On track to deliver the world's most cost-effective and eco-friendly public transport system

Beverley Nielsen, chair of Ultra Light Rail Partners Ltd (ULRP), introduces the company's pioneering family of green gas-powered train and tram vehicles

ULRP's mission is to design and deliver the world's most cost-effective, environmentally friendly public transport system.

Ultra Light Rail Partners Ltd (ULRP), founded in 2017, builds on the experience gained from successful pioneering demonstrations of Ultra Light Rail which have taken place over the past 25 years. First, in Bristol between 1998-2000, a zero-emission lightweight electric tram made by Parry People Movers Ltd (PPM10) was successfully demonstrated. Following this the popular, award-winning Stourbridge Shuttle service was launched in 2008, carrying over 6m passengers and operated with a 99.9% reliability track record by Pre Metro Operations Ltd, using PPM139 gas-powered railcars.

The ULRP concept is aimed at reducing the capital, operational and ongoing maintenance/servicing costs of rail-based service solutions, including rail and tramways.

It centres on the BioUltra, a biomethane or green hydrogen-powered train and tram family of vehicles allowing rail-based systems to be used much more widely as the BioUltra Zero Climate Change Transport System, or (BØLT) system.

Ultra light rail vehicles have an axle weight of under / equal to five tonnes. ULRP aims to produce an integrated solution, drawing on locally produced energy and materials from local supply chains.

Products include the BioUltra BioTrain, BioTram, BioRefueling systems. Green gas retrofit activity and no dig railtrack, a 'glue in the road' track which forms a beam to provide structural integrity whilst providing ongoing services access.

Products: The BioUltra and BioTram

ULRP's public rail-based transport system is based on the BioTrain and BioTram's integrated infrastructure, which can operate on standard rail lines.

BioTrain

BioTram

This cost-effective family of BioUltra trams and trains are powered by biomethane or green hydrogen-powered engines accompanied by zero emissions lithium-ion battery packs or flywheels, allowing rail-based systems to be used much more widely, providing an affordable zero climate change lightweight transport system, and eliminating lethal air pollution.

The BioTrams can accommodate up to 210 passengers (54 seated and 156 standing), travelling at speeds of at least 70km/h (50 mph) between stops. The driveline draws on a double-bogie powertrain, allowing for a smoother ride quality for passengers.

The hybrid driveline is powered through two small combustion engine gensets providing power to the lithium-ion battery pack, charged by the engines and through the capture of brake energy recovery and requiring no external power from the national grid or overhead wires. This leads to a substantial saving as the catenary generally accounts for around 30 per cent of total capital costs. A flywheel option for kinetic energy storage has also been developed for use in the pilot vehicle at Long Marston. This ultra-low emissions design through the biomethane power source provides a wholly circular economy solution.

'The use of ultra-lightweight railcars/ trams in built-up and rural environments would significantly help towards achieving the UK government's ambition of a net zero emission status'

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The use of ultra-lightweight trains/trams in built-up and rural environments would significantly help towards achieving the UK government's ambition of a net zero emission status. Trains/trams with steel wheels travelling along steel rails require 85 per cent less power than those with wheels with inflated rubber tyres and deliver greater environmental benefits, requiring significantly less energy and emitting minimal airborne particulates. Whilst zero emissions tailpipe emissions have been targeted by the Department for Transport, 85-90 per cent of road-based vehicle emissions are non-exhaust emissions (NEE) (Timmers, R.J.H., Achten P.A.J. 2016), with tyre emissions 1,850 times higher than tailpipe emissions (Emissions Analytics, 2023).

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Unique Selling Points

Ultra light rail vehtandard rail installations which average nearer £30 million per km and above.

Ultra light rail vehicles have an axle weight of under five tonnes. This means a 210-person vehicle weighs close to 20 tonnes (compared to many urban trams weighing over 50 tonnes), resulting in an installed rail cost of £2 million per km.

Operating on biomethane or green hydrogen provides greater opportunities for energy security, as both fuels are renewable and can be produced in the West Midlands, as well as nationally.

Biomethane as a fuel is completely independent of the electricity grid, which will be under increasing pressure as cars switch to electric propulsion and homes to heat pumps, with many more vehicles, including trains, also looking to increase use of electric power. WMCA (West Midlands Combined Authority) figures estimate that if all cars in the West Midlands were to become electrically powered, three times the electric power would be required to power these vehicles alone.

As a rule of thumb, 1kg of Biomethane has the same calorific value as 1 litre of diesel, or 0.25kg of hydrogen and is equivalent in output terms to approximately 1 litre of diesel or petrol. At any pressure, the volumetric energy density of methane exceeds that of hydrogen by a factor of 4.7.

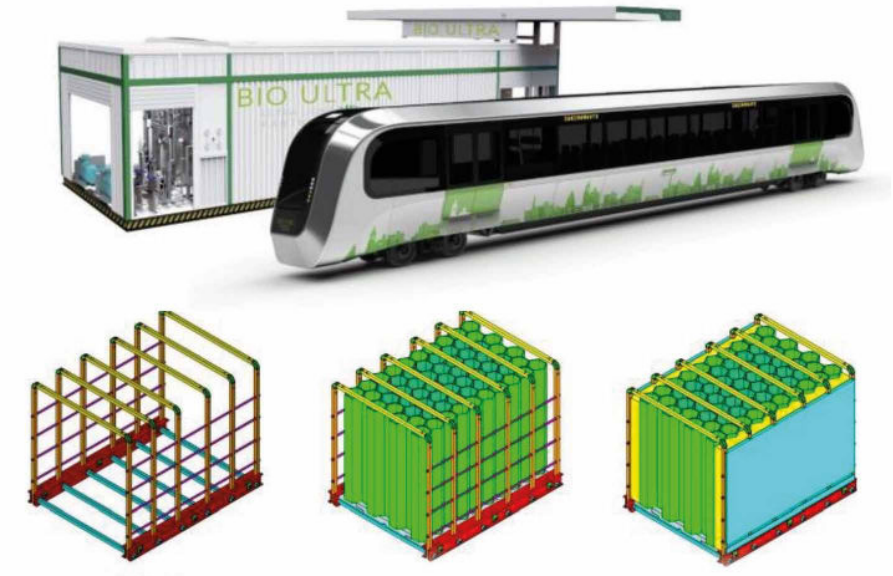
With mandatory food collections anticipated from 2025, cities and metropolitan areas have the opportunity to create a circular economy net zero transport solution providing energy security and locally generated renewable fuel provision, which can be supplied to, and used from, the local gas grid. PMOL's (Pre Metro Operations Ltd) actual experience shows that their entire annual fuel consumption would require merely two days of the biomethane production from the existing Severn Trent Green Power Stourbridge anaerobic digestion facility.

Operating a hybrid drivetrain powered by two very small gensets (0.9 litres, or less than the engine in a family saloon car) and battery pack (or flywheel) provides a 1,000km range and the vehicle does not require any overhead catenary and associated infrastructure or expensive grid connections. Switching to battery power would reduce range to c30km. If a flywheel alone were used, as was the case in our 1998-2000 Bristol tram pilot, range would also be reduced, dependent on external charging either from the grid or a battery pack.

Whilst a battery tram with electrical regeneration might just manage a full day's work before needing its battery recharged, the energy losses of regeneration have a marked effect in an operational regime that requires frequent stop-starts. To be certain that the charge given will last for a day's work, battery-powered trams either require at least double the battery capacity needed for running at constant speed, or the means to recharge during the day. This can be done if there are charging points at the termini during the layover between services but adds significantly to overall project costs. If instead a larger battery is installed, this will significantly increase the vehicle mass and that in turn will increase both the constant speed running loss and the loss due to the many stops (Huber, M. 2023, The Viability of Battery Trams).

Using flywheel regeneration, however, the stop-start losses are only about one-third of those from an electrical regeneration system and this enables a significantly smaller capacity battery to be used. Although comparative first costs for the two systems are not easily to hand, over time the cost of operating with flywheel regeneration should be much less, since fewer batteries are required to be replaced less often. The flywheel is unlikely to need replacing at all, with the total energy use reduced because less is wasted.

Refuelling equipment is limited to one depot for the entire route. The current service and refuelling schedule envisages trams travelling up to 270 miles in a 17-hour day, and requiring only a ten minute-refuelling stop after three days of operation.



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'Operating on biomethane or green hydrogen provides greater opportunities for energy security'

Source of gas for refuelling:

- **1. in the case of biomethane**
  - i) Using gas from the national gas grid by way of the established green gas certification schemes
    - a) from a high ressure part of this grid
    - b) from the normal low pressure distribution network
    - c)trackside generation options
  - ii) direct drawdown from anaerobic digesters
  - iii) Trackside container stores, see 3
- **2. In the case of hydrogen**
  - i) green hydrogen sources
  - ii) Hydrogen from chemical processes otherwise unused, interim
- **3. in the case of either biomethane or hydrogen**
  - i) From gas store refuelled via road or rail tankers

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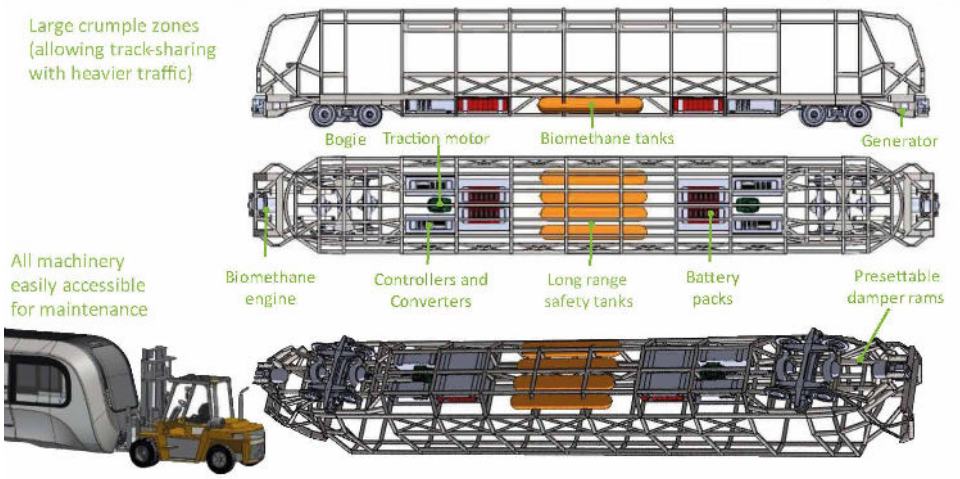
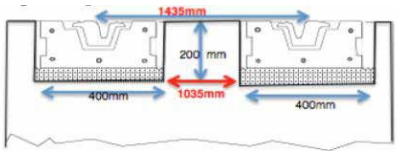


Low cost - £2m / km



Three step process	No dig, 'glue in the road' via shallow recessess in the road service
Forms a beam	Providing structural integrity, and spanning service access features
No need to relocate services	Huge saving. Still accessable after track is laid. Tram can still run also
Proven	Over 20 years and still operational in Sheffield. Over 1.5 million impacts

Trackside storage options

ULRP's BioUltra train is fully compliant, specifically delivering crashworthiness to Category P – III of (GMRT2100) EN15227_ Railroad_crashworthiness_standard, and enabling travel on mixed-use rail lines through enhanced integrity drawing on its spaceframe design.

(From slide) Source of gas for refuelling:

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Track

ULRP proposes the use of an innovative but tried and tested low profile track system. This can be laid quickly, at about 100 metres a week, allowing roads to remain open with minimal disruption and giving smooth, quiet and long-life tracks. It can also be laid without the need to relocate under-street utilities therefore reducing track cost to less than half that of other track systems that need deep excavations of roads and the relocation of existing underground services.

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Other benefits include:

- Full traffic compatibility (rail and road vehicles).
- Low pressures into road structure (less than 200 kN/m2).
- Low/No stray currents resistivity more than 1000 Ω /km.
- Less noise and vibration (under 20Hz ~ 30dB, 100Hz ~ 10dBA, track natural frequency ~ 800Hz).
- Transition rail available to existing girder rail profiles.
- Curves down to 12m radius.
- Compatible with main line trains, tested to 80-tonne axle load for tunnel enlargement.
- Energy efficiency –four times better than rubber tyres, saving scarce renewable energy(note that biomethane exists naturally and does not suffer the 68per cent energy loss in converting renewable energy to hydrogen).
- Vehicle durability - saving embedded energy and materials = cost saving (normal tram durability 30+ years (Blackpool example is 50 - 100+ years) compared to buses 12 years.
- Railtrack compatibility with pedestrian zones (unlike buses) enabling extended zones to eliminate town centre car congestion and reduce pollution.
- Popularity of rail vehicles - established record of high modal shift from cars to public transport + increase in adjacent property values.
- Low maintenance cost of rails (no rutting of roads which occurs along bus lanes).

Fuel supply

The renewable natural gas, biomethane, is available from common waste products including sewage sludge, food, plant and organic wastes, meat processing waste, and poultry and cattle manure. The Anaerobic Digestion and Bioresources Association (ADBA) estimates that over 140mT of organic material is wasted each year in Britain, including around 10mT of food waste.

In addition to reducing environmental pollution and greenhouse warming, capturing biomethane and using it as a fuel offers the ultimate economic solution with ultra-low emissions and a wholly local circular environmental operation with security of supply and control of fuel costs. As stated by the International Energy Agency, the United Nations and recently (7th Dec 2022) confirmed by Lord Deben as president of the Climate Change Committee, the use of biomethane as a fuel causes no climate change whatsoever.

Biomethane has been used worldwide to power all forms of transport, including over 24 million methane-powered road vehicles. It has been readily adopted by HGVs and buses, including in Nottingham, Reading, Peterborough, Bristol, Reading, Darlington, Sunderland, and Merseyside, but has not yet been adopted for rail-based transport in the UK.

Ninety-seven per cent of the 12 million tonnes of animal manure produced annually is unprocessed and the resultant methane emissions are over 80 times more harmful as a greenhouse gas than carbon dioxide. Collecting and processing sewage and manures provides a natural circular economy solution that leads to a net negative carbon emission solution through significant methane emissions savings.

Biomethane is a significant but underexploited renewable energy resource that is 100 per cent renewable compared to grid electricity – which is, at best, today c50 per cent from zero-emissions sources.

Great Britain and, in particular, the West Midlands possess leading capacity and corporate expertise. With biomethane production possible from all organic sources, including farmed algae, supply can be greatly increased. Alongside this, innovations from industry are enabling ever greater efficiencies to optimise the range of difficult feedstocks through, for example, micronisation and additives, which can be used to increase biomethane yields from existing and new facilities. In addition, being able to de-water the digestate will reduce storage and transport costs whilst capturing more nitrogen, phosphorus and potassium in the solids.

There are a number of West Midlands organisations - including Severn Trent, Severn Trent Green Power, Air Liquide, Aquabio, Bohr and CNG Services - which have significant biogas facilities. For example, it is possible for one significantly food waste-fed biomethane plant requiring 50k tonnes of organic waste to produce 40k-50kMWh a year at a capital cost of around £25 million to install and representing a means for the country to become far more energy resilient.

Comparable fuel costs

- 1m^3 of biomethane produces the equivalent of 6.7kWh of energy.
- Biomethane costs only one-tenth of the price of hydrogen and is readily available nationwide.
- Biomethane requires only a quarter of the amount of space compared to hydrogen, as hydrogen has a much lower density and takes up much more space, even when compressed to 700 bar. Operators experimenting with hydrogen as a rail fuel are experiencing challenges in achieving sensible range without a separate tender vehicle to store the fuel.

Technology deployment

This technology is promoted as an affordable option providing a complete circular systems solution. The first BioTram would be produced at a cost of circa £2 million. The lightweight track would cost circa £2 million per km with no overhead lines required, compared with up to £30 million per km cost for the electric tramway. A single refuelling station is required with a £600k capital cost and £20k per annum servicing cost.

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'Biomethane is a significant but underexploited renewable energy resource that is 100 per cent renewable compared to electricity'

References

Emissions Analytics, (2023), How tyre emissions hide in plain sight, January 17th 2023, accessed 13th February 2023 How tyre emissions hide in plain sight — Emissions Analytics

Timmers, V., Achten P., (2016), Non-exhaust PM emissions from electric vehicles, March 2016, Atmospheric Environment 134, DOI: 10.1016/j.atmosenv.2016.03.017, available from https://www.researchgate.net/publication/297889793_Non-exhaust_PM_emissions_from_electric_vehicles [accessed Jan 17 2023].

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Capital expenditure

Ultra Light Rail Partners Ltd creates solutions for rail and on-street lightweight rail, integrating innovators, rail operators, manufacturers, planners and architects. Its goal is to improve the lives of people in urban and semi-rural areas, helping communities, developers and local authorities to solve their future transport needs. Note: Our best estimates are included below.

BioTram	120 capacity	210 capacity (merged carriage)
Railcar body, fixtures and fittings	£485,000	£910,000
Space frame, bogies, motors & batteries	£596,800	£940,000

Operating expenditure

BioTram	120 capacity	210 capacity (merged carriage)
Maintenance (per tram per annum)	£80,000	£90,000
Battery replacement (10 year cycle)	£120,000	£200,000
Biomethane fuel price per 100 km	£25	
Running costs per day	£2,300 (incl driver)	£2,300 (incl driver)
Operating Costs per km	£2	£3

Installation expenditure comparisons with overhead electric powered trams

Twin track rail lines / Depot	Gas	Overhead electric
Track	£2 million per km	£2.71 million per km
Track Annual Servicing	£15,000	£110,000
Depot Fuelling Infrastructure	£600,000 (one per system)	£600,000 x 5 (say) (one per 2.5KM)
Fuel Infrastructure Annual Servicing	£25,000 pa	Each catenary @ £4,000
Depot (including tram storage)	£1million	£1million
Grid connections	£100,000	£1million
Internal Depot track	£1million per km	£1million per km

Potential Markets

UK

Until the 1950s the standard urban public transport in UK was provided by trams. Some 20,000 trams operated in 135 UK towns (list available). With the advent of the motor car and the provision of tarmac roads, electric trams with insulated tracks and overhead catenary systems became unnecessarily expensive and diesel buses replaced them.

The modern imported electric tram is more like a train. Despite their manifest attractions and advantages these mass transit systems are too expensive to install and operate in any but the larger, richer towns and cities. The rest have no real alternative at present other than buses. BioTrams can resolve this problem, by providing the reliability, consistency, luxury and much appreciated benefits of trams, at a much lower capital and operational cost than a bus. Having no catenary system and no high voltage electric currents the installation and infrastructure cost of the Ultra Light BioTram is easily amortised within the first 12 years of operation, the working lifetime of a bus. Thereafter the system will continue to operate at a fraction of the cost of a bus. BioTrams could very quickly be adopted worldwide with the UK now having the opportunity to lead the market before competition takes over.

EU, US

The UK could pioneer the rapidly growing market for low cost BioTrams in smaller towns before local competition follows.

Africa, Asia, Latin America and Pacific Rim countries

150+ countries have now signed the Global Methane Pledge and are committed to cutting their methane emissions by 30% before 2030. Organic waste is a major source of methane emissions that needs urgently to be processed. The opportunity to use this unrecognised, but potentially valuable resource, to solve the problem of providing urban public transport will open up a massive new international market for the country that pioneers the introduction of BioTrams.