FUEL CELL TODAY

Opening doors to fuel cell commercialisation

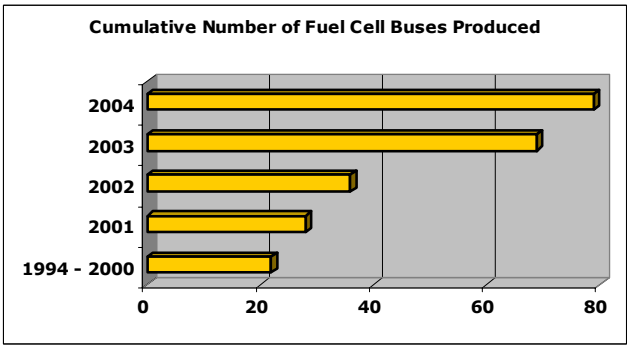
Fuel Cell Market Survey: Buses

Kerry-Ann Adamson, – Fuel Cell Today, November 2004

Introduction

Although the number of new fuel cell buses that has been delivered since we last reported has only been ten[1], 2004 has again represented a successful year in the move towards commercialisation of fuel cell buses, with over 65 buses in daily use and the announcement of a number of new deliveries scheduled for 2005.

A steadily growing number of fuel cell buses are now in daily use, in different climates, using different technology combinations and fuel storage techniques. The one common factor between these different buses is the apparent success with which they are being operated.



The highlight of 2004 was the delivery of three fuel cell buses for the **Sustainable Transport Energy, Perth (STEP)** project, to Perth, Western Australia, in time for the *Hydrogen and Fuel Cell Futures Conference*. These Citaro buses will be put through their paces until 2007, during which time a number of studies will be undertaken, not just on the technical performance of the buses, but also in areas such as public perception and cost/benefit analysis. The STEP project is closely

[1] Although not all the CUTE buses were delivered in 2003 they were included in our 2003 survey statistics, so they are not counted here.

collaborating with the CUTE and ECTOS projects, which also use Citaro buses. More information on the STEP project can be accessed at http://www.dpi.wa.gov.au/ecobus .

Two of the three Perth Citaro fuel cell buses that will be in daily operation until 2007

Technology Type and Fuel Choice

In terms of technology type, in fuel cell buses at least, there appears to be a consensus on PEM fuel cells, with this year being the fourth consecutive year that all new buses have employed PEM stacks. Fuel choice also seems fairly settled on direct hydrogen with the majority employing compressed hydrogen.

An important point to note is that the current market for fuel cell buses is not operating under what could be termed free conditions. Because the vast majority of the current bus fleet is, at some level, government sponsored, and therefore keeping the market open to various alternative combinations, it is difficult to spot any but the obvious trends.

Each year a significant fraction of the fuel cell bus fleet is comprised of hybrid buses, currently representing the only major fuel cell bus design variation. Hybridisation of fuel cell buses currently comes in two main forms:

1. The fuel cell providing the primary power with a battery providing auxiliary or backup power.

An example of this is the **ThunderPower** hybrid bus which has a UTC 170 kW fuel cell as the primary propulsion unit, and the battery providing power to the drive axle, power inverters and the gearbox.

2. The fuel cell providing backup power to the primary propulsion unit.

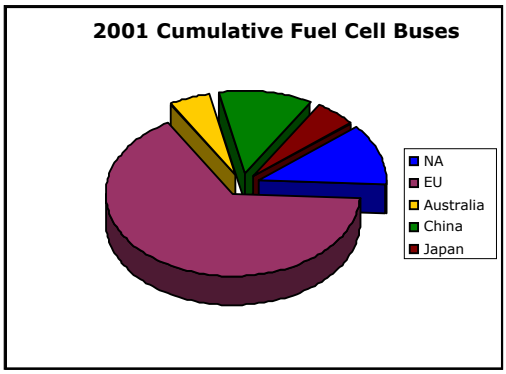
Here an example is the new fuel cell hybrid bus at Hickam Air Force Base in Hawaii, with a 20kW fuel cell which charges the main battery propulsion unit, and to a limited extent extends the driving range.

The 30-foot flight crew shuttle bus at Hickam Air Force Base is the first fuel cell vehicle operated by the US Air Force.

Region of operation

Again this year it is Europe that has by far the highest number of fuel cell buses. With four major fuel cell bus projects funded by the European Union, and DaimlerChrsyler, MAN and Volvo, amongst others, being located in Europe this is one area in the application of fuel cell technology where Europe is leading the pack.

If we look at the cumulative total of buses from 2001 – 2004 we can see that Europe, which here includes Iceland, has a two thirds market share, and China and North America each have 12%.



Both North America and China have a number of fuel cell buses on order, to be delivered in the next year or so. It will be interesting to see, therefore, if China can continue in the medium to long term, to hold such a large market share with increased interest from North America.

China's contribution to the commercialisation of fuel cell buses came this year from the fuel cell developer, **Shanghai ShenLi**, and **Tsinghua University** who developed and showcased their efforts at this years *Hyforum*, which was held in Beijing. This bus may be part of the **Global Environment Fund (GEF) Fuel Cell Bus Programme**, but the information on this is unclear. It is not yet in daily use.

The "863 No. " fuel cell bus developed by Tsinghua University and Shanghai ShenLi

What is interesting in this market is that Japan continues to be relatively quiet, with no new buses released this year. So far of the Japanese automotive manufacturers only Toyota has been active, having released a very limited number of buses for testing, all in Japan. It is scheduled to release, in conjunction with Hino, an update of its FCHV-BUS, the FCHV-BUS2, in 2005, at the World Expo in Aichi.

Market Issues

Bus fleets are being seen as a good early market for fuel cell and hydrogen technology for reasons such as central refuelling, predefined routes (so operators can calculate time between refuelling and distances), high public visibility, size and weight of the stack not being as critical as in the light duty vehicle market, and more design space for hydrogen storage tanks.

The positives of the situation are still countered somewhat by the economics, which are not seen by all as attractive. Unlike in the light duty vehicle market, which is a

direct competition between diesel and petrol using the internal combustion engine, the heavy duty market is currently a lot more open to competition from different fuels and technologies. Natural Gas is a well established fuel for buses, and different powertrain options such as electric and hybrid also have a significant market share. Hythane, a blend of natural gas and hydrogen, is being increasingly discussed in terms of a commercial fuel for buses. One company alone is planning on replacing *ten thousand* Chinese buses in Bejing with Hythane for the 2008 Olympic Games. Compare this with the previously announced *one hundred* fuel cell buses for the Olympic Games. Note though that this one hundred appears to be reducing with current numbers expected to be around the ten fuel cell bus level.

This 1995 Hythane Bus in Montréal, Québec, Canada shows that this technology has been under development and trials for a number of years already

Demonstration Programmes

As with other fuel cell applications, a bus demonstration programme can have anywhere between one and tens of units. **Clean Urban Transport for Europe (CUTE),** with its 27 buses is still by-far-and-away the largest of its kind, with most current, or planned programmes, employing somewhere between one and six buses. The only trial that is currently being planned on anything like the same scale as CUTE is the badly delayed **UNGEF** project. See our 2003 Bus Survey for an overview of the UNGEF project.

This year saw two very different projects hitting the roads. The Australian **STEP** project received its three Citaro fuel cell buses, which are now in daily use, and Hawaii's Hickam Air Force Base received its hybrid fuel cell bus early this year for testing and evaluation. Although during 2004 the announcement of new projects has been minimal, this is to be expected with the level of investment that is currently tied up in major ongoing projects such as **Ecological City TranspOrt System**

(ECTOS), or projects that are due for delivery within the next 1-2 years, such as the **Natural Resources Canada Fuel Cell Bus Programme**. One announcement that has been released is the development, by Hydrogenics, of a hybrid bus for **Ministry for Transport Energy and State Planning, North-Rhine-Westphalia**, Germany, with a demonstration planned for next year. Also next year will see a new model **Honda** hybrid FCHV-BUS2 operating at the **World Expo**[2] in Aichi, Japan.

It can sometimes be confusing to distinguish where one project ends and the next starts, as for example **CUTE**, **ECTOS** and **STEP** have formed the Fuel Cell Bus Club (www.fuel-cell-bus-club.com) to compare and disseminate results. STEP is also collaborating with similar projects in California, we assume the proposed **Californian Fuel Cell Partnership Fuel Cell Bus Programme**, which will supply 7 buses (three late 2004, the other four during 2005) to AC Transit, Sunline Transit and Santa Clara VTA.

In Europe, especially, there are four projects that need to be distinguished between; **CUTE**, **ECTOS**, **CityCell** and the **Fuel Cell Bus Project**. The table on the next page shows an overview of the different projects, their locations, and a number of other key points. What can be seen from the table is that the CUTE project is set up not only to test the fuel cell bus, the Citaro, but also focuses on different hydrogen production routes and infrastructure options[3]; whilst the beleaguered CityCell project was designed to test hybrid buses. Currently a question hangs over the CityCell project, which originally included Berlin, as even though it is currently featured in a number of EU publications on hydrogen and fuel cells, and it is not due to end until 2005, the development and the delivery of both the Paris and Turin buses has been halted, and the Madrid bus appears to have been taken off the road.

ECTOS is part of the integrated project to turn Iceland into the world's first true hydrogen economy and is therefore a part of a bigger picture, which will include light duty vehicle demonstrations and developing a hydrogen fuelled fishing vessel. The Fuel Cell Bus Project for Berlin, Copenhagen and Lisbon was the only project

[2] The 2005 World Expo is turning into something of a fuel cell expo with fuel cell buses, mobile phones, laptops and power plants all in use and on display.

[3] An excellent report on the CUTE fuel production and infrastructure can be found at the Fuel Cell Bus Club homepage, under the publications link.

designed to test liquid hydrogen. Results from this project, which appears to have ended in 2002, are difficult to find but would be of interest.

Without doubt the two most successful EU projects are CUTE and ECTOS, with ECTOS fuel cell bus trials due to finish next year.

Table of European Union funded fuel cell bus trials

	No. of Buses	Engine Configuration	Power Output (Stack Developer)	Bus Type	Onboard Fuel	Fuel Storage	Fuel Production
CUTE (2001 – 2005/6)							
Amsterdam, Hamburg, Stockholm	3	Direct	250 kW (Ballard)	Citaro (EvoBus)	CH_2	Gas Cylinders	Onsite electrolysis[1]
Barcelona	3	Direct	250 kW (Ballard)	Citaro (EvoBus)	CH_2	Gas Cylinders	Onsite *solar* electrolysis
London, Luxembourg, Porto	3	Direct	250 kW (Ballard)	Citaro (EvoBus)	CH_2	Gas Cylinders	Centralised off site production[2]
Madrid, Stuttgart	3	Direct	250 kW (Ballard)	Citaro (EvoBus)	CH_2	Gas Cylinders	Onsite SMR natural gas
ECTOS (2001 – 2005)							
Reykjavik	3	Direct	250 kW (Ballard)	Citaro (EvoBus)	CH_2	Gas Cylinders	Onsite electrolysis[1]
CityCell (2003 – 2005)							
Madrid, *Turin*[5]	1	Hybrid with battery storage	62 kW (UTC)	Cristalis (Irsibus)	CH_2	Gas Cylinders	Onsite SMR natural gas[3]
Paris[5]	*1*	*Hybrid with battery storage*	*75 kW (Axane)*	*Cristalis (Irsibus)*	*CH_2*	*Gas Cylinders*	
Fuel Cell Bus (1999 – 2002?)							
Berlin, Copenhagen, Lisbon	1 [4]	Hybrid with battery storage	75 kW	NL A21 (MAN)	LH_2	Cryo-cylinders	

1 – the electricity for electrolysis has been certified as "green",
2 – for the centralised production the hydrogen is tanked in, with London being the only city to tank in and store liquid hydrogen,
3 – the refuelling station in Madrid is being used by both the CityCell and CUTE project
4 – the Fuel Cell Bus project had one bus in total, unlike CUTE which has 3 per city,
5 – here italics represent planned buses that have not been delivered.

Fuel Cell Bus Technology Development

Unlike the light duty vehicle market, bus producers tend to produce the chassis only, with the propulsion unit developed by a separate company. Fuel cell buses therefore need stacks developed and produced that can be placed within the current bus architecture. This section covers the major fuel cell bus producers and the stack manufactures that they are involved with.

Bus Manufacturer

DaimlerChrysler (Germany) through its daughter group **EvoBus** has, so far, the largest percentage of fuel cell buses being tested. This includes the CUTE, STEP and ECTOS projects. Future orders for the EvoBus product include the Chinese Ministry of Science and Technology (MOST) which are expecting, in 2005, the delivery of three fuel cell powered Citaro buses. With its worldwide sales and support network, and its relationship with **Ballard**, Daimler sees itself sitting squarely in the middle of any upcoming fuel cell automotive market.

Gillig (USA) is the second largest producer of transit buses in North America. As well as cooperating with Ballard and UTC on fuel cell buses, it is also developing what it sees as other nearer term options such as diesel electric hybrids. Gillig fuel cell buses will form part of the upcoming demonstration in Santa Clara, California.

Gillig's impression of a future fuel cell bus

Irisbus (France), which is part of the Fiat group, was due to produce the fuel cell buses for the CityCell project. A growing company with active links in the former Eastern Europe and a strong presence in China, Irisbus is looking at a range of alternative fuels / propulsion systems such as clean diesel, biofuels and natural gas.

MAN (Germany) is one of the leading commercial vehicle manufactures in Europe with a hundred year history in production and product innovation. MAN released its

first fuel cell bus in 2000 and this year produced two of the ten new buses released, both in Germany.

MAN's Bavarian fuel cell bus

Neoplan (Germany) released, in conjunction with Proton Motors, its demonstration Bavaria II fuel cell bus in 2000. Since then it has been quietly and successfully developing a small number of fuel cell buses that are being used and tested in Germany.

New Flyer (Canada) is the largest manufacturer of buses in North America. As well as developing fuel cell buses for the Natural Resources Canada Fuel Cell Bus Programme, it is also currently the largest manufacturer of CNG and diesel / electric hybrids.

ThunderPower's (USA) fuel cell buses received a substantial boost when the Californian governor Arnold Schwarzenegger used one as the backdrop to the signing of the executive order for the "Hydrogen Highway". Unlike some other companies ThunderPower appears to have a range of close to off-the-shelf fuel cell hybrid bus designs. ThunderPower is a joint venture between Thor Industries and ISE. ISE research focuses on the integration of hybrid drive systems in heavy duty vehicles.

Arnold Schwarzenegger at the signing of the executive order of the Californian Hydrogen Highway

Toyota (Japan) released its FCHV-BUS, in joint partnership with **Hino**, a manufacturer of diesel trucks, buses and industrial diesel engines, who Toyota have a 50.1% stake in, in 2002 and since then has been developing a refined model which is due to be released at next years world expo in Japan. Toyota so far seems to be focussed exclusively in the Japanese market and has released only a very limited number of these buses for testing. The FCHV-BUS is currently in daily use between Tokyo Station and Odaiba, the site of the FC Expo 2005.

Van Hool (Belgium) has been contracted to provide the bodies for seven of the buses for the Californian Fuel Cell Bus Programme. The bodies will be used by ThunderPower, who will integrate the UTC fuel cells, sometime during 2005.

Volvo Bus (Sweden) was due to develop two fuel cell double-decker buses for Berlin. Apart from the initial press release there has been scant information on this and it now appears to have been cancelled. **NovaBus**, a subsidiary of Volvo Bus, is involved in producing zinc air fuel cell buses for a demonstration project in Las Vegas.

Stack Manufacturers

Ballard Power Systems (Canada) has supplied all the CUTE, ECTOS and STEP buses with their 205 kW stacks and continued to work with DaimlerChrysler. They have also been involved in bus demonstrations for the Californian Fuel Cell Partnership, the Zebus Demonstration Programme and the Chicago & Vancouver Demonstration Programmes. Next year will see this relationship deliver buses to China. Ballard stacks currently represent over 50% of all the fuel cell buses surveyed.

Enova Systems (USA) provides 240kW stacks for direct propulsion units in heavy duty vehicles, including buses, and also works on smaller units for hybrid bus development. This year Enova signed an agreement with China's First Auto Works (FAW) for parallel hybrid drive systems for its hybrid buses. Enova also supplied the US Air Force in the development of its fuel cell hybrid bus for Hickam Air Force Base.

Hydrogenics (Canada) although not directly focusing on stack development for fuel cell buses has seen a number of orders from North America and Europe to integrate

its stacks for hybrid propulsion. Hydrogenic's latest order is to develop a "midi-bus" for the German State of North-Rhien-Westphalia. This vehicle is due to be demonstrated in 2005.

Proton Motor (Germany) seems to be focusing more exclusively on transport and in particular heavy duty applications for its PEM stacks. As well as producing stacks for a number of the European fuel cell buses in this survey, Proton has also released a prototype fork lift truck powered by a fuel cell. Proton's 2002 fuel cell bus built for SGL Carbon is currently winding its way through the German city of Augsburg, where it is on loan.

Proton Motor's Fuel Cell Fork Lift Truck

Shanghai ShenLi (China) has been developing and manufacturing PEM technology since 1998. It has been involved in a number of major government-run research and development programmes within China, including the National Ninth Five Year Key Science and Technology Project "PEM fuel cell Technology", the National Tenth Five Year 863 High Technology Project, "Fuel Cell Engines" and the first and second phase of the "Fuel Cell Engines for Passenger Car and City Bus" High Technology Project. Working in conjunction with **Tsinghua University** they demonstrated this year their fuel cell bus, which will be tested in daily use from next year on.

UTC Fuel Cells (USA) is one of a small number of companies that are, currently, using their technology base in multiple fuel cell applications, including heavy duty vehicles. UTC has development and demonstration agreements with Thor Industries, ThunderPower's parent company, and Irisbus.

Summary

Fuel cell buses could be an early first market for fuel cell applications, for the reasons discussed earlier in this report, but as with any other market the economics of the situation have to be acceptable. With the current "market" price of a single fuel cell bus being well over the million US$ mark and the price of a top of the range diesel bus under US$500,000 the cost considerations are still considerable[4]. The fuel cell market cannot afford to be complacent and assume that fuel cell buses are the only, or best, future option for heavy duty vehicles. They are facing, and will continue to face, growing competition from natural gas and hythane, both with a far more proven track record, as well as the growth in diesel electric hybridisation of more traditional technology, paralleling what we are seeing in the light duty vehicle market.

Another major issue that is that the current majority of buses are "bespoke" being created and built to single order / project specifications. It is only really the Citaro fuel cell bus that can claim to be being tested in fleet applications. Ramping up production and standardisation of technology for buses, and other heavy duty applications, still appears to be a long way off, but this is not to say that this cannot and will not change. With China currently taking something of a lead in the Pacific Rim countries, and having at least one upcoming major demonstration project and a number of other small scale projects due to hit the streets next year, we could see a healthy "neighbourly" competition develop which could help to speed up fuel cell bus development.

One major factor though in favour of fuel cell buses, that is hard to quantify, is their political value. Unlike the problems of congestion and social exclusion, which are attached to light duty vehicles, buses are seen by the policy makers as a socially good thing, and something that government policy can directly support. When this is coupled with technology, such as the hydrogen fuel cell combination, which addresses environmental issues, governments could potentially be a major early adopter of fuel cell buses, speeding up the adoption curve.

Currently though fuel cell buses are very much in a testing and evaluation phase. Major projects are underway testing not only the running of the buses but also the

[4] By comparison according to the Diesel Forum the additional cost of the natural gas bus is around US$40,000 – 60,000 and a diesel electric hybrid US$100,000 – 130,000 per bus.

surrounding issues of public acceptance, refuelling and government codes and standards. This foundation laying work will help to ensure that when the next batch of fuel cell bus hits the streets next year in the United States, Canada, China, Japan and Europe, their success will be built upon and taken forward.

London's CUTE Bus crosses Tower Bridge

Further references

Fuel Cell Today, http://www.fuelcelltoday.com, is the focal point for the global fuel cell industry. Features of the site include regular news, fuel cell images, a fuel cell shop and in-depth commentary on and analysis of industry developments, including market surveys like this. If you have any more information for this or any other survey, please contact us on editor@fuelcelltoday.com.

About the authors

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