

# analyst view

## Fuel Cells and the Future of Global Bus Fleets

16 JANUARY 2013



*Travellers alight from a fuel cell bus in Covent Garden, London (Source: Ruth Sharville)*

Public transport use around the world is booming. This is being driven by a number of factors including increasing population size, higher rates of urbanisation, and the ever-rising cost of petrol and diesel. These increases come at a time when the world is trying to decrease its emissions in the face of climatic instability and, in urban areas, air quality and health concerns. The EU, for example, is committed to reducing its greenhouse gas (GHG) emissions by at least 80% from 1990 levels by 2050; it has from 2008 also held tight [air quality standards](#) that Member States can be fined against if reduction goals in specific areas are not met.

The International Association of Public Transport (UITP) predicts that urban mobility as a whole will double from 2005 levels by 2025, and there will be an impetus to move as much of this demand as possible onto public transport systems, where fuel-efficiency-per-person is dramatically improved and where emissions can be managed centrally by transit operators. The recent focus of emissions reduction efforts in the bus market has been on the increasing use of biofuels in internal combustion engine buses, the implementation of compressed natural gas (CNG) fuelled buses, and the deployment of diesel–battery hybrid buses.

The widespread use of biofuels using conventional production methods is a deeply contentious issue; however the increase in number of diesel–battery buses on the roads is a positive development and a good stepping stone to zero-emission public transport. It is notable that the ‘[New Bus for London](#)’, the first bus to be built specifically for the city since the iconic double-decker Routemaster of the 1950s, is a series hybrid with an electric drivetrain and regenerative braking; the diesel engine only operates when the battery needs charging.

Moving beyond such bridging efforts, what options exist for a truly zero-emission bus? A recent EU report *‘Urban buses: alternative powertrains for Europe’* evaluates the merits of four ICE options (diesel, CNG, diesel parallel hybrid and diesel serial hybrid) and four zero-local-emission concepts: hydrogen fuel cell, trolley, opportunity e-bus and overnight e-bus. The report, which was undertaken by McKinsey on behalf of the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU) finds that opportunity e-buses and hydrogen fuel cell buses are the most promising zero-local-emission powertrains. However, neither technology is without its limits.

Opportunity e-buses rely on comparatively small battery packs and/or supercapacitors that are briefly charged at locations along their route. This allows for cheaper buses than overnight e-buses, which use large battery packs that charge overnight; however, a larger infrastructure spend is required to install quick charge points (usually in the form of overhead wiring) at chosen bus stops along the route. This method is only viable in situations where the buses take a set route; the setup has extremely limited flexibility – its bus stock is captive and the whole operation can easily be disturbed by occurrences such as road closures. Despite this, total cost of ownership is expected to be less than that of overnight e-buses for the foreseeable future.

Of all the zero-emission bus options, hydrogen fuel cell buses are the most comparable in operation to conventional buses, with high driving performance and route flexibility, refuelling at stations and depots. GHG emission reduction potential is high, varying from 75–100% depending on the hydrogen production mix. Infrastructure, as with all fuel cell transportation, is the major obstacle to be overcome, both logistically and financially; despite this, the FCH-JU report expects a price premium of only €0.3–0.6/km compared to the conventional diesel bus in 2030.

These findings, although focused on Europe, hold true across the world. A US Department of Energy (DOE) report, *‘Fuel Cell Buses in U.S. Transit Fleets: Current Status 2012’*, published in November, finds that the fuel cell buses currently being demonstrated in US transit fleets give fuel economies 1.8 to 2.4 times higher than those of baseline diesel buses, averaging at 7.41 miles per diesel gallon equivalent (mi/DGE). The Department of Transportation’s Federal Transit Administration’s (FTA) target for fuel cell bus fuel economy is 8 mi/DGE, two times higher than the target for diesel buses; the fact that current demonstration buses are only just behind this target is impressive.

The DOE report assesses bus technology progress with a scale of nine overlapping technology readiness levels (TRL) ranging from basic technology research (1–2), to technology demonstration (5–7) and culminating in product launch and ongoing support (8–9). The table below compares expected progression in CNG, diesel hybrid, and fuel cell buses. (MBRC = miles between roadcalls, a measure of reliability.)

Propulsion technology	Development timeframe	Fuel economy compared to baseline	Propulsion MBRC
CNG	Pilot scale (TRL 6)	-25% to -35%	1,000 to 5,000
	Full scale validation (TRL 7)	-25% to -30%	10,000
	Full demonstration (TRL 8)	-20% to -25%	23,000
	Deployment (TRL 9)	-20% to -25%	30,000
Diesel hybrid	Pilot scale (TRL 6)	+10%	2,000
	Full scale validation (TRL 7)	+25% to +30%	10,000
	Full demonstration (TRL 8)	+30%	10,000
	Deployment (TRL 9)	+30%	10,000
FCEB	Pilot scale (TRL 6)	+45% to +75%	2,000 to 4,000
	Full scale validation (TRL 7)	+90% to +100%	4,000

Table: Development progress by TRL (*‘Fuel Cell Buses in U.S. Transit Fleets: Current Status 2012’*)

The table shows a low MBRC for fuel cell buses offset by an unmatched fuel economy. Add to this significant emissions reduction potential and you are left with a truly compelling solution for the global bus market. There are, however, a number of roadblocks to be overcome.

Infrastructure is an obvious factor here and must not be underestimated, but equally important are cost and integration of components, which are intrinsically linked. Many cite platinum loadings as a key factor for the high cost of fuel cell powertrains, but as equal a hindrance is the cost of the balance of plant and integration of the system into vehicles, which to date has often required substantial optimisation. This is an issue that should remedy itself as production increases and more bus manufacturers work to incorporate the technology.

Almost all fuel cell buses incorporate a battery for energy storage and there is also a balance to be struck in the hybridisation of the fuel cell power plant and this supporting battery pack. While fuel cell costs remain high and hydrogen infrastructure sparse, it may be more economical to employ battery-dominant buses with fuel cell range extenders, a concept most recently demonstrated by General Electric in December. The bus [exhibited](#) by GE Global Research featured a unique combination of two battery technologies – Li-ion for acceleration power and a GE Durathon cell for energy storage. In most battery buses energy storage is compromised for acceleration power, or *vice versa*. These batteries are supported by a hydrogen fuel cell which maintains their charge. GE claims that its proprietary energy management system has the potential to bring down the cost of fuel cell implementation in buses by up to 50%, corroborating the notion that improvements in integration and balance of plant are critical to fuel cell bus cost reduction.

Fuel cell buses are an important demonstrator for the general public, with [projects](#) such as the US National Fuel Cell Bus Program and CHIC in Europe adding buses to cities on a regular basis. In the coming weeks a further three fuel cell buses will join the existing five on London's prominent RV1 route, making it one of the few 100% fuel cell bus routes in the world. This is more than just a demonstration: Londoners are using the buses and rely on their service day in, day out; well over [100,000 miles of service](#) have been accumulated since the buses began operation in early 2011. Work remains in the propagation of infrastructure and the reduction of ownership costs, but it would seem that fuel cell buses are on the cusp of moving from tomorrow's technology to today's solution.

*For a full set of supporting figures and information, please consult the [FCH-JU](#) and [DOE reports](#).*

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