Institute of Transport Economics
Norwegian Centre for Transport Research

Summary

Battery Electric and Fuel Cell Trains
Maturity of Technology and Market Status

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Whilst hybrid train solutions have been in regular operation for some time, the past decade has seen huge growth in the development of trains powered by standalone batteries or hydrogen fuel cells. Across Europe, commercial passenger service of these trains has begun, and the next years will no doubt see large-scale uptake of these technologies for stretches of rail where traditional electrification is not an option.

Zero emission trains for non-electrified lines

The majority of trains in Europe today are powered by electricity from a third rail or overhead line, which requires a catenary system and contact with a pantograph. Although electrification of main rail lines is progressing in line with emission reduction targets, it is not always cost effective, particularly for low-density passenger and freight lines. In addition, it can be difficult to fully electrify freight lines across national borders due to interoperability issues. For these lines, viable zero emission alternatives to diesel propulsion are hydrogen fuel cells or rechargeable energy storage systems such as batteries.

The technology and market is developing in Europe

Battery electric and hydrogen fuel cell technologies have developed significantly in recent years, and have seen growing application in the transport sector. Multiple manufacturers are investing now in the development of battery electric and hydrogen fuel cell trains, and there have been an increasing number of these trains in operation (for trials and commercial service).

Currently, all zero emission train projects relate to passenger trains, with (to the authors' knowledge) no dedicated battery electric or hydrail solutions for freight trains yet used. Whilst there are several examples of battery electric trains in small-scale passenger commercial service in Asia, these trains have so far mostly been in a testing period in Europe. However, Stadler is now production ready with the Flirt Akku (with over 50 commissioned in Germany) and other battery electric trains produced by Bombardier and Vivarail have been successfully tested and continue to be developed for launch. Regarding fuel cell trains (hydrail), a passenger fuel cell train manufactured by Alstom was launched in 2018 for commercial service in Germany and there are plans to additionally implement passenger fuel cell trains in other countries. Experience from these battery electric and hydrail projects so far is positive.

Infrastructure is needed

Changes in rail transport are not possible without the support of an adequate network, which must be highly planned. This is particularly important for hydrail, since no mass production of hydrogen for transport applications (and associated infrastructure) is yet in place. Key infrastructure considerations for both battery electric and hydrail technology include cost effectiveness, shareability with other types of vehicle and sustainability. The latter is a particularly key issue since the energy source and technology used to produce the electricity and hydrogen will heavily influence the overall (lifecycle) greenhouse gas reduction potential. Renewable energy sources, possibly in combination with carbon capture, are therefore required.

Partial electrification solutions to be prioritised in Norway for non-electrified lines

No fuel cell or battery electric trains have yet been tested in operation in Norway, but the Norwegian Railway Directorate (Jernbanedirektoratet) has worked through their project NULLutslippsløsninger For Ikke-elektrifiserte Baner (NULLFIB) to find zero emission train solutions for stretches of line such as the Nordland line that are difficult to fully electrify. The conclusion of this project was that partial electrification involving battery operation was the most favourable solution at the current time for use on the currently non-electrified lines in Norway, including the Nordland line.

However, the question of which zero emission train solution is best is not clear cut, and other work looking to the future performed by SINTEF found that whilst in the 2020s, battery electric technology may be most attractive in Norway, from the year 2030 hydrail may be the best overall option. Differences in these results reflect inherent uncertainties and differences in scope, methodology and assumptions.

In summary, it has now been decided by Jernbanedirektoratet to move ahead with a solution involving battery operation and partial electrification for non-electrified lines, and not proceed with any hydrogen train project. This decision has now been validated by the Ministry of Transport.

Conclusion

The European rail sector has seen significant developments in battery electric and hydrail train technology and availability in recent years, and both technologies have the potential to be technologically mature in the next decade. With current focus on implementation of part electrification involving battery operation in Norway and implementation of both battery and hydrail solutions across Europe as a whole, it is clear that this trend is set to continue.