RAILWAY INDUSTRY ASSOCIATION
Championing a dynamic rail supply sector

Battery Freight Locomotive Feasibility Study

July 2026

Supported by:

RailEI
Formerly known as the PWI
RAILWAY ENGINEERING INSTITUTION

RFG
Rail Freight Group

Battery Freight Locomotive Feasibility Study – July 2026

Executive Summary

This report summarises a research study assessing whether battery and battery-hybrid locomotives could play a significant role in decarbonising UK rail freight. Commissioned by RIA, RFG and RailEI and undertaken by the University of Birmingham, the research study used simulation modelling to test the technical feasibility of battery-only and hybrid (electric plus battery) locomotives on a range of representative UK freight routes.

The overarching conclusion is unequivocal: **battery-only locomotives are not viable for mainline UK freight and do not represent an alternative to electrification**. Even when fitted with very large batteries well beyond those currently deployed in the UK and challenging to accommodate within the UK loading gauge battery-only locomotives were unable to reliably deliver any of the representative freight diagrams assessed. Their practical application is therefore limited to shunting and very short-distance movements with tightly defined duty cycles.

Hybrid electric-battery locomotives show more promise but only in narrowly defined circumstances. They are not a direct replacement for diesel traction and cannot replicate its historic flexibility. Instead, feasibility is highly route and traffic specific, depending on the length of unelectrified sections, gradients, trailing loads and recharging opportunities. Due to the need to accommodate equipment for both electric and battery operation it will be even more challenging to accommodate large batteries in a UK gauge hybrid locomotive.

Strategic implications

Hybrid freight locomotives may gain value as passenger led electrification expands and battery technology improves, particularly where they can exploit discontinuous electrification. However, **freight decarbonisation remains fundamentally dependent on electrification**, with hybrids offering targeted, supplementary capability rather than a system-wide solution.

This report should be read in conjunction with the following University of Birmingham research study which this report summarises:

> *Simulation of key freight routes to objectively establish the feasibility, or otherwise, for Freight Operations of discontinuous electrification with on-board battery storage.*
>
> *Stuart Hillmansen, Professor of Traction Systems at the University of Birmingham*
>
> *April 2026*

The simulation model

RIA, RFG and RailEI commissioned the University of Birmingham to undertake simulation modelling to assess the potential contribution of battery power to freight decarbonisation. The modelling created 'virtual' battery-only and battery-hybrid (battery plus pantograph) locomotives with performance characteristics comparable to current diesel and hybrid locomotives (Table 1).

These virtual locomotives were then simulated across a range of real freight routes with differing levels of electrification. The routes were selected to represent extremes in gradient and trailing loads (Table 2). Each route was modelled using every locomotive type and three categories of trailing load—Multimodal, Aggregate, and Jumbo Aggregate. This meant that some load types were tested on routes they do not normally operate, to explore boundary conditions.

Virtual Locomotive	**Current Locomotive undertaking similar duties**
General Purpose Battery only loco	Class 66 Diesel
Heavy Haul Battery only Loco	Class 70 Diesel
4 axle Hybrid Loco (Electric and Battery)	Class 93 Tri-mode (Electric, Diesel, Battery – 0.08MWh[1]
6 Axle Hybrid Loco (Electric and Battery)	Class 99 Bi-mode (Electric, Diesel)

Table 1 Virtual locomotives modelled in the simulation

Route/ Freight type represented	**Key characteristics**
Felixstowe – Hams Hall (cross country route) Intermodal / multimodal	Major port-to-Midlands flow, 282km route length, 13% electrified, 244km not electrified, moderate gradients

[1] https://www.railengineer.co.uk/re-engineering-rail-freight/

Felixstowe – Coatbridge (via London) Long-distance intermodal	774km route length, 97% electrified, 25km not electrified.
London Gateway – Doncaster Intermodal / mixed freight	316km route length, 99% electrified, 4.5km unelectrified.
Merehead – Acton Heavy aggregate	172km route length, 47% electrified, 81km unelectrified, very high trailing loads, challenging gradients, severe test of power and energy capability

Table 2 – representative freight routes modelled in the simulation

Battery size and capacity assumptions

The University of Birmingham report includes an assessment of battery technology as it exists today and as projected for 2035/40. For the purposes of the simulation, the virtual locomotives were assumed to have **5 MWh battery** which would have a **usable battery capacity of 4MWh**, with a **volume of 18–28 m³** using current (2026) battery technology.

For comparison, this volume is substantially larger than the diesel power pack in a large UK-gauge locomotive such as the Class 70, or the diesel module in a bi-mode locomotive such as the Class 99. Another comparator is that the volume of 5MWh 2026 battery would occupy between 4.5m and 6.9m of the length of a typical 21.5m long UK loading-gauge freight locomotive[2].

It is therefore unlikely that a battery pack of this size could be accommodated within a UK loading-gauge locomotive especially a hybrid-locomotive which, in addition to the two cabs needs space for the transformer, inverter, rectifier and other equipment to operate from the overhead line. The use of a battery tender was discounted, as it would reduce revenue-earning consist length and hinder operational flexibility, including running-round movements.

The simulation was also run using a **2.5 MWh battery (2 MWh useable capacity)**, which with 2026 technology would occupy between 2.2m and 3.5m of the length of a UK locomotive.

Battery technology is expected to improve substantially, and the modelling therefore included a scenario with a **10MWh Battery** (8 MWh usable capacity), which by 2035 is projected to occupy a similar volume to a 5 MWh battery today. Today a 10 MWh battery would have a volume of 36-56 m³, equivalent to between 9m and 14m of the length of a UK locomotive and is therefore considered impractical in the short term.

For comparison the largest battery in a current UK freight locomotive is the 0.08MWh[3] battery in the Class 93 tri-mode over 60 times smaller than the 5MWh battery modelled. Another current real world comparison is the recently introduced 08e electric shunter which has a 0.6MWh[4] battery pack.

[2] Assuming a useable cross-sectional area of 4m²
[3] https://www.railengineer.co.uk/re-engineering-rail-freight/
[4] https://www.heidelbergmaterials.co.uk/en/news-and-events/new-class-08e-electric-shunting-locomotive

Simulation results

The simulation assessed how many single journeys each locomotive configuration could complete and categorised the results as follows:

- **Less than one single journey** was deemed a **failure** (**red**), as the locomotive could not complete the route.
- **Between one and two single journeys** was classified as **"not technically possible"** (**pink**), as this provides insufficient margin for operational variability, including perturbation, battery degradation, and reduced cold-weather performance.
- **Between two and three single journeys** was classified as **"not operationally possible"** (**amber**), as such limited range would severely constrain utilisation and result in a small, bespoke fleet tied to a single traffic flow—an unattractive investment proposition.
- **More than three single journeys** was considered **feasible** (**green**), although not necessarily commercially viable.

A summary of the simulation results is provided in Table 3 below.

Route/ Freight type represented	**Conclusions - Hybrid Locomotives**	**Conclusions - Battery only locomotives**
Felixstowe – Hams Hall (cross country route) Intermodal m ultimodal (244km unelectrified)	The hybrid locomotives are unable to deliver this diagram even with **5MWh (4 MWh usable) of onboard energy storage**, and they remain **not technically feasible** even when modelled with **8 MWh** of useable onboard storage.	The battery-only locomotives are unable to deliver this diagram, including with the lightest trailing load (multi-modal) **with 10MWh (8MWh useable) of onboard energy storage.**
Felixstowe – Coatbridge (vi a London) Long-distance intermodal (25km unelectrified)	The route is feasible for both the hybrid locomotive with **2.5 MWh (2MWh usable) of battery storage,** and a **multi-modal consist**. The **6-axle hybrid locomotive with 5MWh (4 MWh of usable)** of storage is capable of hauling an **aggregate** train on this route, however aggregate flows are not currently operated on this route.	The battery-only locomotives are unable to deliver this diagram, including with the lightest trailing load (multi-modal) **with 10MWh (8MWh useable) of onboard energy storage.**

	Despite the short unelectrified section, the **4-axle hybrid locomotive** cannot haul an aggregate train on this route due to gradient limitations. Neither locomotive type can haul a **jumbo aggregate** train. However, aggregate flows are not currently operated on this route.	
London Gateway – Doncaster Intermodal / mixed freight (4.5km unelectrified)	The route is feasible for the hybrid locomotives with **2.5 MWh (2MWh usable) of battery storage** when operating with either a **multi-modal** consist or an **aggregate** consist, although aggregates are not a current flow on this route. The **6-axle hybrid locomotive** can also haul a **jumbo aggregate** consist, whereas the **4-axle hybrid locomotive** cannot. However, jumbo aggregate flows are not currently operated on this route.	The battery-only locomotives are unable to deliver this diagram, including with the lightest trailing load (multi-modal) **with 10MWh (8MWh useable) of onboard energy storage.**
Merehead – Acton Heavy aggregate (81 km unelectrified)	The **6-axle hybrid locomotive** can deliver this **jumbo aggregate** diagram when equipped with **10 MWh (8MWh usable) of onboard energy storage**. With **5 MWh (4MWh of usable)** of storage, the **4-axle hybrid locomotive** is feasible only for a **multimodal** consist; however, this does not reflect the traffic currently operating on this route.	Battery-only locomotives cannot operationally deliver this **jumbo aggregate** diagram even **with 10MWh (8MWh useable) of onboard energy storage.** With 10MWh (8MWh useable) of storage the battery-only locomotives can achieve c2 single trips with multimodal or normal aggregate consists, **but these are not the traffic currently operating on this route**.

Table 3 Summary of simulation results

Discussion

The analysis identifies the following key findings.

Battery-Only Locomotives

- Battery-only locomotives are unable to deliver any of the representative freight diagrams assessed, even with 8 MWh of usable onboard energy storage. This level of battery capacity is not considered feasible in the foreseeable future.
- This confirms that pure battery locomotives are not suitable for general mainline freight operations. Their application is therefore likely to be limited to shunting duties or very short-haul movements, where the duty cycle and range can be matched closely to the available battery capacity.

Hybrid Locomotives (Pantograph and Battery)

- Hybrid freight locomotives demonstrate clear potential, but they are not a direct substitute for diesel (or fully electric) locomotives. The simulations show that each route and traffic flow must be assessed individually to determine whether hybrid operation is feasible with a given battery capacity. In many cases, additional investment in power supply enhancements and charging infrastructure would be required.
- This represents a fundamental departure from the "go-anywhere" capability and long-range flexibility historically provided by diesel freight locomotives.
- A significant advantage of hybrid locomotives is their ability to operate as conventional electric locomotives where overhead line equipment is available and adequately powered. This has the potential to increase freight capacity by enabling higher operating speeds compared with diesel haulage.
- For routes where the unelectrified section is very short (less than 25 km), a 2.5 MWh (2MWh useable) battery capacity is sufficient to enable hybrid operation for multimodal traffic. However, for heavier loads such as aggregates, the same battery capacity is insufficient due to gradient constraints. Increasing the battery capacity to 5 MWh (4MWh useable) would enable a six-axle hybrid locomotive to haul an aggregate train over the Felixstowe–Coatbridge (via London) route, which includes a 25 km unelectrified section, although this is not a current commercially operated flow.
- Routes with a low proportion of electrification are not feasible for hybrid locomotives operating existing commercial freight traffic.
- More work is needed on the packaging of batteries for UK loading gauge locomotives and this is challenging for hybrid locomotives which also need significant space for the transformer, rectifier, inverter and associated equipment for operating on the overhead line.

Whole system implications for Infrastructure and Rolling Stock Strategies

- These findings suggest that hybrid locomotives will have increasing value on multimodal routes, particularly where passenger-led electrification—whether continuous or discontinuous—reduces the length of unelectrified sections.

Harmonising the maximum permissible gaps in passenger electrification would help inform and optimise hybrid freight locomotive design.

- As with passenger hybrid operation, careful route-by-route assessment is essential. Factors such as gradients, the length and frequency of unelectrified sections, recharging opportunities, and the need to achieve commercially viable rolling-stock utilisation must all be considered.
- Charging represents a major challenge for freight hybrid operation. On existing electrified routes, power supply limitations already restrict the ability to support additional electric passenger traffic, let alone freight with its higher power demand. The limitations on current draw from the overhead line imposed by interface standards means it cannot be assumed that a hybrid locomotive can both operate and recharge simultaneously under the pantograph; accordingly, the simulations assume no direct charging from the overhead line.
- The installation of fixed chargers at depots or terminals would require substantial capital investment and would further constrain locomotive utilisation, making the business case for such investment more challenging. Given the conclusion that hybrid locomotives have potential application on routes with short unelectrified sections (<25km) a careful analysis would be necessary comparing the whole system costs of installing charging facilities for more expensive hybrid locomotives against the cost of electrifying these sections.
- Charging enroute could also be examined as an option. However in addition to the cost of the charging infrastructure this would need to consider the potential costs of additional siding/ loop infrastructure, potential rail congestion and the impact on rail freight economics of extended journey times.

Conclusions

Battery-only freight locomotives are not an alternative to main-line electrification and are highly unlikely ever to become so. Their application is limited to shunting duties and very short-distance movements, where operational requirements can be closely aligned with the constrained range and power capability of onboard batteries.

Hybrid freight locomotives (electric with battery) are potentially feasible for multimodal trains where the length of unelectrified route is very short (less than 25 km), provided that a battery capacity of at least 2.5 MWh (2MWh useable) can be integrated. While this energy requirement is modest in absolute terms, it nevertheless represents a significant volume when compared with the diesel power module of a Class 99 locomotive, with clear implications for packaging, axle load, and vehicle design. More research is required to assess the feasibility of packaging a battery of this size in a UK loading gauge hybrid locomotive which also requires space for AC traction equipment.

Gradients and the ability to restart trains under battery power are critical limiting factors for hybrid operation. As a result, every proposed diagram would require careful assessment, including allowances for recharging, operational perturbation, cold-weather performance, battery degradation over life, and recovery from in-service disruption.

The viability of hybrid freight locomotives is expected to improve over time as battery energy density and durability increase, and as passenger-led electrification expands across the network. Subject to gradients, trailing loads, and charging strategy, hybrid locomotives are likely to be able to exploit discontinuous electrification installed primarily for passenger operations.

When operating in electric mode, hybrid freight locomotives can achieve higher operating speeds and faster acceleration than diesel haulage. This creates opportunities to increase network capacity and improve performance resilience, particularly on mixed-traffic routes.

However, the capital and operating cost of a hybrid freight locomotive will always be greater than for a pure electric freight locomotive.

For all these reasons, it is essential that freight and passenger operations are considered holistically, as components of a single railway system, when developing integrated infrastructure and rolling-stock strategies.