FROM DIESEL TO ZERO – DEVELOPING THE POTENTIAL OF ZERO EMISSION TRAINS

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Conclusions

The Conference examined recent activity in the development of zero emission trains in the UK and Europe. It looked specifically at the development of hydrogen, fuel cell and battery electric trains. The urgency of action to develop these trains has been stressed in the UK Committee on Climate Change Report in May 2019 recommending a net zero emissions target for the UK by 2050 which was made into law in June 2019 and by the Final Report of the Rail Industry's Decarbonisation Task Force Report in July 2019. Around 60 participants registered for the Conference and they came from a wide range of backgrounds which included policymakers, transport authorities and participants from the hydrogen and rail industries. The Conference mainly discussed developments in the UK but also looked at international developments and included speakers from the European Commission and mainland Europe.

Currently, transport is responsible for around a quarter of EU emissions and will be the largest emitter after 2030. Some rail stations in the UK have major problems with air pollution and these stations include Birmingham New Street and London Paddington. In the EU, around half the rail network is electrified compared with 42% of the network in the UK. Even allowing that there is a strong case for some additional electrification, there is a large amount of track that would need to operate zero emission self-powered trains such as battery and hydrogen fuel cell trains.

Zero Emission Trains – The Policy Framework

The Conference heard presentations from the Department of Transport, RSSB, the European Commission, the NOW Programme in Germany and the Tees Valley Combined Authority. There was also an outline of international developments in zero emission trains. The **UK rail industry** has reacted positively to the net zero target by 2050 set under the Climate Act 2008. The industry will play a key role in supporting and achieving these targets. Meeting the targets will involve a fundamental change of mindset and, although rolling stock will be a key issue, it is crucial that the Network as a whole is examined.

It is important that both the Government and each component of the rail strategy work together to deliver rail's contribution to zero emission targets. The Government should set clear, consistent and enabling

policies and the development of Delivery Plans is essential for each part of the rail industry. Five Year Research and Development Programmes will also be a key part of the Strategy.

The Strategy in **Germany** covers both the electrification of tracks, the acquisition of vehicles and the respective charging/refueling infrastructure. Regional rail transport is intended to be supported through investment grants for fuel-cell-hybrid-railcars including facilities & depot modifications as well as the construction and operation of hydrogen refueling stations. A funding programme is included in the Strategy and €13.4 million from 2019 until 2024 is available. Funding guidelines are currently in preparation. There have been Expressions of Interest for over 300 battery electric and hydrogen fuel cell trains.

The **European Commission** looked mainly at the introduction of hydrogen fuel cell trains. In May 2019, the Hydrogen Fuel Cell Joint Undertaking (FCH-JU) and Shift2Rail produced a Study on the market potential of hydrogen fuel cell trains. The Study argued that "Hydrogen offers an attractive alternative especially when it is not cost effective to electrify lines. The cost of introducing Hydrogen trains in the network is estimated to be about half of the cost for electrification."

In **Scotland,** the Scottish Government has made a commitment to reduce emissions from Scotland's domestic passenger railways to zero by 2035. This will be done by the continued electrification of the network, the procurement of battery powered trains and the exploration of the potential of hydrogen powered trains.

The Conference also looked at the role of zero emission trains in broader regional strategies and the hydrogen strategy of **Tees Valley** was outlined. The Tees Valley is a major producer of hydrogen from the chemical industry but it has much potential from renewable energy, and Carbon Capture and Storage. This will allow a variety of transport usage both in the ports and on rail. There is an ambition to make the Bishop Auckland to Saltburn-on-Sea line one of the first hydrogen lines in the UK. This line passes through Darlington and Stockton which was the route of the Rocket two hundred years ago. This was the first steam train to be built.

Development of Zero Emission Trains – Worldwide

The most advanced train hydrogen fuel cell train is the Coradia i-Lint from Alstom. Two trains are currently operational on the Elbe-Weser network in Germany running between Cuxhaven, Bremerhaven, Bremervorde and Buxethude. There were other initiatives around the World and these include:

- The development of the Siemens Desiro ML Cityjet. Eco This is a battery electric train and operating in Austria by the Austrian Federal Railways (OBB)
- The Stadler Flirt Akku operating in Schleswig-Holstein which is a battery electric train with a range of around 150 km.
- The Bombardier Talent 3 battery electric train operating in Germany

Japan has three battery electric trains operational. These include:

- EV-E301 - four two car sets operational since March 2014.
- EV-E801 - one or two car sets operational since March 2017
- BEX 819 - seven two car sets operational since October 2016.

Japan is also trialing a hydrogen fuel cell train, the RTRI Hydrogen Prototype MU and the trials began in September 2019.

Siemens is developing the Siemens Mireo Plus+ with a Ballard fuel cell. The project began with the development of the fuel cell system in 2017 and will be completed in 2020. The trains will be refueled once a day and there will be two configurations for the trains. One configuration will be a train with two cars and 120 seats. It can cover 800km per day. The second configuration is a three car train of 165 seats which can cover 800 to 1000km.

A number of countries have adopted rail decarbonization strategies. As well as the United Kingdom and Germany, strategies have been developed in Austria, France, the Netherlands and Switzerland.

Development of Zero Emission Trains - United Kingdom

The Conference looked at trains that were in development to operate on the UK train network. This included the Vivarail Class 320; the Bombardier Electrostar Battery Electric train; and the Breeze and HydroFlex Fuel Cell trains.

Vivarail Class 320

Vivarail has designed and built Class 320 trains able to operate as diesel/battery hybrid; battery electric or hybrid. Five three car hybrids are being built for Transport for Wales. A battery electric train was trialed in Scotland (October 2018) and Vivarail is working with Arcola Energy and Ballard to develop hydrogen trains.

Power module rafts can be exchanged in less than 15 minutes whether diesel gensets, battery or fuel cell as well as a 25kV pantograph to take advantage of part-electrified lines.

Vivarail has designed and patented an Automatic Charging Point which enables the easy installation of battery trains on part electrified lines where the trains can use OHL or third rail to charge during the journey. The battery bank enables the train to operate on non-electrified lines whilst a pantograph or fuel cell acts as a range extender to zero emission trains. A 25kV battery train has an unlimited range under the wires and then an extra 60 miles on pure battery power. The hydrogen train is forecast to have a range of 650 miles.

Bombardier Battery Electric Multiple Units

The Bombardier Electrostar Battery Electric train began passenger service for Greater Anglia in January 2015. Bombardier has retrofitted Class 379 trains and the train can run at 120 km/hour for up to distances of 50km.

Bombardier is working with Irish Rail to replace Diesel Multiple Units with Aventra battery electric trains on the Dublin DART system. These four car units will be replaced by Electric Multiple Units. The proposal is a 'hub and spoke' network whereby the stock moves out to the suburbs on battery before returning to an electrified 'core'. Fast-charge stations can be provided at the extremities of the network if required.

The Alstom Breeze Train

The Breeze train is a retrofit Class 321 electric train. The first Breeze unit will be built so that train level testing will commence in early 2022. Fleet build will begin in late 2022 and it will be in passenger service by mid 2023. The Breeze Train is a collaborative venture with Eversholt Rail. Rail leasing companies invest in new and retrofit trains and will play a key role in the introduction of zero emission trains.

In order to get to this stage, Alstom will undertake the:

- Completion of business cases with operators to include full system provision –trains, fuelling, operation and technical support
- Approval to proceed, including appointment of hydrogen supplier
- Launch system safety case approval process with operator
- Detailed design of the train conversion including the hydrogen propulsion system integration
- Parallel design of the hydrogen refuelling facilities

The Porterbrook/BCRRE HydroFlex Train

The prototype HydroFLEX train was unveiled at RailLive in 2018. It is a collaboration between the leasing company, Porterbrook, and the Birmingham Centre for Railway Research and Education (BCRRE.) The train is a converted Class 319 Multiple Unit powered with a fuel cell and battery. It uses a 100 kW Ballard fuel cell and can store 20kg of hydrogen which allows for operation of around four before refuelling. This refuelling takes 10 – 15 minutes. The train has InnovateUK funding for mainline testing and approval which is likely to be complete by mid 2020.

Shunters

Many of the existing shunters are now at the end of their working lives (many from 1950s to 1960s.) Diesel shunters are high maintenance and have lower availability. They are often noisy with high levels of exhaust which is a problem with neighbours.

Battery shunters are near maintenance free, have high availability and are emission free. However, lithium and hydrogen are high-risk in some industrial environments, for example in steel works with large amounts of molten steel.

Ballard has been involved in the development of fuel cell shunter locomotives in the US and in India. The shunter in the US moves railroad cars over short distances. The shunters have 300-500kW gross power with 60kg of hydrogen capacity. The shunters are refuelled at a hydrogen refuelling station in the station yard.

Clayton Equipment shunters can be between 1.75 tonnes to 135 tonnes and work in a wide range of environments. Their 90 tonne Battery Electric hybrid Bo-Bo fleet for Tata Steel is the largest UK designed and built loco for over sixteen years and the size of the battery allows for one day operation.

Mainline Locomotives

The introduction of Zero Emission Mainline Locomotives is a major challenge for the rail industry. CMB Technologies outlined an approach by moving to zero emission ICE trains. Before zero emission technology can be widely used, low emission technology should be used to 'kick-start' the process. It was argued that rail and shipping need incremental innovation and that a dual fuel ICE would lead to a 65% reduction in emissions while a Mono Fuel ICE would cut emissions by 98%.

The largest BeHydro engine with hydrogen technology can fit with standard locomotives such as the GE ET 44 and cylinders of compressed hydrogen can replace three tons of diesel.

Research and Development Programmes

In its Report to Ministers, the Rail Industry Decarbonisation Task Force has set out a number of R&D issues. These include ideas on how to remove diesel-only passenger trains by 2040 and highlights the challenges of fully decarbonising freight traction . A number of projects are under development including standards for hydrogen infrastructure and fuelling; standards for battery infrastructure and charging and a clear carbon footprint for the railway. The Network Rail System Operator has begun a Traction Decarbonisation Network Strategy to consider how to select the most economical combination of low carbon solutions across the whole network. It will report back in Autumn 2020.

Research and Development Programmes will be pivotal in the development of zero emission trains. The Task Force recommended that the industry should set out a clear periodic 5-year research plan. The FCH-JU and Shift2Rail Study have also looked at the contents of a Research and Development Programme and felt that the Programme could include:

- Large scale demonstration of Multiple Unit train fleets.
- Development, engineering and prototype operation of shunters and mainline locomotives.
- Technology, development for optimized hydrogen storage systems for FCH applications.

In terms of mainline locomotives, improvements in fuel cell and hydrogen storage technologies may allow hydrogen to have a role in freight and mainline locomotives. For instance, increasing the power density of fuel cells and higher storage pressures may increase hydrogen's viability for locomotives. Other hydrogen-based solutions such as synthetic fuels or ammonia may also offer cost effective solutions over time.

Research Centres and Universities will play a key role in the R&D Programmes and the Conference heard about the work of the Manchester Fuel Cell Innovation Centre and the new Hydrogen Incubator planned in Birmingham was also outlined.

Zero Emission Trains – Infrastructure

The infrastructure needs of the two Coradia i-Lint trains in Germany gives us some indication about the infrastructure needs of fuel cell trains in the United Kingdom. The trains have been operational since September 2018 and have clocked up more than 100,000km. The trains take one hour to refuel and have achieved 95% availability. It should be pointed out that the trains are refuelled by a temporary refueller and that refuelling times could be significantly reduced.

In terms of the infrastructure needed to service UK regional trains. The multiple Units will have a top speed of around 75 MPH. The train's range will be 600+ miles with hydrogen being consumed at 0.2 kg per kilometre and this means that each vehicle will consume 70-100kg per day. It is important that a refuelling station can store around 1.5 day's supply.

Hydrogen will be produced locally and the most urgent need is to reduce the cost of hydrogen so that it is more competitive with diesel.

Final Thoughts

The Vision of the Decarbonisation Task Force is for the UK to have the world's leading low-carbon railway by 2040. The Mission is to move UK rail to the lowest practicable carbon energy base by 2040, enabling the industry to be world leaders in developing and delivering low carbon transport solutions for rail. If this is delivered, it will be a major achievement as the Conference saw that other countries are making determined efforts to decarbonise their rail networks.

The demands set by the Climate Change Committee are challenging and have now been transposed into climate change legislation. This means that trains have a major role to play in achieving these goals. The Panel at the end of the Conference did pose the question "Is the rail industry going to meet the emission targets set by the UK Government?" It is a key question and will no doubt be a major topic as the Decarbonisation Plan is realised. The scale of change means that there needs to be a fundamental change of mindset to realise the vision and the emission targets and the whole industry needs to be mobilised to meet the challenge.