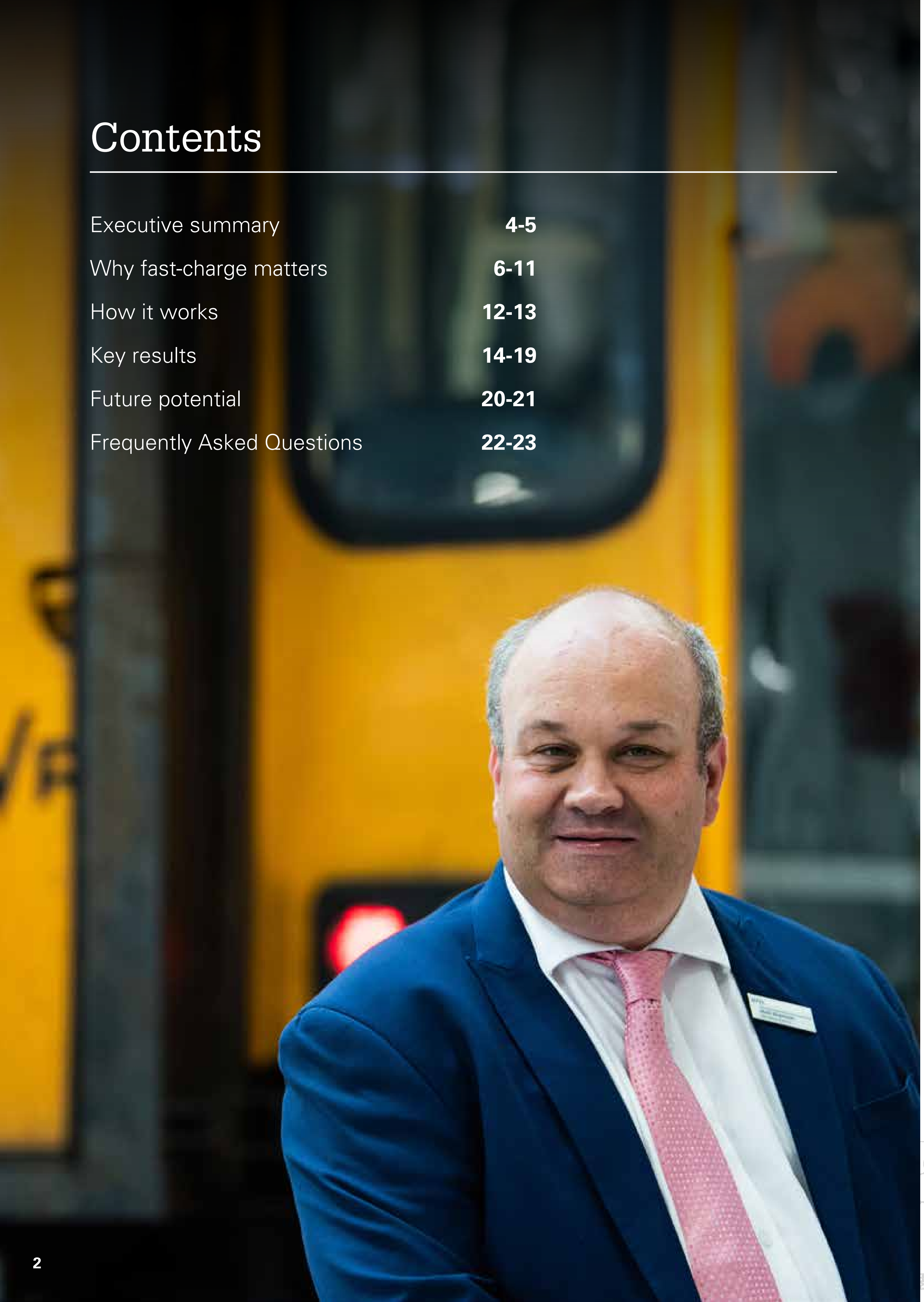
GWR | Innovation

Fast-charge battery technology: A viable option for regional rail?



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Foreword

The past decade on the Great Western Railway was defined by transformation: a once-in-a-generation programme of investment that reshaped the long-distance, high-speed spine of the regional network.

From infrastructure enhancements to the introduction of our modern Intercity Express Trains, we laid the foundations for a railway fit for the 21st century – one that supports the needs of our customers, our communities and our economy.

Now, we are turning our attention to the next challenge facing our network: the renewal of our regional and local services that are the lifeblood of so many of the communities we serve.

At the heart of this is the need to renew our regional diesel fleets, many of which are approaching 40 years' service and needing increasingly costly maintenance to keep them on the tracks in the coming years.

To avoid the need for newer diesel trains, which lead to higher long-term costs, increased emissions and a compromised customer experience, we need to expand our horizons and start making decisions today.

That is one of the reasons why we embarked on our trial of fast-charge technology on the Greenford branch line – a trial that has shown GWR to be at the forefront of cutting-edge research, delivering evidence for the benefit of the wider rail industry.

One of the key motivations was to explore how discontinuous fast-charging can be used to support battery-electric trains calling at interim station stops.

The results have been extremely promising, enabling us to demonstrate how this technology could help to remove the reliance on overhead lines which are costly and disruptive to install.

The trial also explores the potential for growth and how the railway can be the catalyst for change in how energy is stored, with 'community battery hubs' installed at locations across the network.

We are proud to share the findings of this trial through our White Paper, which aims to build understanding and support across government, industry and regional stakeholders.

It is an option for change – a chance to align investment in rolling stock and infrastructure and avoid locking in diesel dependency for another generation.

The Secretary of State for Transport, Heidi Alexander MP, and Rail Minister Lord Peter Hendy have already gone on record with their support for the future introduction of battery-electric trains.

We know what's at stake. If we miss this opportunity, we could end up having to lock in outdated diesel technology – trains that will be more expensive to run, harder to maintain, and inconsistent with the UK's net zero commitments.

We stand today on the shoulders of railway giants. The original Great Western Railway – born in Parliament in 1835 – redefined what rail could be, transforming the South West, Wales and the West of England before changing the world.

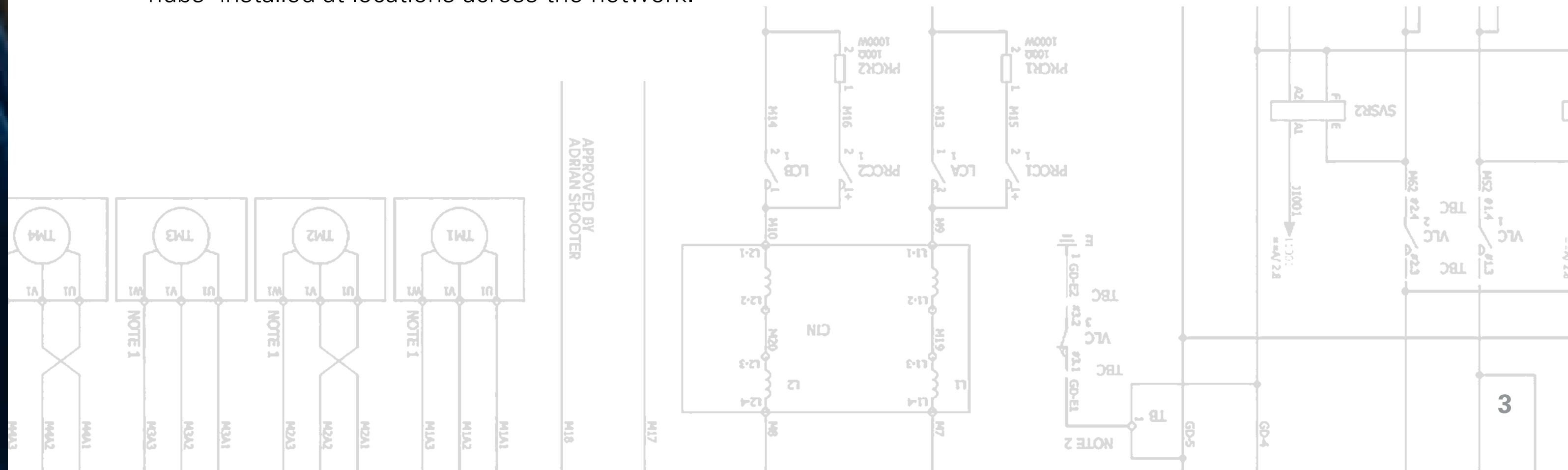
Nearly two centuries later, this spirit of innovation, resilience and unwavering commitment to service continues to inspire us.

Fast-charge technology provides the opportunity to recreate a golden age of rail for the modern era – driving economic growth and connecting our communities with cleaner and greener trains.

We've shown that the technology works. Now we need to bring it into daily service.

Mark Hopwood

Managing Director



Executive summary

If you take one fact away from this report, it's this: Fast-charge battery trains work.

And they're cheaper than keeping ageing diesel trains and cheaper than full electrification over the long-term for branch lines and quieter routes.

This matters because Great Western Railway's diesel trains are reaching the end of their lives. The oldest date from the mid-1980s. They're becoming more expensive to maintain, leaving GWR with little choice but to look to replace them.

The question is with what. Rolling stock manufacturers are moving away from diesel trains, as is government policy. Battery trains are in regular operational use but only for short stretches of track. Pure electric trains have run on Britain's rail network for over 100 years.

Their technology is established, but it comes with high upfront costs in installing the masts and wires needed to deliver electricity to trains over longer distances.

Thanks to government funding and in collaboration with Network Rail, GWR started a trial to test the capability and viability of fast-charge battery technology in a real-world environment.

Using a converted London Underground train as a testbed, GWR put batteries and the systems that charge them through their paces for a year on the five-mile return trip between West Ealing and Greenford in London's western suburbs. This is a line usually served by diesel units.

The results are positive. Not only do batteries work but the trial found that the infrastructure they need to charge them is cheaper than full electrification.

This gives a potential route forward that replaces GWR's ageing diesel fleet and delivers a railway that is cheaper to operate, saving taxpayers' money.

The battery idea tested by GWR comprises two elements. One is a bank of batteries sitting by the lineside and connected to a simple DNO electrical supply on one side and, on the other, to a set of charging rails placed on the track. The second element is an electric train equipped with batteries and retractable shoes that connect with the charging rails.

The shoes and rails allow the lineside batteries to rapidly charge the train batteries in a matter of minutes, allowing the train to continue its journey, carrying passengers to their destinations.

For the trial, the fast-charge team took batteries housed in small shipping containers – normally used as emergency power sources in hospitals – and installed them by the side of the line at West Ealing.

On the tracks alongside, GWR installed two sets of charging rails. Installation was quick, simple and with easy access, requiring no special tools and permission from only a small number of stakeholders.

In addition, the technology is completely safe. Unlike other types of electrification on the railway, the fast-charge system does not require the rails to be live all the time: They only go live during charging, when they are covered by the train.

GWR's tests over the year that followed have allowed its Innovation team to assess how this fast-charge technology performs and develop planning tools to assess where to place charging points.

These tools give GWR confidence that fast-charge battery trains could help deliver services across branch lines in the Thames Valley and in Devon and Cornwall, including the long line from Exeter to Barnstaple. Crucially, the results from GWR could be applied to other, similar routes across Britain.

The success of the trial allows GWR to look more confidently at a future without diesel, providing alternative options that are cheaper to deliver while achieving the common goal of a cleaner, greener railway.

Jonathan Prince and Jon Harris, from GWR's Innovation team, monitor the fast-charge performance

Why fast charge matters

Great Western Railway operates a mix of rail services that range from long-distance trains running between London and the South West and South Wales, to commuter services serving London and major towns and cities across its network, as well as local branches providing lifelines for residents and sightseers alike.

While its core network has modern electric or hybrid diesel electric trains, all of its branch lines and much of its regional commuter services run with diesel trains that are 30-40 years old. Other train operators work in similar circumstances.

Increasingly detailed and onerous maintenance regimes keep those older trains in passenger service, but it's inevitable that maintenance costs will rise as they need more extensive work to keep them in good order. No modern bus operator would rely on vehicles that are approaching 40 years old. The same principle should now apply to trains.

Which means we must look at the next generation of trains. Every indicator suggests we must move away from diesels to electric trains. By almost every measure, electric trains are better than their alternatives, including diesel trains. They are cheaper to operate, cheaper to maintain and cheaper to buy. They bring better acceleration and their brakes regenerate energy, which cuts overall fuel bills and reduces brake wear, when compared with diesel trains.

Great Western Railway's regional diesel trains are reaching the end of their lives

The challenges of full electrification

There's one downside to electric trains and that's getting the electricity to the train. Modern railways use Overhead Line Equipment (OLE), which comprises masts and wires to deliver current to trains.

This comes with high up-front capital costs and long construction times. Once installed, the system of masts and wires is good for decades of work but when budgets become constrained, it's harder to justify the initial outlay, particularly on quieter lines.

There's no doubt that for extended stretches of busy lines, overhead wires and electric trains remain the ideal way of delivering rail services. But it's just not realistic to deliver that level of infrastructure in the time available to support an electric fleet – as a guide, the Great Western Electrification programme took two decades to deliver from conception to completion.

That's why GWR has been thoroughly testing the viability of powering trains with batteries in West London.

This trial set out to test whether trains equipped with batteries could provide a realistic and cost-effective alternative to diesel trains. It tested how well fast-charging facilities worked in daily operation and examined what data could be gathered to test and model wider deployment of this ground-breaking technology.

Overall, we looked at whether batteries could unlock electric rail services without having to wait decades for full electrification.

What we set out to prove

This report explains what we found and maps out how we can take those findings forward to align with Department for Transport goals for achieving a cleaner, greener and more efficient railway for both us at GWR, but also across the wider UK rail network.

Cost of ownership

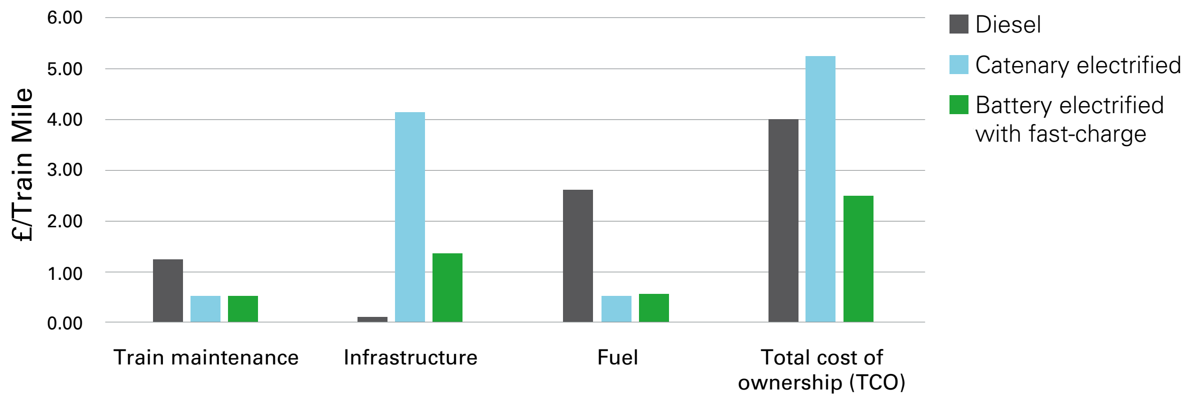


Fig 1 Cost of ownership

Cost of ownership comparison based on a typical 2-car multiple unit, comparing diesel, overhead electrified and fast-charge battery options.

An EU study into the use of fuel cells and hydrogen in the railway environment found that a typical two-car diesel train costs around £1.25 per train mile for maintenance while equivalent electric trains come in at about 55p per train mile.

An electric train is about the same in fuel costs - 57p per train mile - while diesels are much more expensive at around £2.60. However, the infrastructure for a full electric service, all those masts and wires, cost over £4.15 per train mile while battery electric trains produce costs of £1.39 per train mile.

This gives total costs of ownership for diesels at over £4, electrics at over £5 per train mile while battery electric trains are cheaper at £2.52, all measured per train mile and taken from studies across European railways.

These costs depend on the assumptions behind them. For GWR's battery electric technology, its developers assumed two fast charge battery stations at £1.3 million each per 100km of route.

The overall conclusion can only be that battery electric trains offer a saving over diesel trains.

This makes the answer to what should replace diesel trains much easier. In many cases, the answer is batteries. So it's batteries that have formed the basis of tests over the last year by Great Western Railway using a converted train running between West Ealing and Greenford in West London. Work so far by GWR suggests a total cost of ownership of about £2.50 per train mile.

Compelling alternative

In separate work, consultant Arthur D Little looked at the costs of electrifying the line from Bristol Parkway to Penzance, comparing it with using a mix of electrifying Bristol-Exeter and battery chargers further west. The result was that this second option performed best in whole-life costs out to 30 years, potentially saving nearly £800 million over 30 years.

Taken together, our work and Arthur D Little's report point the same way – that battery trains are cost-effective as a way of replacing ageing diesel trains.

When money is tight and passengers and stakeholders want cleaner and greener services, that's a saving we can't ignore. That's even before we look at how these lower costs might feed into fares or the cost to taxpayers of providing rail services, which is not part of this report. For regional and branch lines like the one in our trial, batteries offer a compelling alternative.

The idea of using batteries is not new. Back in the 1950s, British Railways tried something similar in Scotland. More recently, Network Rail conducted a battery trial in 2014. What's changed since then (and certainly since the 1950s) is the technology behind the batteries themselves. This drive has come from rail's great rival, road transport, which can now provide electric cars driven by batteries from almost every car showroom.

Motorists with electric cars charge them slowly overnight from domestic supplies at home. Or they can use fast-chargers in places like service stations or supermarkets.

GWR used the same principles with its testbed train in West London. For test purposes, the train's battery rafts were charged slowly overnight in a depot and then with every visit to West Ealing station during the day. From a test perspective, it made sense to start a day with full charge and the fast-charge bursts during the day were essential to test the system.

Running a fast-charge battery train in normal service would adopt a different regime. Trains don't return to depots every night but when they do it makes sense to trickle charge their batteries, just as diesel trains receive fuel in depots. But unlike diesel trains, fast-charge battery trains can be charged as they run, either from overhead wires or fast-chargers in stations.

GWR's test-bed only runs five miles between fast charges because that's the distance from West Ealing to Greenford and back. In other tests, it has run over 80 miles on a single charge. Modelling suggests it has the potential for much more. Clearly, replacing this sort of power draw takes longer than the 3-4 minutes tested at West Ealing and might typically take just over 15 minutes in a single charge.

For the test bed, this fast-charge comes from a set of rails laid in West Ealing station, with one set charging each of the two battery cars of our three-car testbed. Each set is connected to a large battery sitting in a container by the side of the line. Charge reaches these large batteries from conventional electricity network supplies in exactly the same way it reaches homes, shops and offices.

The train then takes short bursts via those rails to keep itself topped up. This ability to top up its batteries from lineside supplies gives GWR's testbed train unlimited range. And, as part of the trial, GWR developed simulation software that can predict power consumption and allows it to suggest where to place lineside fast-chargers along particular routes.

This demonstrates the potential to convert branch lines such as those in Devon and Cornwall (even the 40 miles from Exeter to Barnstaple) or the Thames Valley, to battery-electric trains. Power comes from normal electricity supplies via unobtrusive lineside structures. The result is cleaner transport using electric trains with no emissions at their point of use.

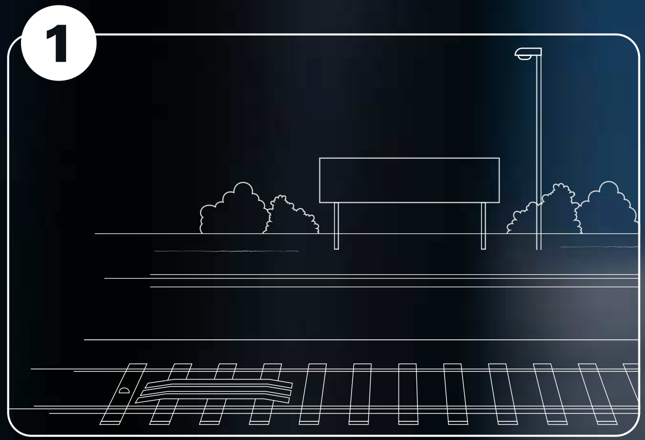
The simulation tool is just as important as the batteries and chargers because it allows more certain planning. It can model the effect of multiple services and of delays or cancellations on services (none of which GWR wants but remain factors that it can't ignore) as well as on-train problems with batteries or motors, or lineside charging problems. Taken overall, the tool allows train operators to provide sufficient resilience to deliver a reliable service to passengers.

The battery banks are housed in small shipping containers at West Ealing.

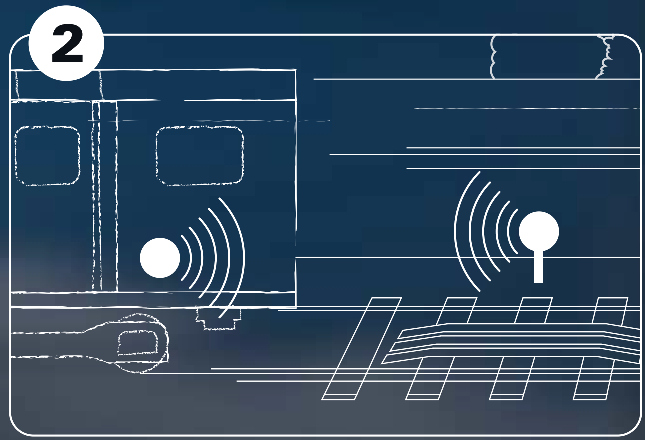
"GWR has always been at the forefront of innovation, since its inception nearly 200 years ago through to today with this cutting-edge trial. I'm now eager to see how it takes this project forward to address the challenge of renewing its regional fleet, so the railway can continue to serve customers not just of today but for generations to come, and make a significant contribution to reducing harmful CO2 emissions."

Lord Faulkner of Worcester,
Chair of the GWR Advisory Board

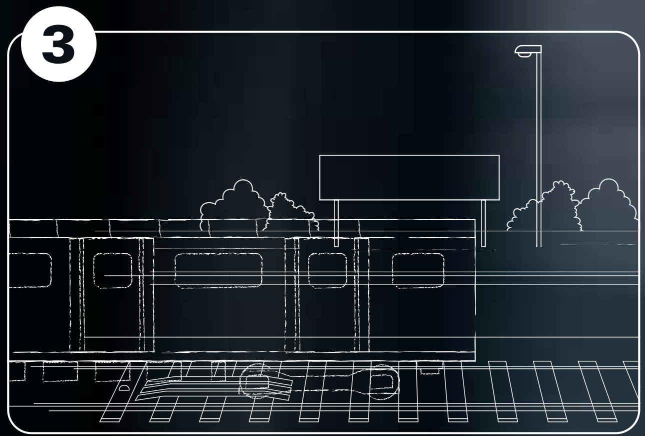
How it works



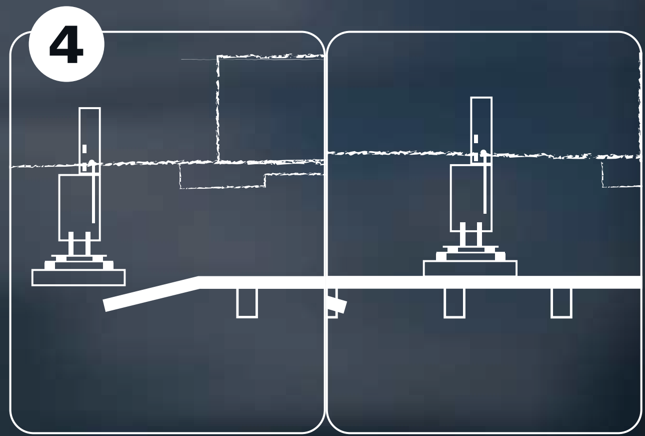
Fast-charge rails are installed within the running rails and require no lengthy engineering work or line closures. If time is limited, installation can be split to fit available windows without disrupting services.



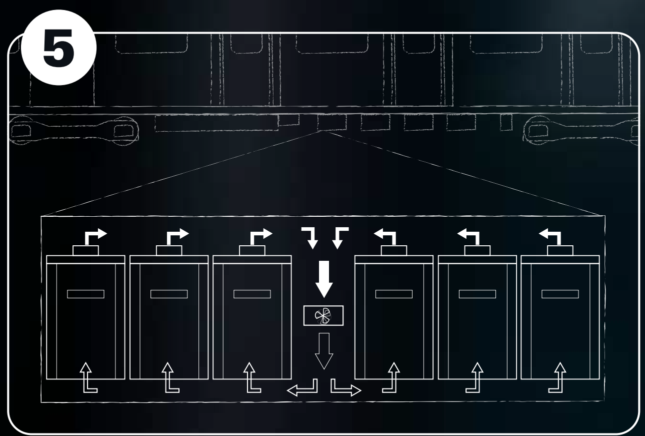
As the train approaches the station, sensors fitted to the train and trackside prime the fast-charge system ahead of charging.



As the train approaches the fast-charge rails, the contact shoes under the train drop into position ready for charging.



The lowered charging shoes ride up the short fast-charge rail approach ramp and make solid contact with the top of the rails.



Once the train is confirmed by sensors to be in the correct position, with charging shoes on the rails, the lineside batteries start sending current into the train's batteries.

The batteries take the fast-charge they need until they are full or the train driver moves the power handle in the cab, at which point the shoes retract and the train is ready to go.

7 When the train has left, the lineside batteries continue receiving a trickle charge from the National Grid supply, ready for the next train to arrive. They don't need to be fully charged when a train arrives. This system places no spikes in demand on the grid and needs no large electrical infrastructure to install.

Key results

Fast-charge batteries work. They take electricity from ordinary supplies, store it in lineside batteries and feed it as needed to batteries on trains through electrified rails that sit on the track.

Great Western Railway's year-long trial proved the concept and generated useful data that can guide more extensive use of this technology which is relatively simple and much cheaper to implement than the overhead lines that power most of Britain's electric trains.

The technology sitting behind GWR's trial is simple. It's easy to install.

And it's safer than other electrification systems because the charging rails are only live with electricity when the train is positioned over them. Otherwise, they are electrically dead which cuts overall risk.

Choice of test train

The testbed itself is a former London Underground train that was converted especially for this fast-charge project. Although it can and has carried people, it's not our intention at GWR to use it in regular service in the long-term.

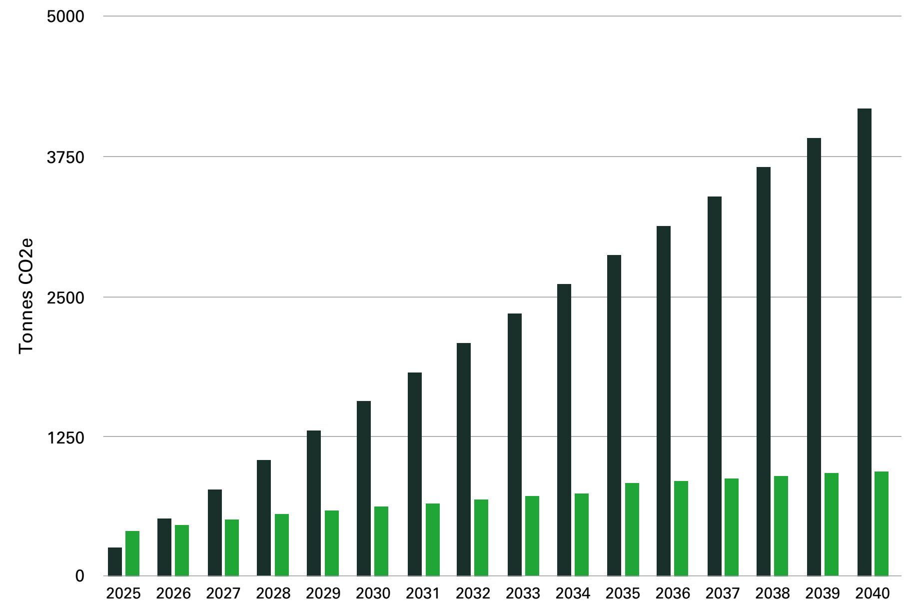
It fully demonstrates the concept of fast-charging but we expect its technology would need to be integrated into new trains before any wider roll-out across the UK rail network. However, major manufacturers already offer battery trains in other countries and Transport for Wales is beginning to use battery trains in South Wales.

Real-world emissions

The battery train works in rain or shine. And with an overall system efficiency of 79% and power consumption of approximately 2.4kWh/carriage/mile, it performs better than a diesel train on equivalent duty.

In terms of the environmental impact, our trial reveals as a headline figure that the fast-charge battery testbed train produces carbon emissions that are 80% lower than an equivalent diesel train. This figure would be even lower with carbon-neutral electricity supplies, around 26kg CO2e per day compared with a diesel train's 960kg per day and our train's 235kg per day using typical electricity supplies.

Taken on a cumulative basis, the difference in carbon emissions between a diesel and a battery train running between West Ealing and Greenford quickly become apparent as this graph shows.



DMU tonnes CO2e cumulative

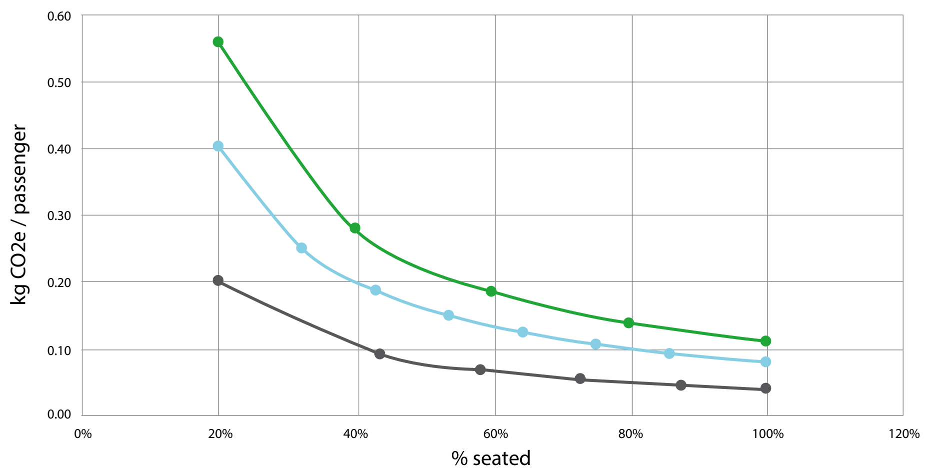
BEMU CO2e tonnes cumulative

Fig 2a Carbon emissions battery train v diesels

Cumulative carbon emissions over a 15 year period, comparing a converted fast charge battery train with a diesel multiple unit, including the emissions associated with converting the battery train, and fitting replacement traction batteries after 10 years.

The test-bed has returned emissions figures lower than cars, even electric ones, when based on the amount of CO2 emitted per passenger, as the graph below shows.

Emissions per passenger for EV/diesel car/battery train from West Ealing to Greenford



Battery train 230001

2021 MG5 EV

DMU (2 car Class 165)

Fig 2b Battery train v EV

Comparison of carbon emissions per passenger for diesel and battery electric trains and cars, ranging from 25% seated to fully seated, for the trip from West Ealing to Greenford.

230 volunteers took part in a passenger load test in April 2025

The testbed train has carried plenty of people too. In Spring 2024, it hosted media and journalists, including the BBC, and we carried senior delegates from a variety of national and international organisations over several days in December 2024.

After seeing GWR's fast-charge trial at first-hand, Richard Bowker CBE, former chairman of the Strategic Rail Authority, said:

"It's absolutely terrific technology. To see a real-life application in practice like this is amazing. I'm just so amazed – it's quiet, it's efficient, it's clean and it works. What Great Western Railway is doing is enabling testing and technology that could be applied across the whole of the country's railway. It's just superb… well done."

Testing the system's resilience

GWR's team has conducted thorough tests to prove that fast-charging works. These tests confirmed how well the system operates, even with some of the train's batteries switched off. They showed how the system can tolerate worst-case scenarios, for example the train turning up late and reducing the fast-charge time.

And they've placed heavier loads on the train with saloon heating in winter, demonstrating no significant effect on energy consumption, in line with our calculations. We've carried different numbers of volunteers as passengers, including 230 of them in April 2025, which gave us a 22-tonne load. We've encouraged our team of drivers to push limits in a controlled and repeatable way so we can assess how different driving styles affect the batteries.

We've even stuck crisp packets to the charging rails to simulate the effect of litter and other debris. We've tested the effect of leaves on the line.

Our air-monitoring equipment reveals much lower pollution on days when no diesel trains run, particularly for Nitrogen Dioxide (NO^2), which gives us confidence that fast-charge battery trains help to cut local air pollution. They're quieter too, peaking at around 63dB compared with a diesel train's 93dB.

The importance of driving precision

In early tests our drivers had to stop the train very precisely before charging could start. This led us to adjust sensors to allow a tolerance that matches normal driving standards. The reason is simple, the charging rails down at track level remain isolated from electrical supplies as a safety measure until the train is properly positioned.

The train lowers its conducting shoes as it approaches the charging rails. The shoes run onto a short approach ramp that forms part of the rails. Only when sensors confirm the train is correctly positioned can current flow. This is not a flaw but a feature so that were someone to fall from the platform when the train isn't there, then there's no chance of electrocution.

Wet weather performance

While the system works in wet weather, our sensitive monitoring equipment noticed small currents leaking to earth through wet leaves which led to an automatic cut to charging power. This is correctly safe but inconvenient from an operating perspective, so we've coated the underside of the charging rails to prevent such nuisance leakages.

Pre-production tests looked at the effects of snow, pictured right, on charging shoes and rails and reported no problems.

Differing driving styles

The batteries on board the train gradually discharge with each trip but we found that driving style had less effect than we expected and it was overall time on the charger that made the difference to the batteries' state of charge. Even with this, it mattered little overall provided the train's batteries received current for 3-4 minutes every trip.

How does fast-charge work

The batteries by the lineside gradually discharged during the day. Typically, they might start the first trip of the day at 100%, drop during a train charging and then slowly trickle upwards after the train leaves. When it returned, the lineside batteries would again drop and slowly trickle up.

Early tests showed that the batteries would drop to around 70% by the end of a day. When the Innovation team doubled the power coming from the train's regenerative brakes, the batteries stayed pretty much topped up all day, needing little lineside charging and so less overall drain on the lineside batteries.

This suggests that even if supplies to the lineside batteries failed and they became depleted, we could keep running a service for several hours.

The lineside batteries are an 'off the shelf' product more typically used as back-up power supplies in hospitals. The lineside batteries partially fill a small shipping container that's equipped with air conditioning to keep them cool and a fire suppression system for emergencies.

The container takes a standard DNO three-phase feed of 63 amps at 400 volts, taking some of this power for its air conditioning and using the rest to charge the batteries. This demand is equivalent to a light industrial unit so well within the capability of local power grids across the rail network.

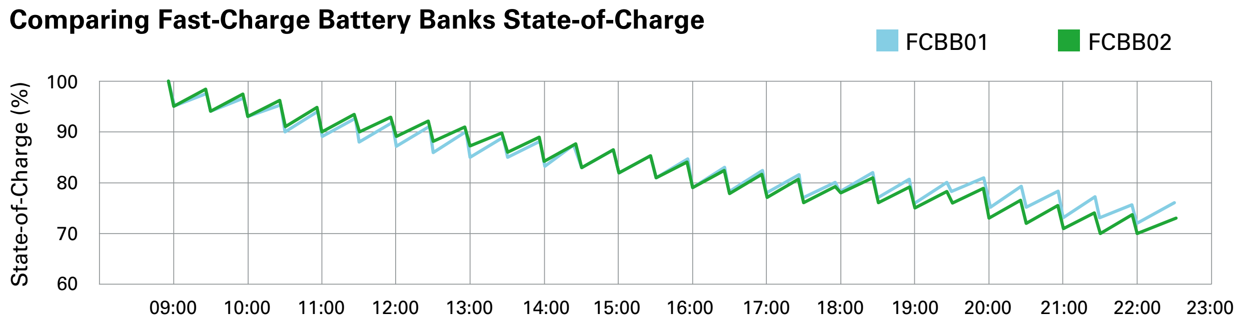
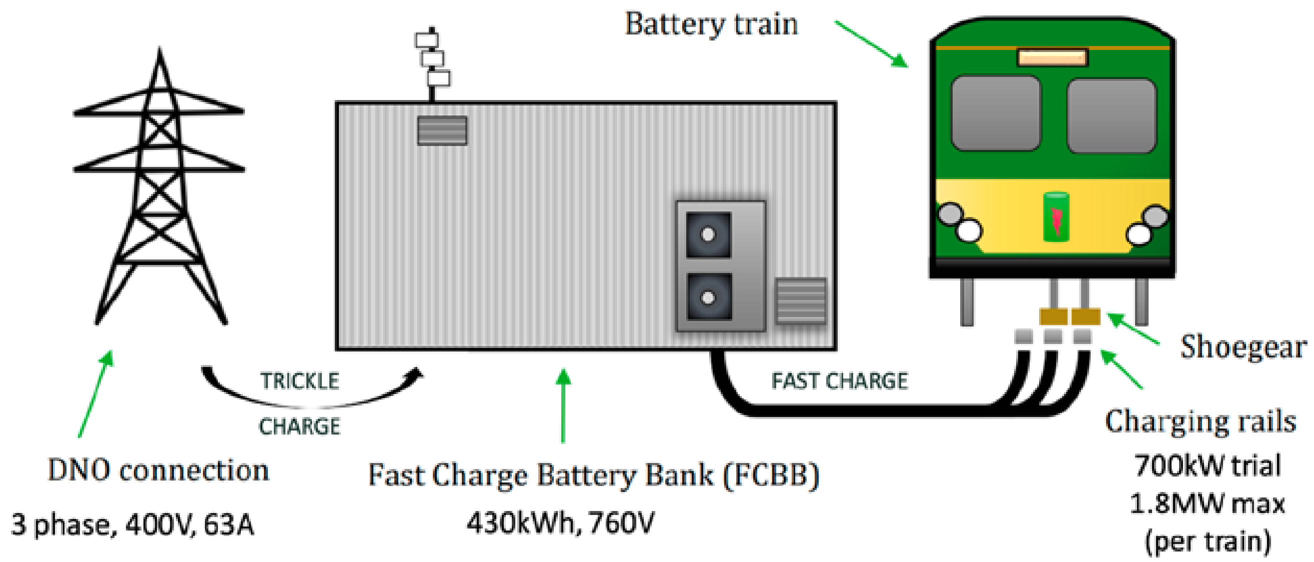


Fig 3a FCBB State-of-Charge

State-of-charge for Fast Charge Battery Banks 1 and 2 during a typical timetable for the West Ealing – Greenford Branch line. Test data from "Full Timetable Test Day" on 30 June 2025. Regenerative braking switched off, standard auxiliary loads, tare.



The Fast Charge Battery Bank (FCBB) has special interlocks so that it only supplies current to the charging rails when a train is in position, with systems to detect earth leakage or other problems.

Each FCBB supplies a set of charging rails which come as a triple set with a positive rail in the middle and negative rails on either side so that the orientation of the train doesn't matter.

They take power from the lineside batteries at up to 1MW and feed it into the train via two shoes. From there it's stored in three 84kWh batteries made by Hoppecke under each power car, giving the whole train over 500kWh.

The shoes under the train can also take up to 1MW in power during charging. With two sets under our test-bed train, that means every minute of charging gives the train approximately 7km of range.

This is more than we needed for Greenford (which is an 8km round trip from West Ealing) so our team scaled back the charging current from its maximum 1000 amps to 350A, equating to 2.3km per minute charging.

Each of the three charging rails is four metres long and weighs 70kg, which makes installation easy, allowing them to be installed in a single shift. An FCBB weighs only ten tonnes which makes its installation within the capacity of a lorry crane. And they take an ordinary power supply so there's little need to make special arrangements with electricity supply companies.

Each power car also has a traction convertor unit which controls the rate at which the batteries can charge and draws power from them to the train's traction motors as the driver requires.

In common with most modern electric trains, the testbed is also capable of using regenerative brakes which use the traction motors as generators to feed power back into the batteries as the train slows down. This keeps energy that would otherwise be wasted as heat from brake discs.

The overall result is clear. This technology works. We've applied it to a train and we've installed what's needed at the lineside. Our test train has shuttled back and forward for a year. It's carried passengers. It's done everything we need a train to do.

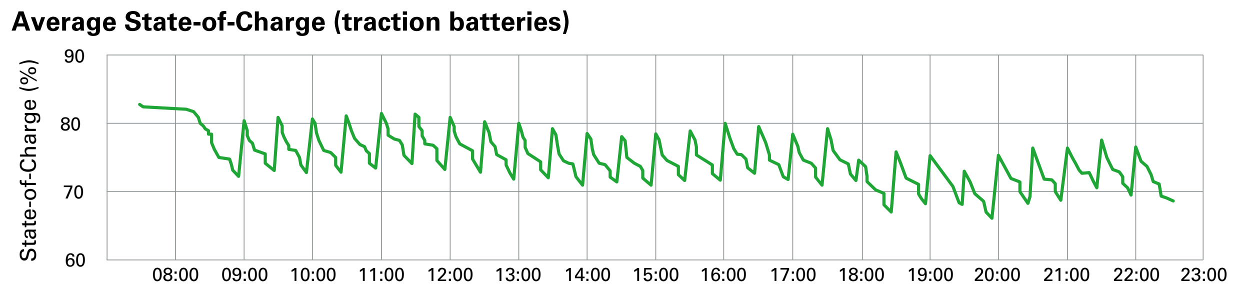
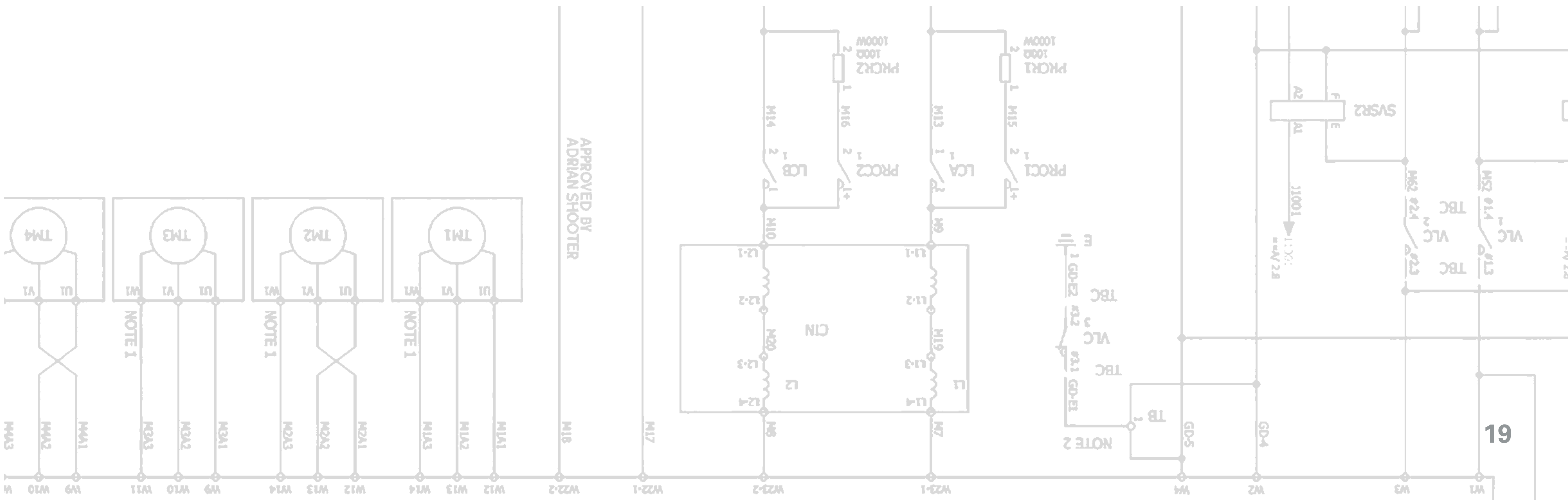


Fig 3b Average State-of-Charge

State-of-charge for train batteries on unit 230001, during a typical timetable for the West Ealing – Greenford Branch line. Test data from "Full Timetable Test Day" on 30th June 2025. Regenerative braking switched off, standard auxiliary loads, tare.



Future potential

Great Western Railway has spent 2024 running a test-bed battery train back and forward between West Ealing and Greenford in all weathers to test the concept of fast-charging battery trains that need far less money – around half – spent up front but with the potential to deliver a cleaner and greener service we all want.

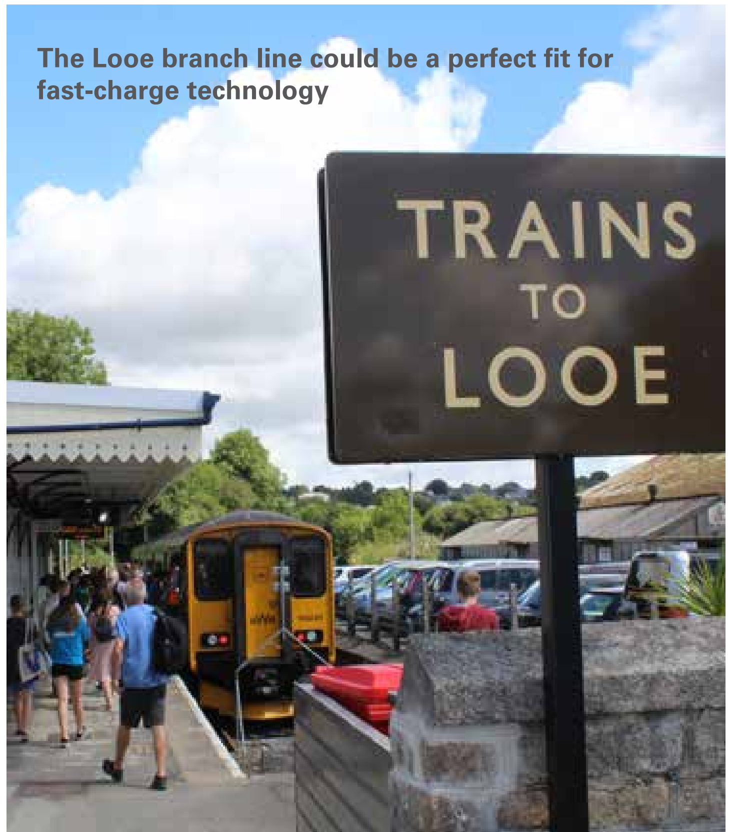
It believes that such trains have a clear future. At Bristol Temple Meads, for example, GWR could turn over local commuter services to battery trains, reducing diesel fumes from under that grand station roof. Doing our bit to make Bristol even better.

Further west, the lovely shuttle from Liskeard to the pretty port at Looe is perfect for a train that tops up its batteries between every trip. Likewise, St Ives, Falmouth or Newquay.

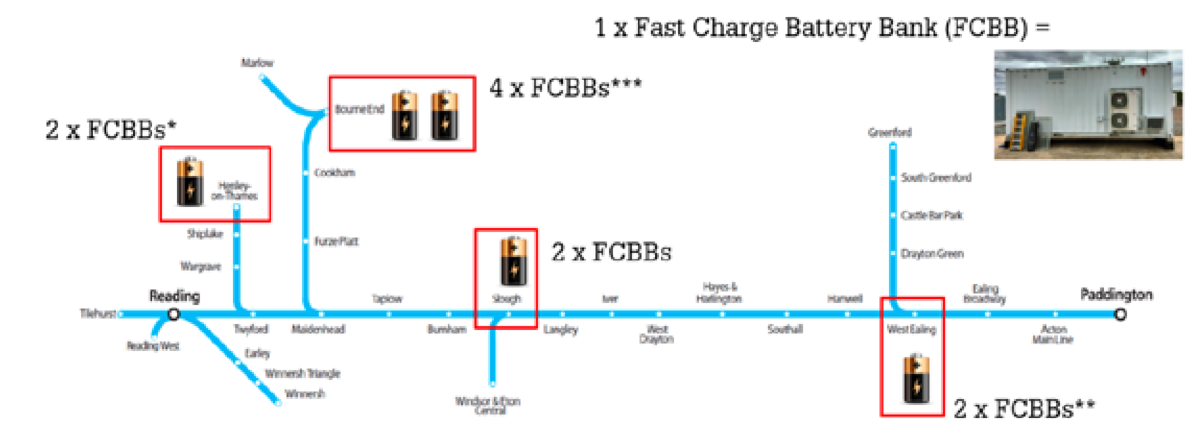
Fast-charging stations significantly reduce range anxiety. Trains need only stop for a few minutes to take power and because they stop anyway for passengers, it makes sense. With the information taken from our trial, our engineers and planners can plot the best places for charging points and build timetables around them so that we can cover longer distances such as the Barnstaple branch or the cross-country routes from Bristol down to the South Coast.

We could not have said this just a few years ago when we didn't have suitable batteries or fast-charge technology. But with many hours of testing under our belts, we can more confidently explore a future powered by battery trains.

It's too early to roll out a plan. Our train is only a test-bed; it's not a model geared for mass production. There's more work to do with manufacturers to incorporate fast-charging equipment into their designs.



The Looe branch line could be a perfect fit for fast-charge technology



* 4 x FCBBs will be required at Henley if 2 x 3-car battery trains are to be coupled and used during the Regatta. Put them at Henley to avoid the complication of whether the bay or the mainline platform is used for charging at Twyford.

** The 2 x FCBBs already placed at West Ealing Platform 5 may need upgrading; see report FCBTT-00019 for details.

*** 2 x FCBBs serving Platform 1 and 2 x FCBBs serving Platform 2. It has been confirmed that a 3-car Class 230 will fit in both platforms.

Fig 4 Battery banks for Thames Valley

Schematic showing top-level feasibility assessment for operation of fast-charge battery trains on the Thames Valley branch lines: number of battery banks and locations.

Where overhead power lines already exist, we picture our next generation of trains boosting their batteries on the move, ready to switch when they reach the limit of those lines.

Striking the right balance

This means we can develop the best balance between fast-charge rails at stations - ideal for one end of a branch line - with short stretches of overhead lines for on-the-move charging. This brings the prospect of a network of battery train services running with infrastructure that's been optimised to provide the best overall value for money for passengers and taxpayers alike.

The benefits come in that value and come in the cleaner air that electric trains bring. They're quieter too so we don't disturb our lineside neighbours. And more resilient because they don't come to a halt the minute that mains power disappears.

Fast-charge batteries have applications beyond the regional and local trains mentioned here. Today a Great Western Railway train from London to Penzance switches from electric to diesel power at Newbury, only 53 miles from Paddington and with over 250 miles to go. With batteries on board and some judicious installation of masts and wires along the way, there's potential to reach much further West without burning diesel by fast-charging its batteries along the way. This is essentially a bi-mode approach but not with the mix of diesel and electric power that we already use. A battery train is, at heart, electric so future fleets could run using power from overhead lines where they exist and run with batteries between overhead sections.

There are other advantages to batteries. We put our test-bed batteries under the floor because that's where we had space. But a new train specifically designed for batteries might put them on the roof. This provides the prospect of trains with lower floors that can match Network Rail's standard platforms and provide level boarding which lets passengers in wheelchairs board and alight without having to ask staff for help. It also benefits passengers with heavy luggage and parents wrestling prams on and off trains.

Batteries provide spacial flexibility that's simply not available from diesel engines.

Boosting community resilience

GWR's trial shows that a lineside cabinet of batteries provides more than enough electricity for trains and this raises the prospect of power being shared with critical local consumers as a way of increasing civil community resilience in the face of power cuts.

They could smooth the demand on local distribution networks, ready for the click of kettles when a popular soap opera's credits roll on TV.

Or they could provide increased resilience to rail services by feeding signalling equipment during power outages.

A lineside battery placed at a station to fast-charge trains might also provide power to electric vehicle charging points in the car park for passengers' cars.

They might be charged from solar panels erected over those cars or from other local renewable sources such as wind turbines. We could set the lineside batteries to charge only when cheap electricity is available.

The list of possibilities is only limited by imagination and it all stems from our desire to switch from diesels to cleaner and greener trains.

Frequently Asked Questions

Why are fast charge batteries cheaper than full electrification?

Research by the Rail Industry Association and data from Network Rail suggests that full electrification cost around £1 million per single track kilometre (stkm) on simpler sections of route, rising to £1.5m/stkm for more complex areas.

That comes from the sheer number of masts and lengths of wire needed as well as making changes to bridges and other infrastructure. Full electrification also takes years, with many miles of track to wire as well as electrical supplies to arrange with the National Grid.

In contrast, GWR's experience suggests that fast charge batteries come with costs of around £0.4m/stkm. Their lineside equipment is simpler with batteries housed in containers that can be built in factories and craned into position from a lorry. They don't need special supplies, simply a standard industrial connection that is widely available. Current estimates suggest a fast-charging station will cost £1.3m each.

Our fast-charge rails can be installed and connected quickly with none of the complexities of working at height. A charger has three short rails that each weigh 70kg, making them easy to carry into place and install.

Can the fast-charge system be fitted to other types of rolling stock?

GWR fitted its charging system to a former London Underground electric train. This strongly suggests that it's possible to retrofit it to other electric trains. The key to making retrofitting easy is that the original train has electric motors driving its wheels. Trains with mechanical or hydraulic drive to their wheels from a diesel engine would not be suitable for retrofitting.

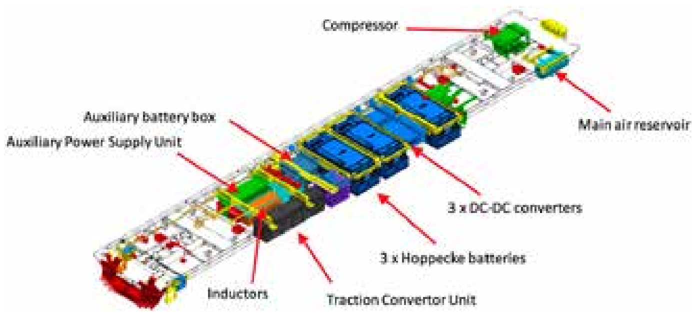


Fig 5 Fitting fast-charge to other rolling stock

Equipment layout for Class 230 unit 230001 BEMU, showing location of major units.

How widely have you demonstrated your fast-charge battery technology?

The branch line between West Ealing and Greenford is only 2.5 miles long with three intermediate stations, but our test-bed train has hosted groups from 26 organisations as well as many media outlets. The 27 are: Transport for London, Network Rail, London Borough of Hounslow, Southeast Communities Rail Partnership, Octopus Energy, Given Agency, First Group, Cambridge University, Arriva Rail London, 3ti Hubs, Rolls-Royce, RSSB, Buckinghamshire Council, Rail Development Group, South Western Railways, Avanti West Coast, England's Economic Heartland, Transport for the South East, Marlow GLOBE Business Park, Slough Borough Council, Metrolinx, British Broadcasting Corporation, Great British Railways Transition Team, Imperial College London, Gatwick Airport, Central Japan Railway Company and East West Rail.

Are battery banks the only compatible lineside equipment or could this fast-charge system be powered in other ways?

Our trial shows that batteries are cost-effective and easy to install. Batteries simply store energy, just as a fuel tank does. Other ways of doing this are available. We looked at flywheels and electrical supercapacitors as alternatives, but they didn't fit as well as batteries.

Does GWR plan to replace its entire diesel fleet with BEMUs or is other rolling stock being considered?

Based on evidence from our fast-charge battery train trial at West Ealing, and growing experience of new technology and electrification, the future for our network is trains powered by batteries and electricity. But before we can switch to battery-electric, we will need the correct infrastructure in place so trains can charge their batteries. That requires investment and won't happen overnight. While we work towards a long-term track-and-train solution, GWR has leased a fleet of Class 175 trains to allow us to rejuvenate our regional and suburban services, enabling existing stock to be redeployed on other parts of the network.

How closely does this tie into the Rail Industry Association's report into total costs published last year, which considered partial and full electrification between Bristol and Penzance?

This report from consultant Arthur D Little for the Rail Industry Association looked at long-term scenarios for bringing electric trains to the line between Bristol Parkway and Penzance, which is a key GWR route that's also shared with other operators.

It looked at three scenarios stretching forward 30 years. The three are keeping the status quo, full electrification with electric trains, and partial electrification from Bristol to Exeter with battery trains. It found the last option to provide the lowest total costs over 30 years. This option included two battery charging points between Exeter and Penzance.

Using public finance, Arthur D Little concluded that the break-even point between partial electrification and the status quo came at 14 years. Over the full 30 years, it estimated an overall saving of nearly £800 million as well as carbon savings of 780,000 tonnes.

If funders opt for private finance for trains and infrastructure, the partial electrification option with battery trains is still cheaper than the other two options but overall savings are less over 30 years at almost £600m.

Is GWR exploring any other options to achieve a cleaner railway beyond fast-charging?

Over the past three years, GWR and Network Rail have been working on plans to deliver a 'whole railway' solution to our long-term rolling stock needs. This vision provides value for money, is affordable, environmentally sustainable and, most importantly, benefits our customers. Our track-and-train solution is based on a minimal amount of electrification investment to permit battery-electric operation. Short sections of overhead lines, combined with fast battery chargers represent a small proportion of the overall cost of replacing our ageing an increasingly expensive diesel fleet. New trains and infrastructure provide the opportunity to work with partners to support modal shift to public transport, unlock economic growth and development, and achieve local decarbonisation targets.

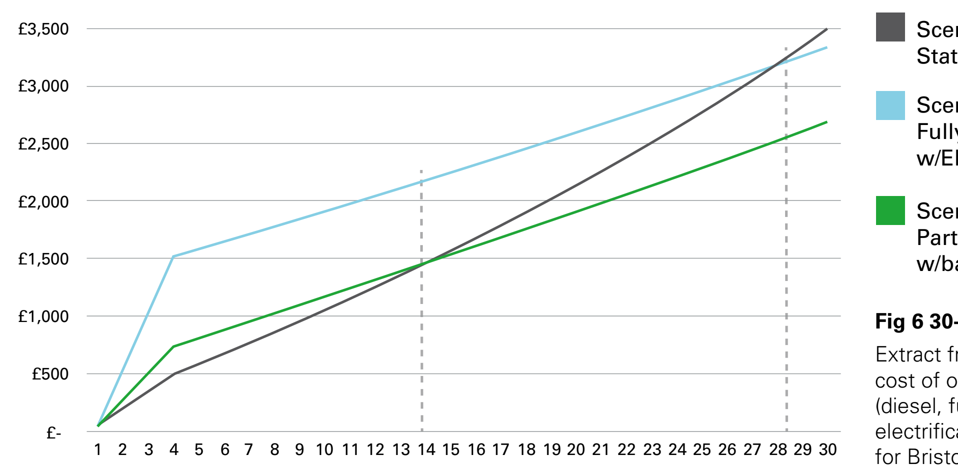


Fig 6 30-year graph

Extract from Arthur D Little Total cost of operation comparison (diesel, full electrification and partial electrification with battery trains) for Bristol Parkway to Penzance.

Notes and Methodology

Test data: measured data from unit 230001 is based on data transmitted from Traction Control Unit and Battery Management Systems on the train. The output has been checked using calibrated measuring equipment. The figures and data expressed within this report, relating directly to GWR battery train 230001, are calculated from real measured data. GWR branch line DMU comparison data is based on measured fuel consumption from a sample of class 165 trains operating over the same branch, using traceable recorded data from depot fuel logs. Environmental impact assessments, including DMU emissions evaluations, carried out based on data in the Department for Transport Carbon Emissions TAG Table A 3.3. Similarly, UK emissions data has been taken from Greenhouse Gas Conversion Factors 2022 issued by the Department for Energy Security and Net Zero, noting that future carbon intensity projects are based on a combination of TAG Table A 3.3 data and "Power sector carbon intensity outlook in Great Britain 2020-2050" Published by Ian Tiseo, May 26, 2025

Cost of ownership European study data source: Study on the use of fuel cells & hydrogen in the railway environment - Report 1, State of the art & business case and market potential. EU Shift2Rail Joint Undertaking and Fuel Cells and Hydrogen Joint Undertaking, 2019. Figure 12. https://www.fch.europa.eu/sites/default/files/Report%201.pdf

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