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FUEL CELL POWER

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HEADLINE NEWS

At an International meeting in Birmingham, UK, speakers discussed the operation of fuel cell combined heat and power (CHP) installations in homes, industrial premises, hospitals, offices and shops. Although capital costs are not yet at grid parity, fuel cells powered by natural gas or renewable biofuels substantially reduce primary energy use and cut customers' fuel bills.

Operating locally 24/7, hydrogen fuel cells provide efficient back up for renewable energy from intermittent wind or solar power. Electric vehicles powered by batteries and/or fuel cells, also help to balance the electrical load and contribute to improved energy security and reduced C02 emissions.

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BIRMINGHAM TAKES THE LEAD INTO A NEW ENERGY FUTURE

Cllr Paul Tilsey, Deputy Leader of Birmingham City Council, welcomed delegates to the 7th International Conference entitled Generating the Hydrogen Fuel Cell Society. He said that the price of oil keeps rising and that supplies will peak within the next fifteen to twenty years. In that timescale, by 2026, Birmingham City Council is aiming to reduce their C02 emissions by 60%. Birmingham is aware of its responsibilities as the second UK city. They have introduced three new local distributed energy systems and are demonstrating electric vehicles, including fuel cell cars. Birmingham is accelerating manufacturing processes in order to bring forward fuel cell demonstrations and they look forward to leading the world into a new energy future with hydrogen and fuel cells.

STATIONARY FUEL CELLS

The Chairman of the Conference, Prof Kevin Kendall of Birmingham University, introduced Dr Peter Podesser CEO of SFC Energy and explained that small fuel cell generators, powered either by direct methanol or propane, have already found niche applications in auxiliary and portable power markets. SFC Energy has sold over 20,000 fuel cells so far in the low to mid-power range, said Peter Podesser. So far they have achieved over 8 million operating hours, with the advantage of long lifetime guaranteed by warranties. Fuel cells are now easier to use and are cheaper and have a more attractive supply chain. SFC finds that many customers are reluctant to abandon old technologies but they tell them "Whatever you have, forget it, fuel cells are the new thing!" SFC explores the gaps in the market and looks for the downside of an existing technology. Fuel cells provide a longer term energy supply than batteries for industrial and defence markets and SFC's portable units are lightweight. Peter Podesser showed a picture of a small girl holding a 10 litre methanol cartridge which contained 11kWh of electrical energy. Methanol cartridges are designed to be extremely safe and easy to use and SFC is expanding the number of outlets where they can be obtained. They are also supplying portable fuel cells for use in combination with solar PV. This adds more stages to the electrical value chain, as electricity is available on site whenever it is required.

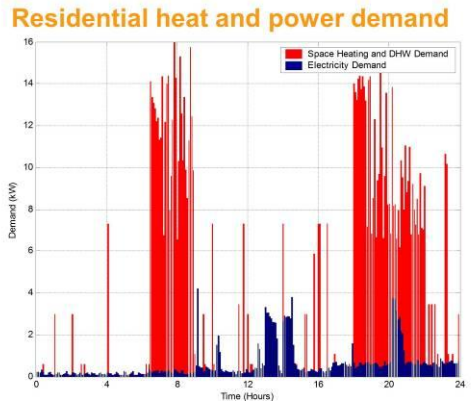
SFC's EFOY brand means 'energy for you'. They already have fifty outlets in Canada while they are building up markets in Europe. Fuel cell costs are between €2,000 and €5,000 for markets including recreational vehicles, motor homes, cabins and boats. Many people want an eco-conscious way of generating power and the EFOY is a dependable energy source, giving longer run times off-grid and a better return on investment. SFC is making fuel cells acceptable as part of the low carbon market for consumers and industry and they give a five year warranty with no limit on use. The cost of fuel cells is not yet at grid parity, but the manufacturers are reducing it and the methanol fuel only costs 30 cents per litre.

Aaron Crumm of Ultra Electronics (AMI) explained that their solid oxide fuel cells (SOFC) are used mainly for military applications, but that they are now addressing the potential for commercial markets. They are reducing the size of the SOFC and improving the efficiency of manufacture. They are aiming for the market sector for generators smaller than engines, but bigger than batteries. A small 3 watt hour (Wh) battery costs $1 and a larger 170Wh battery costs $90, which compares with 1,000Wh of propane fuel costing only $2. Their fuel cell is ideal for

unmanned air vehicles (UAVs) which require high power and is capable of powering a plane from dawn to dusk. For leisure uses they generate 6 kilowatt hours of electricity per day. They are starting with propane but SOFC can address dirty fuels like paraffin. For military use the infrared signature of high temperature SOFC is visible, but this is unavoidable, as even the footprints of people walking by can be seen.

Jeremy Harrison, Technical Consultant to E.ON Engineering UK, outlined the role of natural gas powered fuel cell micro CHP (mCHP) in a decarbonising energy system. Firstly, it contributes to energy security, as mCHP reduces the need for the back-up capacity required for intermittent supplies of wind and solar energy. Secondly, the electrification of heat with heat pumps will increase the problem of balancing the load on the grid and could add up to 40GW to the peak electricity demand in mid winter. If mCHP were used, it would mitigate this demand, as it would contribute to peak electricity as well as meeting part of the heat requirement. In the UK it is planned to install wind turbines which would generate up to 150GWe peak. This would require extensive back-up from mCHP when wind availability was low and the use of electric powered heat pumps and storage with electric vehicles to ensure that the wind energy is utilised efficiently when demand is low. The solid oxide fuel cell (SOFC) has a high electricity to heat ratio, producing 50% electricity and 40% heat. At present, each unit of electricity from the grid costs more than a unit of heat and also emits more C02. Therefore each kilowatt hour (kWh) of electricity generated by natural gas powered mCHP costs 3.3p but is worth the 10p cost of a unit from the grid. The generation of each unit of electricity by mCHP emits 0.22kg of C02 but saves 0.57 kg C02, compared with electricity from the grid.

Prof Nigel Brandon of Imperial College, Director of the Energy Futures Laboratory, explained that at present 94% of UK primary energy is fossil based. Heat contributes 39% of our C02 emissions, electricity 33% and transport 28%. In order to reduce C02 emissions, we must cut demand, increase efficiency, use biofuels, and/or use electric vehicles powered by hydrogen, batteries or hybrid systems. The cost of hybrid battery/ fuel cell systems is reducing, but there will still be C02 emissions until we get renewable hydrogen.



Demand for electricity and heat in a UK dwelling are misaligned, as illustrated in the graph for a typical winter day. However, it is economically rational to invest in micro-CHP, which is 90% efficient for heat and power compared with 35-40% for grid electricity. The main value driver for micro-CHP is the ability to displace onsite electricity demand. This depends upon thermal demand and the heat to power ratio of the micro-CHP unit.

Fuel cell micro-CHP can cost an additional £1,000 and remain a rational investment due to fuel savings. For example, Ceres Power's SOFC natural gas micro-CHP system reduces the energy bill of a customer by around 25% and saves up to 1.5 tonnes of C02 per annum. Under the UK's Feed in Tariff (FIT) scheme, a fuel cell up to 2kW can receive payments for ten years of 10p/kWh for electricity produced and consumed in the home and an additional 3p/kWh for electricity exported to the grid. The carbon benefit value of CHP will reduce as the grid decarbonises. There should equally be efforts to decarbonise the gas supply, by using

biomass and waste and perhaps hythane. Fuel cells offer the highest known energy conversion efficiency for electricity production of any equivalent device. They offer higher efficiency with fossil fuels today, with the prospect of operating on renewable fuels in the future. This has the potential to make a significant impact on carbon emissions in both the transport and stationary power sectors. The UK has strengths in the fuel cell supply chain to allow these benefits to be realized, as well as a strong research base to support development and deployment.

LARGER FUEL CELLS

The state of technology of large-scale fuel cell systems for grid power up to 50 MW, for distributed power, auxiliary power, industrial and commercial applications was reviewed by Brendan Bilton, consultant to E.ON. Solid oxide fuel cells (SOFC) are available up to 100kW and systems up to 1MW are under development. The main manufacturers are Bloom Energy and Rolls Royce. Rolls Royce's pressurized 1 megawatt (MW) SOFC system is due for field testing in 2013. Proton Exchange Membrane (PEM) fuel cells are being scaled up and between 100kW to 1MW systems from Ballard and Nedstack are already operational. Molten Carbonate fuel cells (MCFC) between 125kW and 3 MW are available from MTU, POSCO, FuelCell Energy and Ansaldo. AFC Energy is developing larger alkaline fuel cells (AFC).

The phosphoric acid fuel cell (PAFC) from UTC Power, ranging from 250-400kW, has the longest life. They have 95% availability and are operating for over 75,000 hours. A comparison with other low carbon technologies shows that the return on investment can be better than that for solar PV or wind turbines, due to the high availability of the fuel cell. The high availability can also enable much greater reductions in annual carbon dioxide emissions compared with wind and solar energy. UTC's high temperature PAFC can be fuelled either by hydrogen or fossil fuels – it is on the cusp of large scale production. The first markets for larger fuel cells include California, where there is a ban on diesel generators in down-town areas. In South Korea there is Government support for 100s of megawatts of large scale generators. There is also a growing need for distributed power to recharge electric vehicles. Chlor-alkali plants have hydrogen as a by-product, which can be used to meet on site requirements for electricity and process heat. Water treatment facilities are also being powered by on site fuel cells. There is great demand for clean combined heat and power in hospitals, hotels, offices and shops. The market is growing and it is a cash generating business for the end user.

Chris Rogers, energy consultant and formerly with Honda Europe, envisaged that in the future energy will be stored as hydrogen just as digital is now the universal data storage. He referred to Jeremy Rifkin's concept of the Third Industrial Revolution in which the same design principles and smart technologies that created the internet and the vast distributed global communications networks are beginning to be used to reconfigure the world's power grids. This will mean that people can produce renewable energy and share it, just as they now produce and share information, creating a new, decentralised form of energy use. There will be expanded generation of renewable energy stored as hydrogen and buildings, with new insulation materials and a smart bi-directional inter-grid, will become positive power plants. Electric vehicles could also contribute to meeting peak power demands: if just 25% of European drivers used their electric vehicles as power plants to sell energy back to the inter-grid, all the major power plants in Europe could be eliminated!

FUEL CELLS FOR TRANSPORT

Ben Madden of Element Energy outlined progress with fuel cell

powered vehicles in Europe. We are now in a pre-commercial phase with projects underway in several countries. In Germany the Clean Energy Partnership was established in 2004 and hundreds of fuel cell vehicles are now with customers. National organisations in Norway, Sweden and Denmark are working together to build the Scandinavian Hydrogen Highway. Hyundai has already made a commitment to deploy their hydrogen fuel cell vehicles there. Other original equipment manufacturers (OEMs) are interested and Scandinavia's high up-front car taxes are an added incentive. A network of hydrogen filling stations across Europe is emerging and the German company, LBST, shows on their website the hydrogen stations which are already operating or planned. www.h2stations.org

The European Clean Hydrogen In Cities project (CHIC) is assisting with the deployment of 26 hydrogen fuel cell buses. The biggest demonstration in the UK is that for eight London buses, which will be expected to have the same performance as diesel buses, operating for 20 hours per day, 365 days per year. Five of the buses are already on the road. London also has demonstrations of fuel cell cabs and scooters and provides the secretariat for the Hydrogen Bus Alliance. There are projects with hydrogen fuel cell vehicles in Scotland and the Midlands, where there is a strong manufacturing base.

There is growing political interest in hydrogen and fuel cell powered vehicles and nascent companies are supplying the niche markets for taxis and buses. Asian OEMs are particularly interested in the UK demonstrations. Mercedes is investing in a factory in Canada for series production of their fuel cells. A study sponsored by a coalition of the European motor industry and analysed by McKinsey, found that hydrogen fuel cell vehicles would be the only viable pathway to zero carbon transport for longer range, larger vehicles. In Germany, H2 Mobility is providing information and preparing the public and private sectors for the introduction of hydrogen powered vehicles from 2015. In answer to a question, Ben Madden believed that vehicles would be powered by gaseous hydrogen compressed to 350 or 700 bar, although there is ongoing research into liquid hydrogen.

Peter Podesser, CEO of SFC Energy envisaged a role for small fuel cells in hybrid electric vehicles. His company is combining fuel cells with batteries in a German electric vehicle development project. In winter up to 60% of the battery's power is required to heat the vehicle and the lithium ion batteries. They are working on the development of a hybrid fuel cell system which will contribute two thirds of its energy in the form of heat and the remaining third as electricity to extend the range of the battery electric vehicle.

Masahiro Watanabe from the Fuel Cell Nano-materials Centre in Japan gave an interesting review of technical developments with PEM fuel cells. Nano materials are improving performance and reducing costs. The Nano-materials Centre is working to reduce the platinum loading of PEMs

to about one tenth of the present loading and they aim to reduce the cost of the fuel cells to about one-twentieth. Advances with materials are enabling them to reduce degradation and improve reliability. They are also developing new processes for the production of clean hydrogen and ensuring that they meet all regulations.

Peter Gray, Sales & Marketing Manager of Johnson Matthey, said that there is particular interest in Polymer Electrolyte Membrane (PEM) fuel cells for cars in Japan, Korea and Germany. PEMs are also used in buildings, where the cost is coming down. It takes time to ensure the highest quality development. Over the past three years they have reduced to a third the cost of the Membrane Electrode Assemblies (MEAs) which are the core components of PEM fuel cells. For small order production of up to10,000 MEAs per annum, capital cost is low but labour costs are high. In larger volumes, that is in millions for OEMs, the MEA design is frozen and there are high capital but low labour costs. Intermediate volumes, in the100,000s, are more flexible and have low labour and moderate capital costs. The advantage of PEM fuel cells is that they can operate 24/7 and contribute to peak demands. Johnson Matthey does not envisage any problems with platinum supply, as Pt in MEAs will be recycled and platinum reserves significantly exceed forecast future MEA demands.

For the future, Chris Rogers, energy consultant, envisaged that by 2050 there would be a smart, totally integrated and balanced transport infrastructure with high speed rail. For personal mobility, cars will be electric, they will have advanced smart communications technology and will not have accidents. They will be powered by zero emission hydrogen fuel cells and rechargeable batteries, which will help to balance the electricity loads from intermittent renewable sources. In answer to a question about the oil companies losing their investment he replied that they will have to diversify anyway as the car industry is changing fast.

HYDROGEN STORAGE

Hydrogen has an important role in storing energy, particularly from intermittent renewable sources, explained Stephen Jones of ITM Power. It is also a clean fuel. There is already an existing hydrogen infrastructure, with large industries using up to 1,000 kgs per day and vehicle fleets and depots using up to 50kgs per day. The use of hydrogen in the home will be between 1 to 5 kgs, but this is further in the future. Japan, the USA and Germany are committed to hydrogen and the UK is beginning to get its act together! However, we need Government backing for a mobility plan, like the German H2 Mobility which aims to provide hundreds of hydrogen fuelling stations by 2015. ITM's HOST project produces hydrogen on site by electrolysis for fleets of vehicles. 15 kgs per day is sufficient for three transit vans, each with 100 miles range. Twenty one commercial trial partners are involved and operational data will be collected over a year. Hydrogen fuel is available for use now – we do not have to wait for ten years! The Chairman of the session, John Turner, commented that it is good to involve companies which have no connection with the hydrogen and fuel cell industry.

Ian Williamson of Air Products said that they produce over 5 million kgs of hydrogen per day, with 120 hydrogen stations providing 300,000 fuellings per year. There is a step change in the USA, where they are moving from research and development to the retail sale of hydrogen. There is also rapid growth in hydrogen power for materials handling in the USA. Air Products makes use of the hydrogen produced by the existing industrial infrastructure whenever possible. The maintenance and efficiency of compressors is a big issue. In his view there is negative energy input over 500 bar, but the automotive companies

want 700 bar because they have not taken the necessary steps to reduce vehicle weight.

In Torrance, California there is a hydrogen pipeline down the middle of the road. Europe is doing more with the bus industry. Transport for London has a dual phase liquid hydrogen tanker still in the introductory phase.

Significant volumes of hydrogen and power can be generated from waste. A molten carbonate fuel cell in Europe produces a ton of hydrogen per day, in addition to electricity and heat. This green hydrogen is obtained from the gasification of 30 tons of municipal waste per day. Air Products is planning a plant which would provide 50MW of power from 900 million tons of waste per day. The gas turbine would be replaced by a large fuel cell, which will need to have longevity. The timescale to build a commercial plant and bring it on stream is three years. In answer to a comment that waste contains halogens, etc, which damage fuel cells, he replied that Air Products is expert in cleaning up gases – their entire process has 15 stages to produce pure hydrogen.

Most users want green hydrogen but it is expensive, so H2 Mobility in Germany is introducing green hydrogen gradually, over a period of time. For the future hydrogen will come from multiple feed sources, from biomass, geothermal, wind, solar, nuclear, coal and methane reforming.

Steve Perham of the Airmax Group said that their on-board hydrogen additive system enables i.c. engines to burn more cleanly, adding power, improving fuel economy and lowering C02 emissions. Airmax is supplying some of the largest fleets in the UK and overseas with electronics which monitor all aspects of vehicle performance and costs. Their aim is to reduce customers' costs as well as their C02 emissions. Their engine control unit (ECU) achieves 15% gains in efficiency and they are working on a micro fuel source, using solar energy to create sustainable hydrogen.

Andrew Haslett of the Energy Technology Institute (ETI) considered the role of hydrogen in the future supply of energy. Hydrogen storage will contribute to sustainability and to meeting climate change targets to cut carbon dioxide emissions by 80%. Hydrogen will be obtained from a variety of sources, from fossil fuels with carbon capture and storage (CCS), nuclear and renewable energy, mainly offshore wind. If hydrogen is obtained from coal with CCS, there will be a significant requirement for hydrogen storage and there is sufficient capacity for this in salt cavities in the UK. Obtaining hydrogen from biomass and then capturing and storing the C02 would be the cheapest way of mitigating global warming gases.

MEETING GOVERNMENT TARGETS

At the working group meeting of the UK Hydrogen Fuel Cell Association (UK HFCA), Celia Greaves proposed that there should be a co-ordinated response to the Government. The HFCA has responded to the consultation on Electricity Market Reform as well as to the consultation on renewable energy and fuel quality directives. They have provided information for the Whitehall Hydrogen Action Team, the Technology Strategy Board and for the Bow Group, which has published an excellent report on

hydrogen storage. Their aim is to accelerate the commercialisation of fuel cells and hydrogen through advocacy and other means. A report by a German consortium entitled Portfolio of Vehicle Drive Trains, which was analysed by McKinsey, found that fuel cell vehicles are the best low-carbon substitute for family size cars. There is also interest in fuel cells for high speed rail. During the discussion, a delegate proposed that Government policy should cover all the technologies which reduce carbon dioxide, rather than just renewables. Distributed energy generation could make a substantial contribution to meeting their targets and the Government should avoid making technical choices. It was pointed out that by 2020, 85% of the UK's energy would still be fossil fuel. There is a paucity of understanding amongst policy makers, who need to be educated. Lobby groups influence the media so some technologies will be favoured more than others, but we can counter this with factual information about fuel cells. Government measures to facilitate the commercialisation of fuel cells could include forward procurement and other financial incentives. Hydrogen could be used in many applications. 60 million tons per year are already being used and renewable energy targets cannot be met without hydrogen storage. For the automotive industry, the well to wheel efficiency of hydrogen from wind can be further improved with local generation. www.UKHFCA.co.uk

Norberto Fueyo of the Numerical Fluid Dynamics Group at the University of Zaragoza, Spain gave his own version of the European Union proposal for 20% renewable energy and a 20% cut in energy intensity by 2020. Is 20-20-20 possible? He estimated that for Spain there could be 20% extra cost, 20% more visual impact and this with a tariff shortfall that is already reaching €20 billion. He assessed the technical potential and the full costs of different types of renewable energy, on and offshore wind, solar, hydro, marine energy, waste and biofuels. People want their governments to take action to deal with the possible deleterious effects of fossil fuel emissions, but has anyone carried out large scale rigorous quantifications?

Claire Castel represented the EU Fuel Cells and Hydrogen Joint Undertaking (FCH JU). The first markets for fuel cells envisage portable systems and fork lift trucks and the EU is now backing stationary and transport applications. Regarding transport demonstration projects, the Scandinavian project "H2 Moves Scandinavia" based in Oslo, including Daimler as a partner, has received 8 M€ support from the EU for a total budget of 20 M€. The Clean Hydrogen In Cities (CHIC) project for 26 fuel cell buses in five cities has started in London. Other projects with fuel cell cars and buses are underway with the support of the European Regions and Municipalities Partnership for Hydrogen and Fuel Cells (HyRAMP). Regarding stationary demonstration projects, the FCH JU is supporting the deployment of 40 PowerCubes in Europe (laboratory validation units) and Africa. The FCH JU is a public private partnership between industry, research and the European Commission and is providing €470 million funding over several years, matched by in kind contributions by industry. Information about the next call for funding proposals is available from: www.fch-ju.eu Full presentations from the meeting are available together with information about future events at: www.climate-change-solutions.co.uk

NEWS

FUEL CELLS WITH BIOGAS AND CARBON SEQUESTRATION

FuelCell Energy, Inc. has announced their participation in a research contract with the US Environmental Protection Agency (EPA) to evaluate the effectiveness of Direct FuelCells® (DFC®) to efficiently separate carbon dioxide from the emissions of industrial operations such as refineries, cement kilns and pulp and paper mills. These industrial operations generate flue gas, a waste product that contains CO2. The award from the EPA will fund initial testing of the ability for Direct FuelCells to consume flue gas instead of ambient air for the power generation process and their ability to cost effectively separate the CO2 within the flue gas. Efficiently and effectively separating the CO2 enables sequestration, preventing the release of this greenhouse gas into the atmosphere. Chris Bentley, Executive Vice President Government R&D Operations, FuelCell Energy, said that carbon capture is an important area of focus for reducing greenhouse gas emissions and their team is excited to be undertaking this leading edge research. The research under Phase I is expected to take up to six months. Successful results may lead to a demonstration project at an industrial site using a DFC power plant to provide ultra-clean electricity and usable heat for the industrial operation, while separating CO2 from the flue gas for sequestration. Capturing CO2 for sequestration is a potentially large global market.

FuelCell Energy is also participating in a contract with the U.S. Department of Energy to demonstrate advanced biogas desulfurization technology. Direct FuelCells can be fuelled by renewable biogas generated by industrial processes such as food processing, agriculture and wastewater treatment. However, the biogas contains a high level of sulfur that must be removed prior to being used as a fuel. The biogas demonstration projects will determine the market feasibility of a new high capacity, expendable sorbent developed by TDA Research, which efficiently removes sulfur from renewable biogas. If successful, the sorbent could reduce the cost of fuel cells operating on biogas, as it has an expected lifespan that is up to thirty times longer than the technology currently in use. FuelCell Energy currently has 20 megawatts of DFC biogas power plants installed and in backlog. TDA Research, Inc., the prime contractor under this U.S. Department of Energy program, developed the sorbents for the projects, which will be demonstrated at a wastewater treatment facility and a family-owned dairy farm, both located in California. The demonstration projects are expected to last 18 months. www.fce.com

I2BF INVESTS IN ACAL ENERGY

The international clean technology asset management group, I2BF has invested £1m in ACAL Energy, the UK based developer of FlowCath® fuel cell technology systems. David Waserstein, Partner and Director of Investments at I2BF, said: "We are delighted to be involved in early stage companies like ACAL that are developing and commercialising cutting-edge clean technologies. ACAL's technology can play a significant role in the adoption of fuel cells as a clean and efficient way of generating electricity, which is particularly interesting to the major global automakers that are developing fuel cell electric vehicles for commercial launch in 2015. In addition we see exceptional growth potential in markets where distributed generation is critical and natural gas is readily available."
www.acalenergy.co.uk

CALL FOR UK RENEWABLE ENERGY STORAGE INCENTIVE (RESI)

Summary of a report entitled RESCUING RENEWABLES: How energy storage can save green power, by Tony Lodge, Chairman, Bow Group Energy and Transport Committee

At present the demand for electricity fluctuates and may double at peak times, but the supply is always available so that blackouts are very rare. The electricity industry works hard to ensure that they meet this fluctuating demand, but the introduction of intermittent energy from wind and solar sources means that supply and demand are both fluctuating at different times. This causes inefficiencies and could damage the grid and lead to blackouts when supply is not sufficient to meet demand. To avoid this happening, fossil fuel plants are used as a back-up when the wind is not blowing and there are already instances when wind turbines have had to be closed down when demand was low. This means that the full benefit of a green unit of electricity, a kilowatt hour (kWh), entering the grid cannot be realized because 1kWh of green energy cannot displace 1kWh of fossil generated electricity.

HYDROGEN 'WAREHOUSE'

Balance is the key to the electricity industry. The production and consumption of electricity are dynamically coupled; supply must match demand in a sub-second timescale. The addition of new unpredictable components, like weather dependent wind and solar energy, undermines the balance. Even small variations in system voltage and frequency can cause damage to modern electronics and other electrical equipment. When electricity is made it must be delivered, so a 'warehouse', or electricity storage system, would be of great value to the electricity industry.

The present means of storing renewables include pumped storage, like the Dynorweg hydro-pumped storage power plant in Wales, which is 74% efficient. However, there are few suitable sites for pumped storage in the UK. The inertia in large rotating steam turbines powered by coal is also a form of energy storage when these plants are kept active as a 'spinning reserve', but there are fewer of these stations as coal is now being phased out. Gas turbines do not provide spinning reserve, nuclear power can only be used to provide base load as it cannot be ramped up and down and oil fired plants are expensive, inefficient and carbon intensive. Batteries are only suitable for small scale, short term storage, but hydrogen storage is feasible at multi megawatt (MW) wind farm sites and, on the distributed level, for districts, streets, farms, villages and homes. This mass storage deployment would enable reductions in capital costs.

For comparison, the Scottish island of Eigg uses batteries for storage and the Norwegian island of Utsira uses hydrogen. Eigg found that its storage was not sufficient and is now considering an Utsira-style hydrogen storage system, which has provision for three days of stored power if a wind-

free period occurs and this can be increased as required by expanding the hydrogen storage capability. Utsira could also boost its renewable energy portfolio with the installation of solar PV, wave and tidal capability. Denmark has a large number of wind farms which could in theory meet 70% of the country's peak demand, but this is rarely matched by supply when it is needed. Averaged over the last five years, wind power has only provided 9.7% of Denmark's annual electricity demand. Denmark therefore exports much of its surplus electricity via the grid to neighbouring countries at a discount to the cost of generation.

COST BENEFIT ANALYSIS

Over a 20 year period the net cost benefit of the UK Government's renewable energy policy is negative. This could be improved if local hydrogen storage is introduced with the following benefits:

- improved efficiency as supply matches demand
- the need for fossil fuel back-up is removed
- lower carbon emissions
- less investment in infrastructure costs
- reduced stress to the system as ramping up and down is minimized
- grid stability and continued freedom from blackouts
- community, business and individual self-sufficiency

RENEWABLE ENERGY STORAGE INCENTIVE (RESI)

However, further technical improvements and cost reductions are necessary to make wind power with hydrogen storage more viable and competitive against diesel generators. For this reason there is a strong argument for fostering a distributed renewable system which generates, stores and utilizes green energy at the point of use. As with other immature renewable technologies, initial financial incentives will be required to help cover the cost of systems of renewable energy plus storage. Alongside Feed in Tariffs for renewable energy, it is proposed that there should be a Renewable Energy Storage Incentive (RESI), which would offer huge potential benefits to the operational effectiveness of the grid. The value of storage from the commercial point of view is illustrated when at times of peak demand the electricity price can jump in half an hour from around £35 per megawatt hour (MWh) up to £140. There is little to be gained if homes export electricity to the grid at times when availability is high and demand is low. Energy storage would address this by mopping up intermittency in the form of a clean fuel consumed at household level. The Government should add a 10p tariff for storing green electricity to the present FIT rates, as renewable storage will reduce rather than increase fuel bills.

The Department of Energy and Climate Change (DECC) has published their Low Carbon Transition Plan, which recognizes the problem of back-up power for intermittent renewable energy but does not solve it. There is also likely to be an energy gap from 2017 as oil, coal and nuclear plants close down, even if wind power meets its targets. Biomass power plants are not the answer as they could cause significant pollution in urban areas and mis-spent Government subsidies on biofuels have encouraged the cultivation of non-sustainable crops, they have driven deforestation and caused rises in food prices. Local renewable energy storage is the only viable way both to slash UK carbon emissions in the short term and to meet strict renewable targets.

The mismatch between electricity supply and demand occurs with high peaks for a few hours per day and particularly at weekends. The peaks can be reduced by demand side management, but are best dealt with locally through the use of energy storage.

BRITISH POLICY LEAD

One British company is taking the lead with hydrogen for transport. Yorkshire-based ITM Power is developing a hydrogen infrastructure for transport operators and has a demonstration home powered by hydrogen at its factory. They are working with the global wind turbine manufacturer, Vestas, which is aiming to generate the most sustainable return on wind for their customers.

The electricity industry is extremely conservative and is reluctant to take on the risk of developing new technologies, so the Government should encourage the energy storage sector in the same way as it has done with the Renewable Obligation Certificates. The UK currently has less than a 5% share of the global market for green technology – less than Japan, France, Germany, Spain or the US. Analysis of R & D investment indicates that UK companies invest less in R & D regardless of their size as compared to their G8 competitors.

The proposed renewable electricity storage incentive (RESI) should now be made available for the micro-generation of green hydrogen by electrolysis. Various studies have shown that this route of absorbing excess renewable electricity at times of peak supply for use at times of high demand offers flexibility - for example, in emergency backup power and car refuelling. It is likely that a significant proportion of consumers will discover that they have a new role as micro-generators of green energy as well as users.

It would help those who wish to achieve more autonomous energy solutions and a low carbon footprint with the installation of suitable equipment such as a home hydrogen refueller. Green energy storage provides a 'localist bottom-up' solution for the Coalition Government towards energy and environment policies, without Ministers having to cherry-pick technologies or pick winners.

Scotland has set a target to become 80% self sufficient in renewable energy by 2025, but this would not work without renewable energy storage. If the wind's power can be harnessed as stored energy to be used later, when it is required to meet demand, the potential for Scotland and the rest of the UK is huge. Countries that are early adopters of these energy storage technologies will benefit most in the development of hydrogen and fuel cell industries.

The flexibility of hydrogen energy storage is that it can do more than just clean up the power system, it can also clean up the transport system, improve air quality in towns and cities, dramatically reduce carbon emissions and provide the UK with a global manufacturing and engineering edge. Unlike batteries, hydrogen is a fuel which can be stored for long periods and therefore provides the security that society seeks, as well as independence from diminishing oil and gas reserves.

www.bowgroup.org

INTELLIGENT ENERGY MOVES TOWARDS THE LOW CARBON ECONOMY

SUZUKI BURGMAN SCOOTER OBTAINS WHOLE VEHICLE TYPE APPROVAL

Intelligent Energy and Suzuki Motor Corporation, have announced that the jointly developed Suzuki Burgman Fuel Cell Scooter has obtained Whole Vehicle Type Approval (WVTA) – the first time any fuel cell vehicle has achieved this level of certification in Europe. WVTA qualifies the Suzuki Burgman Fuel Cell Scooter design as safe to use on public roads without having to be inspected and tested individually, and brings zero emission motorcycles a step closer to becoming commercially available.

First exhibited at the 41st Tokyo Motor Show in October 2009, the Suzuki Burgman Fuel Cell Scooter, equipped with the latest version of Intelligent Energy's unique, air-cooled hydrogen fuel cell system, has been participating in a UK public road testing program run by Intelligent Energy and supported by the UK Government's Technology Strategy Board. The Suzuki Burgman Fuel Cell Scooter design has now met with specified EU performance standards meaning that the vehicle and its components are approved for production and sale within Europe.

Chris Huhne MP, Secretary of State for Energy and Climate Change visited Intelligent Energy and is seen here on the WVTA Certified Suzuki Burgman Fuel Cell Scooter. Also in the photograph are from left to right, Yasuhara Osawa, Managing Director of Suzuki GB, Dr. Henri Winand, Chief Executive of Intelligent Energy, and Dennis Hayter, VP Business Development, Intelligent Energy.

The Chairman and CEO of Suzuki Motor Corporation, Mr. O. Suzuki, stated: "Suzuki Motor Corporation is pleased to announce that the Suzuki Burgman Fuel Cell Scooter has become the world's first fuel cell vehicle to earn Whole Vehicle Type Approval in the European Union. Our aim is to make eco-friendly fuel cell scooters increasingly common in Europe, in line with the establishment of hydrogen filling stations and other necessary infrastructure." The city-friendly Suzuki Burgman Fuel Cell Scooter was jointly launched in Europe at London's City Hall in February last year. At the event, the Chair of the London Hydrogen Partnership and London's Deputy Mayor for Policing, Kit Malthouse, hailed the zero emission scooter as a "fantastic piece of kit which shows how we can combat climate change." A fleet of the scooters will now undergo a further test program in various public road conditions at sites in the East Midlands and London.

Earlier Dr. Winand and Rolls Royce Chairman, Sir John Rose, had briefed UK Government Cabinet Ministers, including the Prime Minister David Cameron, the Chancellor of the Exchequer George Osborne, the Business Secretary, Vince Cable and the Secretary of State for Energy and Climate Change, Chris Huhne. The briefing followed news earlier this year that Dr. Winand had joined the Government's new Green Economy Council, composed of senior business leaders across the industrial sector, including Ford, Centrica, and IBM. "Ministerial visits such as these help us to convey both the significant progress

Intelligent Energy is making towards the commercialisation of clean technologies on an international stage, and support our shared goal to position the UK as a leader in the deployment and manufacture of low carbon technologies," explained Dr. Winand. www.intelligent-energy.com

NEWS

HFUEL HAS ACHIEVED ROAD COMPLIANCE

ITM Power has announced that its HFuel transportable hydrogen refueling product has satisfied the requirements of the UK's Department for Transport for road use.

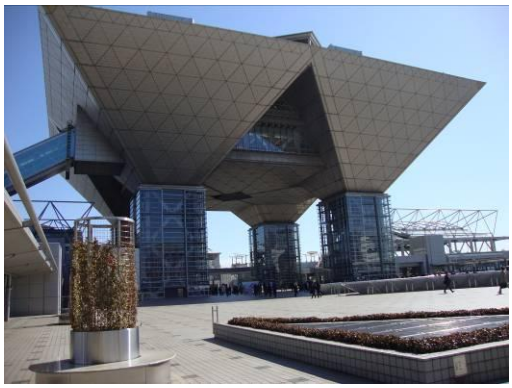
In preparation for the HOST (Hydrogen On Site Trials), ITM Power has undertaken a thorough assessment of system safety and the required approvals. This has generated a suite of documentation to evidence the legal transportation of HFuel on UK public roads with a full inventory of hydrogen and to satisfy local fire and Health & Safety authorities. As part of the assessment, the Company has created a documentary resource covering the elements required by the Dangerous Goods Division of the Department for Transport. This has involved independent pressure testing to 1.5 times working pressure, assessment by an independent ADR Notified Body and interaction with specialist chemical plant consultants. Similarly, Revolve Technologies has subjected the hydrogen internal combustion engine Transit vans to the appropriate level of assessment. This has included independent leak testing of on board pressure systems, crash test simulation and the implementation of a dynamic leak detection strategy. This has resulted in the vehicles being granted a Vehicle Special Order Type Approval by the Department for Transport to enable them to be used on the road whilst transporting goods for trials and demonstration purposes. www.itm-power.com

TRIAL OF LOW COST FUEL CELL

This summer ACAL Energy and its development partners are installing the world's first FlowCath® fuel cell technology system to be used in a practical application at Solvay Interox Ltd. The field trial will provide critical back-up power for an environmental remediation plant at Solvay's Warrington plant. The technology is expected to significantly reduce the balance of plant costs by eliminating the need for hydration, pressurization, separate cooling and other mechanical sub-systems commonly required when using conventional PEM fuel cells. ACAL Energy is completing the low cost design and validation activity in its new laboratory testing facilities, with the support of partners including Johnson Matthey Fuel Cells, UPS Systems plc, the University of Southampton and the Manufacturing Engineering Centre at Cardiff University, with part funding from the Technology Strategy Board.
www.acalenergy.co.uk

VISIT TO TOKYO FUEL CELL EXPO 2011

By Ronald Hodkinson, Diverse Energy Ltd



What started as the Fuel Cell Expo (FC Expo) has now grown into the Japan Renewable Energy Week, with six concurrent exhibitions filling the halls at Tokyo Big Sight. Alongside the FC Expo were the Intelligent Grid Expo, the Eco House and Building Expo, Photovoltaic (PV) Expo, PV System Expo and the Battery Japan Rechargeable Battery Expo. There is also a world class conference on renewable energy. Japan Renewable Energy Week attracts more than 100,000 professional visitors from around the Globe and is undoubtedly the premier event in the fuel cell calendar. This year the fuel cell exhibits were slightly reduced in number, but this was deceiving because of a significant number of National Pavilions. Canada, Finland, Fukuoka Prefecture, the USA, Taiwan, France, Germany, Kanawa Prefecture and Okaya City all had pavilions. The Japanese Domestic CHP Program continues to make headway under the auspices of the New Energy Coalition.

Two fuel cell technologies could be seen to be making headway, the solid oxide (SOFC) for domestic CHP and PEM for the latest fuel cell vehicles. Whilst PEM Systems running on natural gas give circa 37% efficiency fuel to electricity, the latest SOFC plants are now achieving 50% (Tokyo Gas) and both types achieve 85% efficiency including waste heat recovery.

PRACTICAL FUEL CELL VEHICLES

There were six vehicles for demonstration at the Japan Hydrogen and Fuel Cell Demonstration Project. My colleague, Dr Mike Rendall, and I drove the Honda FCV Clarity and the Toyota FCHV-adv electric vehicles. Both vehicles performed faultlessly in bitter northerly wind conditions, but the Honda had the edge on performance being a newer design.

FCV's have arrived as practical driving propositions - the Clarity gives 400km range on a 350bar hydrogen tank and can be refuelled in less than 5 minutes. The Japanese car industry estimates that these vehicles currently cost around £75,000 to manufacture and intend to halve this figure for market launch in 2015, due to economies of scale and simplified fuel cell architecture. Other vehicles available for demonstration were the Nissan X Trail FCV and the Mazda 5 Premacy FCV.

RELIABLE BALANCE OF PLANT

For those interested in balance of plant this show was an Aladdin's Cave. All the tier one suppliers showed their latest products. At last we can have pumps and blowers which are efficient and reliable for continuous duty operation. We are even beginning to see good quality hydrogen pumps such as the Agura units used on Ballard's fuel cell buses. There were also specialist steels and ceramics for high temperature fuel cell components.

DISTRIBUTED GENERATION AND STORAGE

The Smart Grid Expo was dominated by the big electrical names in Japan such as Toshiba, Hitachi, Fuji, NEC and Mitsubishi - all keen to provide solutions for grids with millions of consumers and distributed generating sources - as

opposed to a few central ones. This involves forced commutation of the frequency sync signal and the ability to isolate zones to prevent islanding, with signalling for controlling power demand and measuring kilowatt flows.

Fuel cells will have a major role in distributed energy generation, either powered by natural gas or biogas. Hydrogen fuel cells will also have an important role in balancing the electrical load from intermittent renewable energy sources. The PV System Expo was about large scale solar systems - megawatt scale inverters, steerable mirror arrays and similar techniques. At last year's Expo the 2x1 metre 250 watt panel was the new standard. This year there were a thousand stands of PV solar, with a truly global spectrum of companies present. There were three main themes:

(1) System efficiency is being improved by developing panels that respond further into the infra red spectrum. This means that the best designs can have up to 30% conversion efficiency.

(2) Development of see-through solar panels – the panel looks like a green windscreen tint on a transparent sheet and the light goes all the way through.

(3) Development of flexible solar panels which permit lightweight and complex shapes to be constructed.

There is no doubt that solar power is expanding fast due to reductions in capital cost per watt. The Eco House and Building Expo was about efficient insulation, lighting, air conditioning, solar blinds and other techniques. The West Halls were entirely occupied by the Rechargeable Battery Expo, now in its second year.

The ground floor was dedicated to battery production equipment and the upper floor to the battery technologies themselves. There was a global presence but Lithium Ion was the dominant technology and Japanese/Chinese companies dominate this area of activity. One interesting growth area is the big improvement in the use of ultra-capacitors.

Related Conference

Overall it was a fantastic exhibition with a great deal to study. There was also an interesting conference. We were not able to attend all the concurrent presentations but Mike attended those on the subject of PEM and I attended those on solid oxide fuel cells. In the PEM area, the main theme at present is work to eliminate humidification and reduce platinum loading, in order to get stack costs lower in anticipation of the 2015 launch of fuel cell vehicles in Japan, Europe and the United States. The key to achieving this is to increase the stack temperature from 65°C to 90°/100°C.

All the car manufacturers have working fuel cell vehicles and, apart from stack cost, the other area of significance is cost reduction of the high pressure hydrogen storage system. Latest designs perform well across a wide envelope of environmental conditions, but there is more work to be done on self humidifying stacks in hot, dry conditions.

Solid Oxide Fuel Cells

The presentations on solid oxide fuel cells showed that there has been solid progress with both small domestic CHP units and large industrial systems. Ceramic Fuel Cells and the Japanese company, NGK, gave presentations on their recent experiences.

Adobe gave a very interesting paper on how a building energy management system significantly cuts electricity demand and costs at its headquarters in San Jose, California. The key is to synchronise the switching of the various loads to minimise overlap and reduce peak demand. Bloom Energy's 1.2 MW fuel cells provide approximately a third of the electricity requirements at Adobe's HQ.

In the big SOFC stakes, Rolls Royce is back on track with its 1Megawatt fuel cell in a container system which has been achieved by introducing a two-loop system to overcome problems with humidity control under hot humid conditions. Wartsila reported on its fuel cell activities, especially in ships in Finland and, last but not least, Mitsubishi gave a paper on a 400 Megawatt solid oxide fuel cell it is developing to replace steam turbine generating sets. It is interesting to note that their control scheme is a three-loop system. The first full scale working model is planned for 2020. If you want to attend next year's event, be sure and pack a comfortable pair of shoes – you will need them as there is a great deal to study and take in in just 3 days!

www.diverse-energy.com

www.fcexpo.jp/en/

NEWS

RETAILER JOHN LEWIS PLANS FUEL CELL TRIALS

John Lewis has signed a deal that could lead to it trialling alkaline fuel cell technology to generate low carbon electricity at one of its Waitrose stores. The company has signed a commercial memorandum of understanding with Surrey based AFC Energy to evaluate the economic potential of its technology. Following successful evaluation, John Lewis will order and demonstrate the system in store as part of an integrated low carbon energy project.

John Lewis Partnership has pledged to deliver an absolute reduction in its carbon emissions of 15% by the end of its 2020/21 trading year, while at the same time targeting a doubling of revenue. This commitment is supported by a range of initiatives and targets covering operational emissions from energy, refrigeration and cooling, transport, waste and water. The retailer says it could save a potential 200,000 tonnes in carbon emissions by taking 150 stores off grid to generate their electrical and thermal energy.

Toby Marlow, engineering manager, John Lewis Partnership, said: "AFC Energy's alkaline fuel cell gives us the opportunity to make clean electricity on site: it is a revolutionary prospect with exciting potential. This first demonstration could be the beginning of a mutually beneficial long-term relationship." AFC Energy's alkaline fuel cell has the capability to significantly reduce carbon emissions for commercial buildings. An integrated system powered from bio-methane with carbon capture and storage (CCS) offers the ultimate prospect of carbon negative energy generation. www.afcenergy.com

SCANDINAVIAN HYDROGEN HIGHWAY PARTNERSHIP

The Scandinavian Hydrogen Highway Partnership (SHHP) is working towards making Scandinavia a region where hydrogen is available and used in a network of re-fuelling stations.

One of the first fuelling stations has been operating for several years in Malmö with hydrogen from wind power. The aim is to have a network of hydrogen stations ready by 2015 for 100 buses, 500 cars and 500 speciality vehicles.

The SHHP constitutes a transnational network that catalyses and coordinates collaboration between three national bodies, HyNor of Norway, Hydrogen Link of Denmark and Hydrogen Sweden. Within the Nordic countries there is a long standing and strong collaboration between Icelandic New Energy and the Scandinavian Hydrogen Highway Partnership, with the purpose of deploying fuel cell vehicles and constructing and clustering hydrogen fuelling stations in a cross country infrastructure network.

From December 2011 Hynor Oslo Buss will operate 5 fuel cell buses, with hydrogen as the fuel. The project includes the building of a hydrogen station and is part of the European demonstration project (CHIC) of fuel cell buses.

The Belgian Company, Van Hool, is supplying the hydrogen buses.

SHHP has announced that Hyundai Kia Motors and key hydrogen stakeholders from the Nordic countries, Sweden, Denmark, Norway and Iceland have signed a Memorandum of Understanding (MoU) with the aim of collaborating towards market deployment of zero emission hydrogen powered fuel cell electric vehicles (FCEV). The Memorandum was signed in the Swedish Embassy in Seoul, Korea.

Following the signing of the MoU, Hyundai Kia and the Nordic partners plan to collaborate on advancing the deployment of an increasing volume of FCEV's and widespread hydrogen infrastructure in the Nordic countries, setting the scene for commercialization in 2015, as announced by most of the key automotive players. www.scandinavianhydrogen.org

FUEL CELL HYDROGEN BUSES IN EUROPE

The Clean Hydrogen in European Cities Project (CHIC), is the essential next step leading to the full market commercialization of Fuel Cell Hydrogen powered (FCH) buses.

The project involves integrating 26 FCH buses in daily public transport operations and bus routes in five locations across Europe – Aargau (Switzerland), Bolzano/Bozen (Italy), London (GB), Milan (Italy), and Oslo (Norway). The CHIC project is supported by the European Union Joint Undertaking for Fuel Cells and Hydrogen (FCH JU) with 26 million Euros, and has 25 partners from across Europe, along with industrial partners for vehicle supply and refueling infrastructure. The project is based on a staged introduction and build-up of FCH bus fleets and the supporting hydrogen refuelling stations and infrastructure, in order to facilitate the smooth integration of the FCH buses in Europe's public transport system.

FUEL CELL BUSES NOW IN SERVICE IN LONDON

3 CHIC fuel cell hydrogen buses are now in service in London and by the end of 2011 there will be a total of 8 in operation there. The buses are running on the RV1 route, which takes passengers to Covent Garden, the Tower of London and the South Bank. Boris Johnson, Mayor of London, said: "These buses are a marvel of hydrogen technology, emitting only water rather than belching out harmful pollutants. They will run through the most polluted part of the city, through two air pollution hotspots, helping to improve London's air quality."

David Brown, Managing Director for Surface Transport at Transport for London (TfL), added: "London faces many environmental challenges but we believe alternative fuels, such as hydrogen, will bring genuine long term benefits in tackling CO2 emissions. The arrival of these hydrogen hybrid fuel cell buses marks an exciting new chapter for London Buses as we embrace new technologies to further build on the excellent work we are doing to improve air quality for Londoners."

The buses will run from a specially designed maintenance facility housed in First's bus depot at Stratford in east London. This will include the UK's largest permanent hydrogen refuelling station to be maintained by Air Products. London has always been at the forefront in using and developing new technology, initially pioneering hydrogen buses in the UK when it took part in the Cleaner Urban Transport for Europe (CUTE) trial. TfL operated three trial hydrogen buses on the route RV1, using the findings from these trials and that of European partners to seek out the suppliers who have developed these next generation hydrogen fuel cell buses to operate in central London. The latest bus project is jointly funded by TfL, the Department of Energy and Climate Change (DECC) and the European Union via the Clean Hydrogen in Cities (CHIC) project.

Kit Malthouse, Deputy Mayor for policing and Chair of the London Hydrogen Partnership, is seen here at the driving wheel. He said: "The arrival of a flagship fleet of hydrogen powered buses places London at the forefront of this revolutionary fuel cell technology. We are thinking big and have ambitious plans to promote the use of hydrogen on the ground, propelling vehicles and powering buildings. With these buses, people can now see, touch and feel this technology for themselves and help play an exciting part in London's energy future."

The London Hydrogen Partnership (LHP) launched an action plan in early 2010 setting out ambitions to create a 'Hydrogen network' by 2012, to help accelerate the wider use of this zero-polluting, zero-carbon energy. The LHP is working with London boroughs and private landowners on plans to deliver six refuelling sites to run hydrogen-powered vehicles in the capital over the next two years. It also aims to encourage a minimum of 150 hydrogen-powered vehicles on the road in London by 2012, including 15 hydrogen powered taxis. www.london.gov.uk/lhp

EVENTS

28th June – 1st July 2011, European Fuel Cell Forum. International Conference and Exhibition, Lucerne, Switzerland. www.efcf.com

26th-27th September 2011, f-cell congress. International focus on mobile applications: fuel cells and batteries moving the future. Stuttgart. www.f-cell.de

31st October – 3rd November 2011 Fuel Cell Seminar and Exposition Florida, USA. www.fuelcellseminar.com

Fuel Cell Power will now bring you news about fuel cells and related technologies as it arises. Our new Blog covers all types of fuel cells and their applications for portable power, CHP and transport. Fuel cells utilize fossil fuels or energy from waste very efficiently. They can be powered by hydrogen which balances the electrical load obtained from intermittent renewable energy sources. Articles and features on the operation of fuel cells will enable potential operators to plan for long term energy efficiency, price stability and cuts in harmful emissions.

www.fuelcellpower.org.uk

Fuel Cell Power provides information on the practical application of fuel cells.
It is produced by the family and friends of the late Dr F T Bacon OBE, FRS,
who dedicated his life to the development of fuel cell technology.

Information can be obtained from: Jean Aldous, Editor, Fuel Cell Power, The Gallery, The Street, Woolpit, Suffolk, IP30 9QG.
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www.hydrogen.co.uk www.futureenergies.com www.fuelcellpower.org.uk