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Welsh Government

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Case Study 09

Palestra Building Retrofit

Owner:
Transport for London

Architect:
Pringle Richard Sharratt

Fuel Cell specialist:
Logan Energy Limited

Location:
Southwark, London, UK

Building Types:
Offices

Project Description

In 2006, Transport for London (TfL) relocated into the Palestra building in Southwark. TfL were keen to improve Palestra's emissions BREEAM rating from "Very Good" to "Excellent" by generating energy locally to the building. This would generate significant savings in annual running costs of the building. Additionally, introduction of a decentralised energy supply to Palestra ensured TfL were adopting one of the key strategies to align with the Mayor of London's carbon emissions reduction commitment.

TfL therefore decided to implement an extensive retrofit scheme of Palestra to make it more sustainable. Extensive energy efficiency upgrades, such as lighting refurbishment and a CO_2 controlled ventilation system were implemented. An on–site 1 MWe Combined Cooling, Heat and Power plant (CCHP) was installed and integrated into the existing heating, chilled water and electrical systems. The new CCHP system includes a hydrogen fuel cell CHP unit located in a public area of the building, in addition to a reciprocating engine CHP unit located in the basement.

Key Drivers

A key driver for the project was the Greater London Authority's target of reducing carbon dioxide emissions by 60% before 2025, compared to 1990 levels.

At the time of development of the Palestra scheme, TfL had previous experience with hydrogen fuel cells which had been installed in a fleet of fuel cell powered buses. They wanted to showcase the benefits of the hydrogen fuel cell to the public.

Key features

- 200 kWe, 238kWth Hydrogen fuel cell;
- 500 kW absorption chiller;
- 75 m^3 thermal storage tank; and
- 834 kW reciprocating engine CHP unit.

Other low and zero carbon electricity generating technologies which were installed at the Palestra building by the LDA prior to TFL's refurbishment programme include:

- 63 kW polycrystalline photovoltaic array; and
- 14 kW (2No. 1 kW) micro wind turbines.

Renewable & Low Carbon Technologies

- Hydrogen fuel cell CHP
- PV array
- Wind turbines

The Palestra building
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The hydrogen fuel cell is the UK's largest building integrated fuel cell.

Procurement

TfL acquired a 20 year lease for the Palestra building in Southwark in 2006 and now occupies eleven of the building's twelve floors. The remaining floor is occupied by the London Development Agency (LDA), with total staff numbers at 2800.

The hydrogen fuel cell unit was manufactured by UTC Power, based in the USA. The unit was supplied to the site by Logan Energy Limited. The PV array and micro wind turbines were installed by the LDA.

Scheme costs and finance

The overarching retrofit scheme cost in the region of £5.8 million. The hydrogen fuel cell and associated plant cost £2.4 million, with funding secured from TfL's climate change fund.

Operational cost savings of the fuel cell CCHP have been estimated at £90,000 a year when compared against conventional grid supplied electricity and mains–fed gas fired boilers.

While the capital cost of a fuel cell plant is high, the savings in fuel and maintenance can result in reduced payback periods where all the heat is utilised for water heating and cooling via absorption chillers.

Technology Selection Process

When designing the system, the annual electricity, heating and cooling demands of Palestra first had to be assessed and modelled. A summary of the approximate average winter and summer heat and electricity demands of the building are provided below.

	Winter	Summer
Electricity (kWe)	932	972
Heat (kWth)	830	697
Hours of demand (hr)	5088	3672

Annual energy demands of the Palestra building
Data provided by TfL

Due to the buildings usage as offices the building has a relatively high baseload, which had to be accounted for when selecting the most appropriate renewable and low carbon technology combination. Additionally, the selected technologies had to be retrofitted into the existing heating and cooling system; consequently connection issues and plant space availability had to be taken into consideration.

CCHP was selected as a suitable low carbon technology for the site for a number of reasons, including:

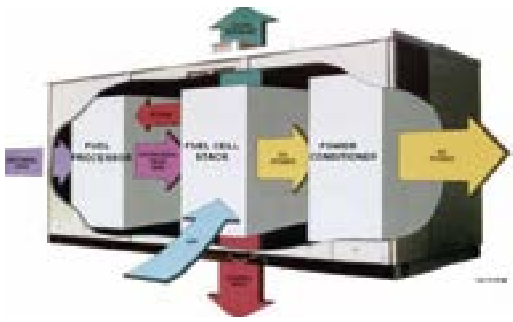
- CCHP systems provide a reliable source of electricity, which is important for a building with a high baseload where control rooms and server rooms require a constant energy supply;
- A single CCHP system can provide heat, electricity and cooling for the building which minimises space requirements; a key consideration for a retrofit scheme; and
- A CCHP system can provide substantial CO_2 emissions savings against conventional heating systems.

It was decided to install a hydrogen fuel cell CHP system, in addition to a reciprocating engine CHP (RECHP) system. While the RECHP system was sized to provide the majority of the energy demand, the system was designed so that the fuel cell CHP (FCCHP) was able to provide a significant proportion of the heat demand in addition to generating electricity and reducing the run–time of the RECHP. The fuel cell was also configured to meet the base electrical load based on its consistent output. The key benefits of the fuel cell are not only CO_2 savings, (which are lessened due to the requirement to transform natural gas into hydrogen), but its virtually silent operation, increased availability and reduced maintenance downtime (less moving parts), and also lower pollution in terms of NOx.

A phosphoric acid fuel cell system, supplied by Logan Energy Ltd, was selected for FCCHP. Due to the quiet operation of the fuel cell and its negligible emissions, it could be located in a public area on the ground floor of the building as an educational resource and visual, 'low carbon' element.

Hydrogen Fuel Cell Operation

In the Palestra fuel cell, hydrogen is extracted from a mains natural gas supply by a steam reformer. Oxygen is sourced from an ambient air supply to the unit. The fuel cell comprises a phosphoric acid electrolyte sandwiched between two electrodes. Air and hydrogen are respectively passed over the two electrodes and energy released in a chemical reaction is converted into low–voltage DC electricity, with heat and water produced as by products. Individual cells only generate a small amount of power and so several cells are assembled into a stack to provide sufficient power for the Palestra building. Hydrogen fuel cells work continuously, providing a supply of hydrogen and oxygen fuel is maintained.



Schematic of Palestra fuel cell CHP
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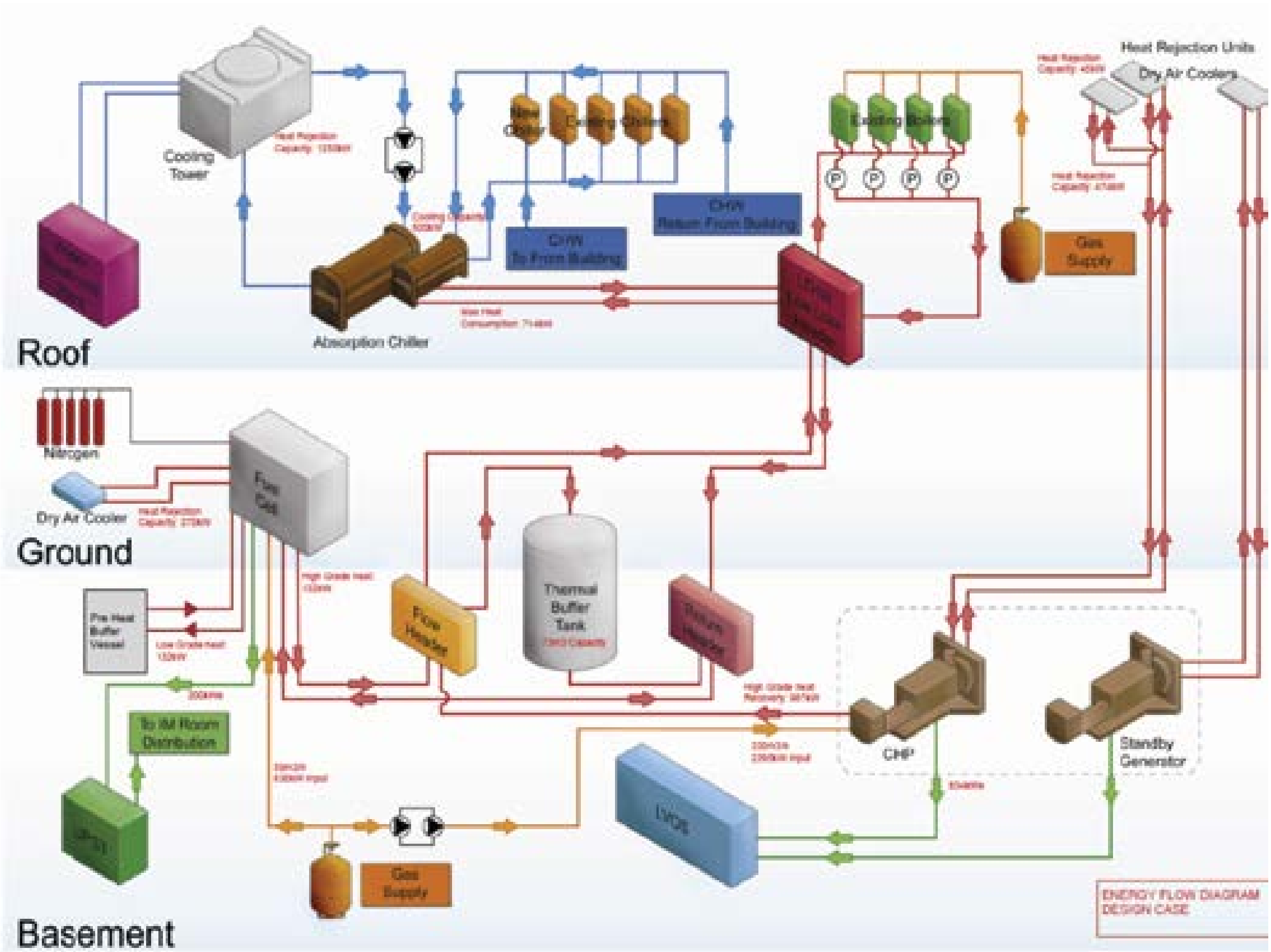
The unit (PureCell Model 200) is capable of providing 200 kWe of electricity, in addition to 138 kWth of heat. This, in addition to heat generated by the RECHP, is used to pre–heat the building's domestic hot water supply. The RECHP is capable of supplying of 834 kWe electricity and 987 kWth of heat, giving the combined CCHP system a power capacity of 1034 kWe.



Schematic and energy flow diagram of Palestra CCHP system
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Approximately 130 kW of high grade heat from the fuel cell and reciprocating engine CCHP system, is used to supply the buildings space heating system, or feed an absorption chiller which provides chilled water for cooling of the building in the summer months. An absorption chiller uses waste heat to drive the cooling process via a pump, generator, condenser and evaporator. The condenser for the Palestra absorption chiller is water cooled, with the cooling tower located on the roof.

A 74,000 litre thermal storage tank is located at the front of the building and stores surplus heat generated on site for usage in the heating system. This allows an uninterrupted heating supply during periods of peak demand and additionally minimises the waste heat from the unit, increasing the operational efficiency.

A key issue regarding the retrofit scheme was the integration of the new CCHP system into the existing heating system. Bespoke gas CHP and low temperature hot water (LTHW) pipe networks were installed throughout the building.

Monitoring and operation

Monitoring of the FCCHP system in September 2009 indicated that in the period between January and September 2009, the fuel cell had generated 288 MWh of electricity, 332 MWh of heat and had saved around 116 tonnes of CO_2 (against an equivalent conventional power supply). The fuel cell is currently operating at approximately 36% efficiency although over time the electrical output is anticipated to reduce and the heat output will increase.

Independent metering has been fitted to the installation to monitor the electricity generated, the natural gas consumed by the fuel cell and the heat rejected. This will enable TfL to obtain comprehensive understanding of the system performance. The results will be published in future Display Energy Certificates issued by TfL.

The government's CHP quality assurance (CHPQA) scheme is a government led initiative where "Good Quality CHP" (defined as having a Quality Index (QI) of more than 100 and efficiency greater than 20%) is exempt from Climate Change Levy (CCL). Submission of system performance data to CHPQA indicates that the tri–generation system achieved a QI (quality index) rating of 125 in its first year of operation. TfL were therefore able to claim under the enhanced capital allowances scheme and reduce gas costs by CCL exemption.

Emissions from the fuel cell system are significantly lower than fossil fuelled generation processes, with very low nitrogen oxide levels and carbon monoxide levels and with negligible emissions of particulates and hydrocarbons. Waste water generated by the fuel cell is used to top up a rainwater harvesting system to flush toilets in the building.

It has been estimated that the hydrogen fuel cell results in carbon dioxide emissions savings of 30% when compared to a building supplied by a conventional gas and electricity supply.

Thermal store at front of building
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Lessons learnt

Technological supply issues:

- Using a reformer to extract hydrogen from natural gas will reduce the power efficiency of a fuel cell.

Occupant involvement:

- Because the fuel cell does not make much noise during operation, TFL have placed it within an exhibition area on the ground floor. This space is easily visible to the public so TfL has used this opportunity to create a display to explain fuel cell technology and some of the other carbon saving measures incorporated into the building.

Financial Lessons:

- Large stationary fuel cells have a life expectancy of about 20 years. However the fuel stacks need to be replaced every five to ten years and this cost needs to be factored into the life cycle costs.

Awards & Achievements

- 'BREEAM' Excellent.

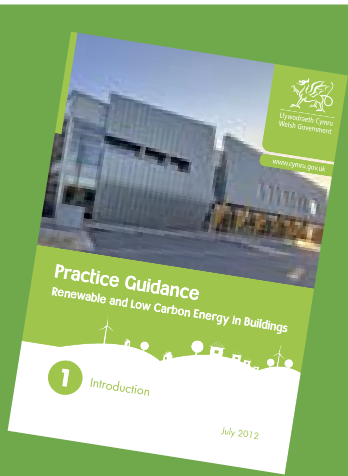
References and Acknowledgements

Andrew Stanton, Head of Sustainable Buildings, Transport for London

Further information

CHP Quality Assurance, DECC
www.chpqa.decc.gov.uk/chpqa–certificates
UTC Power
www.utcpower.com/
Logan Energy Limited
www.fuelcellmarkets.com

These case studies are presented to show examples of how buildings can be designed and built to be low carbon and incorporate renewable and low carbon technologies. This case study is part of a series of case studies supporting a separate practice guidance document on low carbon buildings.
For further information see www.wales.gov.uk/planning



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