Arguments for railway electrification

– towards a railway sustainable in terms of the local and global environment, physical resources and efficient, economic operation, that will provide an attractive alternative to future road transport and will promote good growth

This paper is intended to support an "Electric Charter" campaign by groups spanning the Pennines. The Charter will call for a rolling programme of rail electrification across Northern England, pursuing the Northern Electrification Task Force (March 2015) recommendations which gave highest ranking to the Calder Valley Line.

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Summary:

In July 2017 three electrification schemes were cancelled: Cardiff-Swansea, the Midland Main Line (Kettering to Sheffield) and the Windermere branch. Further comments cast doubt on aspects of The Great North Rail Project, including additional platforms at Manchester Piccadilly station designed as part of the "Northern Hub" to maximise advantages of the new Ordsall Chord railway, and electrification (continuous or discontinuous) of the Stalybridge-Huddersfield-Leeds route as part of the TransPennine Route Upgrade (TRU), with related capacity improvements. We believe the capacity projects should proceed and the TRU should deliver a clean, sustainable electrified railway. Earlier commitments should be honoured and a rolling programme should move forward, not least in the North of England based on Northern Electrification Task Force (NETF) recommendations.

The arguments for electrification remain clear and enduring:

- **Economic and business case –** compared with diesels, electric trains are cheaper to build, more reliable requiring less maintenance, cheaper to operate and longer-lasting. Lighter weight means more passengers can be carried, acceleration is better and journey times can be shorter even with relatively frequent stops. The passenger experience is improved in terms of cleanliness, air quality and noise levels both in stations and on trains (particularly in comparison with diesel/bi-mode units that have under-floor engines). The "sparks effect" means electrification invariably increases demand for travel on the line, promoting good growth.
- **Environment and resources** – to improve air quality, reduce noise, combat climate change and reduce wastage of resources, objectives that can only ever be partially achieved with diesel traction. Even with non-renewable electricity generation, electric trains have 20-30% lower carbon emissions than diesel, an advantage that is already being exceeded with the current renewables mix. As electricity generation moves towards zero-carbon, so will electric transport. The commitment to stop the sale of diesel/petrol cars and vans on UK roads by 2040 must be matched by a commitment to a zero-carbon, zero-emission railway over a similar or shorter timescale.
- **Consideration of alternatives** – bimode trains carrying both diesel and electric traction equipment are inherently heavier, more complex and materials-hungry, less energy-efficient and more expensive to procure and operate than pure electrics. Reliability is unproven and performance unlikely to match that of pure electrics. Diesel bimodes commit the railway for a generation to polluting technology which is planned to be phased out on UK roads. Prospects for hydrogen technology on rail are likely to be limited. On short sections of discontinuous electrification where wiring is difficult, the gaps may be bridged by using electric trains with moderate battery or other energy-storage – but not, surely not, dirty diesels.

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Context – Summer 2017 saw the cancellation by government of planned railway electrification from Cardiff to Swansea, on the Midland Main Line from Kettering to Derby and Sheffield, and on the Oxenholme to Windermere branch (20 July statement to Parliament)[1]. These were three previously committed electrification schemes and the latter two directly affect rail development in the North of England. Midland Main Line premier inter-city trains from the early 2020s are now expected to operate on diesel power for more than half of the journey from London to Sheffield using "bi-mode" trains which will carry both diesel power packages and electric power collection equipment. The Windermere branch, including services to Manchester Airport, may be operated in the near future by still to be tested electro-diesel bi-modes converted from former Thameslink (Bedford-London-Brighton) electrics, or perhaps by new pure diesels (with internal combustion engines in operation "under the wires"), and perhaps, it is hoped, by non-polluting "alternative fuel" trains, possibly using batteries instead of diesel engines on the branch line.

Comments by Rt Hon Chris Grayling MP, Secretary of State for Transport quoted in the Financial Times[2] immediately after the 20 July announcement led to the general understanding that the **TransPennine Route Upgrade (TRU)**, including electrification of the line from Staybridge via Huddersfield to York, completing an electrified intercity route from Liverpool to Newcastle, is being reconsidered and may not be electrified along the whole length. Instead of running fully electric trains, "bi-mode" units will be used and indeed these trains are already on order for the TransPennine Express train operating franchise. Like the possible ex-Thameslink Windermere branch trains these will be electro-diesels with diesel engines for use over sections of line that are not electrified. Unlike the Windermere trains they will, at least, be brand-new. It is generally accepted that that the diesel bimodes will have an inferior performance to pure electrics on routes across the Pennines. The fear therefore is that journey time targets may only be achieved by missing out stops.

A related issue – need for capacity works in the Great North Rail Project (Northern Hub and TRU):

(a) There seems also to be a threat to capacity works that were promised as part of the original Northern Hub project, specifically the proposed provision of two additional through platforms at Manchester Piccadilly station to handle more frequent services that will be developed via the new Ordsall Chord railway over the next few years. It is highly unlikely that "digital signalling" will be able to provide what the additional tracks platforms offer. The two additional platforms would, given necessary dwell times, allow an increased frequency measured as trains per hour through the station, enabling greater timetabling flexibility to get best value from the Ordsall curve which was physically complete in Autumn 2017. The additional platforms are necessary to allow attractive and robust timetables to be devised for train services from the Calder Valley and Huddersfield lines, through Manchester Victoria and round the new line to Manchester Piccadilly and the Airport.

(b) It is also understood that capacity enhancements are under consideration as part of the TRU in the Huddersfield-Mirfield corridor. Increased tracks (restoring 3 or 4 lines instead of 2 or 3 at present) is an obvious possibility benefitting not just TransPennine Express services via Huddersfield but also Calder Valley services via Brighouse. It is acknowledged that resources have now been committed to investigating digital signalling on this route, but this may be many years from fruition and will not provide that opportunities for parallel running that are possible with additional tracks.

It is understood that Network Rail will submit TRU options (including electrification and capacity) for decision by DfT by Spring 2018.

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[1] Statement by Chris Grayling MP, Secretary of State for Transport, 20 July 2017: https://www.gov.uk/government/speeches/rail-update-bi-mode-train-technology

[2] Financial Times article on-line 21 July 2017 available at https://www.ft.com/topics/people/Chris_Grayling

In March 2015, the Northern Electrification Taskforce, a group comprising an all-party group of MPs and local authority representatives from across the North of England, backed by professional input, published its report.[3] The conclusion, on operational, economic and business criteria, placed 12 northern routes in a top tier recommended for electrification during the "CP6" 2019-24 Network Rail control period. A further 20 routes were placed in Tiers 2 and 3, and the task force concluded that all of these routes should be electrified in due course. On the criteria used the top-ranked scheme in Tier 1 was the "full" Calder Valley Line comprising the routes from Leeds to Manchester and Preston via both Bradford and Brighouse and Hebden Bridge. Next in rank order were the second Liverpool-Manchester route via Warrington, Southport/Kirkby, Stockport-Chester, Middlesbrough, the Harrogate Line and Selby-Hull. The last of the above was an already proposed scheme but it has been cancelled recently at the behest of Government. The full list of Tier 1, 2 and 3 NETF schemes is appended to this paper.

It is conceded that delays and cost overruns in the delivery of Network Rail electrification schemes, particularly the Great Western Main Line (GWML) scheme, have led to the present electrification programme (not to mention future schemes such as the Calder Valley) being reconsidered. Even before this summer's announcement electrification to Oxford, Bath and Bristol had been indefinitely shelved. This means that Great Western "electrics" will continue to run trains on diesel power at these destinations, with negative environmental consequences for noise and air quality locally as well as increased carbon dioxide emissions.

Government statements have also referred to overhead electrification structures as being unsightly (in particular with reference to the Windermere branch through a national park), as well as to the existence of bimode technology making full electrification unnecessary. However, the aesthetic objection to overhead electrification does not seem to have held sway, for example, when Crewe to Glasgow electrification was completed through the spectacular Cumbrian fells, a project that took just four years from approval in 1970 to completion in 1974. Bimode "electro-diesel" technology is not in essence new or "state of the art" but carries its own inefficiencies and sources of waste.

The costs of GWML are reported to have perhaps tripled to around £2.5 billion. To put this into historical context, between government approval in 1985 and completion to Edinburgh in 1991, British Railways electrified the East Coast Main Line (north of Hitchen) at a cost of £306M (equivalent to just under £1bn at 2017 prices). The scheme was funded internally through increased productivity.[4] Aesthetic issues were appropriately addressed; for example, the OHLE structures on the Grade 1 listed Royal Border Bridge over the Tweed were approved by the Royal Fine Art Commission.[5] The ECML electrification scheme has been criticised for having insufficiently robust OHLE (for example in high wind conditions); however there seems little obvious reason why using more robust structures need be disproportionately more expensive. Some of the structures used on the current GWML electrification do appear to be very robust and criticism on aesthetic ground is understandable. However, it does not have to be like that on every section. There are alternatives. The respected railway engineer Ian Walmsley, writing in Modern Railways magazine, argues convincingly for a continuing programme of electrification including reinstatement of the cancelled Midland Main Line scheme. Walmsley cites the example of Denmark where electrification designed for 250km/h (156mile/h) was ordered in May 2015 and is already live over 121 km[6] .

Contrasting approaches to rail and road: Also in July 2017 the government also announced, as part of a statement on air quality, that the sale of "conventional" petrol and diesel cars and vans (implicitly this might exclude some

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[3] http://www.railnorth.org/news/electrification-task-force-final-report-revealed/ (includes report as .pdf)

[4] GREEN, C and VINCENT, M: *The Intercity Story* (Oxford Publishing Co, 2013), page 35. See also letter from David Carter to the Guardian newspaper in https://www.theguardian.com/uk-news/2017/jul/24/uks-rail-network-suffering-from-lack-of-joined-up-thinking

[5] https://www.networkrail.co.uk/the-history-of-the-royal-border-bridge/

[66] "STOP – THINK – ELECTRIFY": Modern Railways, November 2017, page 39 (Key Publishing).

forms of hybrid vehicle) would cease in the UK by 2040. This was a pre-existent policy dating from 2011 which also including a commitment to making road transport almost totally zero-emission by 2050.[7] Many who campaign for the local and global environment would question whether these target dates are sufficiently ambitious. Nonetheless, the future prospect seemed to be, in around two decades time, a road transport system moving rapidly forward in terms of sustainability based on electric, perhaps driverless vehicles, whilst UK rail continues to derive a significant part of its traction power from dirty diesels.

Glut of EMUs. Returning to the present-day context, the current situation with franchise renewals where there is an incentive to provide new rolling stock on lines such as Thameslink, Anglia and South Western means there is an increasing glut of relatively modern electric multiple unit (EMU) trains. For example 86 4-car Class 319 trains have been withdrawn by Thameslink: some have come to the North, some are being converted to dieselised "Flex" units (perhaps for lines such as Windermere), but about half at time of writing, looked to be going off-lease into store. The TransPennine Express franchise is to replace express-standard Class 350 units that were built as recently as 2014 with new build. The released 350s were to go to the London Midland franchise but the new West Midlands operator has ordered new trains instead. In this situation it seems illogical not to go ahead with electrification schemes where spare trains, new or refurbished to nearly new standard, could be used.

The general arguments for railway electrification remain strong. Network Rail themselves summarise the arguments as follows on a web page headed simply "Electrification" [8]:

> **"Electrification of the railway allows for faster, greener, more reliable train journeys, improves passenger services and supports economic growth in Britain. Benefits of electric trains:**
>
> - More capacity for passengers: more seats than diesel trains of the same length.
> - Faster than diesel trains: superior braking and acceleration make journey times shorter.
> - Quieter than diesel trains: good news for people living near the railway – our lineside neighbours.
> - Better for the environment: their carbon emissions are 20 to 35 per cent lower than those from diesel trains, and there are no emissions at the point of use, improving air quality in pollution hot spots, such as city centres.
> - Lighter: less maintenance is needed because electric trains cause less wear to the track, so the railway is more reliable for passengers.
> - Good for the economy: faster trains with more seats and better connections with previously hard-to-reach areas improve access to jobs and services, and open up new business opportunities.**"**

We set out a slightly more detailed summary of these arguments below on the following pages.

[7] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/633269/air-quality-plan-overview.pdf

[8] https://www.networkrail.co.uk/our-railway-upgrade-plan/key-projects/electrification/

Arguments for rail electrification – and against a continuing diesel (or electro-diesel) option

1 Commercial, operational and business arguments for rail electrification:

- Reduced capital cost of rolling stock compared with diesel
- Rolling stock maintenance costs reduced by simpler electric technology. Electrics are 30% cheaper to maintain than diesels.
- Track maintenance costs reduced (about 10%) because lower mass electric vehicles (compared with diesels) mean reduced track forces.
- Reduced energy consumption due to increased efficiency of supply and traction system and reduced mass of electric trains compared with diesels meaning less energy required to accelerate to given speed; potential for energy recovery in regenerative braking which is now the norm on new electric trains.
- Reliability – due to mechanical simplicity
- Capacity – potentially more seats on electric train compared with diesel of similar mass, length or power
- **Passenger benefits**
  – performance (in addition to reliability), particularly on routes with frequent station stops or gradients, due to higher power/mass ratio electric trains have higher
  – reduced noise on train, particularly now that underfloor diesel engines are the norm, and in stations
  – improved air quality in stations
  – linked to the above enhance passenger perception leading to ***sparks effect*** attracting more passengers and promoting good growth

2 Rail electrification as sustainable technology to conserve resources, preserve the environment

- reduced energy consumption of electrics as above
- local environment in stations and around the railway more generally
  – reduced noise
  – improved air quality; zero-emission at point of use compared with particulates and NOx from diesels; modern electric trains with regenerative braking also significantly reduce pollution from brake dust by making less use of friction brakes.
  – reinforces perception of railway as “green alternative” to road travel
- global environment, combatting climate change
  – even with non-renewable primary energy sources electric traction has 20-35% lower CO_2 emissions than diesel. This has already improved further given the presence of renewables in the generation mix.
  – potential to be zero carbon as electricity generation moves to renewables (or nuclear[9])
- physical resources – materials – electric traction equipment is longer lasting and requires less replacement of parts during lifetime leading to better conservation of physical resources. Diesel-generator sets have more manufactured components and more moving parts.
- the visual/built environment – whilst overhead electrification masts may be considered visually intrusive in areas of sensitive built environment (e.g, in the city of Bath) or of natural beauty (e.g. national parks), this must be compared with the visual intrusion of modern roads and of national grid powerlines and pylons, as well as the effect of roads in terms of noise and air pollution. Consider the effect of overhead wires on the 10 mile long Windermere branch in the Lake District National Park, compared with the impact of the

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[9] This is not to suggest that all supporters of this statement are supporters of nuclear power.

A590/A591 dual carriageway roads in the same area. The M6 motorway passes just outside the national park boundary through an area of spectacular scenery, alongside the electrified WCML railway: which has the greater visual impact? Not all schemes will require the heavy, apparently over-engineered structures recently installed on the Great Western Main Line; better designs are possible.

- electrifying more railways makes better use of the railways we have already. At present we have many diesel services operating "under the wires". Our front page illustration is a panorama of a large electrified terminus station: of six trains in shot, five are diesels. This seems wasteful in business as well as environmental terms.

3 Alternatives to continuous electrification

The electro-diesel bimode alternative. The idea of an electro-diesel train is not new, although the bimode train with both electric overhead pick-up (pantograph) and underfloor diesel engines is relatively so. The bimode electro-diesel multiple unit trains carries fuel tanks, diesel engine and generator in addition to electric transformers. It thus has greater mass or weight than either a pure electric or a pure diesel of equivalent performance. Carrying both electric and diesel energy collection/traction systems the electro-diesel bimode is the "worst of both worlds":

- compared with either pure electric or pure diesel, the most expensive type of train to buy.
- inherently inefficient, wasteful of energy, due to additional mass to be carried "dead" over long sections (e.g. Windermere-Manchester service carrying diesel under the wires all the way from Oxenholme to Manchester; MML Sheffield-Kettering (electric transformer dead weight), Kettering-London (diesel dead weight); etc. Additional mass causes additional energy use/fuel consumption.
- increased complexity of technology – additional maintenance requirement, unproven reliability of dual technology crammed into small space.
- unsustainable in environmental terms, e.g. noise and air pollution from diesels in stations and other unelectrified sections which are likely to be more urban areas; rail must lead in combating climate change.
- Diesels are obsolescent technology. If East Midlands franchise is required to introduce new diesel bimodes in early 2020s these engines will still be within their useful life when internal combustion engine are rapidly being phased out of road transport.
- The diesel bi-modes are almost certain to have reduced performance in terms of acceleration and hill climbing compared with pure electrics. This problem could be tackled by having more powerful diesel engines but this would mean either larger, heavier engines being used, or uprating the power of the existing small engines, in either case further increasing fuel consumption. There would be increased pollution both climate-damaging CO_2 and also nitrogen oxide and other pollutants associated with diesels which damage air quality. In practice, bi-modes will have greater difficulty meeting journey time targets unless stops are omitted, which would damage services for local communities.
- If diesel engines are to have sufficient power to match electric schedules on heavy bi-mode trains, it will be more difficult for them to comply with ambitious emissions standards.

What about partial electrification with battery or Hydrogen (H_2) bimodes? We take heart from aspects of the government announcement referring to the development of alternative fuel technology. The short (10 mile) Windermere branch could be ideal for battery operation, with the batteries charging in Oxenholme station or during longer runs under direct electric power between Oxenholme and Manchester Airport. Battery technology is moving forward driven by growth in renewables and the demand for low/zero-emission road vehicles. However it is unlikely trains will be built for the new Midland Main Line franchise that will have sufficient battery capacity to operate from Kettering to Sheffield. Hydrogen can be produced by using carbon-free electricity and water so H_2 fuel cell powered trains could be zero-carbon as well as zero-pollution[10]. However rail applications in the short-medium term may be limited to short distances determined by H_2 fuel storage capacity on board the trains. May there also be safety issues to resolve in connection with rail use of hydrogen? The future may also bring sustainable liquid fuels capable of being used in an internal combustion engine – sustainably generated biofuels. However the IC engine (gas, diesel or petrol) will remain inherently inefficient compared with pure electric traction systems.

We hear arguments against continuous electrification of routes based on the cost and disruption associated with increasing physical clearances for the high voltage equipment. We would not oppose the idea of some short sections being left "unwired" (or as long neutral sections), but the whole point of the above argument about bimodes is that the continuing use of diesel engines reduces efficiency, increases energy consumption and damages the local and global environment. We should care where our energy comes from and should start to move away from a railway, as well as other transport, dependent burning fossil-fuel derivatives in an internal combustion engine, towards the use sustainably generated and clean electricity. Where sections of an electrified railway are left unwired or unenergised the gap should be filled by trains with onboard energy storage, probably batteries. The electrification work itself need not result in long periods of disruption to passengers. Much work can be done at night and the need for lengthy blockades minimised. Some recent electrification work has employed long blockades, perhaps to allow projects running late to be completed, but this need not be the norm, the key surely being effective planning and project management.

Another approach to reducing the need for physical work to increase clearances could be the adoption of dual-voltage electrification, with some sections energised at 6.25kV instead of 25kV. Reducing the line voltage by a factor of four has a proportional effect on the resulting electric field strength and required distance of live conductors from physical structures. Dual voltage electric trains are a tried and tested technology and have been in service on many railways across Europe for several decades.

Further information on current electrification programme in parliamentary briefing paper SN05907 Rail Electrification, 27/07/17.

Concluding remarks

Trains are an excellent alternative to road transport in terms of their ability to carry large numbers of people over either long or short distances. Modal transfer to rail is a potentially highly effective way of reducing road congestion and improving air quality as well as reducing CO_2 emissions and will be even more effective with electric railways. Rail must be perceived as modern and also good for the environment if it is attract more people from congested roads. We should be concerned about air quality in train stations as well as on city streets. This principle can be applied not just to commuting or business journeys but to a wide range of personal travel needs – leisure, personal business, local and longer distance journeys, urban and rural (issues caused by road transport including congestion, air pollution and noise are no longer restricted to urban areas).

The Northern Electrification Task Force recommendations should be the basis of a rolling programme of electrification across the North of England, starting with the top ranked schemes in Tier 1. Electrification of the full Calder Valley Line would naturally follow the completion of work on the Huddersfield Line (the so-called TransPennine Route Upgrade). "Full" CVL electrification means both routes from Leeds, via Bradford and via Brighouse, to both Manchester and Preston. Further schemes would run alongside or closely follow, perhaps the Harrogate Line - a relatively easy scheme to do in Yorkshire - and the Southport/Kirkby lines or the Warrington Central line in the North West.

NETF said that the Tier 1 schemes should be carried out in Control Period 6 (2019-24). This may no longer be

[10] Much current H_2 production is, however by steam reforming of hydrocarbons with CO_2 as by-product. Clearly this would only be carbon neutral if offset, or the CO_2 captured and stored without release into the atmosphere.

feasible, but planning should, nonetheless, start now to ensure physical works can start in about 5 years from now (Autumn 2017). This should be seen as perfectly realistic. When physical work starts it should be carried out in as smart a way as possible to minimise disruption. Where "gapped" electrification is adopted the gaps should be filled by the use of clean on-board energy storage such as batteries, not by "dirty diesels".

The rolling programme should build on lessons learnt from recent schemes in terms of working with contractors and project management, gaining in expertise continuously. The idea of a dedicated management team working through a series of projects seems to make sense. Skills need to be retained, maintained, developed, not lost by a stop-go approach.

The initial costs of electrification may be high. But to abandon electrification on such grounds is short sighted in both environmental and business/economic terms. Electrification costs are balanced by savings for train operators later in terms of more cost-effective rolling stock. This was the principle on which the East Coast Main Line was electrified in the early 1980s. A similar approach based on the whole costs of running the railway is required by the DfT today.

The aim should be to eliminate diesel operation and create an ultra-low emission, zero-carbon, high technology railway across the North of England over the next two decades.

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