BALLARD™

CASE STUDY

Fuel Cell Zero-Emission Buses for the City of London

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Situation

Like many cities around the globe, London has recognized the need to cut greenhouse gas emissions to limit climate change. The Mayor has set a target to reduce London's carbon dioxide emissions by 60% of their 1990 level by 2025. Currently, approximately 20% of London's carbon dioxide emissions are generated by transportation, making it an ideal industry

of focus for reductions. Transport for London (TfL), the city's transit agency, is actively working to cut energy use from transit and use new alternatives to diesel buses to reduce emissions.

Solution

Fuel cell buses emit only water vapor, eliminating air pollutants such as nitrogen oxides, sulfur oxides and particulate matter. Robust fuel cell buses deliver the route flexibility, range, gradeability and top speeds demanded by transit operators.

TfL has led the way in adopting these ultra-low emission vehicles, most notably with their fuel cell bus fleet. Originally, TfL operated three fuel cell buses between 2003 and 2006, under the EU and UK government funded CUTE and HyFleet: CUTE programs. Based on this success, TfL took delivery of five next generation fuel cell buses in 2010. Three additional zero-emission hydrogen fuel cell buses then joined the fleet in 2013. All of the fuel cell buses have been powered by Ballard's FCvelocity® fuel cell module.

The eight current buses are operated as part of CHIC, the Clean Hydrogen in European Cities project, which is the essential next step leading to the full market commercialization of fuel cell hydrogen powered buses. The project involves integrating 26 buses in daily public transport operations and bus routes in five locations across Europe. The CHIC project is supported by the European Union's Fuel Cells and Hydrogen Joint Undertaking (FCH JU), and has 23 partners from eight countries across Europe, which includes industrial partners for vehicle supply and refueling infrastructure.

As a next step, London will expand their fleet with two additional fuel cell buses produced by bus manufacturer Van Hool. The project, which has been given the name 3Emotion (Environmentally Friendly, Efficient, Electric Motion), will run for five years (2015 – 2019) and oversee the deployment of twenty-one new fuel cell buses throughout Europe. 3Emotion is also funded by the EU through FCH JU.

Site	**London, UK**
Application	**Eight zero-emission hybrid fuel cell buses, with two additional buses planned**
System	**FCveloCity®-HD power module integrated onto Wrightbus chassis**
Fuel	**Hydrogen provided by Air Products >5,600 refueling events >96,000 kg hydrogen supplied**
Objectives	**To support London's publicly stated goal to reduce CO2 emissions by 60% from the 1990 level by 2025**

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Fueling

Air Products provides hydrogen fuel and fueling facilities for the fleet operating in London. The hydrogen is generated in the Netherlands and then shipped across the English Channel as liquid hydrogen and trucked to the transit bus maintenance facility. As of July 2015, more than 5,600 fillings had taken place, with over 96,000 kilograms of hydrogen supplied. London operators are able to fill a bus from empty in less than ten minutes on average.

Today, the majority of hydrogen for transit bus fleets is produced by large-scale steam methane reforming (SMR). This is currently the most cost-effective method of hydrogen production. Longer term, hydrogen can be produced from renewable sources, such as excess wind or solar power, making the vehicle truly zero-emission on a well-to-wheel basis.

Result

Transport for London (via their contractor Tower Transit) has been running zero emission hydrogen fuel cell buses on route RV1 between Covent Garden and Tower Gateway from 2011 to early 2020. This is the first time a whole route has been fully operated by hydrogen powered buses in the UK.

Together, the eight buses have logged more than 215,000 hours of service, covering over 2.0 million kilometers. A single FCveloCity® power module installed in a TfL bus recently set an important milestone of 30,000 hours of continuous operation without replacement or repairs. This performance milestone demonstrates the viability of fuel cell systems as a strong competitor for diesel buses, in terms of fuel efficiency and reliability, with the added benefit of reduced greenhouse gas emissions. One of the most significant results of the trial program is the improvement in the fuel economy. On average, CHIC program buses consume approximately nine kilograms of hydrogen per 100 kilometers, which is more energy efficient than a diesel bus.

Runtime	Over 215,000 hours of service
Distance Travelled	Over 2.0 million kilometers of service
Bus Range	250 – 300 km
Daily Operation	16 to 18 hours
Refueling Time	<10 minutes

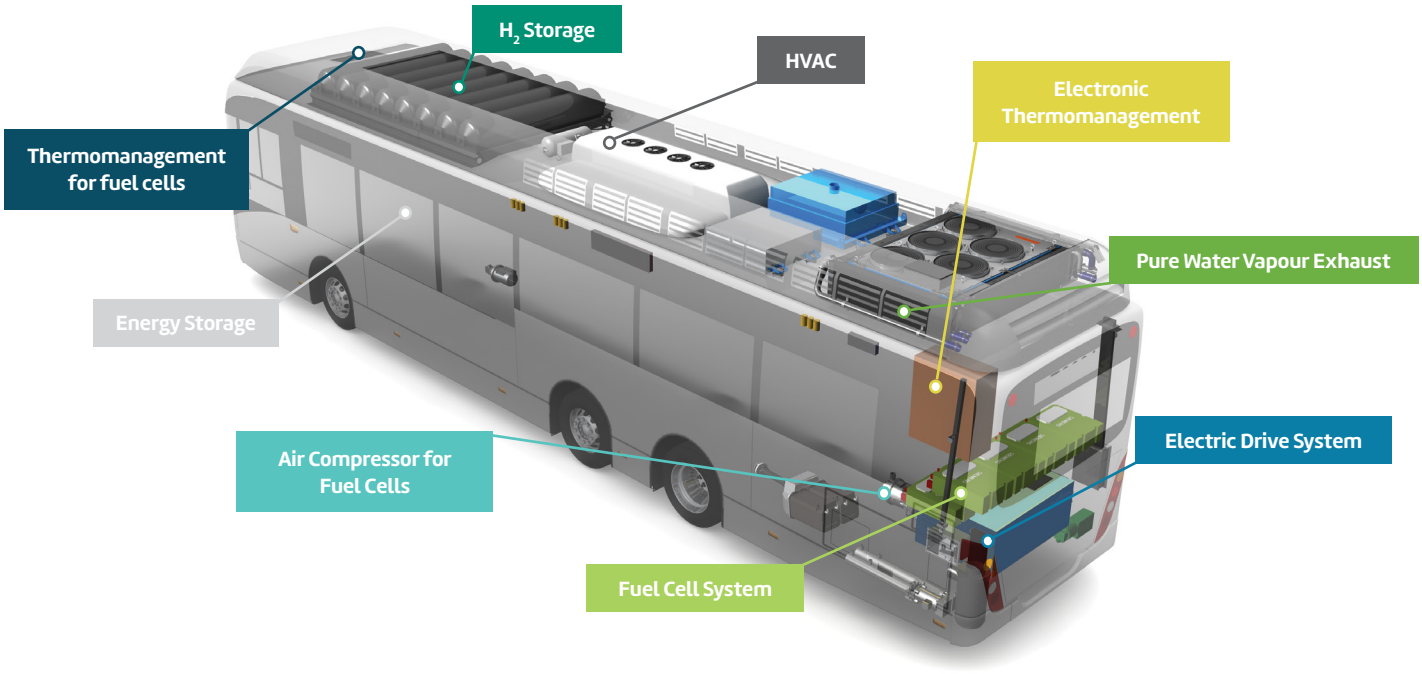
As Mike Weston, Transport for London's Director of Buses has stated, "We are very pleased with the performance of the fleet of fuel cell buses, as well as with the ongoing service and support that Ballard is providing. We remain committed to the achievement of our clean transportation goals and these buses are an important part of our solution."

Tower Transit, the agency operating the buses has trained several technicians to look after the preventive and corrective maintenance of

Zero Emission Bus Technology

A fuel cell bus is an electric vehicle that uses compressed hydrogen as the fuel, rather than storing energy in large batteries. Fuel cell power modules onboard the bus generate electricity through an electro-chemical process, producing only water and heat as byproducts. The electricity generated by the fuel cells powers the hybrid electric motors and charges the energy storage system. Regenerative braking on the buses increases the fuel economy. High pressure tanks located on the roof of the bus store hydrogen fuel, providing sufficient range for a full day of operation, over 16 to 18 hours. This compares well with the previous generation of fuel cell buses, whose range was less than 200 km, where buses were forced to operate in half day shifts before fuelling.

Fuel cell power modules onboard the bus generate electricity through an electro-chemical process



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Ballard Power Systems,Inc.
9000 Glenlyon Parkway
Burnaby, BC V5J 5J8
Canada

Contact us
(+1) 604.454.0900
marketing@ballard.com
ballard.com