Hydrogen trains

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Part of the Tranzinfo Hot Topics series, this issue offers a selection of material on hydrogen trains. Interest in hydrogen-powered vehicles has grown in recent years due to the urgent need to reduce greenhouse gas emissions in the transport sector. When produced as green hydrogen using electricity from renewable resources, hydrogen is a zero emissions fuel.
Hydrogen fuel cells are a promising technology, especially for applications where batteries might be difficult to implement, such as heavy vehicles, shipping, aviation, and rail, where recent interest has focused not only on light rail but also freight and heavy haul trains. A feasibility study into hydrogen-powered freight trains is currently underway in Queensland.

A hydrogen-powered train – sometimes known as a hydrail - is one that uses hydrogen as a fuel, either within a hydrogen internal combustion engine or through a reaction with oxygen within a hydrogen fuel cell.
Current technology focuses on the use of hydrogen fuel cells, as hydrogen combustion technology in traditional engines is not well developed. A fuel cell generates electricity by combining hydrogen stored in tanks on the train's roof with oxygen in the air. A battery is used to store the electricity and power the train.

The benefits of hydrogen-powered trains include zero emissions at the point of use; the ability to retrofit existing train lines without the cost of adding electrification; a longer range than battery powered trains; low maintenance costs; and quiet running. There are hopes that hydrogen will be instrumental in decarbonising the rail system, which in many countries relies on diesel.

Disadvantages include the storage space required for hydrogen fuel, and its inferior energy efficiency and greater expense compared with electric traction. Hydrogen trains are often hybrids, using renewable energy storage like batteries or super capacitors to supplement the hydrogen fuel, improving efficiency and reducing the amount of hydrogen storage space required.

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The technology

What is a hydrogen train and how do they work?
TWI Ltd, 2022
In the most basic terms, a hydrogen train is one that uses hydrogen as a fuel, either within a hydrogen internal combustion engine or through a reaction with oxygen within a hydrogen fuel cell.
All hydrogen powered rail vehicles, whether large or small, are categorised as 'hydrail,' whether the fuel is used for the traction motors, auxiliary systems, or both.

A review of hydrogen technologies and engineering solutions for railway vehicle design and operations
Sun, Y et al., Railway Engineering Science, volume 29, 2021, pp. 212–32.
The paper identifies that fuel cell technology is well developed and has obvious application in providing electrical traction power, while hydrogen combustion in traditional IC engines and gas turbines is not yet well developed. The need for on-board energy storage is discussed along with the benefits of energy management and control systems.

Fueling the future of mobility: hydrogen and fuel cell solutions for transportation
Deloitte & Ballard, 2020
This paper provides an introduction to hydrogen and fuel cell technology, as well as a deep dive into a total cost of ownership view of fuel cell, battery-electric, and traditional internal combustion engine vehicles.

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Benefits and challenges

Next stop, hydrogen? The future of train fuels
Railway Technology, 15 July 2021
The use of hydrogen as an alternative rail fuel brings many potential benefits, the most noticeable being that it is a clean energy source that supports zero-carbon strategies. Hydrogen fuel cell technology also provides a more powerful and efficient energy output compared to fossil fuels.

Hydrogen-powered trains and their benefits in noise and vibration reduction
Global Railway Review, 28 November 2019
In addition to zero-emissions, hydrail power runs silently, a major improvement on the noise and vibration from their ICE diesel-electric counterparts. Several proof-of-concept and in-service hydrail systems have been demonstrated over the last 20 years, and it is gaining traction as an attractive and economically viable technology, especially for low-power, short-haul applications in the rail industry.

Japan and the UK: emission predictions of electric and hydrogen trains to 2050
Logan, KG et al., Transportation Research Interdisciplinary Perspectives, vol. 10, June 2021.
Electric trains (ETs) and hydrogen trains (HTs) offer an opportunity for both Japan and the UK to meet their national targets as part of the Paris Agreement. Although ETs and HTs are considered zero emission at the point of use, their true environmental impact is dependent upon non-tailpipe emissions from fuel/energy production and vehicle manufacture, maintenance and disposal. Although ETs produced the lowest level of emissions, it is likely that a mix of both ETs and HTs will be required to meet passenger demand and for travel within rural areas.

The trajectory of hybrid and hydrogen technologies in North American heavy haul operations.
Oldknow, K, Mulligan, K, McTaggart-Cowan, G 2021, Railway Engineering Science, vol. 29, Iss. 3, 2021, pp 233–47.
The central aim of this paper is to provide an up-to-date snapshot of hybrid and hydrogen technology-related developments and activities in the North American heavy haul railway setting, placed in the context of the transportation industry more broadly.

Techno-economic analysis of freight railway electrification by overhead line, hydrogen and batteries: Case studies in Norway and USA
Zenith, F et al., Proceedings of the Institute of Mechanical Engineers Part F: Journal of Rail and Rapid Transit, August 15, 2019
Two non-electrified railway lines, one in Norway and the other in the USA, are analysed for their potential to be electrified with overhead line equipment, batteries, hydrogen or hydrogen-battery hybrid powertrains. The results indicate the potential of batteries and fuel cells to replace diesel on rail lines with low traffic volumes.

Study of hydrogen fuel cell technology for rail propulsion and review of relevant industry standards
US Federal Railroad Administration, 2021
Hydrogen can provide many benefits to rail locomotive power operations, specifically offering interoperability, scalability, fast-refuelling, and lightweight energy storage at scale.

Why hydrogen trains will be a rare sight in the UK
The Engineer, 17 March 2021
Hydrogen will play an important, but niche, role in the decarbonisation of the UK's rail network, as it can't compete with the huge advantages of electric traction such as energy efficiency and lower whole-life cost.

VDE study finds battery trains 35% cheaper than hydrogen
International Railway Journal, July 26, 2020
A study of the cost-effectiveness of battery electric multiple units (BEMU) and hydrogen electric multiple units (HEMU) as alternatives to diesel found that BEMUs could be up to 35% less expensive to buy and operate compared with their hydrogen fuel cell equivalents.

The future for hydrogen trains in the UK
Institution of mechanical engineers, UK, 2019
Although it is potentially part of the decarbonisation solution for railways, there is a wariness with respect to hydrogen fuel cell technology, where hydrogen's low volumetric energy density does not encourage rail traction applications when weight and space are critical design constraints in rail vehicle design. In addition, if hydrogen is produced by electrolysis, it requires three times the energy across the whole system of an electric train.

Electric and hydrogen rail: potential contribution to net zero in the UK
Logan, K. et al., Transportation Research Part D: Transport and Environment, vol. 87, Oct 2020.
Electric trains produce the lowest level of emissions from the comparison of conventionally fuelled trains, electric trains and hydrogen trains and that there should be wider implementation of the infrastructure required to electrify the rail lines. This strategy may benefit from the phased integration of hydrogen trains although the business case for the electrification of the railways remains strong.

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Trials

World's first hydrogen train leaves station in Germany
Euractiv, 19 September, 2018
Commuters will be able to get around the German region of Lower Saxony via a train powered solely by hydrogen fuel cells, after French manufacturer Alstom delivered its Coradia iLint train to the north-eastern province.

What is known about hydrogen trains in Germany
RailTech.com, 20 May 2020
For a year and a half, the passengers in Lower Saxony were able to travel the hydrogen-powered trains. Two Alstom-made Coradia iLint vehicles have

proved their efficiency for regional routes. Germany as the first country to use these innovative trains plans to start their regular operations in 2022.

Hydrogen fuel cell technology on rails: embracing the future
Alstom press release, April 2021
A webinar on Alstom's hydrogen solutions & ambitions for European rail in Salzgitter, Germany, featuring its Coradia iLint, the world's first hydrogen train.

Arup to assess the feasibility of hydrogen trains
H2View, 27 November 2019
UK rail industry body RSSB has appointed Arup to investigate the potential for hydrogen-powered trains on the Great Britain mainline.

Concept development and testing of the UK's first hydrogen-hybrid train (HydroFLEX)
Calvert, C et al., Railway Engineering Science, vol. 29, iss. 3, 2021, pp 248–57.
In October 2018, Porterbrook and the University of Birmingham announced the HydroFLEX project, to demonstrate a hydrogen-hybrid modified train at Rail Live 2019. The concept of modifying a Class 319 Electric Multiple Unit was developed, with equipment including a fuel cell stack, traction battery, 24 V control system and hydrogen storage elements to be mounted inside one of the carriages. The project demonstrated the feasibility of using hydrogen fuel cells as an autonomous fuel for railway propulsion systems, which has the potential for full decarbonisation.

UK's first hydrogen train takes to the mainline marking major step towards decarbonising Britain's railways
University of Birmingham, 2021
The trials of the train, known as HydroFLEX, which have been supported with a £750,000 grant from the Department for Transport, follow almost two years' development work and more than £1million of investment by both the University of Birmingham and Porterbrook.

Green trains on their way to power one of the world's most abundant mining regions
ABC News, 29 December 2021
Australian rail company Aurizon has partnered with British mining giant Anglo American to replace diesel trains with hydrogen in the North West Minerals Province in Queensland.

Hydrogen-powered freight trains on the Aurizon for the renewable State
Queensland Government media statement, 13 December 2021
A feasibility study will explore whether hydrogen fuel cell and battery hybrid power units could be used in heavy haul freight rail operations on two Queensland rail corridors.

Chevron, BNSF, United expand hydrogen for trains and planes
Forbes, 17 December 2021
BNSF railway, Caterpillar, and Chevron Motors announced plans to construct a locomotive powered by hydrogen (H2) fuel. The proposal aims to

demonstrate the feasibility of using hydrogen as an alternative to traditional rail fuel sources such as electricity and diesel.

First China-developed hydrogen fuel cell locomotive starts trial runs
Green Car Congress, November 2021
The first China-developed hydrogen fuel cell hybrid locomotive—from core power to main components—has started trial runs on a 627 km railway line for coal transport in north China's Inner Mongolia Autonomous Region.

Japan's first hydrogen hybrid train gears up for trial runs
Nikkei Asia, Feb 2022
Japan's first hydrogen-powered hybrid train, with a zero-emissions system developed with Hitachi and Toyota Motor, is expected to start a commercial service by 2030.

Canadian Pacific's hydrogen fuel cell locomotive to debut before year's end
Trains, November 2021
Canadian Pacific's first hydrogen fuel cell locomotive, a converted SD40-2F dubbed H2 0EL for 'hydrogen zero-emissions locomotive,' will roll under its own power by the end of 2021 and then enter test service in 2022.

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