

Battery electric multiple unit

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A **battery electric multiple unit (BEMU)**, **battery electric railcar** or **accumulator railcar** is an electrically driven **multiple unit** or **railcar** whose energy is derived from **rechargeable batteries** driving the **traction motors**.

Prime advantages of these vehicles is that they do not use fossil fuels such as **coal** or **diesel fuel**, emit no **exhaust gases** and do not require the railway to have expensive infrastructure like electric **ground rails** or **overhead catenary**. On the down side is the weight of the batteries, which raises the vehicle weight, and their range before recharging of between 300 and 600 kilometres (186 and 373 mi). Currently, battery electric units have a higher purchase price and running cost than petrol or diesel railcars. One or more charging stations are required along the routes they operate, unless operation is on a mixture of electrified and unelectrified track, with the batteries being charged from the electrified track.

Battery technology has greatly improved over the past 20 years broadening the scope of use of battery trains, moving away from limited niche applications. **Vivarail** in the United Kingdom claim their trains have a range of 100 miles on only battery power, with a 10-minute charging time.^[1] These sorts of ranges and battery recharging times greatly widens the scope of use of battery or battery-electric trains. Despite higher purchase, on certain railway lines battery trains are economically viable as the very high cost and maintenance of full line electrification is eliminated. Previously, incorporating lightly used unelectrified lines into an electrified network meant extending expensive electrical infrastructure, making many extensions unviable. Modern battery-electric trains have the ability to operate on both types of track. A number of metro networks around the world have extended electrified metro lines using battery-electric technology, with a number of networks considering the option.

From March 2014 passenger battery trains have been in operation in Japan on a number of lines. Austria has overhead wire/battery trains which became operational in 2019.^[2] Britain successfully trialled fare paying passenger hybrid overhead wire/lithium battery trains in January and February 2015.^[3]



The **Japanese** lead the world in battery trains with at least 23 battery electric multiple units in regular operation, replacing **diesel multiple units (DMU)** on non-electrified routes or non-electrified sections of route.

By country [edit]

Australia [edit]

The [Byron Bay Train](#) service in [Byron Bay](#), [New South Wales](#) operates a heritage [600 class railcar](#). The railcar was formerly diesel powered which was operational from 1949 to 1994. The railcar had the diesel equipment stripped out with electric traction motors fitted, being converted to solar power using a battery set to store solar generated energy from the cars' roof panels. The solar train came into operational use on a formerly disused section of line through Byron Bay in 2017. It is believed to be the world's first solar-powered train.^{[14][15]}

[CAF Urbos 3](#) supercapacitor powered trams operate on the [Newcastle Light Rail](#) network with trams being recharged at each stop. The Canberra and Parramatta light rail networks are also planning to introduce battery powered CAF Urbos 3 vehicles on their networks. They will operate on battery power on select parts of their networks.^[16]



The solar-powered Byron Bay Train ↗
in Byron Bay, Australia

Austria [edit]

The Austrian Federal Railways has purchased 189 [Siemens Desiro ML](#) trains from 2013 to 2020. One of these trains was converted to a battery electric multiple unit and branded as *cityjet eco*. The battery-electric version of the Siemens train is equipped to operate with batteries and overhead wires, with a battery only range of 80km reaching a maximum speed of 100 km/h in battery mode. The trains are to be tested on regional and suburban rail lines on electrified and unelectrified track. The test services began in September 2019 on the [Kamp Valley](#) line between [Horn](#) and [St. Pölten](#).^{[2][17]}




Siemens Desiro battery train being ↗
trialled in Austria

Denmark [edit]

From the end of 2020, [Stadler FLIRT Akku](#) battery trains will be trialled on two lines, the 25 km Helsingør to Hillerød line in North Zealand, and the 18 km Lemvig line in northern West Jutland.^[18] If successful it is viewed the trains will be fully operational replacing the existing diesel trains in 2025.



Stadler FLIRT Akku battery train, to be trialled in Denmark 

France [edit]

In January 2021, [Bombardier](#) signed a new contract to retrofit and introduce a pre-series of five [AGC](#) battery-operated trains by 2023, in collaboration with [SNCF](#) and five [French regions](#) including [Auvergne-Rhône-Alpes](#), [Hauts-de-France](#), [Nouvelle-Aquitaine](#), [Occitanie](#) and [Provence-Alpes-Côte d'Azur](#). The 5 AGC trains will be modified into battery-operated to help decarbonise French rail transport. The idea is to convert dual-mode ([catenary](#) and diesel-powered) high capacity self-propelled trains to dual-mode battery-powered AGCs. This project offers a [proof of concept](#) and a way forward to eliminating diesel trains by 2035, a target set by the [French government](#) and [SNCF](#).^[19]

Germany [edit]

In 1887 the first German accumulator railcars were placed in service by the [Royal Bavarian State Railways](#).

DB Class ETA [edit]

Pre-[Second World War](#) classes ETA 177 to 180. The post-war [DB Class ETA 176 \(later 517\)](#) and finally ended with [DB Class ETA 150 \(later 515\)](#). The latter were used until 1995 having been since modernised into the *Nokia ETA*, painted light grey and green and deployed onto the so-called *Nokia Railway* (timetable number RB 46), nowadays the *Glückauf-Bahn* from [Geisenkirchen](#) via [Wanne-Eickel](#) to [Bochum](#).

Stadler Flirt Akku [edit]

In July 2019, Schleswig-Holstein rail authority NAH.SH awarded Stadler a €600m order for 55 battery-powered [Flirt Akku](#) multiple unit trains along with maintenance for 30 years. The trains, which offer 150km of battery range, will start entering service in 2022 replacing DMUs on non-electrified routes.^[20]

Siemens Mireo Plus B [edit]

The five routes of: Offenburg to Freudenstadt/Hornberg, Offenburg to Bad Griesbach, Offenburg to Achern, Achern to Ottenhöfen and Biberach (Baden) to Oberharmersbach-Riersbach will operate from December 2023 on electrified and unelectrified track, the 120 seat [Seimens Mireo Plus B](#) battery-powered/overhead power line trains. On only battery operation the trains have a range of 80 kilometers.^[21]

Georgia [edit]

The [New Athos Cave Railway](#) in Abkhazia in the country of [Georgia](#) has three narrow-gauge battery electric multiple units built by the [Railroad Machinery Plants of Riga](#) in [Latvia](#). Two Ep «Tourist» trains were built in 1975 and later modernized in 2005 and 2009, and the new Ep-563 train was built in 2014.^[22] Since 2014 this it been the only train in use. The first Ep train is based at Anakopea station for doubling the Ep 563 train in case of malfunction. Another Ep train is based at the depot.^[22] Each train consists of 6 cars, including 1 [control car](#) with motors and power equipment and 5 trailer cars for passengers.^[23] Both models can run either on a [third rail](#) with 300 V DC or batteries with 240V DC being used for short unelectrified sections at switches without a third rail, and also at passenger stations where the third rail has no voltage for safety reasons.^[24]



Operating in Germany, Siemens Mireo Plus B battery-overhead wire trains, with a range of 80 km on battery only operation. [edit]



Ep-563 train at Anakopea station, New Athos Cave Railway in [Georgia](#) [edit]

Hungary [edit]

Fifty battery-electric trains will be gradually delivered from 2023 to 2029 for use on Hungary's railways. The trains will have a range of 80-120 km with a speed of 100 km/h. Line 29 will take the first batch of trains then further trains operational on the reconstructed Budapest-Lajosmizsei line. The new battery-electric trains will also be operational on the lines: Győr to Szombathely, Miskolc to Ózd, Esztergom to Komárom, Győr to Keszthely to Kaposvár to Pécs and Szolnok to Hatvan to Somoskőújfalu.

The battery-electric trains will be capable of operation on both electrified overhead wire 25kV 50Hz lines, and non-electrified lines using the battery power.^[25]

Ireland [edit]

Between 1932 and 1949, two [battery electric trains](#) ran successfully between Dublin and Bray. Two additional trains were built and placed into service in 1939, also running until 1949. The train's batteries were charged at each terminus via an overhead pickup. The train could reach 60 mph/105km/h, though service speeds were typically limited to 40 mph/66 km/h. ^[26]

In 2019, [Iarnród Éireann](#) announced they would purchase 250 new carriages, with an option of up to 600, over a 10-year period, for use on the [DART](#) network. The order will consist of both [electric multiple units](#) and battery electric multiple units.^{[27][28][29][30]}

Japan [edit]

N700S bullet train [edit]

The N700s train had battery backup introduced in June 2020. The batteries power the train at reduced speed to the nearest station when power outages occur. The train operates on the [Tokaido Shinkansen](#) line between Tokyo and Shin-Osaka, and the [Sanyo Shinkansen](#) line between Shin-Osaka and Hakata.^[31]

NE Train Smart Denchi-kun [edit]

In Japan, [JR East](#) tested a "NE Train Smart Denchi-kun" battery electric railcar from 2009. This vehicle is capable of operating under 1,500 V DC overhead wires or on battery power alone for a distance of up to 50 km away from an overhead power supply.^[32] The batteries are charged via the pantograph either when running under an overhead electric supply or at a specially built recharging facility.^{[32][33]}



N700 bullet train with battery backup. ↪

EV-E301 series [edit]

From March 2014, a two-car battery electric multiple unit, the [EV-E301 series](#) with 1,500 V DC overhead wire and battery power capability, entered revenue-earning service on the 20 km (12 mi) long non-electrified [Karasuyama Line](#).^[34]

Since March 4, 2017, battery electric trains have completely replaced diesel multiple units on this route. There are four two-car sets in operation, each set equipped with a 190 kWh lithium-ion battery.^[35]

The trains recharge their batteries at [Karasuyama Station](#) (the end of the line) via their [pantographs](#), using a rigid conductor bar placed where the overhead wires would be, connected to the local electric grid. At the other end, at [Hōshakuji](#), the Karasuyama Line meets the electrified [Tohoku Main Line](#). The trains then continue over the electrified Tohoku Main Line to [Utsunomiya](#), where passengers can change to [Shinkansen](#) high-speed trains.



EV-E301 charging from the overhead conductor bar 📷

BEC819 series [edit]

From April 2016, [JR Kyushu](#) started trial operation of a two-car [BEC819 series](#) BEMU train, nicknamed "DENCHA", on part of the [Chikuhō Main Line](#), with revenue-earning service scheduled from October of the same year, and six more trains planned to be introduced on the line in spring 2017.^[36] It can also be powered via overhead AC power line. The [BEC819 series](#) battery-electric trains became operational on the through services on the Fukuhoku Yutaka Line in October 2016, which is electrified at 20 kV 60 Hz AC and the non-electrified Chikuhō Main Line, known as the "Wakamatsu Line", between Orio and Wakamatsu.^[37]

The battery capacity is 360 kWh.

In 2019, a total of 11 new BEC819 trainsets were introduced on the [Kashii Line](#), replacing all [diesel multiple units](#) previously operated on that line.^{[38][39][40]} This brought the total number of BEC819 trainsets in revenue service to 18.



BEC819 at Kashii Station 📷

EV-E801 series [edit]

A new [EV-E801 series](#) two-car BEMU train was introduced on the 26.6 km (16.5 mi) long non-electrified [Oga Line](#) in [Akita Prefecture](#) in March 2017. It shares some characteristics with the BEC819 trains: it uses a 360 kWh battery and is recharged from a 20 kV 50 Hz AC overhead supply instead of a 1,500 V DC overhead supply used by the earlier EV-E301 trains.^[41]



EV-E801 at Oiwake Station, Akita 📷


United Kingdom [edit]

Historically, a number of battery electric trains have been used on British railways. The [British Rail BEMU](#) was taken out of service because the line from Aberdeen to Ballater in Scotland was closed in 1966. The trains have been renovated being ready for reuse on the [Royal Deeside Railway](#).^[42] The [British Rail Class 419](#), motor luggage van, was operational from 1959 to 2004, which could run on either on batteries or a [third rail](#), being used for short unelectrified section on quaysides.

The United Kingdom has almost two-thirds, 58%, of the 20,000 mile rail network on non-electrified track, which consumes 469 million litres of diesel each year. Mark Carne of [Network Rail](#), who are responsible for the tracks of the British rail network, in March 2017 stated: "The idea that you need to electrify an entire route is no longer necessarily the case. I think that where we have got hybrid trains, that opens up quite a lot of interesting opportunities for partial electrification." Carne also stated: "technology was advancing at such a pace that better reliability could be achieved without the construction of unsightly overhead cables." He added that developments in batteries are such that it might soon be cost-effective to swap diesel engines for battery or hybrid devices, therefore saving the vast cost of installing power lines above every section of track.^[43]

Company's such as UK based [Hitachi](#), [Vivarail](#) and [Bombardier](#) have committed to or are producing battery-electric trains. These trains will be either new units or conversion of existing units, to fulfil the aims of Network Rail's introduction of battery powered trains.^{[44][45]}

In 2015 a single [Class 379 Electrostar](#), after electric lithium batteries were installed, began passenger operations on the [Mayflower Line](#) in Essex. The train can travel up to 60 miles (97 km) on energy stored in the batteries also recharging the batteries via the overhead-wires when on electrified sections of the line, at stations and via [brake regeneration](#). The trial lasted one month from January to February.^[46] Network Rail refer to this prototype model and its possible future descendants as *Independently Powered Electric Multiple Units* (IPEMU).^[47]

A month after the trial in March 2015, the introduction of battery-powered trains was proposed by Network Rail for consideration for the fifteen station 27 miles long diesel operated [Wrexham to Bidston, Borderlands Line](#).^{[48][1]}  The aim is to merge the line into the electric 3rd rail [Merseyrail Wirral Line](#) extending into the underground section of [Liverpool](#)'s city centre, making Wrexham one of the branch terminals of the line. The line is diesel train operated unable to progress into the electric 3rd rail underground Birkenhead and Liverpool Merseyrail tunnels & stations. If battery trains are introduced that run into the tunnels, the Borderlands line will be incorporated into the Wirral Line becoming an urban metro line between Liverpool and Wrexham.

The diesel operated trains on the slow Borderlands line terminate at [Bidston railway station](#) in Birkenhead, with passengers having to change trains onto the Merseyrail electric network to proceed into Liverpool's centre. Network Rail proposed using dual battery powered/3rd rail pickup rolling stock without full electrification of the line, providing a cheaper method of incorporating the line in the Wirral Line. The trains will only terminate at Wrexham, while at the Liverpool end of the line trains will proceed around the loop of the electrified Liverpool city centre underground tunnels with thirteen station stops. As the train proceeds on the looped electrified line from Bidston and back, the train's batteries are charged.



Class 777 [edit]

The [Liverpool City Region Combined Authority](#) announced in July 2021 that trials of a BEMU version their new [Class 777](#) on the [Merseyrail](#) network had shown that they were capable of travelling up to 20 miles (32 km) without a charge.^[49] The battery-electric version of the Class 777 would allow the possibility of Merseyrail services from Liverpool to [Skelmersdale](#), [Wrexham](#), [Warrington](#) and [Runcorn](#), without full line electrification.

Class 230 [edit]

[Vivarail](#) have produced the [Class 230](#) train which is converted from redundant [London Underground D-Stock trains](#). The second demonstrator unit, the two-car 230002, has been fitted for battery power in contrast to the diesel-electric power of the earlier 230001 demonstrator unit. Vivarail have developed a fast charger giving a 100-mile range with a 10 minutes recharging time.^[50] Power is provided by two lithium-ion batteries per car giving four per train, providing 106kWh, with an expected life of seven years for the batteries.^[51]

In 2017, Vivarail battery trains were being considered for use on the [Valley Lines](#) network in South Wales. The trains would be battery powered, capable of being recharged via 25 kV [OHLE](#).^[52]

United States [edit]

The Edison-Beach battery railcar was developed by [Thomas Edison](#) and Ralph H. Beach. The latter headed the *Railway Storage Battery Car Company* and the *Electric Car & Locomotive Corp.*^[53] Car No. 105 of the [Alaska Railroad](#) was an Edison-Beach car,^[54] and examples operated on the [Central Vermont Railway](#) running between Millers Falls, Northfield and West Townshend.^[55] A notable feature of the Edison-Beach cars was the Beach drive system. Each wheel was mounted on [ball bearings](#) on a dead axle and was driven by an individual [traction motor](#) through [gearing](#).^{[56][57]}



Class 777. Stadler, conducted battery-electric trials in [Liverpool](#). [edit]



Vivarail battery electric train [edit]