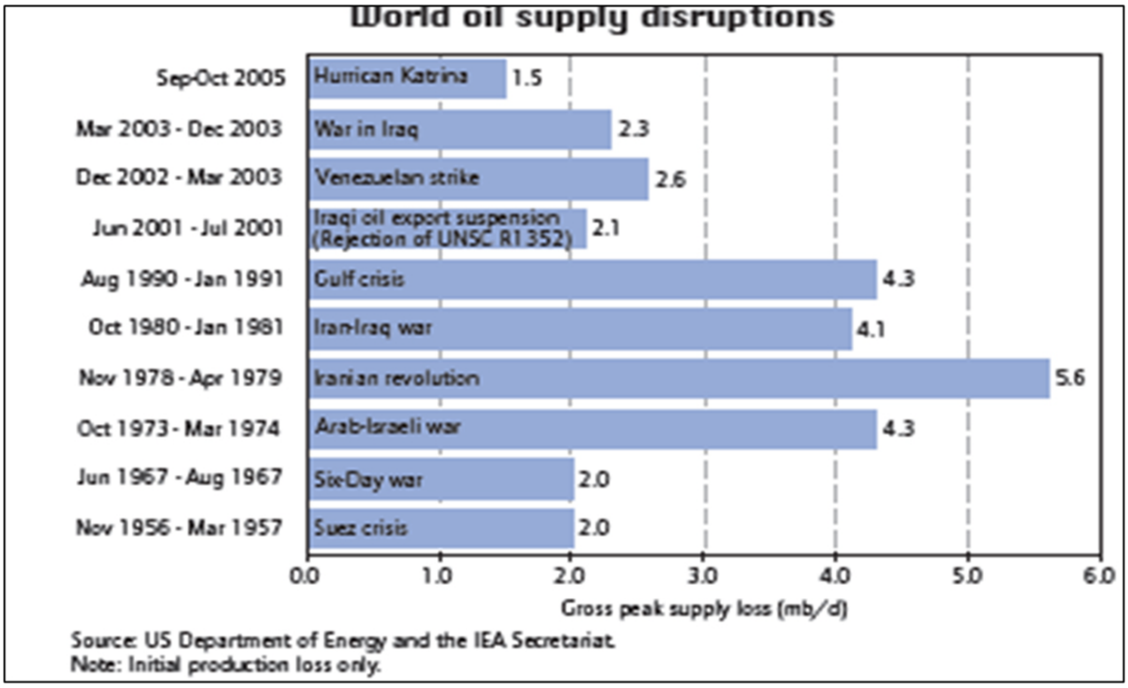


Figure 5 - Loss of gross supply of oil from disruptive events

The research has highlighted that availability of oil will be subject to short term variations, and long term decline of supply.

It is also important to see these issues in the context of the shape of UK's petroleum industry which hints at a even greater reliance on exports. The UK Petroleum Industry Association (UKPIA) represents the oil refining and marketing interests of the nine main downstream oil companies in the UK. The member companies operate all the major crude oil refineries, supply one-third of primary UK energy demand and 85% of the transport fuels and other oil related products used in the UK. In their submission (31 March, 2011) to the energy and climate change committee's inquiry, they suggested that UK refining faces many challenges. These partly stem from difficult market conditions (weak demand, low return on capital employed), competition from new export orientated refineries in Asia and a depressed outlook for refining margins to 2020 (energy analysts Wood Mackenzie report).

However, there are also mounting costs associated with meeting tougher EU/UK legislative requirements (EU Emissions Trading Scheme, EU Renewable Energy and Fuels Quality Directives, EU Industrial Emissions Directive which together will impose a £1 billion plus burden on the UK refining industry) that do not apply to non-EU refineries, and UK only policies on climate change (eg CRC Energy Efficiency Scheme, Carbon Floor Price etc) that may penalise UK refining versus its EU and global competitors.

The refining sector also faces a growing imbalance in petrol and diesel supply/demand. The effect of fiscal policy and the better fuel efficiency of diesel vehicles have increased diesel demand in the UK by ~38% since 1998. Petrol demand has been in steady decline since the peak reached in 1990 and the surplus is exported, much of it to the USA. The same trend is apparent in the rest of the EU. Addressing this imbalance is a growing challenge for UK refineries; solutions include substantial investment (£500 million+ per refinery) to equip refineries with upgrading units to produce more diesel or alternatively greater reliance upon imports.

There are also consequences for air quality and for refinery emissions in meeting this additional diesel demand - more energy intensive refining processes to upgrade heavier residues into diesel with associated increases in CO_2 and other emissions.

Increasingly, EU/UK refineries are facing competition from new large-scale refineries in Asia designed to maximise the output of diesel, aviation fuel and kerosene with a low proportion of heavier residue products such as fuel oil for marine use. These refineries in the shorter term have a significant export capability and crucially do not face the same burden of legislative cost as UK refineries so a future even greater reliance on external sources for diesel might be a real possibility thereby increasing the risks exposure to geo-political events.

It raises the key question, if there are future shortfalls in diesel availability as expected, then how long will the railway stock last if it relies too heavily on diesel as a key fuel?

6.9 Electricity will be as cheap as diesel

Both electricity and diesel prices are expected to rise considerably in the future. However, electricity prices are likely to rise at a far greater rate than diesel until 2030. These conclusions are based on the latest DECC electricity and diesel long term price projections. DECC's price assumptions inform government analysis of different policy options which affect the demand and supply for energy.

However, it is also important to recognise that most of the literature acknowledges that electricity prices are likely to stabilise beyond 2030 (although specific price projections beyond 2030 would be very uncertain), as the use of renewable sources increases leading to greater economies of scale, more innovation, a maturing supply chain, and ever improving management practices and technologies.

On the other hand, diesel's long term forecasts are much more downbeat in terms of availability and diesel price is very likely to carry on increasing (even more so due to greater political interventions to meet emissions obligations).

DECC uses assumptions for fossil fuel prices in a number of areas, primarily DECC's Energy Model which provides emissions projections which are published annually. In conjunction with the Energy Model, the fossil fuel price assumptions provide a range of scenarios to analyse policies such as Carbon Budgets and the Renewable Energy Strategy. DECC's assumptions are based on the best information available on market fundamentals and the feedback received on previous assumptions.

The projections in different scenarios examine the impact on prices based on demand and supply dynamics, which in turn are affected by political, social, technological, environmental and economic environment that might unfold in the future ie the range of supply and demand futures incorporate all political, economic and other events which may impact supply or demand thereby giving a full range of futures.

It is possible that the reader may feel some political and economic futures are more likely and then focuses more on one or more of the scenarios.

It is also critical that the scenario prices are seen as long term projections (not affected by short term variations) and are not predictions. DECC recommends that all scenarios should be taken into account as long term projections are extremely difficult so a range of futures should be examined to ensure no possible future is discounted due to prevailing conditions and perspectives which are always subject to change especially when long term view is being taken.

Table 5 - DECC's price projection scenarios

Scenario Name	Scenario Description[a]
Central Scenario	Based on central estimates of growth and fossil fuel prices. Contains all agreed policies where decisions on policy design are sufficiently advanced to allow robust estimates of impact
Low Prices	Assumptions similar to central scenario but with lower projected fossil fuel prices
High Prices	Assumptions similar to central scenario but with higher projected fossil fuel prices
Low Growth	Assumptions similar to central scenario but with lower projected economic growth
High Growth	Assumptions similar to central scenario but with higher projected economic growth
Baseline Policies	Contains central price and growth assumptions but only policies that existed before the Low Carbon Transition Plan

a. See http://www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/2933-fossil-fuel-price-projections-summary.pdf for the more details regarding the scenario assumptions. Also see http://www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/2942-fossil-fuel-price-proj-review-sentance.pdf for a review of the scenarios. All price projections can be found at http://www.decc.gov.uk/en/content/cms/about/ec_social_res/analytic_projs/en_emis_projs/en_emis_projs.aspx#2011-projections

More details on the scenarios are provided by the DECC's fossil fuel price assumptions document, which accompanies its project projections[92]. Figure 6 shows DECC's latest projected retail prices for Diesel (Gas oil)[93] and Electricity.

92 http://www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/2933-fossil-fuel-price-projections-summary.pdf

93 DECC have made projections for diesel used by road vehicles, while the railways uses gas oil (red diesel) which is exempt from significant taxes. Gas oil projections are not available, but the current gas oil is around 50% cheaper than road diesel, so for the purposes of this comparison, DECC's diesel projections (which includes all taxes) have been down rated by 50% to reflect future gas oil prices. The key assumption being that the railway diesel will continue to be exempt from taxations levied on road diesel by the same amount.

shows 2011 Quarter-1 actual price of **electricity** for a large industrial organisation

shows 2011 Quarter-1 actual price of gas oil for a large industrial organisation

Just because current prices are on a particular scenario trajectory does not necessarily mean that future prices are likely to follow that trajectory.

If the conditions changed, a 'High Growth' or 'High Price' scenario may be achieved in 2030 even if current price is closer to a low scenario projection.

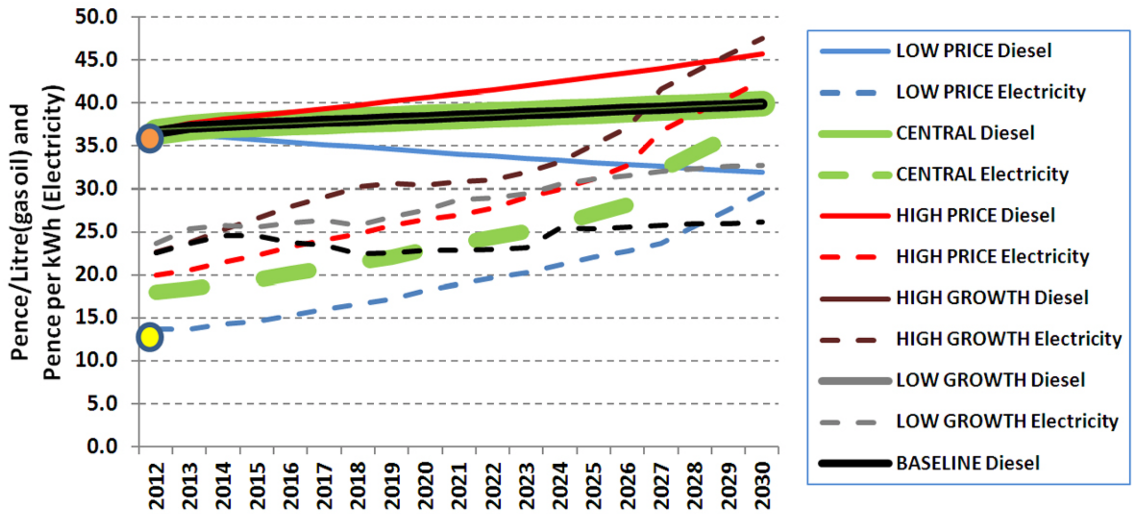


Figure 6 - Gas oil vs. Electricity price projections in pence/litre & pence/kWh respectively (in 2010 prices)

The results in Figure 6 show how electricity prices rise sharply, more than doubling in four out of six scenarios (**average of 84% - highest of 116% and lowest of 16%),** compared to an average increase of only **8% in diesel (highest of 38% and lowest of -12%)** price by 2030. These forward projections are based on supply and demand dynamics and do not take into account of changes to taxation and environmental (European and domestic) policy which will impact the projections. However, comparative fuel retail price does not reflect the true cost of fuel in terms of its use for the railway. Figure 7 uses the future projected retail prices in the different DECC scenarios, and combines them with energy consumption for a given distance to incorporate the relative efficiency of the electric and diesel engines. ATOC's energy and emissions statement 2006/7 provides the required 'normalisers': average diesel energy consumption = 0.52 litres/Vehicle Km and average electricity energy consumption = 1.95 kWh/Vehicle Km[94].

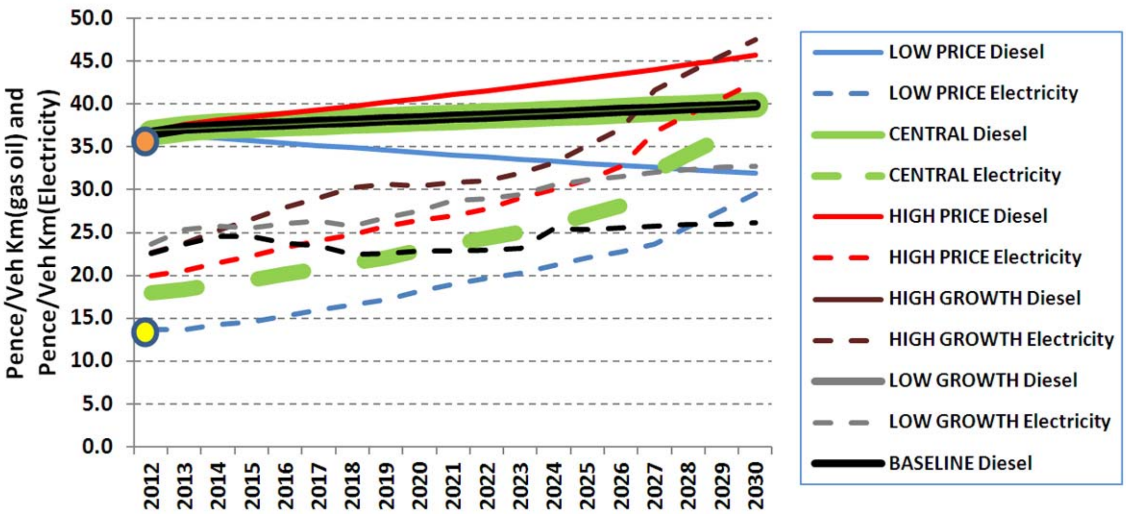


Figure 7 - Diesel vs. Electricity price projections in pence/Vehicle Km (in 2010 prices)

The results show that the gap between electricity and diesel is narrowing. Based on current efficiency levels, diesel is slightly more expensive on average by 13% (higher than electricity in five out of six scenarios) across the six scenarios. In extremes, it is up to 52% more expensive in the baseline scenario, and on the other hand it is 16% less expensive in the high growth scenario. It is important to recognise that if diesel switches to a lower price trajectory while electricity switches to a higher price trajectory, then electricity prices could end up being far higher than diesel (up to 33%) and vice versa (up to 74%). It is also estimated that the fuel efficiency of diesel may be improved through the use of

94 These values are based on total amount of electric or diesel energy used, divided by, the total number of vehicle Kms travelled for diesel or electric vehicles in a year.

diesel electric hybrid trains by up to 20% but hybrids have much higher capital costs.

It is also worth noting that the use of low sulphur gas oil from January 2012 (mandatory due to EU Directive 2009/30/EC) is likely to make fuel costs around 2 pence / litre more expensive than conventional gas oil. This has not been reflected in figures 6 and 7 as the long term impact on the cost of diesel is hard to assess. It could add up to 5% of the cost. Note that the diesel vs. electric debate is much broader that the issues discussed above. Other comparisons between the two forms of power, ie maintenance, availability, reliability, track damage, greenness, etc, are well documented[95] and outside the scope of this work.

RSSB's R&D project *T536 Investigation into the use of sulphur-free diesel fuel on Britain's railways (2007)*[96] also examined the **future of the diesel engine**. The research found that compliance with the emissions limits will require the use of exhaust after-treatment devices. There are significant issues of weight, size and cost for the installation of after treatment equipment in new rail vehicles, and even more so for retro-fit installations (although emissions legislation is not currently retrospective). Future developments will eventually make after-treatment systems lighter, smaller and more efficient. Future developments might also mean that diesel engines may not require the use of the after treatment devices at all. However, detailed examination of these issues and their implications on the use of diesel as a fuel (in terms of economics) is beyond the scope of this work.

6.10 Greater energy efficiency is the key to energy security

The increasing costs of electricity and diesel highlights the need for greater energy efficiency and which would help off-set the rising costs as well as reduced the risks of energy supply security for the railways. The range of energy efficiency measures and in depth discussion in that area is beyond the scope of this work, as it forms part of the industry discussion plans and initiatives (current and future) to mitigate the risks highlighted in this report. It is obvious though that the need to move to more efficient systems of energy distribution and use, however achieved, are critical to securing the energy future of GB rail and the nation in general. The potential sensitivity of costs to greater energy

95 See Network Electrification RUS for case for electrification.
96 http://www.rssb.co.uk/SiteCollectionDocuments/pdf/reports/research/T536_rpt_final.pdf

efficiency and their potential to offset price increases is shown through an illustrative example.

If a largely electrified future railway is assumed, then what would be the likely implications on the cost of energy in 2030 given the greater efficiency of electric vehicles? The three scenarios to explore are:

A. 60% of the diesel consumption switched to electricity

B. No switching, but both systems improve by 30%.

C. Systems improve efficiency and there is a switch.

The example is not a recommendation but is being used to roughly illustrate the impact more efficient systems can make.

For 2009/10, the energy consumption of the railways was as follows[97]:

Diesel Passenger = 481.9 million litres, Diesel Freight = 199.2 million litres,

Electricity Passenger = 3061.3 million kWh, Electricity Freight = 79.7 million kWh

97 National Rail Trends 2010/11 (ORR, 2011) http://www.rail-reg.gov.uk/upload/pdf/nrt-yearbook-2010-11.pdf

A. SWITCH: Basic assumptions for ease of rough calculations to illustrate impact on industry energy costs due to more efficient systems:

- A linear increase in gas oil and electricity prices from now till 2030 as a 20 year rough time scale, all cost increases are in real terms (excludes inflation).
- A bulk 30% switch gas oil to electricity after 10 years and another 30% switch after 20 years; demand and service levels remain stay constant as today.

Table 6 -

					SCENARIO 1: Status quo		SCENARIO 2: 60% switch from gas oil to electricity in two 30% chunks	
	Current traction costs in £m	Relative efficiency in terms of kWh/Km[a]	20-year price rise[b]	10-year price rise	Costs in £m at the 10-year mid-point	Costs in £m after 20 years (2030)	Costs at the 10-year mid-point with a 30% gas oil to electricity switch	Costs in 20 years (2030) with another 30% gas oil to electricity switch
Gas oil	£477	6	30%	15%	£549	£631	£384	£309
Electricity	£220[c]	2	100%	50%	£330	£495	£402	£660
Total	£697				**£879**	**£1,126**	**£786**	**£969**
Costs saved through switch to more efficient system from 10 years onwards					**£879 - £786 = £93 million/year (11% lower)**			
Costs saved through switch to more efficient system from 20 years onwards						**£1,126 - £969 = £157 million/year (14% lower)**		

a. Based on ATOC's energy and emissions statement 2006/7: average diesel energy consumption = 0.52 litres/Vehicle Km equates to 5.7kWh/Vehicle Km. While average electricity energy consumption = 1.95 kWh/Vehicle Km. So the electricity on average is providing nearly 3 times more efficiency than diesel. Please note the relative efficiencies ignore generation and transmission losses for electricity as they are subsumed in the price of electricity charged.

b. Assuming a worst case scenario of a fairly high increase in prices across both diesel (30%) and electricity (100%)

c. Note that the rate of electricity charged to the rail industry is very favourable at the moment due to current contracts, so this figure is likely to be overstating the total costs thereby making actual traction costs by the rail industry closer to between £500 to £600 million than £697 million used here.

This illustrative example does not consider the entire diesel vs. electric comparison. Neither is this example putting forward a case for electrification as that is also beyond the scope of this work as it considers other broader issues than just the price of energy. The example does not incorporate all the other costs and constraints associated with switching from gas oil to electricity, including asset life, capital investment, etc or emissions benefits. However, it does highlight that costs in real terms in 2030 will be significantly higher than today despite efficiency improvements but the scale of change can be somewhat reduced if energy efficiency measures are implemented by the industry. It also highlights the scale of the challenge facing the industry in the face of significant price rises (the example shows a 39% increase in costs despite the switch).

B. DON'T SWITCH BUT BECOME MORE EFFICIENT: Basic assumptions for ease of rough calculations to illustrate impact on industry energy costs due to more efficient systems:

- A linear increase in gas oil and electricity prices from now till 2030 as a 20 year rough time scale, all cost increases are in real terms (exclude inflation)
- A 30% improvement in efficiency in diesel and electric systems. A 10% improvement after 10 years and another 20% after 20 years. **No switch between the two energy sources.**
- Demand and service levels remain stay constant as today

Table 7 -

					SCENARIO 1: Status quo		SCENARIO 2: 30% electricity efficiency improvement + 30% diesel efficiency improvement in a 10% , followed by another 20% chunk	
	Current traction costs in £m	Relative efficiency in terms of kWh/Km	20-year price rise	10-year price rise	Costs in £m at the 10-year mid-point	Costs in £m after 20 years (2030)	Costs at the 10-year mid-point with a 10% improvement	Costs in 20 years (2030) with another 20% improvement
Gas oil	£477	6	30%	15%	£549	£631	£494	£454
Electricity	£220	2	100%	50%	£330	£495	£297	£356
Total	£697				**£879**	**£1,126**	£791	£810
Costs saved through switch to more efficient system from 10 years onwards					**£879 - £786 = £88 million/year (10% lower)**			
Costs saved through switch to more efficient system from 20 years onwards						**£1,126 - £810 = £316 million/year (28% lower)**		

This example shows the impact of efficiency improvements without a switch between the two main energy sources. The scale of cost change has been significantly reduced saving around £315m per year. In terms of total energy costs, this scenario shows an increase of just 16% compared to 39% in scenario A, and a 28% saving when compared to status quo scenario in 2030.

C. SWITCH AND BECOME MORE EFFICIENT: Basic assumptions for ease of rough calculations to illustrate impact on industry energy costs due to more efficient systems:

- A linear increase in gas oil and electricity prices from now till 2030 as a 20 year rough time scale, all cost increases are in real terms (exclude inflation)
- Combined conditions of switching (60%) and efficiency within systems (30%).
- Demand and service levels remain stay constant as today

Table 8 -

					SCENARIO 1: Status quo		SCENARIO 2: Combined switching + efficiency scenario	
	Current traction costs in £m	**Relative efficiency in terms of kWh/Km**	**20-year price rise**	**10-year price rise**	**Costs in £m at the 10-year mid-point**	**Costs in £m after 20 years (2030)**	**Costs at the 10-year mid-point**	**Costs in 20 years (2030)**
Gas oil	£477	6	30%	15%	£549	£631	£346	£223
Electricity	£220	2	100%	50%	£330	£495	£361	£475
Total	£697				**£879**	**£1,126**	£707	£698
Costs saved through switch to more efficient system from 10 years onwards					**£879 - £707 = £172 million/year (20% lower)**			
Costs saved through switch to more efficient system from 20 years onwards						**£1,126 - £698 = £428 million/year (38% lower)**		

This example shows the impact of efficiency improvements and switching between the two main energy sources. The scale of cost change has been significantly reduced saving around £428m per year. This scenario shows that how the energy price increase can be nullified (a 0.14% increase only) in terms of total energy costs, and shows a 38% saving when compared to status quo scenario in 2030.

This shows that with significant effort, the energy cost increases can be offset by improved efficiency!

Also, according to an EU project looking at EU transport energy security in 2050[98], there are five ways to ensure improved energy security:

- Making greater use of indigenous supplies of energy (self generate where possible)
- Increasing diversity of supply (consider having vehicles with dual energy use)
- Establishing long-term supply arrangements (ensure contractual long term security of supply and price)
- Increasing reserves – strategic and operational (consider energy storage options and increase storage capacity)
- Reducing demand (reduce losses and improve efficiency)

The same EU project also examined potential policy options against multiple criteria to assess their potential contribution to improving energy security. The project used a multi-criteria analysis framework to quantify the energy security benefits of transport options. Using this approach, they arrived at numerical energy security ratings for each abatement option (the higher the percentage rating, the better the performance of the option with respect to energy security for the EU). It should be stressed that the results from the assessment presented in Table 9 are based on the current situation with respect to fuel costs, vehicle capabilities, and the current methods used to produce the fuels included in this analysis.

This analysis shows that the optimal energy security benefit is obtained by approaches that reduce the energy demand growth curve which can be achieved through greater energy efficiency. The benefits that more efficient engines and electrification equipment has great potential to reduce the demand requirements.

Electricity and biofuel blends are identified as the next best options for energy security in the transport sector due to their low resource concentration and, for electricity, a low correlation with crude oil prices.

98 EU transport CGH: routes to 2050 (June, 2010).

Table 9 - Transport policy options and their relative performance in terms of abatement of energy security risks in the EU

Transport policy option	Total MCA score (maximum 600)	MCA score as a percentage	Rank
Energy demand reduction	450	75%	1
Electricity	400	67%	2
Biofuel blends and fungible types	350	58%	3
Gasoline/diesel	300	50%	4
Pure non-fungible biofuel	250	42%	5
LPG	213	35%	6
Natural gas	163	27%	7
Hydrogen (produced from natural gas)	163	27%	7

The proportion of road vehicles able to use electricity is however very low but high for blended biofuels, but for the railways there is a greater dependency on electricity. Natural gas and hydrogen produced using natural gas score low in the assessment due to high resource concentration and susceptibility to extreme events. However, it must be noted that the results and rank ordering might look very different if the analysis were to be carried out for future years.

It is important to note that micro generation and energy storage, while in the very early stages of development, is being actively considered by other railways. New concepts and technologies are being explored so that micro generation on the railways is possible, for example designers in Italy have developed a device to exploit the movement of air caused by the passage of trains[99]. The real issue with micro generation is its commercial viability / scale and thus its ability to make a meaningful contribution to energy security.

99 http://www.fotovoltaicodomestico.com/blog/energia-eolica/energia-eolica-impianti-innovativi-montare-linee-ferroviarie.html

Also, applications using trackside flywheels to absorb/recycle energy and generate power for traction are being developed[100]. Anecdotal evidence suggests that these technologies are being considered by other rail authorities, though no formal document based source was found to confirm this.

To see an example of the active role the railways can play in resolving national energy issues is evident from Germany. The German government is actively considering working with Deutsche Bahn under EU directives, to use several thousand miles of high-voltage transmission lines on the railway infrastructure which can be modified to broaden the national energy grid.

The German government has had to find a quick solution to a daunting problem of how to move large amounts of renewable energy from one region to another. Wind turbines spin in the northeast, for example; but cities are growing in the south and west. The German grid will need around 2,240 miles of new high-voltage corridors to make renewable energy viable; about 60 miles have been built so far. Integrating power lines so tightly with the rail system will cost money, of course — but only a quarter of the total estimate for a whole new grid. The work would involve changing the operating voltage on some high-capacity cable or installing whole new lines[101].

Also, the first high-speed train service to Amsterdam from Paris has crossed the border in 2011 utilising electricity generated by a solar tunnel. The tunnel consists of 16,000 solar panels, is 2.2 miles in length and covers an area of 50,000 square meters in Antwerp, Belgium. This is the equivalent of the area of eight football pitches. The solar panels are capable of generating around 3,300MW each hour. This is enough to power up to 4,000 trains every year through the tunnel. The information available on this is thin on specific details, and it is not possible to validate or invalidate these claims in the absence of further evidence.

100 http://www.kinetictraction.com/tech.html. According to the US-based supplier, its unique high-speed carbon flywheel systems feature high cycling composite rotors running on magnetic and hydrodynamic bearings at up to 36,000 RPM to provide 200kW each. The systems are capable of delivering more than 1000 charge-discharge cycles per day for 20 years with minimal maintenance. The GTR flywheel utilises a fully integrated, permanent magnet, brushless, DC motor generator to provide clean energy capture with significantly lower costs than traditional energy substations.

101 http://www.miller-mccune.com/science-environment/plugging-high-speed-rail-into-germanys-power-grid-31304/

According to Frederic Sacre, from rail network operators Infrabel, the electricity generated by the panels supplies the line's infrastructure including power points on the trains, signals and lighting. The first train to use the new power source departed Antwerp on 6 June 2011. For the first few miles heading towards the Dutch border it was being powered by electricity from the solar tunnel. The project was developed by Enfinity, a US based firm. The project cost £12m. It is estimated to reduce emissions of CO_2 by around 2,400 tonnes every year. The full commercial details are not publically available making it hard to assess the commercial viability of the scheme. There are currently no plans to introduce a similar solar power scheme in the UK.

Figure 8 - The Belgian solar rail tunnel[102]

In December 2010 DECC issued a consultation on microgeneration strategy (closed in March 2011). The document acknowledges that micro generation is a nascent market in the UK. There is a need to fully understand to what extent micro generation is being implemented, as well as assess how micro generation could link up with the national grid in the future. These

102 See video of the solar tunnel in use on YouTube http://www.youtube.com/watch?v=Sc7ahEzVt1U&feature=player_embedded#at=172

areas represent requirements for further consultation and research. The consultation document does highlight the potential benefits from smart meters that could improve energy efficiency and policy options and incentives to encourage more adoption.

7 Quantification of energy security risks for the railways

There are several qualitative indices that have been proposed to measure ongoing energy security risks at national and international levels. Sector specific indices are not particularly prevalent though further research could adapt some of these to create sector specific (railways) indices to reflect energy security. Some of them are discussed below.

In 2009, the European Commission DG Environment commissioned a study from the consultancy Ecofys entitled *Analysis of Impacts of Climate Change Policies on Energy Security*, and as part of this research, a comprehensive review of existing indicators for quantifying energy security was carried out. According to this work, there are two types of indicator that can be used for quantifying energy security impacts/benefits, as follows:

- Vulnerability-based indicators: These indicators can be used to quantify the potential risk and/or magnitude of energy security impact should it actually occur.
- Outcome-based indicators: These indicators aim to measure the actual outcome of energy security, in terms of real-world impacts.

According to the report, most studies tend to gravitate towards vulnerability based indicators.

IEA has also developed energy security indices called ***Energy Security Index Price*** (ESI_{price}) and ***Energy Security Index Volume*** (ESI_{volume}).

- ESI_{price} of a particular fuel in a given country is the risk that prices for this fuel are not set competitively due to market concentration, divided by the share of this fuel in the fuel mix of that country.
- ESI_{volume} of a particular fuel in a given country is the degree of physical limitation to the amount that can be imported that is not reflected in its market price, divided by the share of this fuel in the fuel mix of that country.

For example, ESI_{price} is generally very high for oil and often high for coal. ESI_{volume} is high for natural gas that is imported via pipelines and whose price is coupled to the oil price. The coupling to the oil price also results in a high ESI_{price} for natural gas.

There are other indices such as the Shanon index, Supply/Demand (S/D) index, but this is a vast area of study in itself and is out of scope for this paper. Some of these metrics could provide options to transparently report on the energy risks affecting the rail industry as a sector so that policies and discussions are aided via an objective measure.

8 Key questions that may require further exploration

This section highlights a list of questions which could provide further clarity on GB rail's energy challenges and opportunities. **This list is not exhaustive nor is it a specification for future work.** The list is intended to spark debate on what railway specific (micro factors) work is needed to bring more clarity to the energy risks the railways face.

- What kinds of hybrid trains are possible? How do they (need to) perform? What other merits and demerits do they have?
- What is the potential for storing energy centrally and supplying it to sections of the route, ie trackside at substations, etc? How does this change the economic viability of energy storage systems if batteries are not required to be on-board the trains?
- What is the potential for the railway micro-generating its own electricity? What are the associated technologies, challenges and benefits?.
- Can small diesel engines supplementing batteries help in making discrete electrification[103] more economically viable?[104]
- What other ways (other than storing energy) can the railways help in balancing the grid?

103 Work done under the TSLG energy programme (RSSB R&D project T966) disqualified discontinuous electrification for certain scenarios (50m – 2000m gaps) fundamentally due to the cost of batteries – and also pointed to the significant operational risk.

104 See Bombardier's plans for EDMUs (Operation Thor costing £300 million) http://rail-news.com/2010/10/06/bombardiers-electrification-plan-presented-to-ministers/, http://www.independent.co.uk/news/people/profiles/colin-walton-railway-man-trying-to-keep-bombardier-on-track-2002578.html and its TRAXX last mile diesel EDMUs http://www.webcitation.org/5yc5HJwr3

- What are limits and options on improving the efficiency and reliability of diesel engines? What are the key cost drivers making diesel engines more expensive, is this trend likely to continue?
- How much performance can the railways give up in terms of train speeds, operations, etc if future energy supply cannot sustain the current levels of performance expectations? What are the key trade-offs and implications on the competiveness of the railways?
- What kinds of future options exist where the customer can aid in improving energy efficiency and security for the railways?
- What are the areas where improved technology is creating greater energy demands on the railways? Can the railways revert to low tech if energy supplies cannot be secured? What are the likely implications?

9 Recommendations on key knowledge gaps to be addressed

Based on the review of the literature and questions highlighted in Section 8, it was recommended that the following areas could be explored further if further work was deemed necessary:

- Types/options of future hybrid trains, their merits and demerits including high level information on relative performance.
- Rail micro-generation and associated technologies, limits, challenges and benefits.
- The potential for centralised energy storage systems supporting OLE/DC or battery powered trains (for recharging)[105]. Can the use of line side charged batteries improve the case for discrete/nodal electrification?
- Assessment for a worst case scenario (if there is a mid to long term energy supply shortage and significant cost escalation) - what performance expectation changes,

105 See Electricity Storage Network's response (March 2011) to DECC's electricity market reform consultation, which highlights large scale (>1MW) battery installations such as Japan Wind Power has installed a 34 MW sodium sulphur battery at Rokkasho, Japan; Beacon Power commissioned 20 MW flywheel for frequency regulation in New York State; and Tokyo Electric Power Corporation which is linking their network of 200 individual MW size batteries to form a smart grid solution.

operational efficiencies or energy cuts could be achieved rapidly to ensure that the rail services continue to operate? What is the rail energy shortage/energy austerity contingency plan for GB railways? What could be the likely impact in service levels?

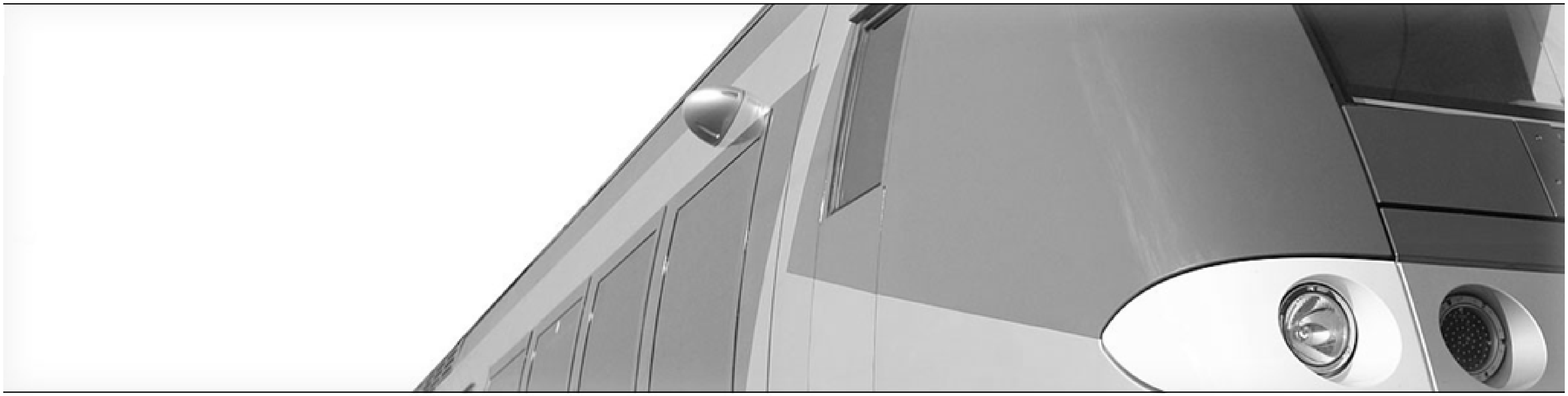
- Assessment of the economic viability of energy efficiency solutions which appear uneconomic at today's prices.
- The V/T E SIC considered the findings and recommendations presented in the report, and concluded that no further work, in terms of key knowledge gaps identified here, is required at this time. It has also acknowledged that Network Rail has developed proposals for the establishment of an Energy Services Team which has taken elements of this work as inputs. The V/T E SIC has also accepted that this work will contribute to the 'Alternative Solutions to Efficiently Deliver Passenger Demand' Route Utilisation Strategy, and the planned update to the Rail Technical Strategy by the TSLG.

RSSB Research Programme
Block 2 Angel Square
1 Torrens Street
London
EC1V 1NY

enquirydesk@rssb.co.uk

www.rssb.co.uk/research/Pages/main.aspx

Electric locomotives for Indian Railways Dedicated Freight Corridors



IRC 2007 Congress and Exhibition

Janis Vitins

New Delhi, 15. February 2007

BOMBARDIER

The Indian Railways are facing many challenges

<u>There is a need of …</u>

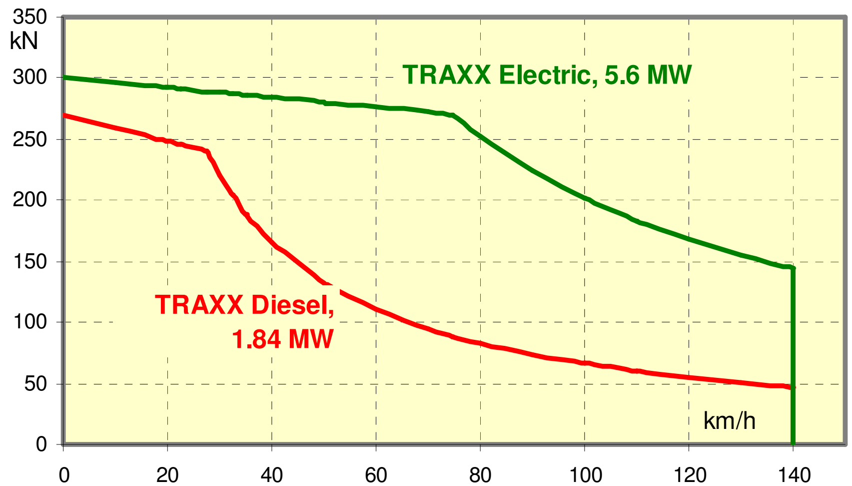
- **Reduction of in unit costs for transportation**
  - Higher axle loads; higher utilization of the loading gauge
  - Double stack container trains / triple level automobile trains
  - Lower energy costs
  - Lower maintenance and life-cycle costs
- **Higher asset utilization**
  - Higher average train speeds; max speed up to 100 km/h
  - Higher availability of rolling stock
- **Higher productivity**
  - High tractive effort – high adhesion capability
  - Optimal train operations on DFC and feeder lines
  - Remote operation in long trains – up to 1'500m

BOMBARDIER

Electric locomotives are up to 3x more powerful than diesel locomotives (power at the wheels!)

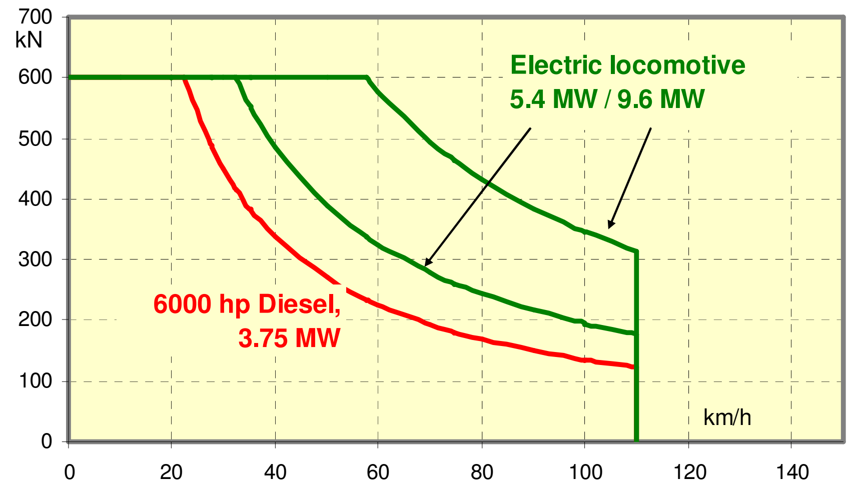
TRAXX 4-axle locomotives

	TRAXX AC	TRAXX DE
Power at the wheel	5.6 MW (7‘500 hp)	1.84 MW (2‘465 hp)
Axle load	21 tons	21 tons



Heavy haul 6-axle locomotives

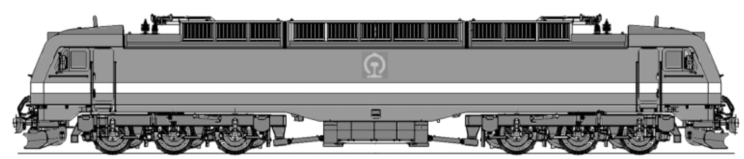
	IORE	9.6 MW Electric	6000 hp Diesel
Power at the wheel	5.4 MW (7‘235 hp)	9.6 MW (12‘860 hp)	3.745 MW (5’030 hp)
Axle load	30 tons	30 tons	30 tons



TRAXX AC

TRAXX Diesel

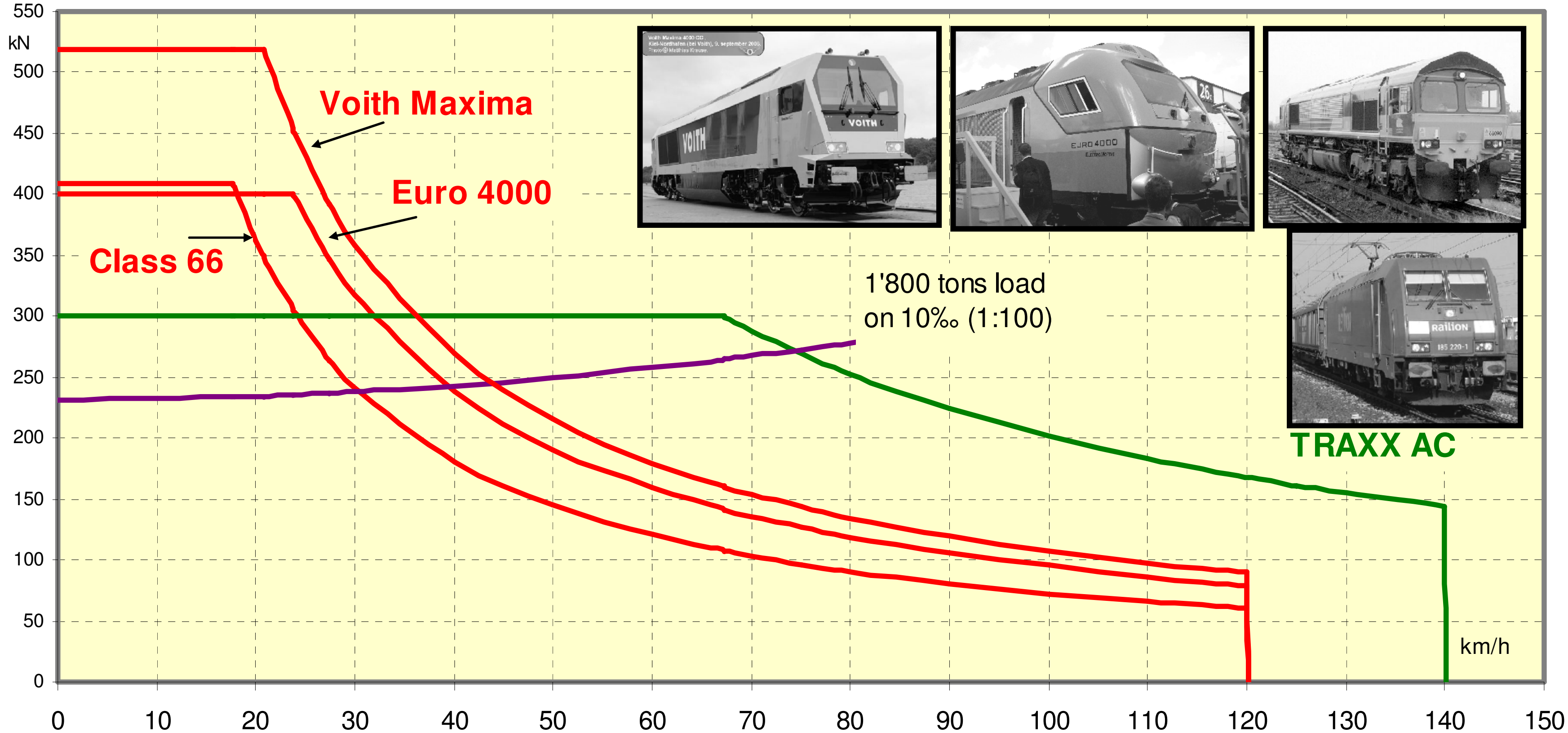
IORE



China: Bombardier - Dalian

BOMBARDIER

The 4-axle electric locomotive is ca. 2x more power than the newest 6-axle diesel locos - at same axle loads



- **Class 66:** 6-axle diesel-electric loco, 2’420 kW (3’240 hp) diesel engine.
- **Euro 4000:** 6-axle diesel-electric loco, 3’178 kW (4’260 hp) diesel engine.
- **Maxima 40:** 6-axle diesel-hydraulic loco with 3’600 kW (4’824 hp) diesel engine.

BOMBARDIER

Yes, electric traction is possible with double stack trains

Double stack trains & triple automobile trains operating under overhead wire in USA and China

New ALP 46 of NJT

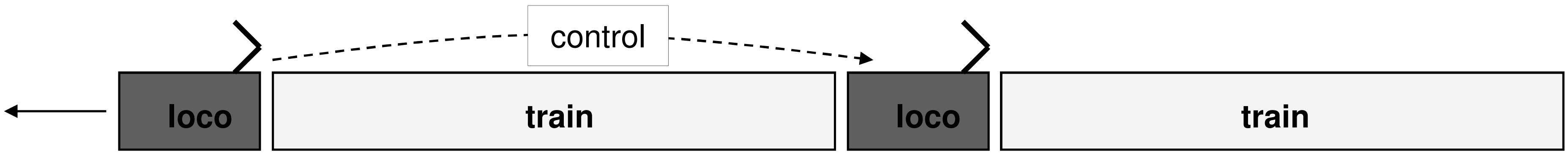
Double stack trains under catenary, China

Double stack trains under catenary, USA

BOMBARDIER

Yes, distributed power is used with electric hauled trains

- Distributed power requires the control of remote locomotives in long trains from the driver's cab of the first locomotive.



- **Remote operation is used today by cable and radio, e.g. with WTB trains bus and GE Locotrol.**
- **Sometime as second driver is cheaper!**

WTB - Switzerland

Locotrol - Switzerland

Locotrol - Australia

Energy efficiency – a clear advantage for electric traction

- **Costs for electrification are typically ~5% of total investment costs**
- **Golden Quadrilateral → Project Report by RDSO, 2005-6: Electric traction is 49% cheaper than diesel traction.**
- **Energy costs: electric <50% versus diesel per Gtkm**
- **Electric energy sources: coal, hydro, nuclear, …**

Power efficiency	Electric traction	Diesel traction
Non-fossil fuel: hydro, nuclear, alternative …	Yes	No
Thermal efficiency a) diesel engine b) combined cycle power plant c) dito with waste heat utilization	a) -- b) 60% c) 85 %	a) 40%
Loco power conversion efficiency (average)	85 – 87%	83-84%
Energy savings by regeneration: a) India (average, estimate) b) Mountainous countries (typical)	Yes a) ca. 10% b) 20 – 30%	No

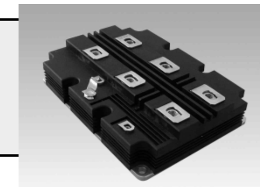
 BOMBARDIER

Bombardier locos use latest IGBT propulsion technology – applicable also to the WAG 9 locomotives

1990 | 1995 | 2000 | 2004 | 2005 | 2007

GTO

IGBT



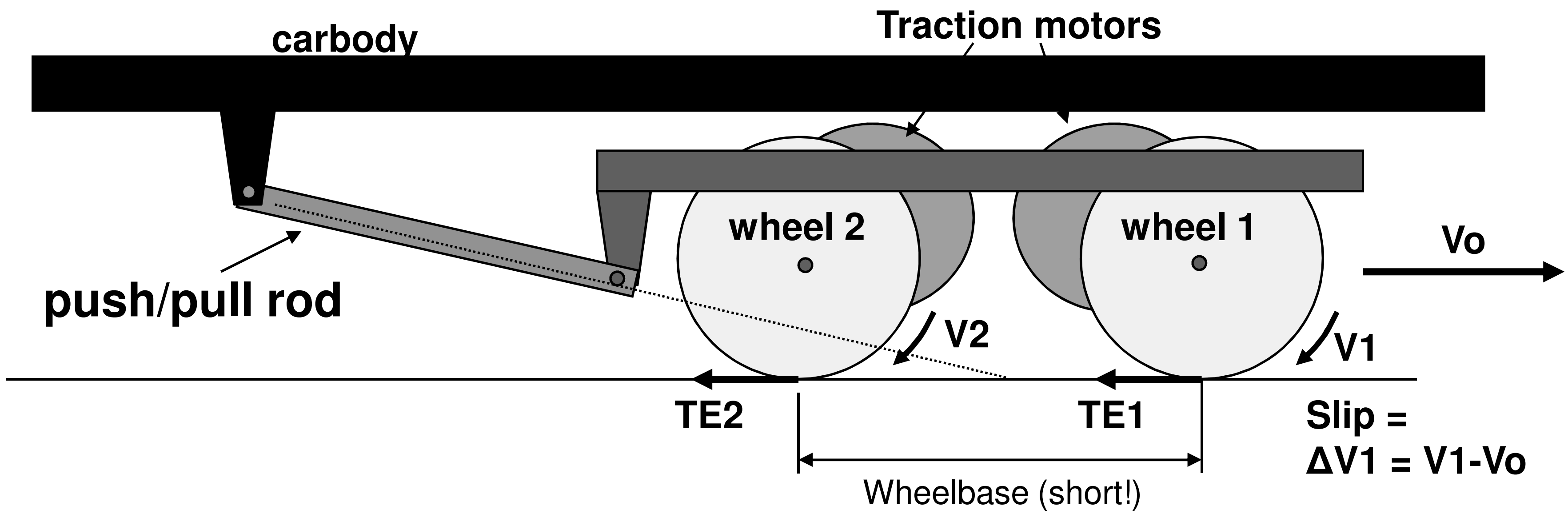
Migration to IGBT

Advantages

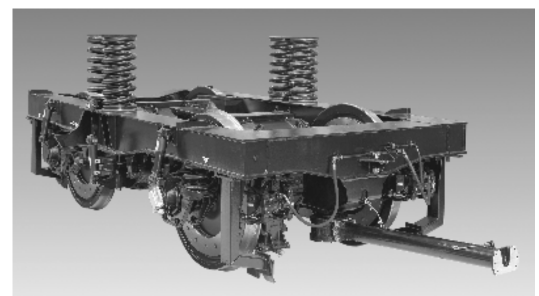
- Higher power efficiency
- Higher tractive effort (adhesion)
- Lower LCC
- Converter with 4.5kV IGBT have similar interfaces to GTO converter, also with 4.5 kV

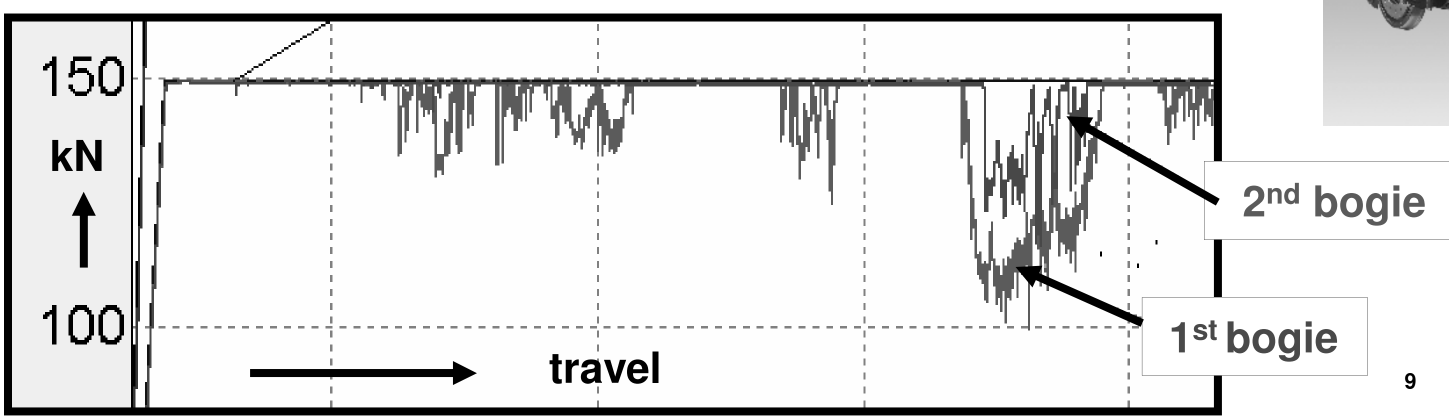
BOMBARDIER

The Flexifloat bogie improves the natural adhesion conditions and increases the tractive effort



- The 1st bogie cleans the track with wheel slip
- The 2nd bogie achieves a higher tractive effort!

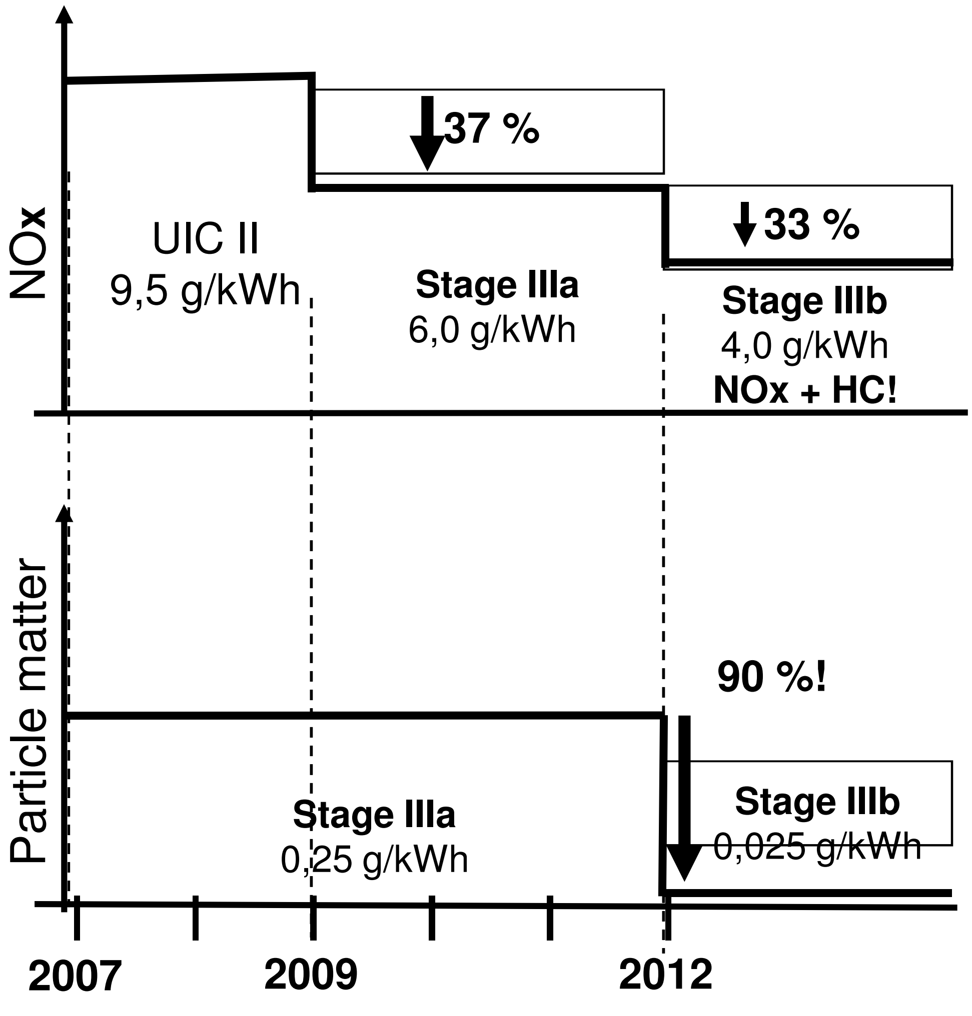




Diesel locomotives are faced with increasing restrictions on emissions. This will lead to higher costs.

- The reduction of particle matter is critical and requires additional filters.
- The SBB Cargo shunting locomotive Am 843 (1.2 MW / 1600 hp at the wheel) is the first series loco in revenue service with such a filter.
- The new emission requirements will increase costs and fuel consumption (ca. +3%) of the diesel locomotives.

Particles are burned in a SiC filter
Diesel engine: CAT 3512



 BOMBARDIER

In Europe by far the most locomotives are 4-axle electric locomotives

80 → 140 → speed → 200 250–350 km/h

Heavy freight

IORE Kiruna

6-axle, Co‘Co‘

(25..30t/axle)

China

Mainline locomotives for Cargo, InterRegio and InterCity

TRAXX Platform

Electric & diesel 4-axle locos

> 1040 locos sold, >400 locos in service

High Speed

AVE S102

(330 km/h)

AVE S130

(250 km/h)

* With Patentes Talgo, S.A.

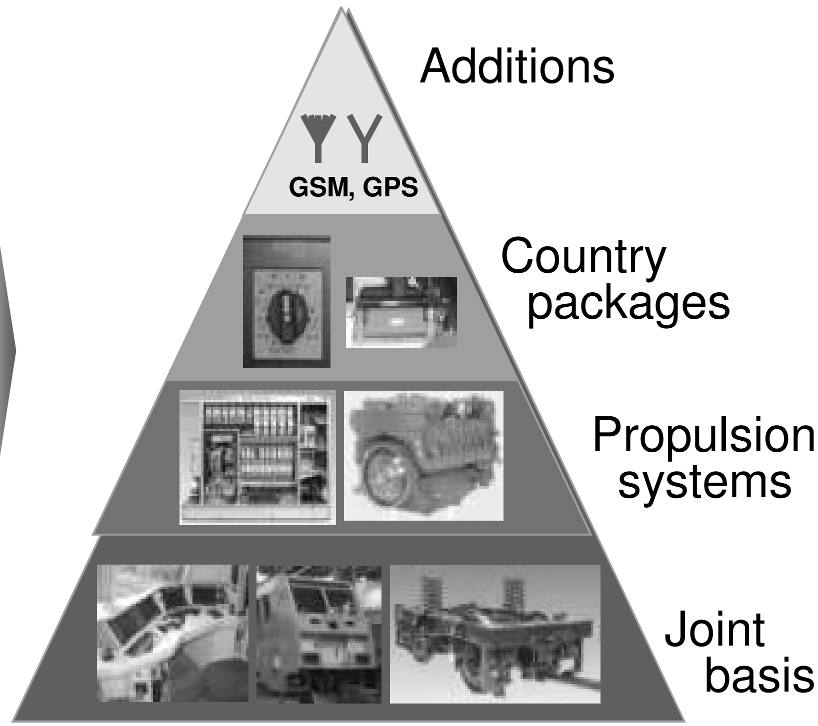
The TRAXX Platform is modular for different operations

Networks

Networks
AC (15 & 25 kVAC)
DC (1.5 & 3 kVDC)
MS (AC & DC)
Diesel

Country homologations

D	CH	F	L	A	DK	S	N	HU	…	I	NL	B	SP



Speed

Cargo 140 km/h

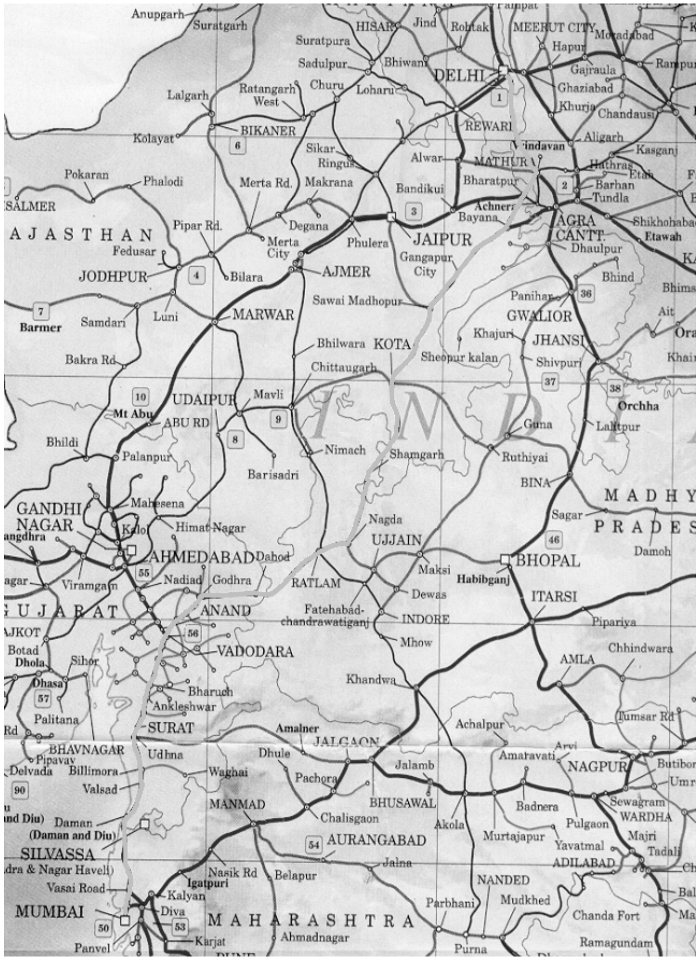
InterRegio 160 km/h

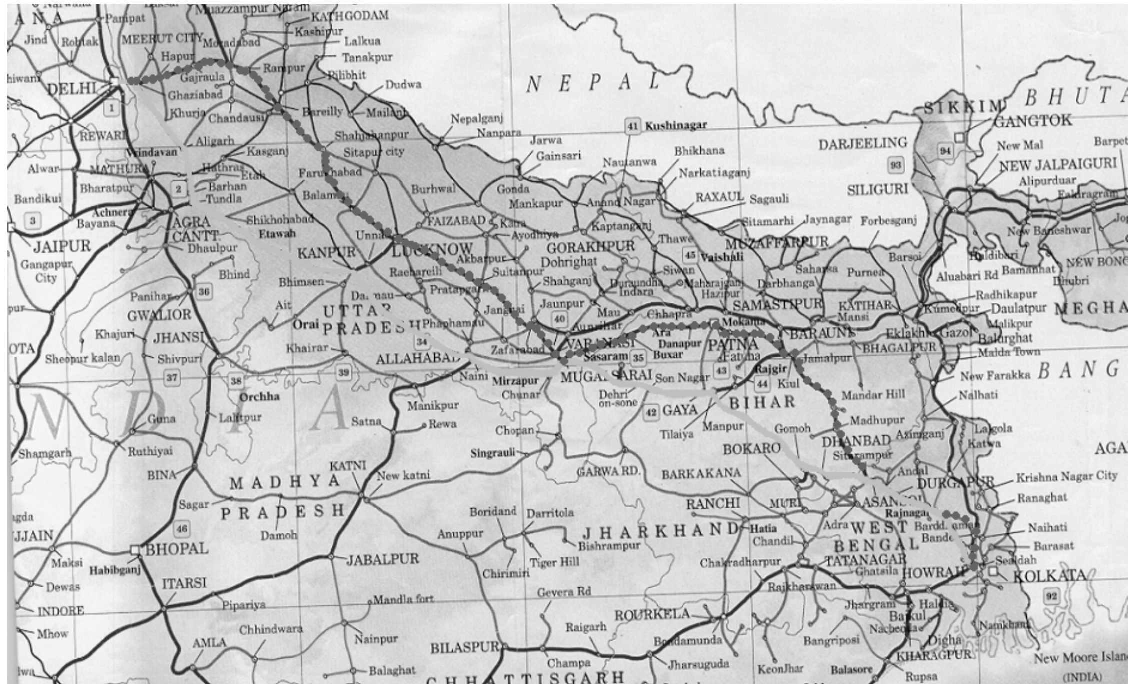
InterCity 200 km/h

- Operation on 25 kVAC catenary is inherent in the platform
- The axle load, carbody, couplers, etc can be adapted to IR requirements

 BOMBARDIER

IR dedicated freight corridors – What locomotive fits best?





Eastern Corridor; Delhi - Howrah

Western Corridor; Mumbai - Delhi

Critical train loads:

- 6‘000 tons on 5‰ (1:200)
- 7‘200 tons on 5‰ (1:200)

Axle loads:

- 25 tons
- 30 tons

BOMBARDIER

Operation on the DFC with the above train loads is compared for different locomotive types

		TRAXX AC	TRAXX AC-H	IORE	WAG-9	TRAXX DE	DE-4400hp	DE-6000hp
Configuration		Bo'Bo'	Bo'Bo'	Co'Co'	Co'Co'	Bo'Bo'	Co'Co'	Co'Co'
Axles		4	4	6	6	4	6	6
Axle load	tons	21	30	30	20.5	21	25	30
Mass	tons	84	120	180	123	84	150	180
Diesel power	kW hp	-- --	-- --	-- --	-- --	2'200 2'950	3'285 4'400	4'478 6'000
Length	m	18.9	18.9	22.9	20.562	18.9	~ 22	~ 23
Power at wheel rim	kW hp	5'600 7'500	5'600 7'500	5'400 7'235	4'500 6'000	1'840 2'465	2'750 3'685	3'745 5'029
Power at wheel per axle	kW hp	1'400 1'876	1'400 1'876	900 1'206	750 1'005	460 616	458 614	624 836
Power at wheel per locomotive weight	kW/t hp/t	67 89	47 63	30 40	37 49	22 29	18 25	21 28
Starting tractive effort	kN	300	429	600	460	270	500	600
Max. adhesion coefficient	μ	0.36	0.36	0.34	0.38	0.33	0.34	0.34

- **TRAXX AC** (standard)
  4-axle with 21t / axle and 5.6 MW.
- **TRAXX AC-H** (ballasted)
  4-axle with 30t/axle and 5.6 MW.
- **IORE** (ballasted)
  6-axle with 30t/axle and 5.4 MW

BOMBARDIER

Operation on the DFC is compared with different locomotive types - continued

- **WAG 9**
  6-axle with 20.5t / axle and 4.5 MW

- **TRAXX DE**
  4-axle with 21t / axle and 1.8 MW

- **DE-4400hp**
  6-axle with 25t / axle and 2.75 MW

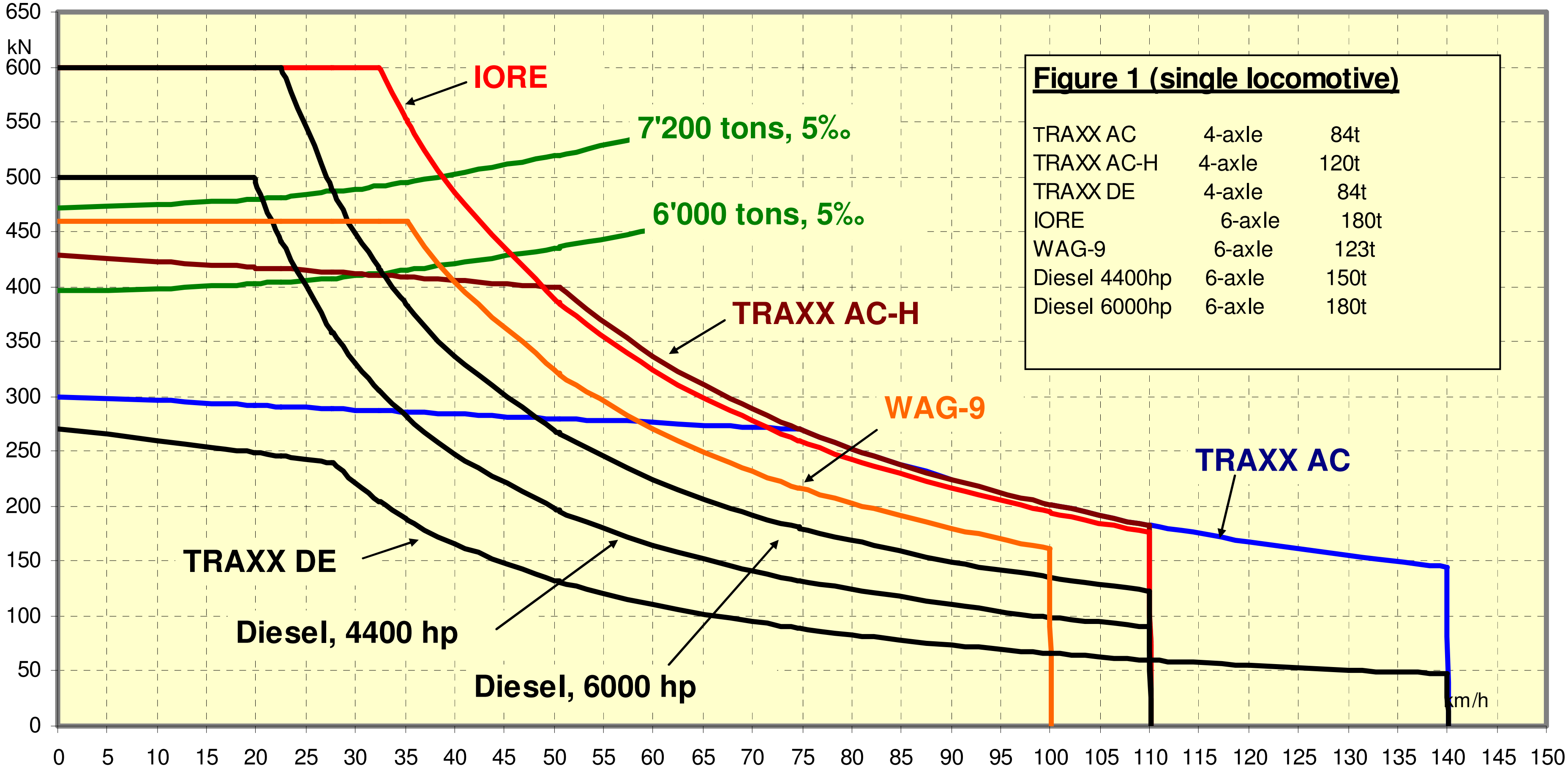
extrapolated

- **DE-6000hp**
  6-axle with 30t / axle and 3.75 MW

Comments to power definitions:

- The <u>power ratings of electric locomotives are defined at the wheel rim</u>.
- The <u>power ratings of diesel locomotives are defined at the diesel engine shaft</u>.

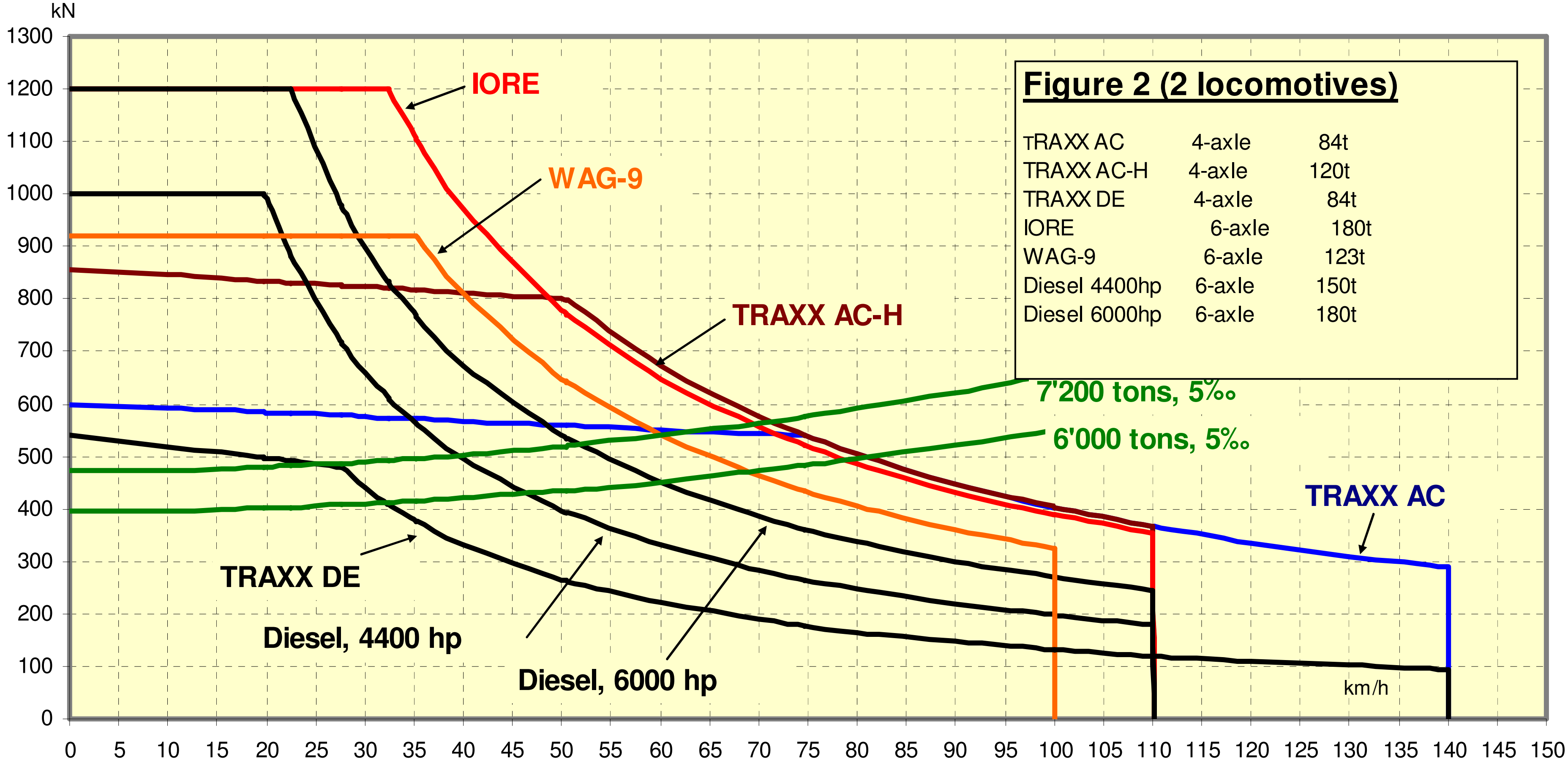
The IORE has the best combination of power & TE



- The highest tractive effort is obtained with 6-axle locos and high axle load.
  - The IORE hauls the 7‘200 tons at 38 km/h
  - The DE-6000 hauls the 7‘200 tons at 27 km/h
- The 6‘000t train can be hauled by the WAG 9!

BOMBARDIER

All loco types can haul the trains in <u>double traction</u>. The highest speeds are reached with electric traction

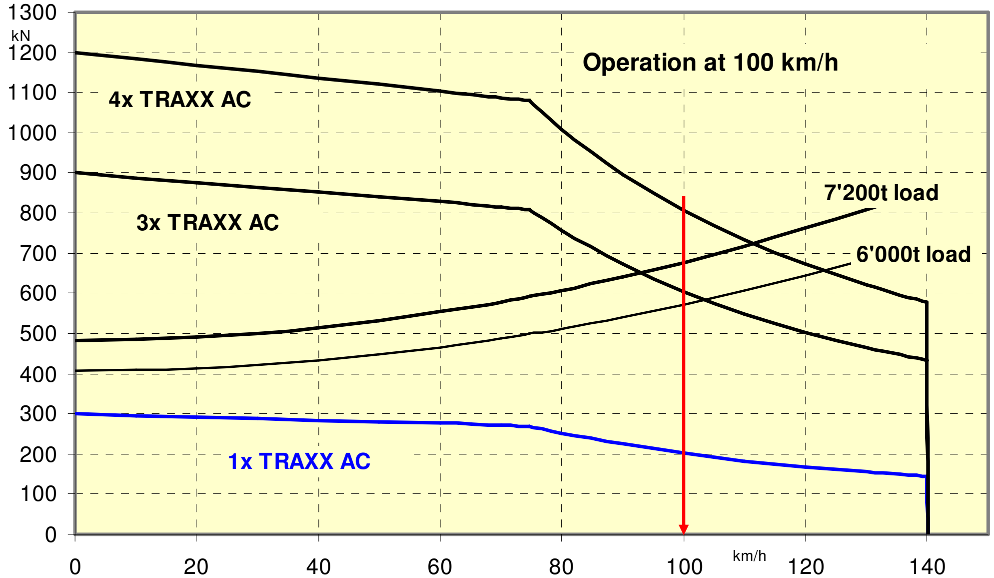


The available power is important for speed!

- The electric locomotives have the highest power and reach ca. 36% higher speeds than diesel locomotives
- An axle load of 20.5t (WAG 9) is sufficient to obtain the needed tractive effort

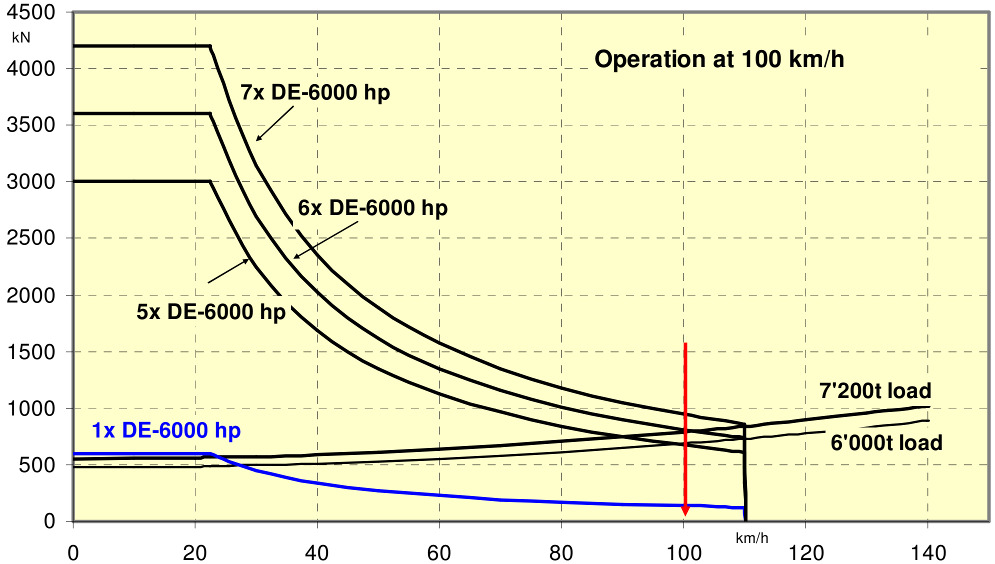
BOMBARDIER

Diesel locomotives have severe disadvantages for train operation at higher speeds, e.g. 100 km/h



4-axle electric locomotives (21t axle load):

- 3 locos can haul the 6‘000 ton train
- 4 loco can haul the 7‘200 ton train



6-axle diesel locomotives (30t axle load):

- 5 locos can haul the 6‘000 ton train
- 6 loco can haul the 7‘200 ton train

Electric locos haul the trains with much less powered axles and at higher speeds

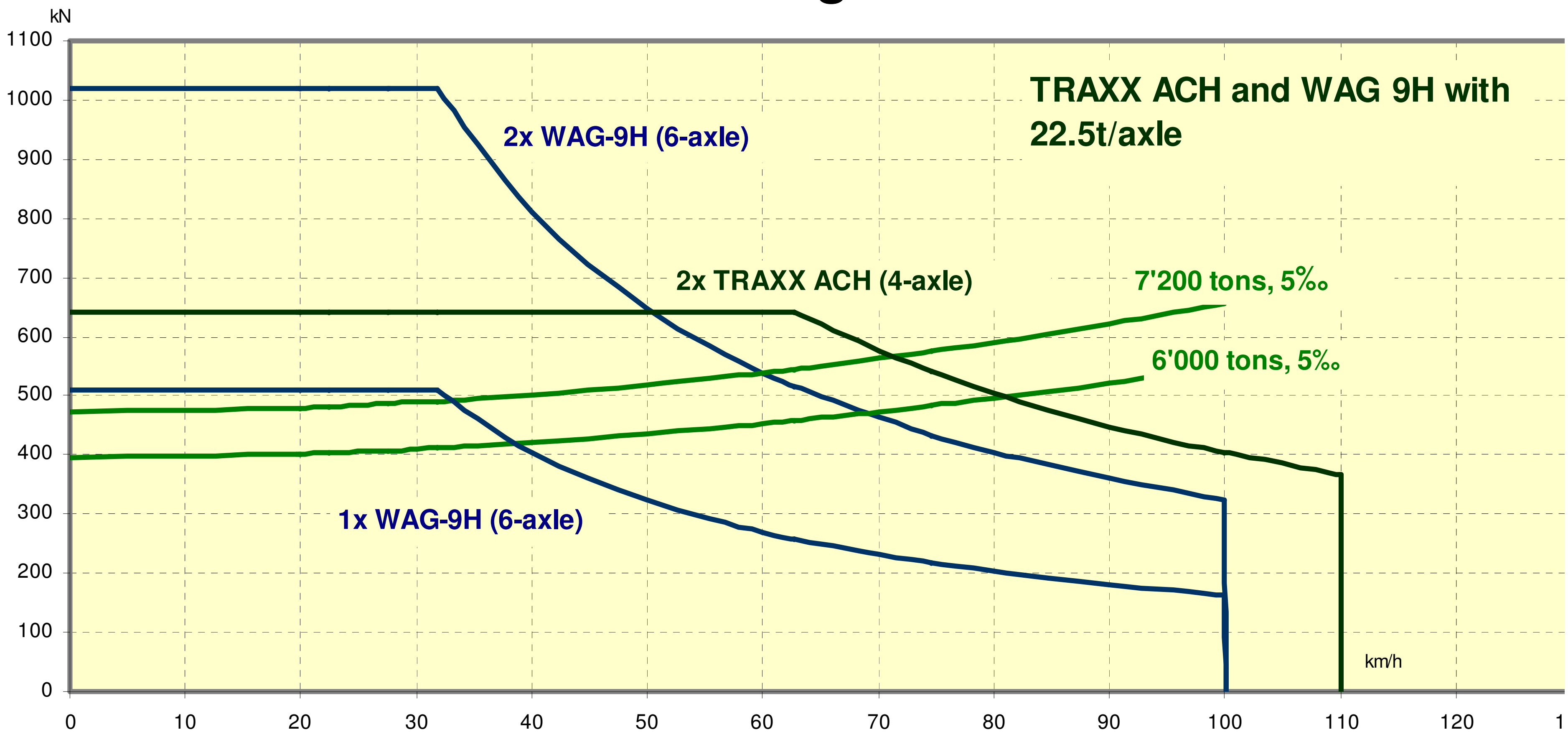
		TRAXX AC	IORE	WAG-9	DE-6000hp
Maximum speed with a single locomotive on 5‰					
Max speed with 6‘000t	Km/h	--	45	38	32
Max speed with 7‘200t	Km/h	--	38	--	28
Maximum speed with two locomotive on 5‰					
Max speed with 6‘000t	Km/h	80	78	68	59
Max speed with 7‘200t	Km/h	60	68	60	52
Operation at 100 km/h on 5‰					
6‘000t	locos	3	4	4	5
Powered axles	**axles**	**12**	**24**	**24**	**30**
7‘200t	locos	4	4	5	6
Powered axles	**axles**	**16**	**24**	**30**	**36**

Advantages:

- Less maintenance costs
- Less loco mass = unproductive weight
- Less total loco length = unproductive train length

BOMBARDIER

The locomotives WAG-9H and TRAXX AC are interesting solutions for DFC and remaining network



Advantages:

- WAG 9H is available and can readily be upgraded to IGBT propulsion
- TRAXX ACH has a good combination of power, TE, axle load and total life-cycle costs (maintenance, energy consumption, etc)

BOMBARDIER

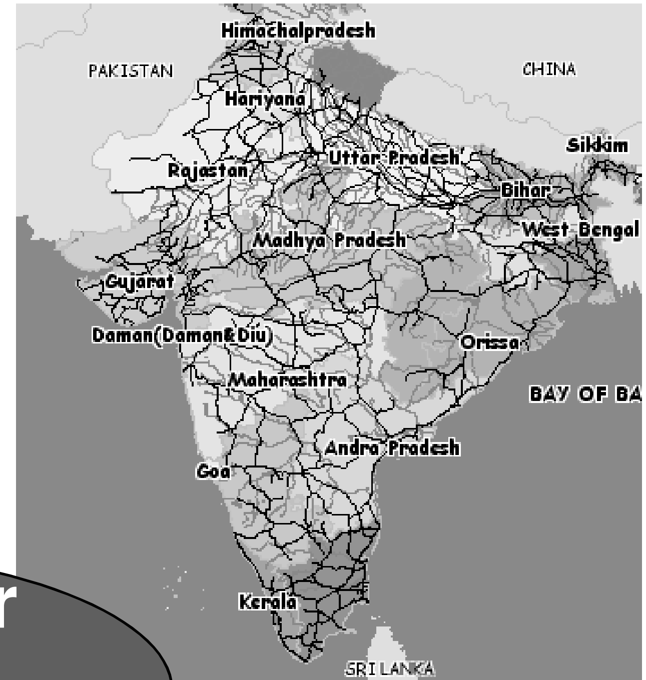
Electric traction has many advantages versus diesels …

- **Up to 3x higher power per axle compared to diesel locos**
- **Higher overall power efficiency: generation to wheel rim**
- **Advantage to national security → coal!**
- **Lower energy costs per GTkm due to …**
  - low electricity prices and power regeneration
  - souring diesel fuel costs
- **Electric traction is efficient in operations**
  - Double stack operation under catenary. Examples: USA & China
  - Low axle loads, 20.5 – 25t, are possible – also for heavy train loads
  - Low track forces → lower infrastructure costs
- **Environmentally friendly**
  - No exhaust emissions and lower noise → Stage IIIb requires particle filter and engine modifications

Summary – Dedicated Freight Corridors

- **Electric traction allows higher speeds with less powered axles**
  - Increased asset utilization
  - Lower life-cycle costs
- **Electric traction gives IR many alternatives**
  - Operation with the existing WAG 9 in single or double traction
  - Upgrade of the WAG 9 to IGBT, increased axle load and higher tractive effort
  - Introduction of new state-of-the-art locomotives
    - TRAXX 4-axle
    - IORE 6-axle
- **Operations**
  - Operation on the DFC and the whole IR network with 22.5 or 25t
  - Electric locomotives can be ballasted to the optimal axle load for the DFC, feeders and overall network

WAG 9



Thank you for your attention!

TRAXX

IORE

Meeting minutes

China Ministry of Railways (MOR), QRN and China Railway Materials (CRM)

6 September 2012

8:30am-11:30am

No.10, Fuxing Road, Beijing, China

Attendees:

Weidong Zeng, Director of Operation, Transportation Bureau MOR

Xuejun Guo, Director of Locomotive, Transportation Bureau MOR

Zhifang Zhang, Director for Permanent Way, Department of Science and Technology, MOR

Qiang Li/Guangjun Zha, Directors for Equipment, Department of Science and Technology, MOR

Zhenlong Yang, Deputy Chief Engineer for Electrification, The Third Design and Survey Institution Corporation

Yongqiang Wang, Engineer for Locomotive, The Third Design and Survey Institution Corporation

Hong Gao, Assistant Director, International Cooperation Department, MOR

Quanhao Wu, Managing Director, CRM Australia

Dongmin Zhong, Deputy Director, Railway Division, International Business, CRM

Cissy Ma - QRN

Matt Cronin - QRN

Minutes/actions

Overview - Daqin Rail Line

- The Daqin rail line is a state owned listed heavy haul (coal) rail transport operator in North East China from Datong to Qinghuangdao.
- Daqin haul coal mainly for the domestic market, with coal distributed from the Qinghuangdao Port.
- The Daqin rail line was extended from ~300 to 653km in length in 1992. It has been extended further, with a round trip now almost 3000km.
- Studies claim that Daqin Rail Line has a higher throughput and efficiency than Pilbara operations.

History of development

Year	Mtpa	Feeder stations	Other comments
1993	46	9 feeder stations (one every 72km)	110sqmm copper wire (OHW)
2002	100		Upgraded to 150mm diameter silver and copper wire to enable expansion to 400mtpa
2004	150		
2005	200	Started research for 300mtpa, + 4 new feeder stations (total of 13, one every 50km)	Increased number of transformers
2006	250		
2007	300		
2008	340	Started research for 400mtpa, including adding 2 feeder stations	
2010	400	+ 2 new feeder stations (total of 15, one every 43km)	Added auto-transformers to select feeder-stations, upgrade from 50MWA to 75MVA
2011	440		
2012	450		400mtpa is the current forecast for 2012, lower tonnage due to market conditions

Meeting minutes

Network characteristics

- Expected life of steel rail forecast to be equivalent to 2 billion tonnes of coal transport
- Typically 75kg rail (Aust 50kg)
- Fully duplicated system, with dedicated loaded and unloaded tracks (75kg v 60kg rail respectively, ie. different axle loads on loaded and unloaded tracks)
- Concrete sleepers all the way
- Continuous welded rail, except for switches
- No level crossings, completely closed track, with 2 meter high fencing all the way
- 2 maintenance windows per year (15 days in October and March each year, for 3 hours per day)
- One 90min planned maintenance window per week
- One control centre in Taiyuan
- Maintenance vehicles produced locally - encourage competition domestically and from overseas
- Rail grinding during 2x annual maintenance windows
- Signalling GSM-R
- 10-15min headway separations (average 12min)
- 4/1000 ruling grade to port loaded downhill
- 12/1000 ruling grade to origin unloaded uphill

Rollingstock characteristics

- Up to 100 consists per day
- 64 HeXie AC consists and 30+ ShaoShan DC consists in operation

Consist configuration

1. 2 x 9600KW synchronised electric locos, 204 wagons, 100t per wagon, 25t axle load, ~ 20,000 tonnes per consist
2. 2 x 6400KW synchronised electric locos, 102 wagons, 100t per wagon, 25t axle load, ~ 10,000 tonnes per consist

- 2 hour service every 3000km (visual inspection, re-sanding, cabin clean, check brakes, etc.)
- Regenerative breaking in use, where energy either used by other trains on network or put back into grid
  - Locomotive energy consumption captured on train, with energy consumption tariff / fee based on average historic / expected use less actual consumption

Overall comments

- Believes electric is more efficient than diesel, better for the environment, lower cost
- The tonnage on Daqin line would not have been possible with diesel operations
- The direction of heavy haul railways in China is electric, no doubters

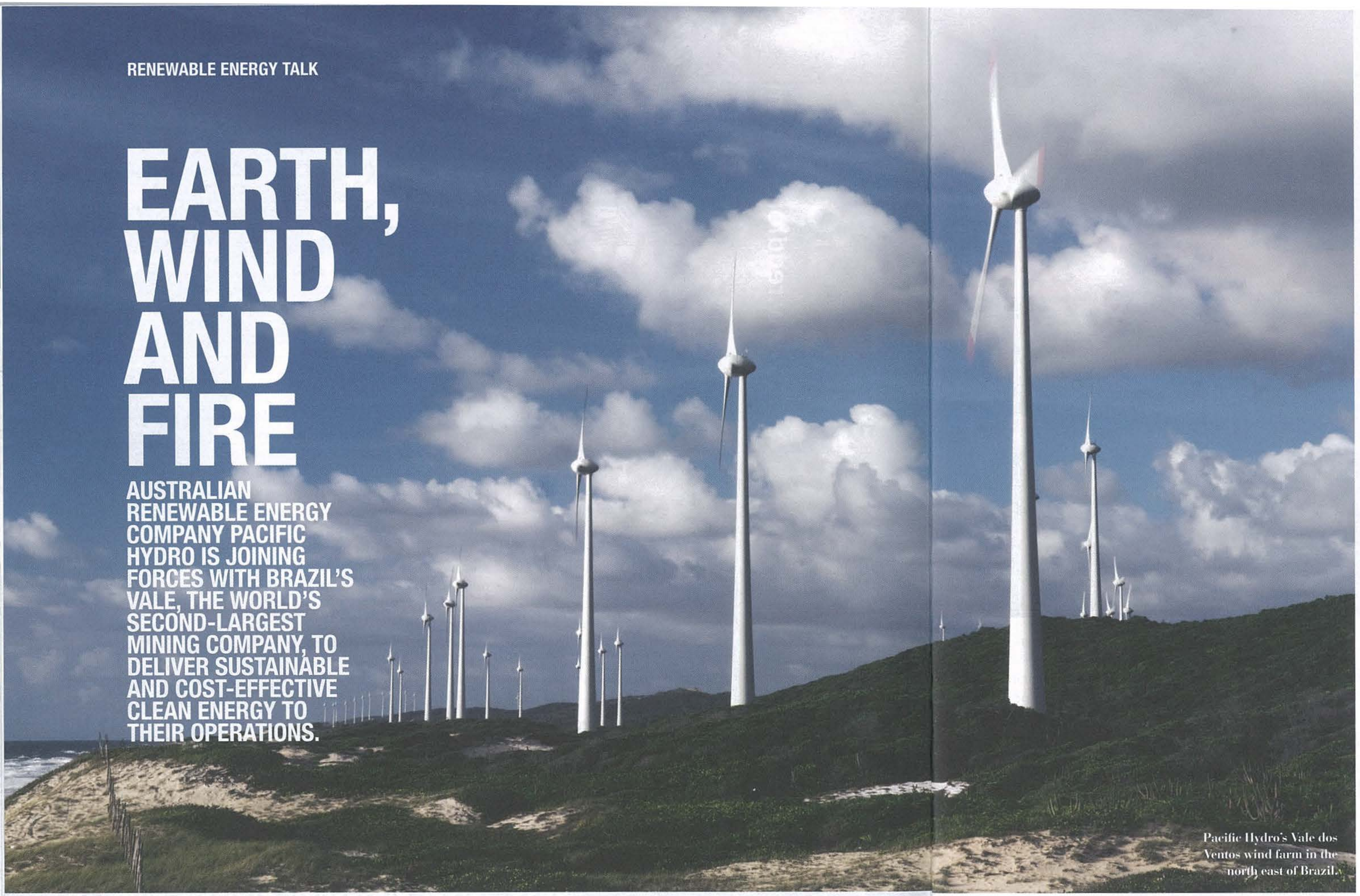
BRAZIL TALK

Vol. IV, 2012 $8.50

Supported by The Australia Brazil Chamber of Commerce Inc.

EARTH, WIND AND FIRE

AUSTRALIAN RENEWABLE ENERGY COMPANY PACIFIC HYDRO IS JOINING FORCES WITH BRAZIL'S VALE, THE WORLD'S SECOND-LARGEST MINING COMPANY, TO DELIVER SUSTAINABLE AND COST-EFFECTIVE CLEAN ENERGY TO THEIR OPERATIONS.



Pacific Hydro's Vale dos Ventos wind farm in the north east of Brazil.

The first visit of an Australian Prime Minister to Brazil occurred during the recent Rio+20 conference on sustainable development, which marked the announcement of a partnership between Pacific Hydro and Vale to jointly build and operate two wind farms in Brazil's north eastern state of Rio Grande do Norte.

Australia's Prime Minister, Julia Gillard, and Brazil's Minister for Mines and Energy, Edison Lobão, announced the consortium agreement between the companies during a roundtable on Green Growth, Energy & Food Security.

Under the agreement, each company will have 50 per cent ownership of both wind farms, which are due for completion by late 2014. The projects will represent an investment of approximately R$650 million (AUD$315 million). Vale will be the sole off-taker of clean electricity produced by the wind farms for a period of 20 years, utilising 100 per cent of its generation as self-production for its operations.

The companies are now progressing with the development of the projects, including equipment supply and transmission connection arrangements.

This is the company's first venture into wind energy and represents an important step for increasing the use of clean and renewable sources in Vale's energy matrix, says Vânia Somavilla, Executive Director of Human Resources, Health and Safety, Sustainability and Energy at Vale.

"Vale's global demand for electricity is expected to increase 150 per cent by 2020 and we've been seeking options to meet this demand, in a sustainable way, using renewable sources such as hydro, wind and biomass. The option to develop wind projects also helps diversify our energy matrix, reduce our emissions and ensure cost competitiveness in the long term."

A MARKET FIRST

Pacific Hydro CEO Rob Grant says the partnership will be the first free market and self-producer commercialisation model for wind farms in Brazil and an important step in Pacific Hydro's strategy in the country.

"This model will allow the Brazilian wind market to expand well beyond the regulated energy auction market, where most of Brazil's wind capacity has been developed so far," explains Grant. "As the world's second-largest mining company and Brazil's largest energy user, Vale is leading the way in the industry by demonstrating not only its commitment to a cleaner world, but to climate change and fuel price risk management."

Pacific Hydro already supplies renewable energy to some of the world's largest resource companies through its operations in Australia and in Chile.

"We have a long-term history of being a trusted partner and supplier to resource companies in Australia, where we supply Rio Tinto with all their clean energy needs at Argyle Diamond Mine, and in Chile, where we supply one third of the energy to Codelco's El Teniente, the world's largest underground copper mine."

LEADING THE WAY IN RENEWABLES

The wind market in Brazil grew exponentially over the last few years from a 25 megawatt (MW) installed capacity in 2005 to a forecast 7500MW in 2015.

This growth has been fuelled by strong domestic demand from its population of 190 million people as well as international demand from China and India for the country's mining and agricultural products.

The market currently has several energy players interested in developing renewable energy projects, leveraging the country's natural resources to meet its increasing electricity demand.

Operating for 20 years and in Brazil since 2006, Pacific Hydro was a pioneer in building wind farms under the Brazilian Federal Government's Proinfa scheme and currently has 58MW of operating wind farms in the state of Paraíba supplying Eletrobrás.

Grant says that Pacific Hydro plans to develop up to 400MW of wind projects in Brazil by 2016, an investment pipeline of nearly USD$1.5 billion, solely following the partnership business model. "Brazil's regulated, or auction market, does not recognise or value track record, certainty of delivery and operation, credibility with stakeholders or long term commitment to the communities in which the wind farms are built," he says.

"Industrial customers in the Brazilian unregulated market need all of these things as well as security of supply, quality and cost-effective prices, not necessarily the cheapest prices."

Pacific Hydro is owned by Australian superannuation funds chosen by workers looking for good, long-term returns on their pension investments.

"We believe that investment in wind provides an opportunity for sustainable, long-term returns not only for Australian investors, but also to Brazilian investment funds and pension funds." z