# Britain's need for an electrified railway

A paper by *Railfuture's* Network Development Team

January 2009

www.railfuture.org.uk

*In 1981, reflecting uncertainty over future energy supplies, a joint British Rail/Department of Transport report established the need for strategic commitment to electrification and called for a rolling programme. In 1982 its findings and recommendations were broadly supported by the Transport Select Committee. However, since 1990, virtually no electrification has taken place. This must change, now!*

**Benefit of Electric Trains**

No pollution at point of use;

Quieter, cleaner, less vibration;

Better acceleration;

Not locked into source of fuel;

Regenerative braking;

Trains are cheaper and have longer life as fewer moving parts than diesel trains;

Capable of operating for longer hours as no fuelling time required;

Visible investment (the "Sparks effect") encourages increased rail use.

**Electric Trains: The Barriers**

Capital cost of electrifying lines plus visual intrusion of OHLE and danger of third rail;

Additional maintenance costs including inspections, de-icing wires, cannot flail vegetation;

Longer possession times as power isolation is required;

Power loss may strand trains;

Disruption if wires unstable (especially high winds)

Most of the disadvantages can be overcome by better design and more efficient working practices. Diesel engines can suffer equivalent problems such as running out of fuel

**Electrified Network**

Network Rail has 32,000km of track, of which 16,000km is electrified; much is multiple track so the proportion of routes is lower. It represents only 38% of the network (23% Scotland and 0% in Wales) since the electrified routes are usually at least dual-tracked, and often four-tracked.

France has electrified 45% of its routes, 49% in Germany, 65% in Italy and 100% in Switzerland.

Apart from Britain's first high-speed line, the Heathrow Airport link and now Crossrail, extension of overhead wires has been limited to a diversionary route on the West Coast Mainline, the reopening of a commuter route south of Glasgow and the rebuilding of the Airdrie-Bathgate route. Little more than 0.1% of the 17,000km network has been electrified since privatisation, whilst wires have been erected over thousands of kilometres of routes across Europe and, expansion of electrification is continuing.

Lack of progress in the UK rests with successive treasury-dominated governments, which seem resolutely opposed to any capital expenditure that brings long-term benefits. All these governments have lacked vision. In the past this has merely affected Britain's prosperity; now it risks our future.

## The need to be 'green'

Rail travel is widely acknowledged to be much 'greener' than road and air-based forms of transport. *Railfuture* believes that the rail industry should be promoting its green credentials much more. However, far too many of the passenger and freight trains operating on Britain's rail network are powered by diesel. This is clearly incompatible with the need to combat climate change, by targeting reducing greenhouse gases, enshrined in British law.

*Railfuture* is concerned that the rail industry and politicians are relying upon development of bio-fuels and hydrogen as sources of energy rather than the best solution acknowledged throughout the world: electrification.

Whilst bio-fuels emit less carbon dioxide than diesel they still produce toxic chemicals; and with lower performance than diesel, more fuel would be used. However, the greatest threat is that vast swathes of rain forests and agricultural land will be given over to growing bio-fuel crops. The resultant fuel would need to be transported – perhaps vast distances, much like oil.

By comparison, the resources used to extract and transport hydrogen will not make it a practical alternative either. Also hydrogen-based fuel cells require a decade of further development before becoming a robust technology (e.g. three such experimental buses in London have been quickly withdrawn from service).

The fundamental flaw of liquid (and solid) fuel is its need to be transported vast distances before it is used: a train filled with diesel once a day (which incidentally takes the train out of service) wastes energy transporting its fuel (also with the risk of more serious rail disasters when collisions unfortunately occur). Electric energy is unique in being obtained at the point of use, can be generated through natural non-polluting means such as wind, wave, hydro and solar power. It also reduces dependency on a particular source or supplier.

## Britain needs electric trains

This paper produced by *Railfuture*, Britain's only national independent organisation campaigning exclusively for a larger and better railway, calls for more of Britain's rail network to support electric trains. As well as environmental benefits it will deliver a better passenger experience, such as improved acceleration, quieter journeys and cleaner stations, which will benefit millions of passengers and encourage a shift towards rail. Also electrically-hauled freight trains are capable of greater acceleration than diesel, thus minimising their pathing impact on Britain's mixed-use railway.

Major investment will be needed for additional overhead lines, and third rail where appropriate: initially small "in-fill" schemes to remove diesel trains running "under the wires" on other lines, followed by extension of electrification on major routes, such as the Midland Mainline, and the Great Western main lines. It is illogical and uneconomic that mainlines forming the core of premium-paying franchises operate using diesel trains, when the capital costs of electrification will be more than offset by the improved performance, capacity, and environmental benefits. Apart from London, we can think of no other major advanced European capital city with such extensive diesel operation on its radiating main lines.

To date electrification has been concentrated on commuter routes around the south east, and major cities in the Midlands, north of England and Scottish lowlands, plus the two key "coastal" inter-city routes. A weakness of limited electric train operation has been the necessity for the whole of a train's route to be electrified. This has, in some cases, led to train services being determined by the infrastructure rather than the passenger needs. However, as the electrified network becomes larger then many more journey opportunities become possible. Likewise the freight operator's reliance on the go-anywhere Class 66 diesel locomotive will be reduced.

Many train operators currently have to maintain both electric and diesel trains, which vastly complicates their depot operations: two sets of equipment, two sets of parts, staff trained in both disciplines and requires fuel supply and storage. Where electrification of a route might appear not to make sense on passenger volumes alone, increased efficiency through all-electric operation may recoup the capital costs of electrification.

Unfortunately, when much less-used parts of the network are electrified the return on investment is lower, and in some extreme cases the additional operational and maintenance costs could outweigh the benefits. In these cases hybrid trains are a sensible alternative.

Electro-diesel hybrid trains, have existed for decades. These make use of the electricity source (with potential benefits such as regenerative braking) when available and switch to diesel when it is not. This maximises the time when a train can operate electrically, although when switching sources the train must slow to engage the pantograph or collector shoe. *Railfuture* notes that the DfT's Intercity Express Programme plans new electric-only and electro-diesel hybrids, but is concerned that new diesel-only intercity trains will be in service from 2014 for 40 years. Diesel trains have a maximum effective speed of 200km/h (compared to the 350kmh limit of electric trains); only Britain operates diesel trains at such a speed.

### Regenerative Braking

In May 2007 c2c became the first TOC to operate 100% of its fleet (all Class 357s) with regenerative braking, which passes on 15-20% of its energy instead of being lost.

Traction motors act as generators by converting kinetic energy into electrical energy as the train is slowed down. The electrical energy is fed back to the supply system for other trains in the same DC section or, in the case of AC, returned to the power supplier via the national grid. It also reduces the effect of friction (disc) braking as the regenerative braking kicks in first with the friction braking only initiating if needed. As well as reducing brake wear it reduces the amount of brake dust released into the environment.

Regenerative braking is not a new idea – it was first used on the Woodhead line in the 1950s.

All modern electric trains can support regenerative braking but only if the network allows it.

Regenerative braking can hide a short circuit from the circuit breakers at the electrical substation. Therefore Network Rail has had to install modern microprocessor relays so that short circuits can still be detected. The Liverpool Street-Norwich route had its relays replaced in late 2006. By mid-2007 only the Midland Mainline and parts of the ECML were outstanding. 100% of the AC route will support regenerative breaking by the end of 2008.

Whilst most DC trains support the facility none are using it.

Regenerative braking on the DC network would pass on only 5%-15% of energy ('receptivity') and requires changes to each of the 800 electrical substations in order to invert DC to AC. Issues relating to detecting short circuits when a train brakes regeneratively still need to be overcome. It may be more economic to capture the energy using on-board batteries, if technological improvements reduce their bulk and weight.

## Exploiting the improvements in battery technology

A new type of hybrid train is possible: diesel-powered but with batteries, which are charged by regenerative braking, to eliminate noise and fumes in stations - where diesel engines currently idle for long periods. Trains could enter and leave stations solely on battery power. As technology improves these could operate for longer periods and trains would be charged at stations, avoiding the need for continuous electrification infrastructure. Because they could also help trains attain top speed when required, smaller diesel engines should suffice. Despite these abilities, such trains would still be powered largely by diesel in the next decades, making them unacceptable as a widespread solution.

*Railfuture* is pleased that companies such as Hitachi – in association with Network Rail - are developing hybrid diesel-battery trains, but whilst hybrids make sense for Network Rail's go anywhere 'New Measurement Train' inspection trains, and also for passenger trains on lightly used routes, they must not be seen as a universal alternative to electrification.

## What else?

Electrification is just one way that the railways can help to save the planet. The environmental impact of trains themselves, whether diesel or electric-powered, can be lowered by better driving techniques and by building lighter trains, and an additional financial benefit is through lower maintenance costs from reduced dynamic forces at the wheel rail contact. Japan has lighter trains, where the mass per seat is around 500kg – six times the weight of the occupant – but the UK train mass is nearly double.

*Railfuture* is pleased that new stations such as Liverpool South Parkway are being designed to function with minimum electricity and collect their own rainwater. Likewise Eurostar has publicly stated its intention that passengers will leave a nil carbon footprint. There are opportunities for movement controlled escalators and lighting. However, these efforts will be pointless if diesel trains - the most visible image of the rail industry - continue to belch smoke. Whilst the 1970's High-Speed Trains are being given new engines and brand new diesel trains are cleaner and more efficient than ever before, because of the expense committed these will be expected to be used for up to 40 years. By comparison widespread efforts by the car industry to manufacture cleaner cars will be felt within a few years. The best way for the rail industry to guarantee to remain the greenest form of transport (after bicycles) is to move towards a major increase in the number of electric trains transporting people and freight.

## What should Britain aim for?

Britain will take decades to reach the 100% use of electric passenger trains achieved in Switzerland. However, *Railfuture* believes that the British government should commit now to a target, such as 8*0% of all passenger carriage kilometres powered by electricity by 2020*. Furthermore, a rolling electrification programme is essential to keep skilled and experienced teams continuously at work, and to avoid stop-start programmes which waste time and training finance, and lose valuable engineers and workers – a problem which occurs now with smaller diversionary and extension projects.

### Alternative to electrification

One hybrid method is to have a battery array on trains. Whilst the overall benefit of this is still to be proven, battery technology has improved dramatically in recent decades. One obvious comparison is mobile phones, where much smaller phones are replacing larger ones due to improved batteries.

Hitachi's battery/diesel-powered hybrid HST (called 'Hayabusa') is the UK's first such hybrid. The train uses battery power when departing stations until reaching a speed of 30km/h. Once travelling on diesel power the battery is re-charged using the engine or through regenerative braking. It uses a high-energy, high-density Lithium-ion battery. Energy density and the capacity of such batteries are increasing (lifetime of 8-10 years) whilst the size and weight are decreasing.

The test train, which has 48 batteries each weighing 20kg (a total of 960kg; about 20 people), was demonstrated on the Great Central Railway (GCR) on 3rd May 2007. It travelled quietly at 30km/h on battery power only.

The HST, which comprises two power cars and several Mk3 coaches, has been undertaking test runs on the GCR - in partnership with Network Rail, Porterbrook Leasing and Brush Traction - to prove the power saving technology. After initial testing it has been running on Network Rail metals with the New Measurement Train.

A problem with the hybrid HST trialled is that the batteries could not be housed in the power car as the axle weight would be too heavy. Instead they were stored in the first coach. This would be a loss of space on loco hauled or HST passenger trains. However, on new build diesels a smaller diesel engine would make space for the batteries. DMUs would have batteries under the carriage. Japanese Railways have been operating passenger hybrids in service since July '07.

In the longer term batteries could be charged whenever the train stops – i.e. at a station.

**Major electrification schemes**

- 1960 – Glasgow 'blue trains' [25kV AC OLE]
- 1960 – first phase East Anglia lines [25kV AC OLE] including conversion of 1500V sections
- 1960 – start of WCML (Euston) [25kV AC OLE]
- 1967 – completion of WCML (Euston) [25kV AC OLE]
- 1967 – Bournemouth extension [750V DC 3R]
- 1975 – WCML extension to Scotland [25kV AC OLE]
- 1976 – first phase of GN suburban [25kV AC OLE]
- 1981 – St.Pancras-Bedford (1988 Thameslink)
- 1991 – completion of ECML [25kV AC OLE]

## What should we do in the meantime?

In the meantime more diesel multiple units will be built. *Railfuture* calls for these to be designed for conversion to EMUs later. The design of all new diesel locos and trains should incorporate the use of hybrid technology to the maximum extent possible. This might include the use of batteries where this is efficient in energy terms: charging through regenerative braking for later use has been shown to reduce fuel consumption by up to 20%. Where feasible electric traction should replace long diesel runs under the wires, with loco changes or with easy level connections where through journeys may be broken (e.g. London-Edinburgh-Aberdeen).

## Improving our Electric Railway

When new routes are electrified the infrastructure must be more robust than at present: passengers must not suffer delays from overheard wire failures. Electrification on the cheap, such as minimising the number of stanchions as on the East Coast Mainline, is counter-productive, incurring other costs and losing passenger confidence.

Investment is needed now to make existing overhead line equipment (OHLE) more resilient, such as increasing the wire tension on the Great Eastern mainline using weights.

**Priority Schemes**

The Gospel Oak – Barking line is the only non-electrified part of the North London Railway franchise awarded by Transport for London. TfL would like to see the line electrified in the future and have talked to Network Rail with a view to bringing the idea to fruition.

It is now widely accepted that both the Great Western Main Line and the Midland Main Line are immediate priorities, both having a high benefit-cost ratio.

The Scottish government has already announced its intention to electrify most of the routes in the south, with proposals to electrify up to Inverness in the longer term.

## What now?

Now that environmental issues have become very urgent, we need to plan for the future. In addition extraction of oil has reached a production peak. Prices per barrel ranged from $60 to $145 and back to $35 in the two years to end of 2008, while world demand fluctuates, a temporary phenomenon arising from the world's financial crisis, but unlikely to last for long. So reducing – or eliminating – transport's reliance on petroleum oil is now imperative. It will take many years to move away from its use anyway; this challenge demands a response now. The promotion by several bodies, including the Association of Train Companies (ATOC), of more electrification is welcomed by all, except seemingly the Department for Transport.

*Railfuture* calls on the UK government to produce urgently a strategy on electrification, much like the one undertaken by the government and British Rail had done in 1981. *Railfuture* would expect the DfT's consultants to produce a prioritised list of routes on the network that should be electrified with, crucially, timescales.

## Further information

The original 1981 BR electrification proposals are now online:
http://www.railwaysarchive.co.uk/docSummary.php?docID=411
The proceedings of the British Railways Electrification Conference 1960 are now available at http://www.railwaysarchive.co.uk/docSummary.php?docID=34.

**_RAILFUTURE_'s MISSION STATEMENT**

*To be the number one advocate for the railway and rail users*

***Railfuture*** **is the only nationwide independent organisation in Great Britain promoting a better railway for both passengers and freight users. Railfuture's campaigning work is funded by its members. Join us!**
*Railfuture* Membership, 6 Carral Close, Brant Road, Lincoln LN5 9BD or e-mail membership@railfuture.org.uk

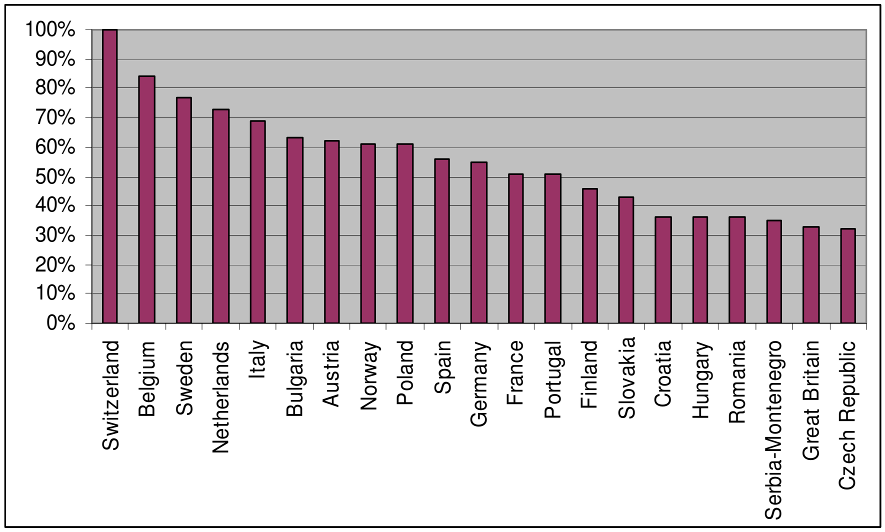
Published by The Railway Development Society Limited - A (not for profit) Company Limited by Guarantee, trading as *Railfuture* Registered in England and Wales No 5011634 - Registered Office:- 12 Home Close, Bracebridge Heath, Lincoln LN4 2LP

## APPENDIX 1 — BRITAIN'S NEED FOR AN ELECTRIC RAILWAY

Proportion of European national railway networks that have been electrified, with widely-published figures pre-EU expansion (1970) and those most recently available (2005). We have excluded countries with small networks of less than 2,500 km, with which no worthwhile comparison can be drawn. These include Albania, Denmark, Estonia, Greece, Ireland, Northern Ireland, Luxemburg (95%), Bosnia-Herzegovina, Macedonia, Latvia, Lithuania, Slovenia, which are either small, less-developed economically, mountainous, mainly rural, have low population density, or a combination of these. In the list below, with over 2,500 km networks, only Czech Republic had lower electrified proportion than Great Britain's 33%, and has almost certainly now overtaken (2008).

| Country | 1970 | 2005 |
|---|---|---|
| Austria | 40% | 62% |
| Belgium | 26% | 84% |
| Bulgaria | ------ | 63% |
| Croatia | ------ | 36% |
| Czech Republic | ------ | 32% |
| Finland | ------ | 46% |
| France | 25% | 51% |
| Germany | 26% | 55% |
| **Great Britain** | **17%** | **33%** |
| Hungary | ------ | 36% |
| Italy | 48% | 69% |
| Netherlands | 52% | 73% |
| Norway | 58% | 61% |
| Poland | ------ | 61% |
| Portugal | 12% | 51% |
| Romania | ------ | 36% |
| Serbia-Montenegro | ------ | 35% |
| Slovakia | ------ | 43% |
| Spain | 23% | 56% |
| Sweden | 61% | 77% |
| Switzerland | 100% | 100% |

Proportion of rail routes electrified in 2005 (in descending order)




**Great Britain was in 21st position** out of 22 European countries. Note: the proportion of the network electrified does not necessarily equate to the proportion of railway track or the trains operated that are electric. Many countries have since added more electrified routes, but Great Britain has not.

## APPENDIX 2

This is a list of main line routes, widely regarded by many organisations as well overdue for electrification. These would eliminate (or substantially reduce) the need for development of the DfT's planned diesel Inter City Express programme, to replace the existing ageing HST fleet.

Great Western main line:
Reading to Oxford, Bristol, Cardiff and Swansea
Bristol to Taunton
Reading to Taunton, Exeter, Paignton, Plymouth and Penzance

Midland main line:
Bedford to Leicester (including Corby), then via Derby and Nottingham, to Sheffield

Trans-Pennine (north) routes:
Liverpool to Warrington, Manchester Picc'y, Huddersfield, Leeds (and to York – see Appendix 3)

Scottish Lowland routes:
Glasgow Queen St to Falkirk (via both routes), and Edinburgh
Coatbridge to Cumbernauld, Falkirk and Stirling

This is a list of short routes which *Railfuture* considers priorities for inclusion in an electrification programme, in no particular order, but most of which are "in-fill" sections between, or close to, other existing electrified routes. The reason(s) for the particular route's selection are categorised.

| Route | | V | E | T | D | F | X | Km | |
|---|---|---|---|---|---|---|---|---|---|
| Woodgrange Park - Gospel Oak | | X | X | X | X | X | a | 16 | |
| Manchester Picc'y – Leyland (Preston) | | X | X | X | X | | b | 44 | 1 |
| Leeds – via Garforth - York/Selby | | X | X | X | X | X | | 55 | 5 |
| Wrexham – Bidston | | | X | X | | | c | 44 | |
| Peterborough – Ely | | X | X | X | X | | | 47 | 4 |
| Northallerton - Middlesbrough | | | X | X | X | | | 33 | |
| Leeds – Harrogate – York | | X | X | | | | | 60 | |
| Coventry - Nuneaton | | X | X | | X | | | 16 | |
| Birmingham - Nuneaton | | X | X | X | X | X | | 32 | |
| Walsall – Water Orton (& for pass'rs) | | X | | | X | X | | 24 | |
| Walsall – Rugeley Trent Valley | | | X | X | X | | d | 25 | |
| Liverpool (Edge H)– St Helens - Wigan | | X | X | X | | | b | 29 | 1 |
| Wolverhampton - Shrewsbury | | X | X | X | | | | 48 | |
| Crewe – Chester | | X | X | X | | X | | 33 | 1 |
| Preston – Blackpool | | X | X | X | | | | 28 | |
| Carnforth – Barrow-in-Furness | | | X | X | | X | | 46 | |
| Oxenholme – Windermere | | | X | X | | | | 16 | |
| Acton – Cricklewood (& for pass'rs) | | X | X | | | X | | 7 | |
| Ipswich - Felixstowe | | | X | | | X | | 20 | |
| Ashford - Ore | | | X | X | | | | 40 | |
| Hurst Green - Uckfield | | | X | | | | | 40 | 2 |
| Reigate – Guildford/Ash-Wokingham | | X | X | X | X | | | 51 | |
| Reading - Basingstoke | | X | X | X | X | X | | 24 | 3 |
| Sheffield – Doncaster/Moorthorpe | | X | X | | | X | | 43 | |
| Newark Northgate - Lincoln | | X | X | | | | | 18 | 5 |
| Amersham - Aylesbury Vale Parkway | | X | X | | | | | 28 | |

D: Diversionary route for engineering works
E: Efficient use of rolling stock / operation (e.g. elimination of small diesel operations)
F: Freight route benefit
T: Through service
V: Volume of present or anticipated traffic
X: External funding possible from a) TfL, b) NWRDA, c) Welsh Assembly/Merseyside PTE, d) WMPTE

1. Eliminates substantial diesel operation under the wires on WCML
2. Uckfield – Lewes reopening would create an extra London-Brighton route
3. Could be either OHLE or 3$^{rd}$ rail – no preference
4. In the RUS: London-Stansted-Cambridge-Peterborough growth route; already an ECML diversionary route but for diesel traction only; would enable electric haulage throughout
5. Eliminates substantial diesel operation under the wires on ECML