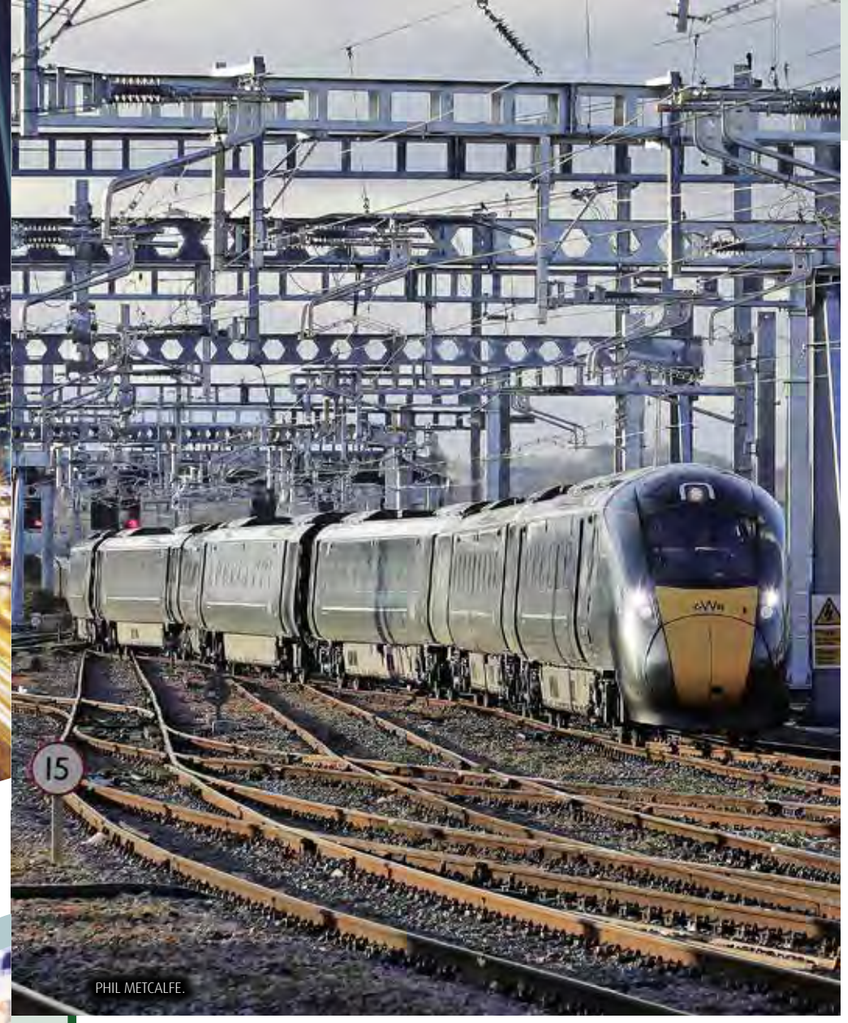
SEE INSIDE FOR: A national traction climate strategy ■ Designing a 'green' project ■ The latest alternative train tech: batteries & hydrogen ■ The case for more wires

Decarbonisation *Special*



PHIL METCALFE.

CONTENTS

Welcome

On June 12 2019, in one of her final acts as Prime Minister, Theresa May announced that the UK will end its net contribution to global greenhouse gas emissions by 2050.

By amending the Climate Change Act 2008 to incorporate this target, it made the UK the first G7 country to legally implement a net zero-carbon policy.

Ambitious as this is, the rail industry was (and remains) ahead of this curve with its own plans to become the world's leading low-carbon network by 2040.

A Rail Industry Decarbonisation Taskforce has been at the vanguard of these efforts, ever since its creation in 2018 in response to the challenge made by former Rail Minister Jo Johnson to phase out diesel traction within the next 20 years.

On pages 46-51, *RAIL* speaks to RSSB's Lead Carbon Specialist Andrew Kluth on his role as technical author of the Taskforce's final report, which was published in July 2019 to plot a way forward for the industry to achieve this vision.

Meanwhile, Network Rail's Head of Strategic Planning Helen McAllister provides an update on the Traction Decarbonisation Network Strategy (TDNS), which is being developed to inform government decisions on providing support for further electrification, alongside the deployment of alternative technologies such as battery- and hydrogen-powered trains.

Whatever pathway is set out later this year by the TDNS, the industry stands ready to deliver the low and zero-emission technologies that will be required - as demonstrated in this special 24-page supplement by the Birmingham Centre for Railway Research and Education (40-41), SYSTRA (56-57) and Furrer + Frey (58-59), plus train manufacturers Siemens Mobility (54-55), Alstom (52-53), Hitachi (44-45) and Vivarail (42-43). ■

PAUL STEPHEN
Features Editor, *RAIL*

EDITORIAL

Managing Editor: Nigel Harris
Deputy Editor: Stefanie Foster
Head of News: Richard Clinnick
Contributing Writer: Paul Stephen
Production Editor: Mike Wright
Art Editor: Charles Wrigley
Sub-Editor: Richard Hampson
Managing Director: Tim Lucas

ADVERTISING

Account Director: Julie Howard

Full steam ahead

The UK could be about to re-take the lead in railway innovation, says BCRRE Managing Director ALEX BURROWS and Senior Lecturer DR STUART HILLMANSEN

2020 is shaping up to be a big year for the Birmingham Centre for Railway Research and Education (BCRRE).

Already the largest institution of its kind in Europe and the lead university partner of the UK Rail Research and Innovation Network (UKRRIN), the final touches are currently being made to a 3,000m² building that will open on the University of Birmingham campus this summer.

More than £16 million has been invested in this state-of-the-art facility that is located at the University's new School of Engineering and will feature meeting and seminar rooms, a range of laboratories, exhibition and catering spaces, workshops and offices.

The building will also house the UKRRIN Centre of Excellence in Digital Systems, where solutions are being developed in partnership with the rail industry and other UKRRIN members in areas such as cybersecurity, data integration, smart monitoring and future train control.

In conjunction with the opening of the new building, BCRRE will also soon host a newly established Centre of Excellence in Rail Decarbonisation.

With a mission to drive forward research, education and innovation in this area, it will be the first dedicated centre of its kind in Europe and will also be officially launched this summer.

"The railways globally have two grand challenges, which are realising the opportunities of digitalisation while also cutting greenhouse emissions and tackling climate change," explains BCRRE Managing Director Alex Burrows.

"In digitalisation there is still a big gap between the aspirations and expectations of what new technologies will be able to do and the tangible products and services that are actually being offered, and so we have the UKRRIN Centre of Excellence here to help bring it all closer together and to accelerate those innovations.

"But we also have significant strengths in decarbonisation, which is why we are launching a new Centre of Excellence to collate the range of skills and capabilities we have, and to present them more coherently as we have already done with digitalisation."

He adds: "There is a clear appetite from the broader population, as well as industry, to cut our carbon footprint and this will help ensure that we play a leading role in those efforts."

The new Centre of Excellence will focus on four specialist areas: power electronics, climate adaption, aerodynamics and sustainable traction systems.

Work being conducted in power electronics will include power supply modelling and optimisation that will build on projects already undertaken with Merseyrail, in Singapore and in the Channel Tunnel in which sensors and infrastructure monitoring devices have been placed to provide real-time data.

BCRRE will also embark on detailed engineering to increase the efficiency of power conversion in traction motors and other parts of the train, and in reducing energy losses in the power distribution network.

BCRRE will be able to capitalise on its involvement in the EU-funded research project E-LOBSTER, in which a new transport grid interconnection system is being installed on the local rail network in Madrid that will maximise the use of local renewable energy sources and make the electricity distribution network and the electrified transport network interact with each other.

Meanwhile, BCRRE's research focus on climate adaption and resilience recognises that the railway not only has to mitigate its impact on the global climate but must also be resilient to changing temperatures and conditions.

According to Burrows, there will be synergies here between the Centres of Excellence in Decarbonisation and Digital Systems. For example, there is the potential for climate data supplied by the Met Office to be superimposed onto simulators and a digital twin of the UK network developed by colleagues working in digitalisation.

Aerodynamics is also an important area for research, as any reduction in drag and air resistance due to structures will improve the energy efficiency of rail vehicles.

Research into sustainable traction systems will include the increased usage of hydrogen fuel cells to power trains, which BCRRE pioneered with the construction of 10¼in-gauge locomotive *Hydrogen Hero*, followed by the creation of the UK's first standard gauge hydrogen-powered train, in partnership with Porterbrook.

Named the HydroFLEX, BCRRE was asked in June 2018 to convert a Porterbrook-owned Class 319, owing to its unrivalled technical and research expertise in this type of traction. A Memorandum of Understanding was signed in September that year before the first HydroFLEX demonstration unit made its debut just nine months later at Rail Live in June 2019.

HydroFLEX will shortly begin main line testing ahead of its planned (although yet to be confirmed) appearance at Rail Live 2020 on June 17-18 at the Quinton Rail Technology Centre, Long Marston.

Senior Lecturer in Electrical Energy Systems at BCRRE Dr Stuart Hillmansen says: "HydroFLEX is the first full-scale hydrogen train in the UK and has been very successful as we look to move away from diesel traction towards a cleaner environment.

"Our view is that the right way to provide traction is via electrification but for less dense parts of the network this is unlikely to be economical. Our analysis over many years and our research in hydrogen shows that it is possible to completely decarbonise by using electrolysis that is powered using renewable energy to create the fuel."

As part of BCRRE's efforts to develop hydrogen traction even further, work is ongoing to design the world's first bi-mode unit that can be powered by overhead wires or hydrogen fuel cells.

Funding has also been secured from Innovate UK to create a company that can provide the necessary infrastructure needed to support hydrogen trains, including fuelling stations and hydrogen generation facilities.

Hillmansen adds: "We are developing a fully modular and scalable solution for a fleet deployment of hydrogen units. We've built the train so now we need to do the fuelling station.

"The company should be set up by March and there will be more information on this at Rail Live, but it demonstrates yet another way in which we are helping to provide the workforce of the future by giving industry the capabilities to deliver the railway of the future.

"Industry will be able to use this knowledge to help to meet the challenge of decarbonisation and develop technologies as we see on HydroFLEX."

BCRRE has already moved one step closer to its goal of securing a commercial procurement of hydrogen trains in the UK through its recent ground-breaking work with Michigan State University.

Researchers from the two universities contributed to a decision in December 2019 by the San Bernardino County Transportation Authority (SBCTA) in California to order the first commercial hydrogen-powered trains for use in North America.

SBCTA's Arrow service will operate over a nine-mile corridor using hydrogen multiple units supplied by Stadler from 2024.

Following this success, Hillmansen is now appealing to government to support a UK train operator to make the same choice.

He says: "The option is now there for the railway to proceed with procuring hydrogen trains and we are here to demonstrate that the technology exists to help government and operators meet their low carbon ambitions. All the building blocks are in place and this is going to happen, and we want to lead that race." ■

The UK's first standard gauge hydrogen train makes its debut at Rail Live 2019. The HydroFLEX went from the concept design stage to carrying its first passengers on demonstration runs in just nine months. NIGEL HARRIS.

> "It is possible to completely decarbonise by using electrolysis that is powered using renewable energy to create the fuel."
>
> **Dr Stuart Hillmansen, *Senior Lecturer, BCRRE***

> "There is a clear appetite from the broader population, as well as industry, to cut our carbon footprint."
>
> **Alex Burrows, *Managing Director, BCRRE***

(L-R) Network Rail Chairman Sir Peter Hendy, DfT Permanent Secretary Bernadette Kelly, BCRRE Managing Director Alex Burrows and Porterbrook Head of Innovation Helen Simpson board the HydroFLEX for a test run at Rail Live 2019. JACK BOSKETT/*RAIL*.

Destination Decarbonisation

BCRRE and the Rail Alliance will be running a sustainability and decarbonisation event in partnership with Quinton Rail Technology Centre at Long Marston on May 20.

Named Destination Decarbonisation, it will build on the success of the inaugural event held at QRTC last September which included an exhibition, workshops and presentations from speakers including David Clarke (Railway Industry Association), Mike Noakes (Department for Business, Energy and Industrial Strategy), Helen Simpson (Porterbrook) and representatives from RSSB and Midlands Engine.

BCRRE Managing Director Alex Burrows says: "We're very excited to be hosting an event that has already attracted lots of interest, and that will look at practical applications for technologies, and opportunities for the supply chain.

"We would like to explore how academia can help government to deliver a better railway. As a university, we are on the same side as every player and we want our knowledge to create the best opportunities for government and wider society.

"We have some exciting announcements to make and will be launching a number of things very relevant to the supply chain."

To find out more, register for your free place, or to exhibit, visit: *www.railalliance.co.uk*

FURTHER READING

***RAIL 881* – Innovation incubator**
***RAIL 872* – Focused on the future of rail**
***RAIL 855* – Fast track to the future**

Vivarail prototype 230002 on test on the Cotswold Line. The three-car train is fitted with batteries and diesel gensets, but Vivarail plans to build trains in the future that don't use diesel power at all. VIVARAIL.

Ready to charge

Vivarail could be about to revolutionise rail traction with its latest innovation

Vivarail continues to lead the way in finding solutions for the decarbonisation of the railways.

The company, which was founded on the back of plans to recycle former London Underground trains and produce high-quality, low-price trains for various routes across the United Kingdom and further afield has contracts with three train operating companies so far, each offering a different product.

The first deal, for three Class 230s for Marston Vale, was for diesel-electric multiple units, using diesel gensets. The second, which enters traffic this year, is a fleet of diesel hybrid trains for Transport for Wales, and the third will be electric trains for South Western Railway's Isle of Wight operations.

The TfW train could provide the launchpad for a number of projects as the issue of emissions becomes a critical issue for 'UK plc'.

> "We have an export plan and clearly there is a market for our Fast Charge product."
>
> **Alice Gillman,**
> ***Head of Marketing, Vivarail***

Testing and training has been carried out on 230002. This is the UK's only battery train approved for carrying passengers in traffic and has been used to develop the TfW fleet.

Alice Gillman from Vivarail explains that the train has an operational range of 40 miles on battery power alone and that this will be improved for future orders.

Vivarail will also be keeping an eye on the Traction Decarbonisation Network Strategy (TDNS) currently being prepared by Network Rail. Rail Minister Chris Heaton-Harris recently told Labour's Luke Pollard that the TDNS will: "Indicate where routes might be electrified or where hydrogen or battery trains could be deployed. The TDNS will, therefore, inform future decisions about electrification."

The three-car train test set is fitted with two batteries in each driving motor vehicle, while it has a diesel genset in the centre car. However, during the various trials conducted at Long Marston and on the main line the centre car is not switched on, meaning the '230' is running purely on battery power. This is the same formation as the TfW trains.

The TfW fleet will have their gensets 'eco-fenced', so they will not be running in stations or designated built-up areas; this will be the first time this method of powering a train will be used by a UK operator.

Gillman also believes these will be the last diesel-powered trains that Vivarail will build. "We eventually want the gensets gone, and we want to keep the 0% emissions going," she adds.

Each lithium-ion battery fitted to the train is rated at 100kWh, yet they are the same size as the diesel gensets fitted to the West Midlands Railway Class 230s. This is because Vivarail's plan is for all its trains to be of the same modular design.

Gillman confirmed there is much interest in the concept and that Vivarail has looked at many routes where a battery train could operate - including the Thurso-Wick line in the far north of Scotland. She said this, and other routes, could run the train to demonstrate how to remove diesel trains from this type of line. With the technology proven and the train approved, such a demonstration could take place in the near future.

Battery trains will be the focus for Vivarail from now on, using a variety of methods to charge the batteries. Gillman said that battery trains can take advantage of existing electrification and fill in gaps to save time and the cost of infrastructure upgrades.

"Take the Thames Valley branches, the diesel units could be removed and battery trains with Fast Charge put in instead, this would immediately remove emissions from key, busy commuter routes, similarly in Cornwall where battery trains could run the shuttle services into tourist hotspots, such as St Erth-St Ives.

"Alternatively, a 25kV/battery train could operate a line such as Glasgow-Anniesland - using the OLE to charge and for traction and then running on battery power for the remaining section."

Prime Minister Boris Johnson's plans to devolve power to local authorities could also be beneficial for Vivarail, as could the Government's plans to spend £500 million exploring the possibility of reversing lines closed by the Beeching Report in the 1960s. Gillman says that the low-cost of the trains and the ability to introduce them into traffic relatively quickly is proving attractive in discussions with authorities.

They could also be used in and around bigger cities she says, and that one losing bidder for a recent franchise had included plans to use the trains around such a location. "People do need to make decisions outside franchising," she explains regarding the infrastructure and trains needed.

The current plan is for the first production battery train to be dispatched to the United States at the end of the year where it will be used to demonstrate its capabilities to prospective customers.

Gillman says that each Vivarail battery train will be delivered with two batteries in each driving vehicle. A two-car train will have a range of 40 miles; a three-car train will have a 60-mile range. "They will be simple. In operation, a Vivarail battery train would arrive at its destination, and as soon as the driver takes the key out the train begins to charge. After ten minutes the train will be fully charged, the driver turns the train on and can then complete another 40 or 60-mile trip depending on the formation."

Concerns over range remain for some customers, rolling stock companies and operators and Vivarail understands this, but

> "We eventually want the gensets gone, and we want to keep the 0% emissions going."
>
> **Alice Gillman,**
> ***Head of Marketing, Vivarail***

Gillman says: "There's a perception that the batteries will run out of power but, just like a diesel engine, you'd never use them until they're completely drained."

Another key area making Vivarail battery trains an exciting proposition is the expected production time. Gillman says that from receiving an order, a train will take nine to 12 months to construct. In theory, an operator that bought a fleet at the start of this year could have had them in traffic by Christmas. "We would look to sell them rather than lease them as we want to be a manufacturer," she says.

Another key moment for Vivarail will be Brexit. The company is well-placed to export its emissions-free trains abroad, selling UK innovation around the world while creating jobs and skills here.

Gillman explains: "We have an export plan and clearly there is a market for our Fast Charge product." New Zealand has been touted as a potential market, where the railway is interested in battery power as it considers its decarbonisation plan.

She also reveals that Vivarail can work on more than just the former D-Stock/D-Trains with which it made its name. "We can re-traction other trains just as easily."

Vivarail is eyeing off-lease electric multiple units that could form the platform for its battery-powered trains, although Gillman is unable to say which fleets might be used.

"Our unique selling point is our Fast Charge system. It's a really compelling offer," she says.

Vivarail has come a long way in the past five years and with this innovative system it is poised to bring about a revolution in rail traction in the 2020s. ■

Transport for Wales has five hybrid Class 230s on order that will enter traffic this year. These will be the first of their kind to operate in the UK. TRANSPORT FOR WALES.

Sparking a revolution

When it comes to powering a zero-emissions train with no overhead line infrastructure, battery power is clearly the answer, according to Hitachi

Hitachi UK Battery train specifications

Battery Electric Multiple Units (BEMU)

Range: 55-65 miles
Performance: 90-100mph
Recharge: 10 minutes when static
Routes: Suburban near electrified lines
Battery life: 8-10 years
Source: Hitachi

Hitachi battery trains have been successful in Japan already and a UK product could be seen as soon as 2021. HITACHI.

Over the next decade around 1,000 diesel-powered vehicles will need to be replaced with vehicles that meet emissions standards.

Hitachi, which has been building bi-mode trains for the UK since 2012, and electric trains since 2006, says that retro-fitting old vehicles alone will not be good enough to improve capacity, reliability or passenger satisfaction.

Battery power is the future - not only as a business opportunity for the company, but more importantly for the opportunities it offers the rail industry. In 2016 it introduced the world's first battery-powered passenger trains in Japan, and brought out an updated version in 2018.

Electrification would be useful in many parts of the UK network. Government policy is currently focused on alternative forms of power, rather than rewiring the railway. In line with this, Hitachi has identified various towns and cities where battery trains would prove useful, including in Manchester, Leeds, Glasgow, Edinburgh, Hastings and Bristol.

Vice President and Executive Officer of Hitachi Ltd, and Group CEO of Hitachi Rail, Andrew Barr explains that when he took up his new role last year he embarked on re-engaging with the broader industry after working in Italy for four years as Chief Executive Officer of Ansaldo STS.

He says that he found himself constantly being asked about battery power.

"Hitachi has experience in this. We launched Hayabusa in 2007," he explains, highlighting the fitting of batteries to a High Speed Train power car and Mk 3 coach that was subsequently tested as part of the New Measurement Train. It travelled more than 62,000 miles without a failure in its hybrid traction.

> "People are waking up to the business side of it. This is about how we can demonstrate the technology."
>
> **Andrew Barr,** ***Vice President and Executive Officer of Hitachi Ltd, and Group CEO of Hitachi Rail***

This formed the test bed for some technology for the Intercity Express Programme train, but without the batteries. "We have run battery trains and hydrogen trains in Japan; the hydrogen train was later converted to battery power. I feel passionate about decarbonising our transport system. My daughter will be 21 in 2040 and we're responsible for the world we pass on.

"People are waking up to the business side of it. This is about how we can demonstrate the technology."

The company points to the success of the Class 385 in Scotland as a train that potentially could be modified.

Seventy have been delivered north of the border, but there is an opportunity to fit batteries on them if required, and this would be very different to Hayabusa. "Things move on. Hayabusa's batteries were twice as big and half as powerful as what's available now," says Barr.

He highlights how other transport modes have embraced change: "buses are fully electric or hybrid. We have electric trains that can regenerate power and the batteries could be charged via the overhead wires."

He says that retrofitting the technology to Hitachi's existing fleets would be easy, and because of their modular design the company can modify any of the new Hitachi fleets operating in the UK, the first of which could be ready as soon as this year if required.

"We have studied what works, and have set targets; we think upwards of 55 miles is possible. We've looked at various routes and the modes required, as well as charging, including the current issues around gradients."

Battery technology is constantly advancing. Barr points to the mobile phone industry as an example, and Hitachi believes costs and weight reduction, as well as increasing capacity and recyclability of batteries, will continue as rail joins the supply chain currently serving the automotive and power sectors.

Not only that, but battery power can deliver big savings for government too. Battery power can be used as part of electrification schemes, allowing trains to bridge the gaps in overhead wires where the costs of altering the infrastructure are high - in tunnels or bridges, for example. This would also have the immediate benefit of reducing noise and emissions in stations or built-up areas.

Barr explains: "Branch lines are often shuttle services run using diesel trains. We think battery trains can replace them on the routes they typically serve - like the Thames Valley for example. The train could run on electric from Paddington and then on batteries on the branch. This could be a way to address emissions in busy stations and bring passenger benefits immediately.

"We have experience in bidding for these projects abroad [Hitachi has been carrying out research and development into alternative fuel trains since 2003] and we know it works in the light rail sector."

As for existing trains on the UK network, Hitachi's submission to the Transport Select Committee last year regarding decarbonisation mentions the possibility of fitting batteries to the Class 800-802 fleets.

Furthermore, Hitachi is expanding its capabilities through the purchase of ABB Power Grids. It describes the company as: "a world leader in charging technology," and says its own experience as a whole-system integrator and prover of new technology gives it a competitive advantage.

For the battery project, positive discussions are taking place with a number of interested parties for a trial, with both Class 385s and Class 800s being candidates for conversion. "There are some great target areas available to us in the UK where passengers would really see the benefits of electric power. Operators are all under pressure to provide enhanced reliability and availability on routes and without long-term infrastructure investment, battery is the best solution for everyone. What is great is that from the people we are having discussions with, the enthusiasm and ambition for decarbonisation is there for all to see." Barr adds.

The company is well aware of the needs of the industry in the future. "New rolling stock bids will need to be ready for alternative power and there will surely be more electrification. I would like to think we will not be building diesel trains in ten years," he says.

Hitachi has welcomed Network Rail's Traction Decarbonisation Network Strategy (TDNS) but it says it must reflect and align with the rapid progress in battery technology and where that will be in Control Period 7 (April 2024-March 2029), CP8 (April 2029-March 2034) and CP9 (April 2034-March 2039). Barr says battery trains can actually enable the business case for discontinuous electrification by bridging some of the gaps.

The company also believes that the current debate is oversimplified - reduced to a choice between diesel or 'clean' fuel.

What it believes is that the transition to decarbonisation will be a sliding scale, such as removing one engine at a time from the '80x' fleets until they all have been replaced.

Barr sums up Hitachi's thinking: "We've got the pedigree. We've had hydrogen and battery trains running in Japan for quite a while now. It is a matter of making it work over here. We'd like to run a train with passengers on in the next 12 months.

"If you look at the trains we've delivered in the UK, we have designed and developed unique solutions to industry problems - such as our bi-mode fleet.

"We have incredible technology available to us and the next step is to deliver an innovative battery product that will support generations for years to come - and I think the time is right for that." ■

Costs and power

The costs of batteries are expected to halve in the next five years, before dropping further again by 2030.

Hitachi cites research by Bloomberg New Energy Finance (BNEF) which expects costs to fall from £135/kWh at the pack level today to £67/kWh in 2025 and £47/kWh in 2030.

United Kingdom Research and Innovation (UKRI) is also predicting that battery energy density will double in the next 15 years, from 700 Wh/l to 1,400. Wh/l in 2035, while power density (fast charging) is likely to increase four times in the same period, from 3 kW/kg now to 12 kW/kg in 2035.

Tri-mode trains

- **Batteries could be installed on Class 800-802/804 trains**
- **Battery-only power for stations and urban areas**
- **20% performance improvements or 30% fuel savings**

Source: Hitachi

A strategy for change

GB Railfreight 59003 *Yeoman Highlander* approaches Swindon on November 15 2019, with the 1123 Merehead-Wootton Bassett. Decarbonising freight and rail plant vehicles has been identified by the Rail Industry Decarbonisation Taskforce as a particularly difficult challenge, given the lack of suitable alternatives to diesel or electric traction. MARK PIKE.

The Traction Decarbonisation Network Strategy will shape the industry's move towards meeting carbon reduction targets, reports **PAUL STEPHEN**

The threat of catastrophic global climate change has forced all energy users to re-evaluate how they source their power and how efficiently it is used.

In a bid to curb the dangerously high levels of greenhouse gases currently being emitted into the atmosphere by human activities, scientists and environmental campaigners have long called for a radical transition away from fossil fuels towards renewable sources of energy.

The UK Government responded last summer by making one of the world's first legally binding commitments to bring all greenhouse emissions to net zero (compared with 1990 levels) by 2050. Ministers in Scotland have been even more ambitious by legislating to achieve the same target five years earlier.

According to figures released by the Department for Business, Energy and Industrial Strategy, some progress has already been made in the UK - estimates show that total national greenhouse gas emissions were some 43.5% lower in 2018 than in 1990.

This reduction was driven mainly by a downward trend in emissions from power stations, as electricity generation switched from coal towards renewable sources.

Such was the scale of the shift that by 2018 transport had replaced the energy sector as the single biggest contributor to all UK greenhouse emissions - it is now responsible for some 28% of the total amount.

In order to tackle transport emissions and to improve air quality, government announced plans in October 2018 to ban the sale of new petrol and diesel cars by 2040 (currently revised to 2035).

This will require the majority of drivers to switch to using electric vehicles, which - provided the UK's electricity supply can be decarbonised even further - will effectively be classed as zero-emission vehicles.

Although responsible for just 2.5% of total transport emissions, the UK rail sector has been handed a similar challenge - in February 2018, former Rail Minister Jo Johnson called for the phasing out of diesel-only traction on the network by 2040.

> "Access to finance is going to drive a lot of the innovation we need."
>
> **Andrew Kluth,** ***Lead Carbon Specialist, RSSB***

The Department for Transport turned to the industry to devise a plan to reach this target, which will require the replacement or conversion of more than 3,000 carriages or vehicles currently used in diesel passenger trains.

A Rail Industry Decarbonisation Taskforce was subsequently assembled, with membership from organisations representing major parts of the industry - including the Railway Industry Association (RIA), Rail Delivery Group (RDG) and Rail Freight Group (RFG).

Chaired by former Angel Trains CEO Malcolm Brown, the Taskforce published an interim report in January 2019 setting out technical options. That was followed by a final report in July that included an economic appraisal and route map for delivery of a low-carbon railway.

"I was recruited in 2018 after Jo Johnson made his announcement to get all diesel trains off the network by 2040," says Andrew Kluth, lead carbon specialist at the RSSB (formerly the Rail Safety and Standards Board) and technical author of the final report.

"He had written to Paul Plummer [Rail Delivery Group Chief Executive] with a request for the industry to set up a group of the wise and great to come up with an independent view that captured the great majority of opinion from across industry.

"In order to be seen as impartial and to represent an industry cross-section, RSSB was a natural place for the Taskforce administration to sit."

The final report concluded that removing diesel-only trains by 2040 was indeed achievable but could only be done with a "balanced and judicious" mix of cost-effective electrification alongside the targeted deployment of hydrogen and battery technology.

Supported by RIA's recently published report on the Electrification Cost Challenge and an RSSB technical report into decarbonisation (known as T1145), the Taskforce said that progressive electrification of the most intensively used lines was without doubt the lowest whole-life cost and whole-life carbon solution. ➤

➤ Elsewhere on the network, where a business case could not as easily be made for electrification, battery and hydrogen-powered trains were deemed able to meet journey time requirements. The report added that it should be possible to convert or replace in excess of 2,400 diesel vehicles to use these alternative technologies by 2040.

The Taskforce's research also showed that diesel-only or diesel bi-modes could have a limited role as a transitionary technology to help reach a more stringent target of net zero-carbon emissions on the network by 2050, although they would have to be re-engined or replaced entirely as part of any bid to bring it to net zero by 2040.

Meanwhile, the report highlighted the need for decarbonisation to be properly incentivised in any new industry structure to emerge from the root-and-branch Rail Review being conducted by Keith Williams.

Other strategic recommendations included the need for government to set out clear, consistent and enabling policies, to allow industry to innovate and deliver against agreed targets in a cost-effective manner.

The report also called for the creation of an industry-wide delivery plan, via a process

A Great Western Railway Intercity Express Train calls at Stroud on January 12. Although more environmentally friendly that diesel-only units, bi-mode trains such as these will have to be replaced or converted in the next 20 years if the rail network is to become net zero carbon by 2040. JACK BOSKETT.

> "It's all very well to say that something needs to be done but government has to make decisions based on cold, hard facts."
>
> **Helen McAllister, *Head of Strategic Planning for Freight and National Passenger Operators, Network Rail***

that was to commence with a strategic review led by Network Rail called the Traction Decarbonisation Network Strategy.

Kluth adds: "I don't think anything in the final report is a revelation, but it was clear from the beginning that it would require an institutional and integrated approach to meet this challenge. The railway as a system is such a complex web and the taskforce was mindful of this from the start.

"There was a recognition in industry that although rail is naturally a low-carbon mode of transport, road transport is decarbonising faster than we could have imagined just ten years ago.

"With the National Infrastructure Commission's new national freight strategy and a report from the Committee of Climate Change also influencing government, the writing was on the wall [for rail]. It was therefore fascinating to see how many people had really good ideas about how to get this done."

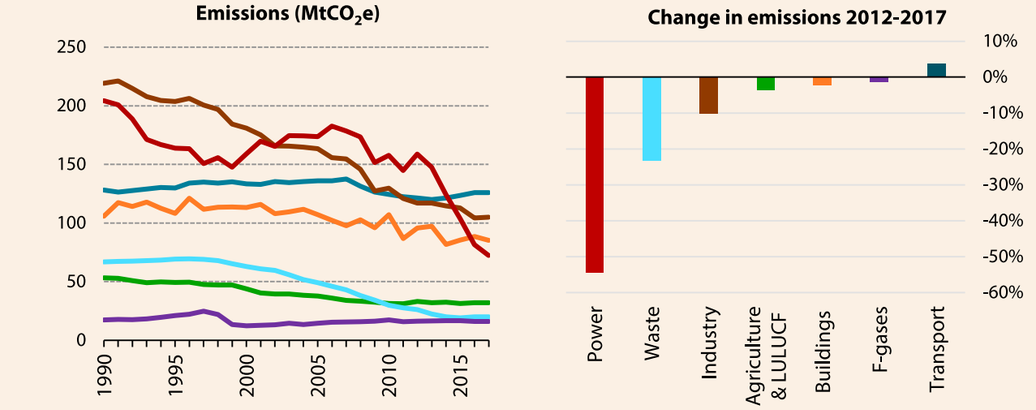
The report was welcomed by government, with former Rail Minister Andrew Jones heralding it as "a clear and ambitious strategy for the rail industry to go further and faster in decarbonising the network".

Current Transport Minister George Freeman subsequently reiterated the Government's support of its recommendations as recently as January 27, when he told (then) Transport Select Committee Chairman Lilian Greenwood in a Commons Written Reply: "The strategy will inform Government decisions in 2020 about the pace and scale of further rail decarbonisation."

Kluth says it is no surprise that no firmer action has been taken by government since last July, given the amount of parliamentary time occupied by the UK's departure from the European Union, the time required to hold an unplanned General Election in December, and the need to wait for the conclusion of the yet-to-be-published Williams Review.

However, he says that policy decisions will have to be made sooner rather than later. Key decisions on the refurbishment

Emissions reductions have been focused in the power and waste sectors



Source: BEIS (2018) *2017 UK Greenhouse Gas Emissions, Provisional Figures*; BEIS (2018) *2016 UK Greenhouse Gas Emissions, Final Figures*.
Notes: The chart on the right-hand side shows changes in sectoral emissions between 2012 and 2017; buildings emissions in this chart are temperature-adjusted. 2017 emissions are provisional estimates and assume no change in non-CO_2 emissions from 2016.

Source: Committee on Climate Change

and replacement of rolling stock must be taken very soon if no more diesel trains, which would have a serviceable life well beyond the proposed 2040 deadline, are to be introduced.

That would also provide more certainty to funders, whom Kluth says are hesitant to invest in any particular type of traction until a more concrete policy direction has been set.

"The report is very clear that it [decarbonisation] has to be policy-led and that the right funding mechanisms need to be put in place," he adds.

"If you speak to rolling stock companies or freight operators, they will tell you that it's very difficult to get finance for diesel trains as funders want an asset that is economically viable.

"The life of a train is typically 30 years or more, and so to fully finance it funders will want it to run for as long as possible. Any train bought now will be running in 2050 - and that has started to affect the market, so access to finance is going to drive a lot of the innovation we need.

"Decisions will be needed in the next couple of years if we are going to procure more trains, and post-Williams we need to look at how to ensure the industry has the right mechanisms to pull together on this."

One output of the Taskforce's final report that is being pursued is development of the Traction Decarbonisation Network Strategy (TDNS), to identify preferred combinations of electrification, hydrogen and battery technologies.

The TDNS will consider not only long-term solutions, but also the most effective transitional arrangements. It is being administered by Network Rail's System Operator function, and following its completion later this year NR's regional and route businesses will develop decarbonisation programmes to support the conclusions of the TDNS though their strategic business planning for Control Period 7 (CP7, April 2024-March 2029).

Allied to the strategy, RSSB, RIA and NR will also set out five-year research plans to reduce technical uncertainties and to address particular technological challenges - such as how hydrogen can be generated and at what cost, and what capabilities batteries will have.

There is also an investigation under way by RSSB (known as T1160) into what alternatives are available for freight and rail plant vehicles, which in most cases cannot currently be hauled by anything except diesel or electrification due to the length and weight of trains and their energy requirements.

Leading the team which is writing the TDNS is NR's Head of Strategic Planning for Freight and National Passenger Operators within its System Operator function, Helen McAllister.

"The Strategy was one of the recommendations of the Taskforce's final report, which sets out that traction is responsible for two-thirds of rail's total greenhouse emissions, and that there are a range of options available that can decarbonise the network and some that can't," she tells *RAIL*.

"It points to some lines where electrification is the probable answer and some where it definitely isn't. And then there's a grey bit in the middle, so there was a need to do something more in-depth and detailed."

She adds: "There is also a need to give information to funders and specifiers, as it's all very well to say that something needs to be done but government has to make decisions based on cold, hard facts.

"The TDNS will go into the mix of all the other information that ministers receive to make future decisions on public funding."

Network Rail was chosen to lead the development of the TDNS not only because creating network strategies is part of its licence conditions, but also due to the fact that as an asset owner much of the relevant network information sits within the organisation.

Initial work began last April, following the publication of the Taskforce's interim technical report, when McAllister and her team "started pulling together the relevant industry bodies and got the programme up and running".

Supported by representatives from NR's devolved regional and route businesses and its central analysis and economics team, plus further resource supplied by RIA, RSSB and the freight and rolling stock communities, McAllister's team has engaged with more than 100 organisations to gather information and viewpoints from industry.

She adds: "I have a team of four dedicated staff, but industry has really come together over this, so resource has not been scarce, and we've been well placed to pull people together and take views from across industry.

"It's great to have had this level of engagement as, ultimately, it gives us the best chance of getting a finished product ➤

> “It’s crucial that we do this now. It’s no good if by the time we give an answer it’s too late to do anything about the problem.”
>
> **Helen McAllister, *Head of Strategic Planning for Freight and National Passenger Operators, Network Rail***

At Welshpool on January 14, passengers hurry to join Transport for Wales 158838 and 158836, which in new TfW livery form the 0729 Aberystwyth-Birmingham International. The Traction Decarbonisation Network Strategy will be submitted to funders including the Welsh Government (which manages the Wales and Borders franchise), the Department for Transport and Transport Scotland for endorsement.

➤ that is credible and that government can support. If we haven’t spoken to anybody then it is purely an oversight, and they are more than welcome to contact us directly or any other organisation like RIA, which is in contact with us.”

According to McAllister, the TDNS is due to be sent to government in two stages later this year, with a completed strategic case going before ministers in July followed by a network economic case in October.

A programme business case will be provided in line with the Treasury-approved five-case business case model. It will explore options for funding, and identify legislative targets for government as well as which technologies should be deployed where and when.

McAllister says that part of the reason to publish the TDNS in two stages is because of the necessity to “move at pace”, given the intensity of the focus on climate change that has emerged in the public consciousness, combined with the rapid rate of change in technology.

Another reason is so that the TDNS is able to incorporate any recommendations made by the Williams Review, as the final Strategy will be designed to allow future franchise requirements to be informed by a long-term vision of traction decarbonisation.

“It’s crucial that we do this now. It’s no good if by the time we give an answer it’s too late to do anything about the problem,” she says.

“Technology is always going to move on, which is a good thing, but we’ve had to draw a line in the sand. We can keep on refreshing the Strategy, but there’s enough to go on now to give us confidence [in our findings].

“I’m also hugely encouraged that Keith Williams has already mentioned decarbonisation, which means that we are likely to be affected by whatever future structure of the industry he recommends.”

Although McAllister will not be drawn on what the final recommendations of the TDNS will be, she confirms that it will address three strategic questions - including how much individual decarbonisation measures will cost, and to what extent they will reduce carbon dioxide emissions.

It will also address how long it will take and how much it will cost to decarbonise traction in order to meet a net zero carbon target of 2050, and a more ambitious target of net zero by 2040.

She explains: “The national target is 2050, so that looked like a sensible date to look at and what additional measures would be needed to exceed Jo Johnson’s diesel-only targets and to go the full way to net zero.

“Lots of organisations would like to do it even quicker, including the Scottish Government’s desire to decarbonise its railways by 2035, so we also picked 2040 as a date to look at. It’s also important to make a distinction between zero carbon and net zero carbon, as there’s an expectation that some industries such as aviation will not be able to fully decarbonise, and so the UK’s ‘netting’ capability will be needed for that.”

Once published, the TDNS should help NR’s regional planning teams to identify and prioritise areas of infrastructure work for CP7 and beyond. Funding should also be easier to obtain if Treasury has approved the principles outlined in the finished document.

It should also provide confidence to those buying and manufacturing trains to invest in technologies and product development, in the knowledge that these technologies will be adopted somewhere.

McAllister makes it clear, however, that for those who think the TDNS will release a deluge of new money from government, she expects the deployment of electrification, hydrogen or battery technology to be incremental.

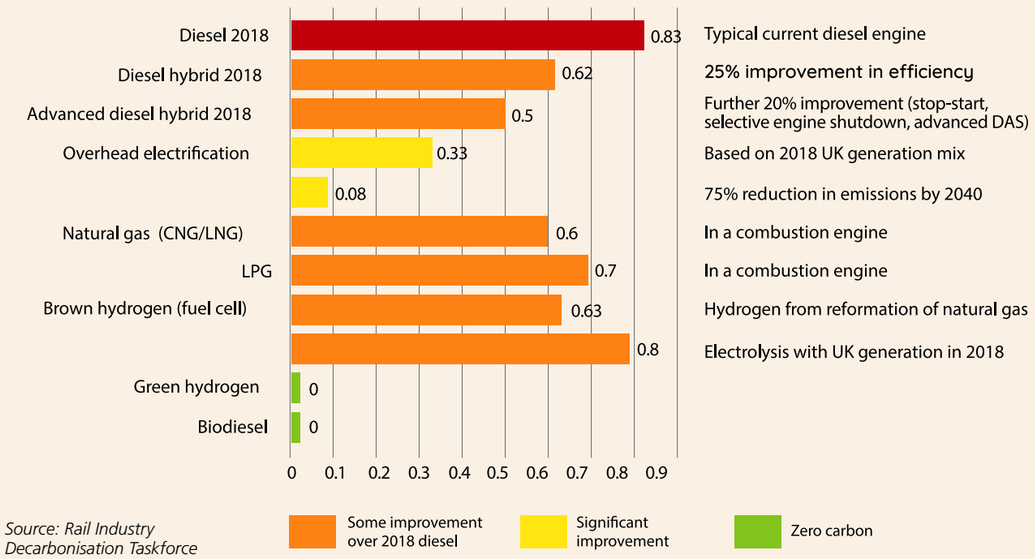
She warns that key lessons will have to be heeded from the scale of Network Rail’s proposed electrification programme for CP5 (April 2014-March 2019), which NR has since admitted was “overly ambitious” after its failure to deliver it in full with the funding and resources it had available.

However, what looks certain is that the TDNS will not be consigned to gather dust in the desk drawers of ministers in Whitehall. They will surely feel compelled to act on climate change - not only for the sake of future generations, but also for the sake of their political careers.

McAllister concludes: “We are wedded to the Enhancements Pipeline and against sweeping spending judgements unless they are bottom-up costed. We want to learn the lessons from the electrification programme, so this is something to ramp up, rather than a big bang.

“This report will have to be kept alive as climate change is not going to go away. The key message is that the railway is capable of zero carbon traction. It is technically possible, but we need to do it in an efficient manner to make it an attractive and cost-effective proposition to government.” ■

CO_2 emissions (kg CO_2e/KWH)



Source: Rail Industry Decarbonisation Taskforce

Andrew Kluth

Andrew Kluth joined RSSB in May 2018 as lead carbon specialist, to support the work of the Rail Industry Decarbonisation Taskforce.

Having previously worked for the Hong Kong Government, Kluth has more than 30 years’ experience in environmental and sustainable policy making, strategy and advisory roles - both in-house and as a consultant to UK and international companies.

He has degrees from Liverpool and Bath Universities and is a Fellow of IMEA.

Helen McAllister

Helen McAllister joined Network Rail in 2004, following the completion of a doctorate at Imperial College London.

She is now Head of Strategic Planning for Freight and National Passenger Operators within NR’s System Operator function, where her remit includes leading network strategies such as the Railway for Everyone Network Strategy and the Traction Decarbonisation Network Strategy.

The market leader

Alstom is already an experienced manufacturer of hydrogen-powered trains, with two of its iLint HMUs already proving themselves in service

There is one company that has more experience than any of its train-building rivals when it comes to putting hydrogen-powered trains into passenger service.

That is because, to date, Alstom is the only manufacturer to have achieved this feat following the entry into service of the Coradia iLint in Germany in 2018.

Launched at the Innotrans international trade fair in Berlin just two years earlier, the train is based on the company's popular Coradia Lint diesel multiple unit as a zero-emissions alternative to providing regional services.

Developed with the support of the German Ministry of Economy and Mobility, hydrogen fuel cells ensure that the vehicle's only emissions are water, while the lack of internal combustion engines means the train can operate in near silence.

The first test run of an iLint prototype took place at Alstom's Salzgitter facility in March 2017. Further trials and formal approval to run on the German main line swiftly followed, before two of the trains went into commercial service in Lower Saxony in September 2018.

According to Alstom, the iLint has proved popular with passengers. Meanwhile, the experience of having the trains in service for the past 16 months has equipped engineers with an invaluable supply of performance data and given operators around the world further confidence in the maturity of this technology.

Head of Business Development in the UK and Ireland Mike Muldoon says: "16 months in service is a long period of experience in operating these trains which no one but Alstom has, and which places us uniquely in the global market.

"Other manufacturers are beginning to place their own interpretations of the hydrogen train into the market but, in practical terms, the iLint remains clear evidence that the technology is viable and is working well.

"We've had no operational issues and the feedback from passengers is that it is a positive upgrade on the DMUs they previously used and a much quieter environment. Performance-wise the train does exactly what a DMU did and demonstrates that someone can seamlessly slot in a zero-emissions solution to take its place."

He adds: "We've also been able to finesse the product, we've seen its estimated range increase and we know a lot more about how the hydrogen is consumed, so there's been lots of incremental lessons learned but absolutely no shocks."

During its time in passenger service, the iLint has proven that it is able to match the Coradia Lint DMU's top speed of 140kph (87mph) while its range now exceeds 800km (497 miles) on a single tank of hydrogen.

Crucially it is also more energy-efficient than its DMU counterpart due to its ability to recover energy through regenerative braking, and from its smart power management and flexible energy storage capabilities.

Using hydrogen fuel cells to supply power and lithium-ion batteries for storage means that electrical energy is only required when the train is accelerating over a sustained period, and that the cells can be almost powered down when the train is braking.

During this initial deployment of the iLint, hydrogen has been sourced from industrial sources and trains are fuelled via a mobile fuelling station.

Alstom is working with partners to provide more permanent hydrogen infrastructure, however, which includes the potential to produce hydrogen locally and in a greener manner via electrolysis and wind energy.

Having signed a deal in November 2017 to build 14 iLint trains for the Local Transport Authority of Lower Saxony, the world's first hydrogen filling station will be erected in Bremervorde prior to the fleet's entry into service in 2021.

An order for a further 27 iLint trains secured in May 2019 also includes the supply of hydrogen and fleet maintenance for a period of 25 years, and these trains will go into service in the German state of Hesse in December 2022 - fuelled from a filling station located on the Hochst industrial park.

The success of Alstom's hydrogen technology is not only confined to Germany, with trials of the iLint in the neighbouring Netherlands announced in November 2019. The company's two demonstrator vehicles in Germany are expected to switch to the line between Groningen and Leeuwarden in the north of Holland early this year, with an ambition to introduce hydrogen multiple units (HMUs) into revenue-earning service by 2023.

International interest in the iLint also extends to France, where state operator SNCF has recently pledged to place an order for 15 hydrogen-powered trains.

This is widely expected to comprise an adapted version of the iLint HMU in Germany and could go into service in as little as two years.

Closer to home, representatives from Scotland's Railway travelled to Germany in November 2019 to sample the iLint as the country embarks on an ambitious target to fully decarbonise its railways by 2035.

Given the success of iLint, Alstom hopes it can play a part in Scotland achieving this goal with its bespoke hydrogen solution for the UK, codenamed 'Breeze'.

Launched in partnership with Eversholt in January 2019, the Breeze design concept involves the conversion of off-lease Class 321 electric multiple units into HMUs.

Alstom's Widnes facility would complete this work to fulfil any UK orders, although Muldoon says that this is unlikely to happen unless a robust business case can be made involving the provision of hydrogen infrastructure in addition to the trains.

In England, Northern has submitted a bid to the Department for Transport for funding of an HMU trial in the north east that would include a hydrogen filling station on Teesside, where sources of industrial hydrogen can be readily accessed.

Meanwhile, the Scottish Government is exploring the possibility of tapping into its abundant sources of renewable energy to produce hydrogen, or the industrial supply at Grangemouth.

Muldoon explains: "Holland was an obvious next step for iLint, given its operational compatibility with the German network, but further steps will be announced very soon to expand its range geographically.

"The next steps are about commercial integration into service which will be driven by regulation and more than just market forces. We need forward-looking policies like the 2035 decarbonisation target in Scotland (and 2040 for elsewhere in the UK) because if we don't have them, this will be difficult to achieve.

"Breeze is now ready to go as a project, and now we just need someone to fire the starting pistol. We are seeing support from stakeholders in the political arena which have to be aligned with our final development and delivery of the product.

"A hydrogen train without hydrogen is no use to anyone, so the devil will be in the detail and we need to get everything right for those stakeholders. Our job at the moment is to share information so they can understand what is possible and what is needed, and then we can move very quickly to actually cutting metal."

Muldoon is confident that the UK's nascent hydrogen infrastructure will expand rapidly, and sooner rather than later.

A trial is under way at Keele University to mix hydrogen with the domestic gas supply - which is now one of the country's largest sources of carbon emissions - while a report published by the Institution of Engineering and Technology last summer claimed that hydrogen could replace natural gas across the entire country both safely and easily, without any need to change domestic boilers or ovens.

Meanwhile, London will become the first city in the world to operate hydrogen-powered double-decker buses later this year, demonstrating the increased appetite for the fuel from other modes of transport and the potential to co-locate manufacturing and fuelling facilities for road and rail vehicles and thus achieve economies of scale.

He adds: "There is an inevitability about all this, but contracts to supply these trains will be something that has to be earned by manufacturers and not assumed. We need to ensure the product provides a good return on taxpayers' money and fundamentally delivers what it sets out to do, as we have done in Germany and are poised to do elsewhere." ■

Alstom's Coradia iLint is the world's only hydrogen train currently in passenger service, having entered into commercial service in Lower Saxony in September 2018. ALSTOM.

> "The iLint remains clear evidence that the technology is viable and is working well."

Mike Muldoon, *Head of Business Development (UK and Ireland), Alstom*

Electrification

While Alstom has made great strides in hydrogen technology, the company is also a major player in other forms of railway decarbonisation, including in electrification.

The company played a key role in the compilation of the Railway Industry Association's Cost Challenge Report that was published in May 2019 to show that the high costs of recent projects such as the Great Western Electrification Project can be avoided in future.

It highlights that projects have subsequently been delivered in the UK for 33-50% of the costs of GWEP – including those in Scotland, where Alstom supplied its lightweight Clever Cantilever for use in Network Rail's Series 2 and Master Series of overhead line equipment.

Helping integrate cantilever installation with high-output wiring was Alstom's wiring train, which was deployed on the Edinburgh Glasgow Improvement Programme (EGIP) in March 2016.

It can run out catenary and contact wire together at full line tension and be used to run ancillary wires such as earth and feeder wires, meaning that a wire can be completed in one shift as opposed to three shifts using conventional methods.

Muldoon explains: "In Scotland we had the opportunity to demonstrate that electrification can be done more efficiently than perhaps commonly thought. Our wiring train has shown how things can be done both safer and quicker, which is a combination that doesn't normally go together.

"We fully support the RIA paper and its findings. To say that we shouldn't electrify anymore is simply wrong and we now need to focus on where we can do it and how we can do it more efficiently."

Mean, green, clean machines

Head of Rolling Stock Business Develoment GRAEME CLARK explains how Siemens Mobility is in step with the UK's aim of phasing out diesel trains

For the UK government to meet its ambitious target to phase out diesel-only trains by 2040, much responsibility will fall on train manufacturers to develop alternative solutions for powering trains that will make them cleaner and greener.

Yet, all this must be achieved without any sacrifice in the performance offered by diesel, however, which has proven to be a robust and reliable form of main line traction for more than six decades.

Siemens Mobility is certainly not shirking this responsibility and has emerged as a provider of traction that not only reduces emissions but also cuts journey times and enhances the passenger experience.

Already a leading supplier to the UK of electric multiple units (including more than 1,000 vehicles for Thameslink's Class 700 fleet), the global manufacturer now stands ready with other low-emission alternatives and will soon be offering its UK customers EMU fleets that can be part-powered by either batteries or hydrogen.

Graeme Clark, Siemens Mobility's head of rolling stock business development, explains: "The railway is not a big part of the problem when it comes to global carbon emissions, but we are in a good position as an industry to make ourselves even greener and to increase the number of people travelling by rail.

"Diesel is still a sound way to propel trains from a technical viewpoint, but we can't discount the obvious environmental impact and so we are keen to play our part in cutting emissions across the network.

> **"We want the UK to become a Centre of Excellence for alternative technology."**
>
> **Graeme Clark, *head of rolling stock business development, Siemens Mobility***

"With just 38% of the network electrified we think the most energy-efficient solution would be for a general scheme of electrification to be restarted by government, but within that there is also a place for alternative technology to provide zero-emissions traction 'off the wires' via hydrogen fuel cells or batteries."

According to Siemens Mobility, battery technology is particularly advantageous as it can be fitted to either existing or new EMUs to enable them to utilise an overhead or third-rail AC supply where available, but also to move independently of electrified infrastructure as required.

The company has therefore developed what it calls X-EMU 'eco' technology that can be charged from an AC supply when a train is running on an electrified line and topped up through regenerative braking.

According to Siemens Mobility, this provides an X-EMU with a usable range of 80km when running on battery power alone, making it well suited to running on short unelectrified branch lines or in sections of discontinuous electrification which feature extended earthed sections.

This second capability could enable railways to be electrified at significantly lower cost, as wires would not have to be erected though areas with restrictive gauge clearances, such as tunnels and bridges.

X-EMU technology features Lithium Titanate (LTO) batteries that can be fully recharged in less than 12 minutes.

The LTO batteries are also fully temperature controlled, ensuring the system remains unaffected by weather conditions, and have an estimated lifespan of 15 years - significantly longer than any other battery type.

In 2019, Siemens Mobility fitted X-EMU battery technology to the roof of a three-car Desiro ML Cityjet train as part of an innovative pilot project with Austrian Federal Railways.

The prototype has since been approved to enter passenger service, marking a significant milestone in the rollout of this technology across Europe.

X-EMU battery technology also looks set to soon arrive in the UK with Clark confirming that there are plans to convert an EMU in this country prior to a full fleet conversion.

A more restrictive loading gauge will preclude the batteries being fitted to the roof of a train, however, but Clark says that existing four-car units could be upgraded to include underfloor 'eco' technology.

He adds: "The Austrian X-EMU has shown itself capable of achieving a range of 80km in battery mode during recent trials in the Linz area of Austria, and opens up opportunities for other trains to be delivered with the same capability.

"The LTO batteries have a long life, and we are seriously looking at introducing a similar train into the UK as soon as possible.

"It will use the same technology as in the Austrian train, but it will need repackaging. We can't place the batteries on the roof so we'll need to put them under the floor in one vehicle of a four-car unit.

"All the conversion work will be done in the UK and we want it to become a Centre of Excellence for this alternative technology where we can enhance the skills of the manufacturing workforce in the UK."

Future Siemens Mobility EMU fleets will be designed to incorporate hydrogen fuel cells to charge the batteries, giving them a greater range away from electrified routes.

Substantially less polluting than diesel and emitting only water vapour, a new generation of hydrogen fuel cells is currently being developed by the company in partnership with Canadian fuel cell manufacturer Ballard Power Systems to provide traction for Siemens Mobility's Mireo train platform.

A prototype is due to enter service on the European mainland next year, before the technology becomes available to new and existing customers procuring EMUs in the UK by the middle of the decade.

In addition to the onboard technology, Siemens Mobility should also be in a position to offer hydrogen manufacturing and fuelling facilities by leveraging the company's wider capability to also build the wind turbines and electrolysers that enable the gas to be produced using renewable energy sources.

The supply of hydrogen will also be aided by the efforts being made by government and other stakeholders to encourage its increased usage across the country as a fuel source, which include the Department for Business, Energy and Industrial Strategy's £20 million Hydrogen Supply programme.

Clark adds: "We have the technology to fuel trains from green sources with energy for electrolysis supplied from wind power off the coast of Scotland, for example. But we can also tap into brownfield supplies of 'grey' hydrogen from places like Grangemouth, so I don't think the production of hydrogen will be a problem.

"Grey hydrogen is fine but is more carbon intensive to produce so we wouldn't want to do it on a large-scale - meaning the majority has to come from renewable energy sources, which is perfectly possible.

"We can offer the complete package, but it requires serious commitment from government. It can't be business as usual - the technology is deliverable and can be implemented almost immediately so there shouldn't be anything stopping us.

"The next phase is to fit that technology to a train and then test it, and there is a programme for that in Germany before it reaches us here in the UK in the mid-2020s."

Clark also welcomes additional action being taken by government to accelerate the adoption of battery and hydrogen technology.

This includes the commissioning of a root and branch Rail Review that is being chaired by Keith Williams, and is expected to address the future of franchising when it is published in the coming weeks.

Recommendations could well lead to greater incentivisation for operators to procure trains using alternative traction, given their higher capital cost when compared to those using diesel.

Meanwhile, other efforts are being made to address this issue, including the ongoing development of an industry-wide Traction Decarbonisation Network Strategy.

He adds: "Discussions with the Department for Transport and various industry working parties are in progress.

"There is an argument that alternative technologies are expensive compared to diesel, but these technologies pay for themselves over the life of the asset on a 'whole life of ownership' basis.

"Under the current franchise system, the higher cost of procurement to the operator is likely to be less attractive. Unless government gives higher priority to environmental credentials the current system won't work." ■

Siemens Mobility's innovative X-EMU 'eco' battery technology has entered passenger service in Austria, with plans to shortly bring it to the UK. SIEMENS MOBILITY.

Getting electrification back on track

In addition to developing alternative traction technology, Siemens Mobility is also committed to reducing the costs of electrification in order to support its more widespread installation across the network as a prime method of reducing carbon emissions.

Justin Moss, head of electrification strategy for Siemens Mobility's rail infrastructure business, says: "It appears that the Government is looking at electrifying major routes, and as a business we have looked at how we can improve that process and make it cost-effective.

"For example, five or six years ago, when government stopped the use of certain fluorinated gases, we developed air-insulated switchgears that are now installed on the East Coast Main Line. We also have the Sicat overhead line solution that enables OLE masts to be installed further apart, and if you can reduce the number of stanchions required then you also reduce the amount of civils needed, meaning less time on site."

Cheaper, cleaner, smarter

SYSTRA explains how its work means that reducing the carbon footprint does not necessarily mean increasing the cost

A new roof and concourse were unveiled at Leeds station in September as part of a £161m redevelopment project. Led by SYSTRA-owned TSP Projects, its energy-saving design includes an innovative new human centric circadian rhythm lighting system that mimics the patterns of natural daylight to stimulate alertness in the morning and promote good sleep patterns at night. SYSTRA.

In June 2019 former Prime Minister Theresa May committed the UK to eliminate its carbon by 2050, and the transport sector was thrown into the spotlight.

As the highest carbon dioxide-emitting sector in the country, the industry is therefore obliged to play its part in helping the nation to achieve this ambitious target.

SYSTRA has long demonstrated how it takes decarbonisation seriously through its impressive global portfolio of projects, and at all stages of the project lifecycle.

This reputation was reinforced in the UK last August following its acquisition of TSP Projects, which has cemented SYSTRA's place as a major UK force in engineering and consultancy for multiple modes of transport and complex infrastructure.

The acquisition brings SYSTRA's combined UK and Ireland workforce to more than 800 employees across 13 locations, with TSP Projects continuing to operate as a separate business unit and providing high-end, specialist technical expertise in design, engineering and programme/construction management until April 1, when it will be fully integrated into SYSTRA.

In addition to expanding SYSTRA's UK footprint, the acquisition represented a good fit between two like-minded companies with a shared commitment to excellence, safety and innovation.

Evidence of an additional shared commitment to reducing the rail industry's carbon footprint was provided in October when TSP Projects was awarded a contract by RSSB (formerly the Rail Standards and Safety Board) to develop and deliver training on the Rail Carbon Tool.

Launched in May 2019, the Rail Carbon Tool is a web-based application that has been provided by RSSB to all rail industry organisations and companies to enable them to calculate and analyse the carbon footprints of projects and activities, identify and assess low-carbon alternatives, and to select low-carbon solutions.

It has so far been used in more than 140 projects and, in line with the recently updated Network Rail, Environmental and Social Minimum Requirements, must now be used for all infrastructure projects worth more than £1 million.

TSP Projects was awarded the training delivery contract owing to the company's Environment, Ecology and Sustainability team having successfully demonstrated its use on a range of innovative projects.

The training is being delivered by TSP Projects Environmental Consultant and practitioner member of the Institute of Environmental Management and Assessment Elliot Shiers, who explains: "We were commissioned by RSSB to develop a series of case studies of carbon assessments and use of the RSSB Rail Carbon Tool. These case studies highlight best-practice carbon assessments that were undertaken for UK rail infrastructure projects, and key messages including that value engineering and carbon reductions can lead to significant cost savings.

"The overall aim is to encourage more projects to undertake carbon assessments, and this web-based tool allows organisations to do that both quickly and easily, to understand their baseline whole life carbon emissions and to implement lower carbon solutions.

"It is a great accolade for TSP Projects to be leading this and the feedback from the first two training sessions has been excellent. The combination of lectures on social requirements, introducing and accessing the tool and running mock projects on the Rail Carbon Tool has been well received, and there is now lots of interest from individual companies for in-house training, in addition to the RSSB-run sessions."

Examples of where TSP Projects has successfully deployed carbon assessments to help clients achieve decarbonisation targets and whole life costs include on the Oxford Corridor Capacity Improvement project, for which the company helped develop the areas around Oxford needed to accommodate the various improvement programmes such as the Great Western Electrification Project and capacity improvements around Oxford station.

For the latter, TSP Projects delivered a full BIM (Building Information Modelling) Level 2-compliant solution that included new LED lighting installed in buildings, platforms, car parks and sidings with automated PIR controls.

Rainwater harvesting systems were also installed to provide flushing water for toilets, while ventilation heat recovery technology was deployed to capture energy from air extracted from buildings to heat incoming fresh air.

Mike Kimmitt, the principal lighting engineer, says: "As part of a multidisciplinary design for Oxford, we worked closely with a lighting manufacturer to design bollards around sidings that reduce glare and are more energy-efficient. These sites can be up to 500m long and hundreds of bollards have been installed over the years, reducing power ratings from 80W in 2011 to 26W more recently.

"We felt confident we could improve even further, and by challenging and working closely with the manufacturer we have designed a 16W bollard solution, spaced eight metres apart, which represents an 80% energy saving from just nine years ago."

Another project is at Gatwick Airport station, where a £120m upgrade is being delivered by Costain in collaboration with TSP Projects and NG Baileys on behalf of Network Rail.

Improvements include a doubling in the size of the concourse area and more escalators and lifts to reduce congestion and improve access to all platforms.

Following a carbon assessment, approximately 1,000m^2 of ethylene tetrafluoroethylene (ETFE) transparent cladding has been incorporated into the project roof design, which will reduce the requirement for artificial lighting, environmental control or supporting structures.

End-of-life use and disposal have also been taken into account as the ETFE is 100% recyclable and can be re-used to manufacture new ETFE systems.

Meanwhile, annual operational costs will be reduced by an estimated £58,686 and carbon emissions by 143.5 tonnes via the proposed installation of a range of other energy-saving measures, including LED lighting in all lifts, reduced speed for escalators, high-efficiency gearless lifts, hybrid heating and cooling systems and instantaneous water heaters.

In September, yet another project came to fruition when work was completed on a new roof at Leeds station. The transparent canopy over the main concourse is part of £161m redevelopment of the station and surrounding area that is expected to be completed by 2021.

The architectural design concept utilised ETFE to make maximum use of naturally-occurring daylight, and human centric circadian rhythm LED lighting designs that are designed to control the new lighting to simulate the colour and temperature of daylight, improving mood, alertness and productivity of both staff and passengers.

Meanwhile, lighting in toilets is programmed to dim to 20% when they aren't occupied, while extensive thermal modelling has been used to demonstrate the suitability of natural ventilation, meaning that no mechanical ventilation has been required, despite the daylight penetration through the transparent roof.

Computational Fluid Dynamics modelling was also undertaken to demonstrate how hot smoke could be removed in the event of fire by natural ventilation alone, meaning that considerable cost and energy savings could be achieved by excluding mechanical smoke extraction systems from the design.

Kimmitt adds: "Leeds was a fantastic project in which to be involved and we used lots of architectural concepts to brighten the concourse and reduce operational energy requirements. Such a large amount of daylight penetration has made the building very energy efficient, while thermal modelling has proved we can ventilate it naturally, despite all the potential for solar gain on hot sunny days.

"We also saved the client a further six-figure sum by establishing that with positive wind load pressure we could get smoke out naturally without the need for a mechanical ventilation system."

Across the SYSTRA group, other methods are also being used to decrease carbon by optimising the materials used in large infrastructure projects and by reducing their lifecycle impacts from the earliest design phase.

These include considering 'build nothing' options, using lowest carbon materials, minimising excavation works, reducing asset maintenance requirements and increased use of standardisation to minimise waste.

With the life expectancy of most railway assets being 50 years or more, it is an example of the importance of conducting a carbon assessment and how decisions made at the earliest stage of a project can have a much wider impact.

Alan Eaton, SYSTRA engineering manager explains: "Civil engineering in large infrastructure projects plays an important role in reducing the carbon footprint of a project. It is a very material-focused discipline so will result in a large carbon negative impact when assessed in isolation, with major benefits achieved later in the life of the overall system.

"In viaducts, for example, one big thing we're doing at the moment is focusing on modularisation and setting up local sites to bring in pre-cast concrete segments to reduce emissions and the impact of deliveries on local roads.

"We're also looking at using recycled materials in concrete, including cement replacement materials such as GGBFS and power station residues while also reducing concrete volumes by adopting bankseat abutments in place of traditional cantilever abutments, for example. Where steel structures are the only option, adoption of weathering steel for bridge beams also reduces the need for paint and protective treatments and.also decreases impacts of future maintenance requirements.

"For major earthworks our focus is on use of suitable recycled materials as fill, together with preloading of embankment footprints to reduce settlement effects and the need for extensive grids of piles as ground improvement."

He adds: "This is just a snapshot of the sort of principles we're using to reduce carbon across the whole project lifecycle from design, procurement and manufacture through to demobilisation, and by maximising the system benefits as a whole by understanding the impact of each element." ■

> "We used lots of architectural concepts to brighten the concourse and reduce operational energy requirements."

Mike Kimmitt, *Lighting Engineer*

Current beliefs

Director of Furrer + Frey NOEL DOLPHIN thinks that electrification is the future of UK railways, but only if we change our approach

Furrer + Frey is heavily involved in a range of overhead line renewals projects, including a scheme on the Great Eastern network between London Liverpool Street, Chelmsford and Southend-on-Sea. Following a hiatus in new wiring projects, it also hopes that a rolling programme of electrification will be resumed by the government. FURRER + FREY.

When it comes to providing e-mobility solutions in the UK, Europe and across the globe, few companies can call on as many years' experience as Furrer + Frey.

Established in Switzerland in 1923 by young engineers Emil Furrer and Arnold Frey, it has been honing its skills for almost a century since winning its first electrification contract in Lausanne using steam-powered wiring trains – and long before terms like 'e-mobility' or 'zero-carbon' became popular.

With its head office located in Bern and branches in Bellinzona, Montreux, Zurich, Guangzhou, London, Rome and Berlin, Furrer + Frey is now an international leading mid-size supplier of overhead lines which it has delivered to projects in more than 30 countries.

Having entered the UK market in 1980, it now has approximately 20 employees working here on nearly all of the most recent major new wiring projects, including the Great Western Electrification Programme (GWEP), the Edinburgh Glasgow Improvement Programme (EGIP), and several others.

In addition to new wiring projects, the company is also heavily involved in renewals of overhead line equipment (OLE) on the estimated 38% of the UK network that is already electrified.

Within this portfolio is the renewal of Mk 1 equipment installed by British Rail in the 1960s between Fenchurch Street and Southend-on-Sea and elsewhere on the Great Eastern network, and the upgrade of OLE on the Tyne & Wear Metro ahead of the arrival of new trains from late 2021.

Furrer + Frey's UK operation is headed by director Noel Dolphin, who says: "We were delivering carbon-free public transport networks long before people started to use those words. We might still be classed as an SME (small or medium-sized enterprise) but we are rapidly expanding and are well positioned to combine the best electrification techniques from mainland Europe with our growing experience in the UK of installing new or renewing existing OLE."

Its UK order book has gradually expanded over the last ten years but the entire industry is currently enduring something of a hiatus in new projects following a controversial government shift in policy on electrification in 2017 - when large cost increases on GWEP prompted then-Secretary of State for Transport Chris Grayling to cancel several projects on the Midland Main Line and elsewhere.

Dolphin believes that this was a short-sighted response to negative headlines in the press about a single project and ignored a much larger body of evidence pointing to most projects in the UK and across Europe actually being delivered to their planned cost.

He adds: "Most major projects are delivered on time and on budget. GWEP was the exception and as a bigger project it had a bigger impact, when most projects were not being run in the same way.

"Most of the problems have been caused by perception when other projects are being delivered successfully. Scotland has stood out for delivering electrification efficiently, the Midland Main Line project is being delivered well, and unit costs on GWEP have also fallen significantly as the project has matured. It's just not in the news because people aren't complaining about them.

"Meanwhile, although projects abroad are never completely commensurate with those in the UK, comparable projects are being delivered in Germany at a third of the UK target costs, so there is a massive opportunity if everyone can be aligned to deliver the same target of affordable electrification."

With industry consensus being that electrification remains the most cost-effective and efficient way to decarbonise intensively used lines, Dolphin stands by the findings of a recently published report from the Railway Industry Association that states electrification can be delivered in this country at 33-50% lower cost than previous projects.

When added to the report published last summer by RSSB (formerly the Rail Safety and Standards Board) and the Rail Industry Decarbonisation Taskforce recommending that 4,000km (about 2,485 miles) of railway needs to be electrified in order to successfully decarbonise the UK network, Dolphin says it's high time that further electrification was given the green light.

"I completely endorse the findings of both of these reports, in which we were partially involved. We all need to do our part to reduce the impact of the railways on climate change, while providing the other benefits of electrification to the travelling public including journey time savings, noise reduction, increased reliability and improved air quality.

"Where I live, GWEP has decreased journey times to London by around 15%, creating a legacy for the next 40 years over the lifetime of the new trains. Getting there did involve a little pain, but no-one is likely to remember the cost overruns in a few years' time."

According to Dolphin, there is another compelling reason to resume the UK's electrification programme, which is for companies to retain corporate memory and the skilled workforce that has been developed in recent years.

> "We are yet again at risk of forgetting lessons learned and losing skills as people move to other industries."
>
> **Noel Dolphin, *Director, Furrer + Frey***

He says that a boom and bust cycle must be avoided at all costs in which projects are rolled out, lessons learned, and skills improved only for no work to materialise.

He adds: "This is a really big concern. The UK has learned a lot from recent electrifications and has proven in Scotland what efficiencies can be gained from a rolling programme, but there is now a big gap before the next projects are likely to commence. People leaving GWEP and the Midland Main Line upgrade will be looking for their next job and cannot wait two years, meaning that people will leave the industry as they have done before.

"Perhaps in five years' time we will decide to electrify from Cardiff-Swansea, or finish the Midland Main Line up to Sheffield, so where is the joined-up thinking? We are yet again at risk of forgetting lessons learned and losing skills as people move to other industries."

Looking to the future, Dolphin says the benefits will be plain to see if a policy U-turn can be achieved. With Furrer + Frey recently winning work in India based on the company's experience maintaining ageing OLE in the UK, he also thinks that embarking on new wiring projects will help to change an unwanted global perception that the UK is only good at managing dilapidated and overused infrastructure.

Megaprojects such as HS2 could help change that perception, but also more innovative schemes such as the partial electrification that has been proposed for the South Wales Metro.

Under this scheme, a fleet of tram-train and tri-mode trains is being procured that will be able to switch between a mixture of battery, electric and diesel power.

This means the trains will not be wholly reliant on overhead wires, which has opened up the possibility for Transport for Wales not to electrify the entire Valley Lines network in South Wales.

> "Comparable projects are being delivered in Germany at a third of the UK target costs."
>
> **Noel Dolphin, *Director, Furrer + Frey***

Tenders have yet to be issued, but it is widely expected that OLE will be widely installed and that earthed sections will be left under bridges and through tunnels where costly civil engineering work would otherwise be required to provide sufficient clearance for OLE.

Dolphin explains: "The South Wales Metro is really interesting. I think the operator is currently focused on taking ownership of the Valley lines from Network Rail and keeping them functioning well, but we'd like to be part of it when they are ready to roll out electrification and decide to go to tender.

"We've worked on lots of similar projects, such as in Stuttgart where there are lots of feeder lines which don't have a strong enough business case to be electrified, and hopefully we can bring some of that experience to Wales."

Although the company will always be the leading advocate for electrification of the wider UK network, Furrer + Frey is also involved in five projects with a number of unnamed rolling stock companies to develop rapid charging solutions for battery trains.

This builds on the company's experience in providing all-in-one charging stations for buses and trams in Switzerland, Sweden, Spain and the Netherlands.

Dolphin believes that this is a useful technology for reducing carbon emissions in the short term, but should never be considered as a long-term alternative to getting a rolling programme of electrification back on track.

He concludes: "I think the Government has the view that we don't need to worry about electrification when we can have all these battery and hydrogen trains running around in a few years' time. But it all comes down to physics and you won't be able to run them on the Midland Main Line, for example, without having to refuel them all the time or take out a huge amount of passenger space for energy storage.

"It is quite interesting and provides a change for our engineers from working on traditional OLE, but batteries and hydrogen don't have the energy density to replace diesel or electrification on our busy high-frequency urban lines or long-distance inter-city routes.

"They may have their place as an alternative on lines that will never be electrified, and they may even help in the transition period before full electrification, but they can never replace it." ■