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www.fuelcellpower.org.uk

FUEL CELL POWER

The transition from combustion to clean electrochemical energy conversion

HEADLINE NEWS

Around the world fuel cells are starting to lead the transition from fossil fuels to zero emission energy, with China leading the change with the Geely bus.

When fuel cells are powered by natural gas, the only emissions are water and carbon dioxide. In some fuel cells the electrochemical process can separate the carbon dioxide for recycling. In a trial development hydrogen from renewable sources is being added to natural gas for use in homes and industry. It is thought that hydrogen will increasingly replace natural gas.

Large quantities of household, agricultural and forestry waste are at present adding to carbon dioxide emissions when they are stored in land-fill sites or burnt. Fuel cells powered by ethanol obtained from organic waste provide electricity, heat and transport fuel with no additional carbon dioxide emissions. They can also store the carbon dioxide produced and recycle it, thereby achieving net negative emissions.

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GEELY LAUNCHES HYDROGEN FUEL CELL BUS

Geely New Energy Commercial Vehicle Group's subsidiary, Yuan Cheng, has launched its first commercial vehicle which utilizes hydrogen fuel cell technology and after a 10-minute refuelling can run over 500km. Hydrogen fuel cells only emit water. No harmful gases are emitted. Along with a high passenger capacity, the new model also has the advantages of being quiet and economical.

The new hydrogen powered F12 city bus was developed by Geely Commercial Vehicles in response to China's national new energy policy and as part of Geely's continuing R&D into fuel cell technologies. Hydrogen fuels have several major advantages, including diverse availability and environmental friendliness. Hydrogen fuel can be extracted from fossil fuels, generated as a by-product of chemical production, or by electrolysis. Hydrogen refuelling is similar to gasoline or diesel, simplifying infrastructure building.

The F12 bus adopts world-class fuel cell stack technology. In real world operational tests, it had an energy consumption rate of 7.5kg of hydrogen per 100km. A full tank is enough for all-day operation. Through extreme environmental tests, such as extreme heat, cold, and high altitude, hydrogen fuel cell technology has been proven to be very adaptive.

In addition to its advantages of low energy consumption and emitting only water, the F12 also comes with an attractive design, comfortable interior, and multiple smart functions.

The model is available in both 12 meter and 10.5 meter long versions, providing a comfortable ride experience and bright interior. In terms of smart functionality, the F12 bus comes with real time remote monitoring, road condition warning, remote fault diagnostic, and other intelligent features to assist companies in scheduling and fleet management.

LEADING THE WAY WITH NEW ENERGY FOR COMMERCIAL VEHICLES

The newly unveiled F12 hydrogen fuel cell bus expands the range of Geely Commercial Vehicles (GCV) into the public transportation market. The unveiling and launch of this new fuel cell bus represents GCV's commitment to green mobility. At the same time, it demonstrates Geely's leadership and strength in R&D, design, manufacturing, and resource integration.

Guided by the desire to reduce pollution and bring blue skies back to the cities, GCV aims to provide society with green, intelligent, safe, and efficient mobility solutions.

At the launch of the F12 Mr. Lin Xiaohu of the GCV New Energy Group said "Geely New Energy Commercial Vehicle Group has been positioned as a technology leader in the field of new energy commercial vehicles since its conception. We will always strive to create the safest, greenest, most energy-efficient refined vehicles in the world."

DOOSAN TO SUPPLY WORLD'S FIRST LARGE-SCALE HYDROGEN FUEL CELL POWER PLANT

The South Korea based Doosan Corporation, Fuel Cell Business Group, announced the start of its hydrogen fuel cell installation at Daesan Green Energy Fuel Cell Power Plant. The 50 MW Doosan Fuel Cell system will be the world's first large-scale fuel cell utilizing hydrogen produced as a by-product. Upon completion of its construction in 2020, the fuel cell power plant will contribute 400,000 MWh of electricity annually, powering 160,000 local homes.

The project is significant in its commercial utilization of hydrogen which has been generated as a by-product in petrochemical plants. Hydrogen is generated as a by-product by various industries worldwide, and countries like China and India are showing great interest in developing fuel cell power plants which utilize this hydrogen. Based on their generation of by-product hydrogen, it is estimated that in Korea and China, the capacity for fuel cell utilization is roughly 3.5 GW and 1GW respectively,

In this hydrogen-air fuel cell a microfilter system installed within the fuel cell purifies the incoming air so that no air pollutants are emitted. In some developed countries preparing for the hydrogen economy, governments are actively supporting the hydrogen fuel cell industry, but these efforts have been limited to demonstration levels of less than 1MW and have yet to be actualized in commercial generation facilities. The commercialization of this 50 MW hydrogen fuel cell power project is a critical turning point for the hydrogen economy and is attracting attention from the United States, China, Japan, and countries in the EU.

The project is significant for the Doosan Corporation, as this fuel cell system will be its largest deployment since entering the fuel cell market.

Doosan Corporation has current operations in 38 countries. Doosan's Fuel Cell Business Group designs, engineers and manufactures fuel cells for commercial and industrial applications.

With its growing team, and focus on innovation and technology leadership, Doosan's stated vision is to be the global leader in the fuel cell industry.

www.doosan.com

MIURA AND CERES POWER LAUNCHING NEW SOFC IN JAPAN

Miura Co. Ltd. is pleased to announce the market launch of a new Solid Oxide Fuel Cell (SOFC) in October this year. The new fuel cell system is a 4.2kW combined heat and power product (CHP) targeting the commercial building sector in Japan and was developed in partnership with Ceres Power in the UK.
The units will operate on mains gas supply and provide both highly efficient, low carbon energy and hot water to commercial buildings.

The systems will also provide businesses with greater certainty of supply, as commercial users can access the electricity and hot water the unit produces from the existing city gas supply even during power outages. This aids business continuity. In order to realise the potential of distributed energy, Miura has been working on system development for solid oxide fuel cells (SOFC), which benefits from particular advantages over other kinds of fuel cell technologies due to its high electrical efficiency and durability. Miura launched the first model of a SOFC system FC-5A which has several improvements including a higher electrical efficiency of 50% net AC lower heating value (LHV). By capturing the exhaust heat as hot water, the overall efficiency of the system reaches 90% meaning users can benefit from both energy saving and a lower carbon footprint.

This is the product of a partnership with Ceres Power. Based in the UK, Ceres Power is a leading developer of Solid Oxide Fuel Cell (SOFC) technology. Ceres Power's SteelCell® is a highly durable SOFC stack which is manufactured using standard processes and conventional materials such as steel. Together with Miura's capability in thermofluid engineering, mechanical design and system integration, the partnership has resulted in the development of the highly efficient and reliable FC-5B SOFC system.

Fuel cell technology generates clean electricity from the chemical reaction of hydrogen and oxygen. Hydrogen can be produced by a variety of methods using either conventional fuels or renewable energy sources and can play a crucial role in reducing the environmental footprint of many power applications. The FC-5B fuel cell will run off readily available natural gas. Given its importance to the energy supply chain, the Japanese Government published "The Basic Hydrogen Strategy" in 2017 and "The Strategic Road Map for Hydrogen and Fuel Cells" in 2019 to show the vision of a "Hydrogen Society" and the role of hydrogen in a cleaner energy future. In addition to fuel cell vehicles and fuel cells for households, the deployment of stationary fuel cells in the commercial and industrial building sector is another area of focus for the Japanese government's strategy.
www.cerespower.com

RIVERSIMPLE AND MICROCAB MOVING TOWARDS COMMERCIALISATION

Riversimple, the Wales-based manufacturer of hydrogen fuel cell electric cars, has been awarded UK government funding of £1.25m, to support the production of a test fleet of 20 vehicles. The grant, from the Office for Low Emission Vehicles (OLEV) will support the production of seventeen of Riversimple's revolutionary, ultra-efficient cars, the Rasa, which will complement three other Rasa models.

In partnership with Monmouthshire County Council these cars will form part of the pioneering Clean Mobility Trial. The fleet will be user-tested in a 12-month trial in and around Abergavenny. The trial, involving 200 testers – including households, businesses, car clubs and councils, will provide data and user insight that will be used to refine the design further, ahead of volume production.

The Office for Low Emission Vehicles (OLEV) said: "The innovative technology these vehicles use has long range (300+ miles) and fast refuelling (3-5 minutes) capability, and will support the Industrial Strategy Future of Mobility Grand Challenge to place the UK at the forefront of the design and manufacturing of zero emission vehicles."

Although this Rasa model is only a two-seater car, the company has announced future plans for vans and family cars to make the product available to a wider range of people. Riversimple have secured £790,000 of leading equity investment. They have partnered with investors to build their movement and appeal to the mass market.

www.riversimple.com

The Vianova is the latest model from Microcab which brings together technical and design development work with three fuel cell vehicle manufacturers. The work was undertaken as part of the SWARM project with demonstrations in the UK, North Germany and Brussels. The Microcab fleet covered about 20,000km in the project.

The Vianova features a fully designed interior with elements demonstrating the latest thinking in circular economy design. Commercial work with German OEM Mahle supported the design of a new contemporary interior with digital driver displays. Close cooperation with the Coventry University Team has resulted in a fully upgraded powertrain and the integration of a new motor, controller and gearbox system.

Microcab has formed working alliances across the UK, Europe, USA, South Africa, China and India. With an emphasis on high quality design and cost effective engineering, Microcab manufactures a range of zero emission, low carbon fuel cell electric vehicles, which are lightweight and highly efficient, making them ideal in urban and peri-urban locations for passenger and light freight use. www.microcab.co.uk

FUEL CELL POWERED BY ETHANOL FROM ORGANIC WASTE

NEGATIVE CO2 EMISSION TRANSPORT

Negative CO2 transport means that from 'well-to-wheel' no gases such as carbon dioxide, nitrous oxides, or carbon monoxide are emitted into the atmosphere. At the moment zero emission transport can only be achieved by using batteries charged by renewables such as solar, wind, or tidal energy. To tackle climate change, transport must be at least carbon neutral, meaning that no additional carbon is emitted during the production, transport and use of the fuel.

Most organic waste is either burnt (i.e. oxidised to ash and carbon dioxide) or decomposed by rotting, turning the carbon into methane (CH4) and carbon dioxide (CO2). However, technology has now been developed to use the fermentation of organic waste to produce ethanol (ethyl alcohol) as a fuel for transport. This process will not produce any more CO2 than would have been produced by the normal decomposition of the waste. In addition, any carbon dioxide produced during the process is captured and recycled.

Fuel cell technology is the key. Fuel cells are electro-chemical devices that convert hydrogen and oxygen into electricity and water. A wide range of fuels which break down to H2 inside the cell can be used in different types of fuel cell. Ethanol is one alternative.

ORGANIC WASTE DECOMPOSITION

Organic waste management is a growing and expensive problem. Most organic waste is centrally burned, releasing carbon dioxide into the air. This is costly, wasteful and potentially environmentally damaging. Decomposition of organic waste in situ removes the need to transport the waste and also produces methane which is a potentially useful and commercially valuable gas. Methane can be reacted with steam under pressure to produce hydrogen (H2) and carbon dioxide. The by-product CO2 is significantly less damaging than the methane produced by natural decomposition, accordingly a reduction in a very damaging climate change gas is also achieved.

ORGANIC WASTE FERMENTATION

However, in the development reported here, ethanol (ethyl alcohol), which is a product of the fermentation of organic waste, is being tested as a fuel for transport. Ethanol is an energy dense liquid which is easily transported and convertible to hydrogen. Fermentation converts 97% of the organic waste into ethanol and is therefore more useful and less environmentally damaging than burning. Compared to burning, the fermentation of organic waste to produce ethanol, which is then used in a fuel cell, results in no additional carbon dioxide being released into the atmosphere.

ELECTROCHEMICAL CONVERSION

Oxygen from the air enters one side of the alkaline fuel cell and ethanol as the fuel is introduced into the other side. From the electro-chemical combination of oxygen from the air and hydrogen from the ethanol the fuel cell generates electricity with water and carbon dioxide as by-products.

The efficiency is between 60 and 70%. This is an efficient method for the conversion of organic waste into electrical energy.

CO2 STORAGE AND USE

The CO2 in the air is removed from the input air as this could damage the electrolyte in the alkaline fuel cell (350ppm to 50ppm). In addition as mentioned above, CO2 is also released during the catalytic conversion of the ethanol in the fuel cell. Both streams of CO2 are captured by the same absorption method and are stored as carbonate (50ppm).

Recent advances in technology have made the storage of carbon dioxide faster and more efficient than in the past so that the storage of CO2 has become simpler and less expensive when used in transport applications. The storage process can be reversed and the stored CO2 released again from the carbonate. It can then be used to replace the industrial CO2 currently being used in other applications, particularly in urban and greenhouse farming to promote plant growth.

FUTURE CLEAN ENERGY FROM WASTE

This fuel cell system, which is powered by ethanol from organic waste and captures the CO2 produced, is both generating clean electricity and taking CO2 out of the atmosphere.

Hydrogen fuel cell vehicles are operating well in many cities and it is recommended that this zero emission technology should replace polluting combustion engines by organisations with trained staff. The general public should have the option of changing to a fuel cell powered by liquid obtained from organic waste.

British scientists have been working for many years to develop the Gasified Anaerobic Digester GAD™, which will enable communities, industries, farmers and individuals to obtain ethanol from waste. This was chosen by London Taxicabs to enable them to achieve net zero or net negative emissions and was given initial support by the UK Advanced Propulsion Centre. However, the Government has stopped funding on the basis that the taxis will have recycled C02 emissions from the tailpipe. As explained in this article, no additional C02 will be emitted to the atmosphere than if the waste were put into landfill or burnt. In fact the process will be 'net negative' as the electrochemical process separates the C02, which can be recycled.

ETHANOL FUEL CELL

The main increase in global warming gases is projected to occur in developing countries which cannot afford to install large renewable energy infrastructures, or invest in carbon capture and storage. They also have to dispose of large quantities of organic waste which could provide zero emission fuel locally without extensive infrastructure. As communities grow more of their own food and extend their forests, the recycled organic waste can produce electricity and heat two or three times more efficiently by electrochemical conversion than if it were burnt. As the waste is not burnt there are valuable residues, including organic fertiliser, which could reduce dependence upon nitrogen.

Another problem with conventional energy systems is that large quantities of water are utilised in power generation, but this is not required when energy is produced by fuel cells. There will also be no need to invest in methods to cut air pollution, as the only emissions of fuel cells are recycled carbon dioxide and potable water. www.fairair.london

BALLARD AND PARTNERS' FUEL CELL VEHICLES

WEICHAI SUPPORTING 2,000 FUEL CELL VEHICLES IN CHINA

Following the agreement between Ballard Power Systems and Weichai Power to introduce hydrogen fuel cell vehicles in China, Weichai have now agreed to support the deployment of at least 2,000 fuel cell electric vehicles (FCEV) by 2021 using Ballard products and components. This is the largest global commitment to date and as they approach commercialisation, it will enable further cost reductions. Weichai intends to be at the forefront of zero-emission FCEV deployments in China. Weichai and Ballard have been moving quickly together to prepare the Weichai-Ballard JV manufacturing facility for the assembly of Ballard fuel cell stacks and modules. They anticipate the facility will be operational by the end of 2019, putting them in a strong position in the China market for 2020.

China has one of the world's most aggressive plans to eliminate fossil fuel-powered vehicles and pollution. Ballard has around 70% of the market share of the 2,500 fuel cell electric vehicles currently deployed there and is well positioned with its strong competitive advantages, including high-performance and durable products.

At a regional level, city governments of Shenzhen and Foshan have put plans in place to use only zero emission public transit buses powered by battery electric or fuel cell technologies and several others will shortly announce similar plans. The province of Hainan took one step further by becoming the first region to announce that it will completely ban sales of all fossil-fuelled vehicles starting in 2030.

EUROPEAN PARTNERS

In Europe, Norled's Ferry will be powered by a combination of Ballard fuel cells and batteries.

Compagnie Fluviale de Transport will demonstrate on the Rhône river in France, that fuel cell powered propulsion offers a cost-effective and practical zero-emission solution for owners and builders of mid-sized vessels carrying more than 100 passengers or the equivalent volume of freight.

Wrightbus is supplying fifteen double decker buses powered by Ballard fuel cells for Aberdeen City Council in Scotland. Each bus will carry up to 64 passengers.

Ballard fuel cell modules have been powering a fleet of 10 single decker buses for Aberdeen City Council for several years. The modules have demonstrated a high level of performance, together with unsurpassed durability in a million miles of revenue service. With the deployment of more fuel cell buses, Aberdeen is reinforcing its reputation as a centre of excellence for hydrogen and fuel cell technologies.

Ballard is supplying fuel cells for buses under the EU Joint Initiative for Electric Vehicles (JIVE) programme. It is also a founding member of the new H2Bus Consortium, whose members are working together to deploy 1,000 zero-emission fuel cell electric buses (FCEBs) and related infrastructure in European cities at commercially competitive rates. An initial 600 FCEBs are being supported by a €40 million grant from the EU's Connecting European Facilities programme, with 200 buses to be deployed in each of Denmark, Latvia and the U.K. by 2023.

The H2Bus hydrogen fuel cell electric bus solution is expected to be the most cost effective true zero-emission option available, with a target single decker bus price below €375,000, hydrogen cost between €5 and €7 per kilogram and bus service cost of €0.30 per kilometre. The zero-tailpipe emission feature of the FCEBs operation will be complemented by zero-emission hydrogen production from renewable energy sources, yielding a "well-to-wheels" emission-free transportation solution.

Ballard's FCmove™ fuel cell module is specifically designed to meet the requirements of transit bus operators. It will be used in the 1,000 fuel cell buses to be deployed by the new H2Bus Consortium, Future products will offer various power outputs to suit a broad range of commercial vehicles including trucks, coaches and trains.

www.ballard.com

FUELCELL ENERGY EXPANDING MARKETS

SURESOURCE FOR EUROPE

FuelCell Energy is relaunching their sub-MW distributed generation Suresource 250 and Suresource 400 fuel cells in the European Market. The fuel cells are manufactured in Connecticut and assembled at FuelCell Energy's manufacturing facility in Germany. "The superior electrical efficiency, ultra-low criteria pollution emissions (NOx, SOx, PM) and low noise profile compared with engines and turbines, make the SureSource sub-MW systems an ideal technology for commercial and retail sectors in Europe," said Jennifer Arasimowicz. "We are expanding our use of fuel cells in Germany, Italy, United Kingdom, Benelux, France and Spain distributed power generation markets." Increasing government initiatives and motivation under a new renewable heat incentive policy are the key drivers in Europe. Recent improvements on fuel cell stack-life reduces maintenance costs, improving the economics of smaller projects.

CLEAN BIOGAS FROM WASTEWATER

The SureSource 250 and 400 can run directly on biogas. Small wastewater treatment plants (WWTPs) that generate anaerobic digester gas can host these fuel cell systems to generate renewable energy and heat without pollutants and particulate matter. In addition to WWTPs, FuelCell Energy's fuel cells benefit biomass markets such as breweries, biomass plants and landfills by producing base-load renewable power, eliminating the emissions of conventional small combined heat and power plants.

Alexander Fenzl of E.ON Business Solutions, Germany said: "Their high electrical efficiency and ultra-low criteria pollutant emissions make fuel cells a good fit for our business and help decarbonize the industrial and commercial sectors in Germany and other EU countries." The first SureSource 400 installation has shown an availability greater than 90%. This plant is operated by FuelCell Energy Solutions GmbH under a 10 year Power Purchase Agreement and owned by E.ON. The fuel cells combine a fuel such as renewable biogas, directed biogas or natural gas, with oxygen from the ambient air to efficiently produce ultra-clean electricity and usable high quality heat via an electrochemical process. Customers benefit with operating cost reductions delivered in a manner that supports sustainability goals and enhances power reliability.

CARBON CAPTURE PROJECT WITH DRAX POWER STATION

FuelCell Energy has entered into a contract with Drax Power Station in the United Kingdom for an application of the Company's carbon capture solution. FuelCell Energy will be supporting Drax with a Front End Engineering and Design (FEED) study evaluating the use of the Company's proprietary carbonate fuel cells to capture carbon dioxide emissions from Drax's biomass boilers.

Drax Power Station is the largest single-site renewable power generator in the UK, with capacity of over 3,900 megawatts of renewable power generation, primarily from sustainable wood pellets sourced from responsibly managed forests.

Carbon dioxide linked to the carbon cycle of forests is considered carbon neutral and therefore, carbon capture employed at this project would make the power station carbon negative. Bio-Energy with Carbon Capture and Storage (BECCS) is one of the most promising approaches to carbon reduction because of the ability to be carbon negative at large scales.

The FEED study will focus on a system that captures up to 85 tonnes of CO2 per day while generating additional power for the station. The ability to co-produce valuable electricity during carbon capture provides a significant advantage over conventional solvent-based CO2 capture systems that consume both heat and electricity to operate. The fuel cell also destroys up to 70% of NOx emissions from the flue gas.

Drax plans to use the CO2 captured within a greenhouse abutting the power station. Potentially any excess CO2 captured could be transported to other greenhouse locations. Once demonstrated, the technology can easily be scaled up to capture a significant portion of the power station's CO2 output. "Carbon capture using FuelCell Energy's solution is a potential game-changer for affordability and efficiency of concentrating and capturing carbon dioxide from emitters," said Tony Leo of FuelCell Energy.

"We are pleased to have the opportunity to partner with Drax and the UK Government for such an innovative and critically important subject as cleaner energy."

Will Gardiner, Drax Group CEO, said "We believe fuel cell technology could help us to meet the rise in global demand for electricity, whilst capturing the carbon dioxide produced during its generation. Our FEED study will help us to understand the technical and economic feasibility of fuel cells, with a view to scaling up the technology, whilst showing that clusters of businesses working together to deliver climate change solutions, can also deliver benefits for their businesses."

20 MEGAWATT FUEL CELL PARK

The 20 megawatt Korean Southern Power Company (KOSPO) fuel cell park in Incheon, South Korea, exceeded its contracted output requirements during its first year of operation.

The fuel cell park consists of eight SureSource 3000™ power plants, manufactured and maintained by FuelCell Energy. It produces electricity and thermal energy to support a district heating system adjacent to the existing 1.8 gigawatt Shin-Incheon combined cycle power plant.

FuelCell Energy operates and maintains the plants under a long-term service agreement and exceeded all contracted output requirements for the first year of operation, www.fce.com

HYDROGEN AND FUEL CELLS POWERING THE FUTURE

The 15th UK International Conference on Hydrogen and Fuel Cells in Birmingham in March 2019 illustrated the change from combustion to zero emission electrochemical energy conversion .

REGIONS LEADING THE CHANGE TO ZERO EMISSION ENERGY

Mark Knowles, Liverpool City Region Combined Authority, said that he wants their region to be at the forefront of sustainable technology and to be a zero carbon city region by 2040.

The Authority believes they can achieve a 75% reduction in emissions by several methods: greater energy efficiency in homes and businesses; improving battery and hydrogen storage; electrifying a large proportion of domestic heating; generating clean electricity from local resources including wind and tidal; creating and using hydrogen as a transport and process fuel; methane replacement; electrifying transport; and encouraging a shift from cars to walking and cycling.

The problems will be with the remaining 25% of emissions from energy intensive industry, heavy goods vehicles and dealing with emissions from international aviation and marine sources which are currently not counted by the Government. Liverpool City Region is working with other partners and thinking mainstream on a large scale.

Nigel Holmes of the Scottish Hydrogen Fuel Cell Association outlined Scotland's rapid transition from oil and gas towards renewables. By 2030 the Scottish Government aims to have 50% renewable energy and a 66% reduction in CO2 emissions. They are moving from centralized to local energy systems. Hydrogen enables energy to be stored and brings together the energy sectors for power, heat and transport. The ten hydrogen fuel cell buses operating in Aberdeen have covered more than a million miles. The range on a tank of hydrogen is 260 miles and they take up to 12 minutes to refuel.

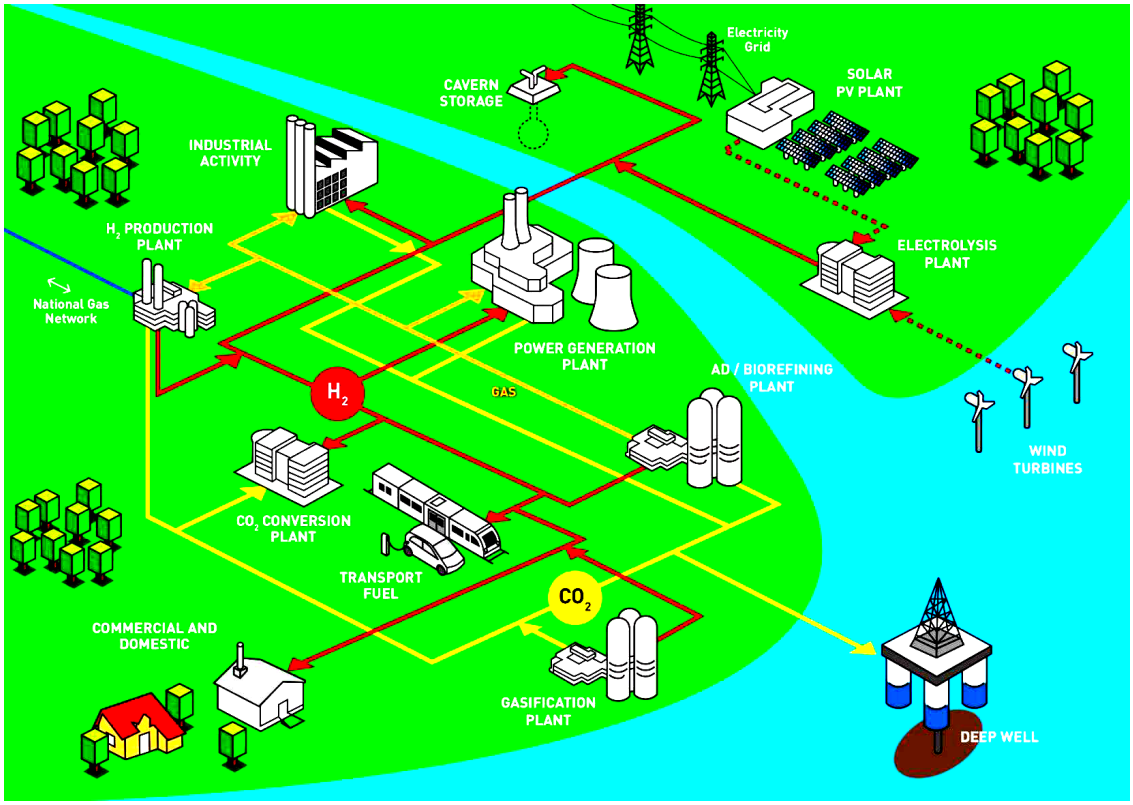
The second hydrogen refuelling station is now operational and is being utilised by the first ten Mirai fuel cell cars.

On the Orkney Islands all the electricity is generated from renewables and the Council uses hydrogen powered Symbio vans. Orkney hosts the European Marine Energy Centre. A 1MW electrolyser is supplying hydrogen for electricity, heat and transport. On the island of Eday a 500kW electrolyser from ITM Power is producing hydrogen. In EU supported projects they are supplying electricity from tidal power into the EU grid and building the world's first hydrogen powered ferry, which will come into operation in the Orkney Islands by 2021.

Mark Lewis of the Tees Valley Combined Authority explained how they will show that an energy intensive region can lead the way to a low carbon future.

They will achieve economic growth from innovation in low emission technology and working within a circular economy. They are establishing pilot projects for heat and transport as they become the 'hydrogen region' for the UK, combined with Carbon Capture and Storage (CCS).

They will also utilise offshore wind and develop and scale-up processes utilising carbon as a feedstock. They plan to attract new industries that can use the wastes, feedstocks and energy produced in the Tees Valley. It is over two hundred years since the first steam-powered passenger railway opened from Stockton to Darlington in the Tees Valley. The new railway will now be powered by hydrogen.



Amer Gaffar said that the Manchester Fuel Cell Innovation Centre has an impressive range of advanced equipment located in seven specialist laboratories. They invite SMEs, researchers, industry and policy makers around the country to collaborate and innovate and to drive growth in the clean energy sector. They have teaching materials on the potential of hydrogen and fuel cells and have regional and national connections to support the introduction of the technology

They are defining a comprehensive research programme to bring together stakeholders and ensure that the region is at the forefront of science and technology on a global scale.

Michaela Kendall outlined the expertise with hydrogen and fuel cells in the area covered by the Midlands Hydrogen and Fuel Cell Network (MHFCN). They are building upon regional centres of fuel cell expertise and moving towards commercialisation in key markets. Several companies have small fuel cells suitable for portable systems. Medium stacks are available for automotive range extenders and large for rail and community CHP. The MHFCN is focussed on leading growth in the UK and internationally.

BALANCING LOADS FROM RENEWABLE ENERGY

Bill Ireland outlined the progress of Logan Energy Corporation, which was established in the USA in 1995. 10 years later Logan Energy Ltd was registered as a spin off in Scotland and is supported by Scottish Enterprise. The Levenmouth Community Energy Project is increasing hydrogen production, which provides heat and power for buildings and a fleet of vehicles.

Recently the N-Tropy Group was set up and Logan Energy remains as the Group's engineering consultant. Their manufacturing facility is based in East Lothian and their four subsidiaries are: Hytec Ltd, a manufacturer of hydrogen energy systems; FuelCell UK Ltd, for hydrogen transport systems; Proton Power Ltd for hydrogen facility operation and maintenance.Enetec Ltd is N-Tropy Group's distributor of hydrogen systems.

H2TEC BV has been established in Groningen and Drente in the Netherlands. Veolia provides hydrogen refuelling stations for Westminster City Council in London. Later this year a solar hydrogen refuelling station will be opened in Saarbrucken, Germany. Logan Energy is also supplying a 500kWe electrolyser for a wind farm in County Antrim, Northern Ireland.

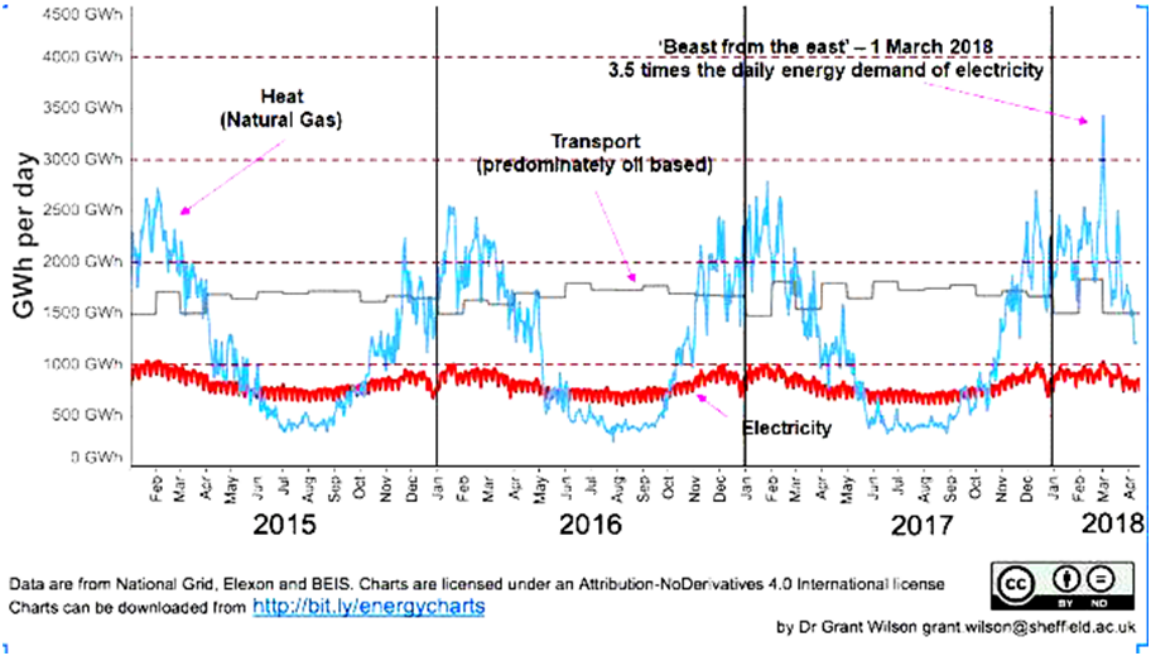
Logan Energy is examining the various means of balancing loads from intermittent renewable energy, storing more solar power in summer and more wind energy in the winter.

A 125 m3/day desalination plant in Tenerife, powered by the wind, will provide hydrogen from sea water for a fleet of fuel cell vehicles later this year.

Mark Kneller of Arup outlined the roadmap to a hydrogen economy by 2035.

Energy demands for electricity and transport are constant around the year but heat demand fluctuates. Demand for heat was at its highest level in the UK in spring 2018 when there was a strong cold easterly wind.

They are progressing with the UK Government programme Hy4Heat, which will establish if it is technically possible, safe and convenient to replace natural gas (methane) with hydrogen in residential and commercial buildings and gas appliances. They are also undertaking a feasibility study on the design and construction of a purpose-built hydrogen distribution network. They have a proposal for a feasibility study for a modular design to produce hydrogen from intermittent renewables to meet the demand profile of a gas distribution network. Overseas programmes include a hydrogen-powered transport system and hydrogen energy for New Zealand.



Ian MacLean explained that Locogen develops, builds and operates low carbon distributed energy projects. They have a biogas project near Dundee, Scotland with a 700kW electrolyser and mobile storage units. There is the potential to supply hydrogen to Dundee Council for hydrogen buses. They have grant funded projects to consider options for hydrogen production from wind and solar power, in which they are assessing local future demand and an achieva ble cost of hydrogen.

They find that biogas CHP can mainly be used directly to meet electrolyser demand and that wind and solar power require more storage by the grid. The projected costs of H2 production with different sources of renewable energy are given, based upon the estimated percentage of demand met:

Technology	**biogas CHP**	**Solar**	**Wind**
% electrolyser demand met by renewables	95	37	73
% electrolyser demand met by grid electricity	5	63	27
Price for production of 1kg H2 – 5.5p/kWh	£3.55	£6.15	£4.53
Price for production of 1kgH2 – 4.5p/kWh	£2.98	£5.93	£4.10

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NATURAL GAS AND HYDROGEN

Andy Lewis of Cadent, reported on progress with their programmes to cut emissions by utilising hydrogen in all sectors. HyNet Northwest will utilise hydrogen obtained from natural gas (CH_4) with Carbon Capture Use and Storage (CCUS). This could provide cost effective abatement from the outset and is planned to be operational from 2025. This will provide a foundation which can be replicated elsewhere.

Hydrogen can also be blended with the natural gas in the existing network and HyDeploy is assessing the safe level at which this can be achieved.

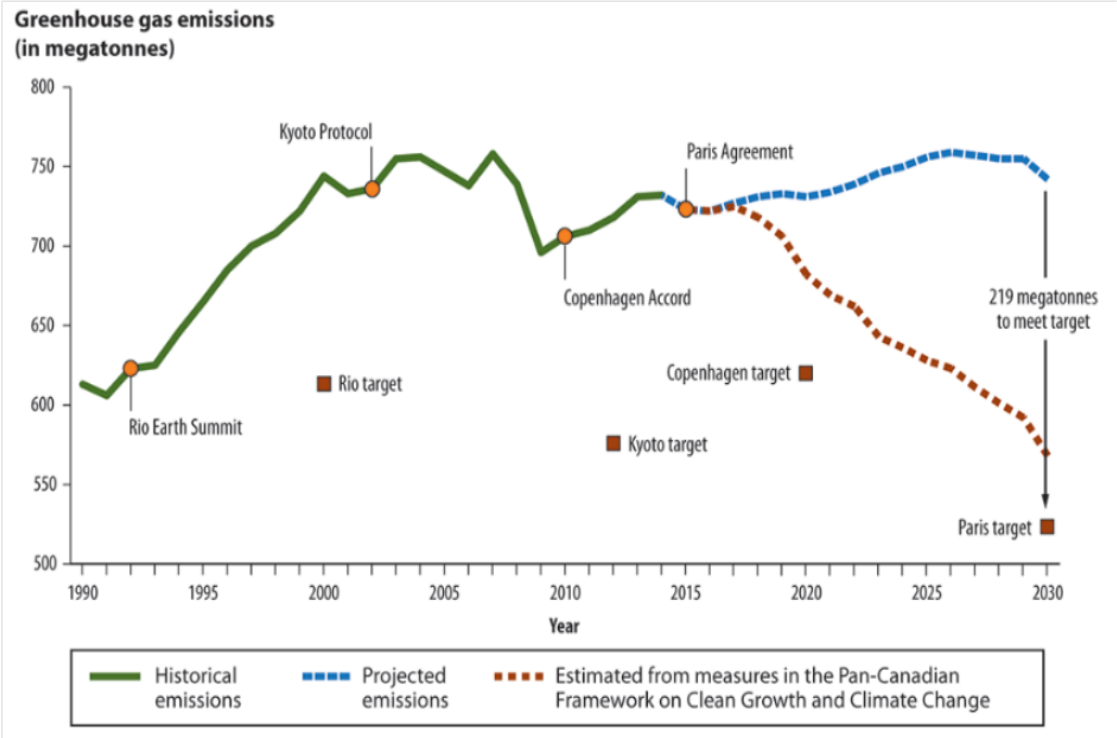
Mark Eldridge of Kiwa Gastec asked if impurity tolerant fuel cells would provide sufficient cost margin to fund the gas infrastructure conversion to hydrogen? Could the industry produce a low cost long life product accepting a few ppm CO? Bulk transport of hydrogen by pipeline could provide both heat and power.

The transportation costs of electricity are seven times greater than that of gas, but locally produced renewable energy could provide on-site cost effective hydrogen.

MEETING EMISSIONS TARGETS

David Fields of Intelligent Energy pointed out that we are too busy focussing on today's demands, but products made today are likely to still be in use in 2030.

We have already missed several targets dates to reduce global warming gases so strong action is needed now. Intelligent Energy fuel cells have high reliability, low component count, high power density and they have lower costs at volume production. They fit well into the space of an i.c. engine. They have rapid start at sub-zero temperatures and operate across a wide climactic envelope. Let us focus now on meeting GHG targets with Intelligent Energy fuel cells and at the same time improve air quality!

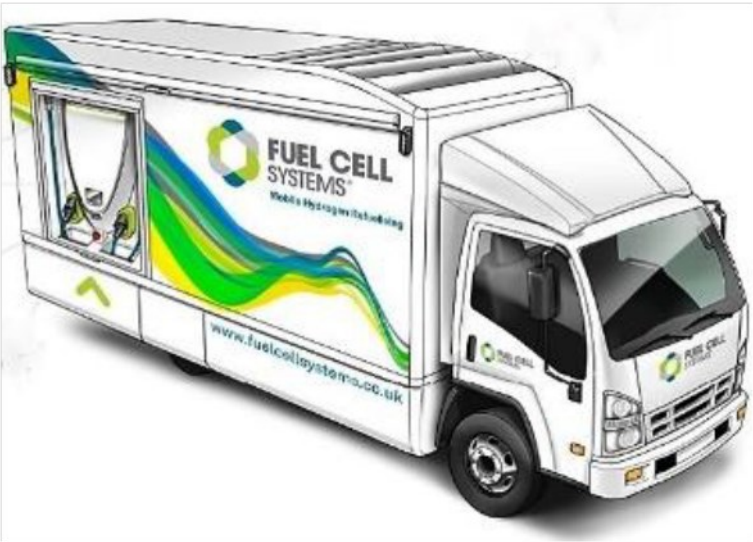


FUEL CELLS FOR A VARIETY OF APPLICATIONS

Beth Dawson of Fuel Cell Systems outlined the benefits of each type of fuel cell, comparing reliability, runtime and cost in different applications. Fuel cells ensure long runtime for CCTV towers, so that engineers' visits are reduced. Fuel cells can be used in all weather conditions and can be deployed anywhere.

Fuel Cell Systems designed and delivered the UK's first fully integrated portable building powered by fuel cell and solar generated hydrogen. They have expertise in designing completely 'green' hydrogen mini-grids. For homes and larger buildings fuel cells are compatible with the National Housebuilders Council specifications. Modular set-up enables the fuel cells to meet differing demands for electricity and heat.

Fuel cells conserve water, emit far less carbon than from the combustion of gas in a CHP engine and emissions of NOx are low. There is funding from the EU's Horizon 2020 programme for Doosan Purecells providing 1.6MWe and 1.9MW thermal energy, in a new building programme in North London.



Fuel Cell Systems supports the introduction of fuel cell vehicles and can provide additional hydrogen for vehicles. They are trying to expedite the number of hydrogen refuelling stations in the UK, which are urgently needed to counter air pollution and climate change.

Patrick Wiltshire of Taylor Construction Plant outlined the challenges of bringing fuel cell hydrogen powered equipment to market.

Their Ecolite CCTV tower has over 240 hours runtime with low noise and no vibration.

Taylor Construction will introduce new hydrogen models and larger power systems, leading to decarbonisation of all their construction plant. Future challenges are the sustainable production of low cost hydrogen and the need to change public perceptions and ensure the right policies and political direction.

SOLID OXIDE FUEL CELLS

Bal Dosanjh outlined Ceres Power's commercialisation of their Steelcell solid oxide fuel cells. With their proven technology they are attracting the world's leading product development companies in key market sectors.

In China, Weichei provides access to the fastest growing fuel cell market. In Europe they are working with Bosch to provide fuel cells for data centres and other applications. Cummins and the US Department of Energy are working with them on commercial scale CHP. Nissan is working with them on their fuel cell vehicle range extender. Their Steelcell is capable of working from 5kW up to MW applications with scaled balance of plant. It is affordable, robust and designed for mass adoption

MOLTEN CARBONATE FUEL CELLS FACILITATE CARBON CAPTURE

Pere Margalev of FuelCell Energy said that their Molten Carbonate Fuel Cells (MCFC) are an extremely efficient, non-combustion technology which emits negligible NOx, SOx or particulate matter. They enable carbon capture, long duration energy storage, and local hydrogen production for transport and industry.

The carbonate electrochemical process transfers CO2 from the air electrode (Cathode) to the fuel electrode (Anode). The CO2 is easily separated from the exhaust gas as it is no longer diluted with air and can be utilised in industrial processes.

Local production of hydrogen from natural gas or biogas avoids both emissions and transport costs. Their tri-generation fuel cell produces heat, power and additional hydrogen for transport. The co-production of fuel with hydrogen provides the most affordable hydrogen.

Their on site Suresource fuel cells range from 1.4 up to 3.7MW with up to 60% electrical efficiency and up to 90% in combined heat and power applications. 100 Suresource fuel cells are already operational and more are on order.

A 2.8 MW fuel cell generates about 23,000 MWh annually alongside 2.2 MW solar generating about 3,000 MWh annually. FuelCell Energy has the world's largest fuel cell park, which generates 59 MW on only 5.2 acres.

GOVERNMENT SUPPORT FOR FUEL CELLS

Alan Malin of the Enterprise Europe Network outlined their programmes to help innovative SMEs to grow internationally. The Horizon 2020 programme starts with funding for feasibility studies, from idea to concept, followed by R & D, demonstration and market replication. They have 3,000 experts available in many locations around the world to support innovation, market information, legislation and standards. They help to build up international partnerships.

Jon Jordan of European Policy Solutions (EPS) outlined the programme to introduce hydrogen in the energy, transport and industrial sectors. Their Hydrogen Valley Project covers the full range of energy uses and is included in the EU's current Fuel Cell and Hydrogen Joint Undertaking (FCH/JU) programme. At least 5,000 kgs of hydrogen per day should be produced, 75% of which should be from renewable sources at the start of the programme and 100% by the end. €1.7billion is allocated to projects till the end of 2022.

Dr Harsh Pershad of Innovate UK said that they help companies of all sizes in all sectors to access the research, partners, investors and markets they need to innovate and grow. Since 2007 they have invested £2.5bn, which with matched industry contributions takes the total value of projects above £4.4bn. The global shift to clean growth will transform many sectors of the economy, including power, transport, construction, energy-intensive industries and agriculture. They are examining the role of regulation in speeding up deployment of proven technologies such as hydrogen and fuel cells. By 2022 they aim to show that local, investable, consumer-centric energy approaches can create prosperous clean energy communities across the UK.

HYDROGEN AND FUEL CELLS FOR TRANSPORT

Sophie Eynon of Element Energy explained that their Zero Emission Fleet Vehicle Rollout (ZEFER) programme is co-funded by the European Union. They are running evaluation projects with fleet operators Green Tomato Cars, the Mayor of London and Hype, the Paris taxi firm. They are demonstrating that fuel cell electric vehicles can provide a viable alternative to diesel or pure electric vehicles in fleet operation. When long range is required they can be the only viable low emission option. 25 fuel cell taxis have been operating successfully in Paris and there are plans to increase this fleet to 600 by 2020. The hydrogen refuelling stations are also coping well with the growing quantities of fuel required.

Helen Simpson of Porterbrook and **Stuart Hillmansen** of Birmingham Centre for Railway Research and Education (BCRRE) outlined the development of the first UK hydrogen train. Porterbrook owns about a third of the UK passenger train fleet. Their first hydrogen fuel cell powered train will be the Hydroflex. These will be suitable where range is up to 500 miles and top speed is 75 mph. The first prototype will be evaluated in June 2019 prior to mainline testing, building up to maximum speed and passenger service. The full paper illustrates the technical design of the prototype, showing the integration with the existing traction system and train controls. They also have a project looking at the requirements for the hydrogen refuelling infrastructure for a fleet of trains.

Robert Steinberger-Wilckens, Fuel Cell and Hydrogen Group, University of Birmingham, discussed the move to hydrogen-fuelled transport. This would entail the change of the distribution infrastructure to hydrogen, with new investment and some asset losses. A carbon recycling economy would be built up. Hydrogen has a much higher specific energy content (33,000Wh/kg) than batteries (500 Wh/kg) and more than double that of diesel fuel (13,200 Wh/kg). Energy could be obtained either from renewable sources or black hydrogen could be utilised with carbon capture, use and storage (CCUS). Heavier vehicles requiring a long range could be powered by solid oxide fuel cells. Fuel cell propulsion could also be utilised for rail, aircraft and maritime applications.

Mike Muldoon said that Alstom supplies rail equipment around the world and their first hydrogen fuel cell powered train has covered 46,000 kms in passenger service. The full fleet of 14 trains will start operation at the end of 2021. In the UK 29% of trains are diesel powered and less than 40% of the network is electrified. Only hydrogen offers an alternative zero emission solution to power long range diesel trains. UK trains have a high floor level and rarely carry equipment on the roof, so solutions must be found to store sufficient hydrogen to ensure 1,000 kms range.

ADVANCED TECHNOLOGIES FOR HYDROGEN FUEL CELLS

Prof Upul Wijayantha of Loughborough University outlined the industry-academic partnership to train future leaders in the hydrogen sector. The Centre for Doctoral Training on Sustainable Hydrogen is built on four areas: low cost production; hydrogen in the whole system; safety; and managing change as hydrogen is integrated into UK energy. Working with stakeholders, the PhD students will undertake research into how hydrogen can enable deep decarbonisation of the energy system. The emphasis will be on working with relevant UK organisations including Hy4Heat, the Leeds Gateway project to replace natural gas with hydrogen, and grid to gas with ITM and Cadent. Also, research will be done on energy storage for islands such as the Orkneys and hydrogen refuelling for trains and road vehicles.

Arnaud de Lhoneux outlined Hydrogenics work with hydrogen produced by renewable energy. He said that supplies of their raw materials, water and renewable energy, are infinite. MW scale projects with renewable hydrogen are functioning well around the world. They are using alkaline and PEM electrolysers. There is potential for cost reductions as they move from projects to product manufacturing.

Hydrogenics are global leaders in the two main technologies, electrolysis and fuel cells, with more than 2000 fuel cell sites and 500 electrolysis plants operational. The hydrogen provides standby power, mobile power modules and MW scale power plants. Hydrogen storage enables grid balancing services and power for vehicle refuelling stations.

Most of the hydrogen used today by the chemical industries and oil refineries is not CO2-free, but renewable hydrogen has the potential to decarbonize a large range of applications.

A new energy regulatory framework with renewable hydrogen is essential to expedite full scale commercial operation.

Duncan Jewitt of Johnson Matthey said that they will enable large scale renewable energy integration, as intermittent solar and wind power will be stored as hydrogen and made available when required. They are also working on emission control catalysts and lithium ion batteries for electric vehicles. They aim to decarbonise transportation, industry, energy and power generation as well as residential heat and power. They are making progress with membrane electrode assemblies (MEA) which will enable fuel cells to meet growing market demands. They are achieving higher platinum activity and stability.

Jeremy Bowman of Hypermotive explained how they will encourage market penetration of hydrogen, based upon changing market needs, technology advances and whole solutions to realise commercial uptake. They will design, build, integrate, test and validate for key sectors, including the automotive, defence, marine and stationary power. Fuel cells have advantages in several applications where they will be competitive with other technologies, providing cost effective reliable energy.

Bill Kim of AVL Powertrain UK said that road transport contributes most to EU greenhouse gas emissions, with 27% of transport emissions coming from trucks and buses in 2015. While passenger cars may utilise battery technology a new strategy is required for commercial vehicles. AVL assesses the power requirements and operating costs for delivery vans, coaches, buses and large trucks. Since battery electric commercial vehicles may have a driving range problem due to the low energy density of the battery, fuel cell technology can be a solution with higher energy density.

The optimum size of batteries and fuel cells in hybrid designs is estimated. Operating costs are assessed, depending upon range requirements.

Chris Murray of Plugpower outlined their role in making hydrogen fuel cells available in the high growth markets around the world. They are working with the Hydrogen Council, a consortium of organisations from industry, transport and energy sectors, which was launched at the World Economic Forum in Davos.

At present industrial and commercial vehicles represent 60% of the electric vehicle market. 25,000 of Plugpower's GenDrive hybrid electric fuel cell systems are powering forklift trucks. Plugpower is seeking more OEM partners to develop zero emission vehicles. The hybrid delivery van has a 20kW fuel cell with a lithium ion battery.

Robotic hydrogen fuelling technology for motive power applications will initially be used to increase the ease and efficiency of fuelling hydrogen-powered vehicles in warehouse settings.

In stationary applications, 4,500 of Plugpower's hydrogen fuel cells are providing backup, which ensures constant high power, with zero emissions and greenhouse gas savings.

Dr Jagvir Purewal senior associate of Forresters, UK Patent and trade mark attorneys, explained how they are helping innovators. They bring together partners who can share their own Intellectual Property (IP) for their mutual benefit.

Jennifer Wen of the School of Engineering, University of Warwick, outlined the safety requirements for large scale applications of hydrogen. The relevant properties of hydrogen were compared with those of methane, propane and gasoline vapour. It is essential for operators changing to new fuels to be able to deal safely with hydrogen as it comes into widespread use.

They have developed reliable predictive tools for quantified risk assessment. Existing measures for Computational Fluid Dynamics for fuels called openFOAM have been modified over the past decade to provide hyFOAM.

Joe Hobbs of NanoSUN said that their vision is for hydrogen to become the major energy vector in a decarbonised world. They respond to the needs of fuel cell users by developing cost effective products that refuel, store and analyse hydrogen safety. For vehicles, they provide on board purification of hydrogen to fuel cell quality and hydrogen storage. They enable convenient onsite refuelling.

Bridging the hydrogen supply gap is important for practical, safe and economic fuel cell deployment. Solutions must be user friendly and fit into customers current business models.

NanoSUN provides low price fuel cell quality hydrogen for portable power. It checks hydrogen quality on board vehicles and enables purification to fuel cell quality.

Jon Hunt, Manager Alternative Fuels, Toyota GB said that 7,800 of their hydrogen fuel cell powered Mirai vehicles have been sold globally.

In the UK, Toyota is working with ITM Power which operates 7 of the 11 hydrogen fuelling stations and is planning more. Hydrogen is a widely available, versatile, zero emission energy carrier. Vehicle electrification is essential. Fuel Cell Electric Vehicles (FCEV) powered by renewable hydrogen will have the lowest life cycle C02 emissions. Toyota is preparing for a future society with life cycle zero emissions in harmony with nature. This will cover their raw materials, energy production, recycled parts, water conservation and vehicle manufacturing.

Ralph Clague, Head of Hydrogen and Fuel Cells, Jaguar Land Rover, explained that huge quantities of hydrogen are already used around the world to produce fertiliser, refine hydrocarbon fuels, plastics and foods. Enough hydrogen was produced in 2018 to drive the entire global fleet of cars, buses and trucks. At present hydrogen is typically made by methane reforming or coal gasification.

China has large incentives for building hydrogen stations. Last year the production of energy from wind turbines was curtailed, but wind energy could be utilised to produce more zero emission hydrogen.

China is working to reduce the costs of hydrogen fuel cell vehicles for widespread use.

Korea, Europe, Japan and the USA, particularly California, are also building up their hydrogen infrastructure.

Michelle Lynch of Enabled Future Ltd said that the fuel cell is a multi-layered structure with many waste fractions for recycling. The future of recycling is a positive scenario but requires participants to be proactive and adaptable in order to succeed. The new recycling infrastructure for Fuel Cell Electric Vehicle (FCEV) needs to be in place by 2025 so it is essential to plan now.

Rami Rashev of Gencell said that the world is in dire need of slashing carbon emissions by 45% by 2030. For many people who have poor access to the grid or need more economic development, they propose 1.2 million off-grid stations by 2020. These could have fuel cells with unlimited runtime, powered by hydrogen or ammonia.

DIAGRAMS

Several organisations provided diagrams giving detailed information about the implementation of fuel cells.

Robbie Wilmot of the National Physical Laboratory illustrated methods for carbon capture and storage.

Niamh Moore of the National Physical Laboratory explained the importance of ensuring the purity of hydrogen for transport.

Several scientists at the University of Birmingham provided diagrams. Peter Mardle shows that thin film catalyst layers will be essential for the large-scale use of Proton Exchange Membrane (PEM) fuel cells. A. Jarvis and colleagues are developing new materials for Solid Oxide Fuel Cells (SOFC).

N. Kahn and colleagues show the results of research into the development of efficient hybrid vehicles incorporating batteries, supercapacitors or flywheels with fuel cells.

Full papers and diagrams are available at

www.climate-change-solutions.co.uk

BLOOM FUEL CELLS FOR DISTRIBUTED ENERGY

DUKE ENERGY COST EFFECTIVE POWER

Duke Energy is acquiring a portfolio of distributed fuel cell technology projects from Bloom Energy, as part of the company's efforts to serve commercial and industrial customers' evolving energy needs and provide behind-the-meter generation. The company is purchasing approximately 37 megawatts of Bloom Energy Servers and has already secured long-term power purchase agreements with customers in California, Connecticut, Maryland and New York.

"Commercial and industrial customers want resilient, clean energy at predictable costs and solutions tailored for their business needs." said Swati Daji of Duke Energy. "We can provide just that to give our customers a more affordable, reliable, innovative generation source with Bloom Energy's fuel cells."

Bloom Energy Servers are unique in the utility sector, producing energy by converting natural gas or biogas into electricity without combustion. Based on solid oxide fuel cell technology, the Energy Servers generate cleaner power around the clock and reduce greenhouse-gas emissions by comparable amounts to zero-emission wind and solar power on an annual basis. Bloom Energy Servers do not generate combustion-related pollutants, such as sulphur oxides, nitrogen oxides or particulate matter.

Customers benefit from low-emission, baseload power 24/7 and fewer intermittent interruptions in power flow for their facilities and operations. Over the next 18 months, the two companies will deploy the servers at more than 30 sites across a portfolio of customers, including hospitals, technology companies, data centers and universities. Duke Energy is one of the largest energy holding companies in the U.S.. It has an electric generating capacity of 51,000 megawatts through its regulated utilities. The Duke Energy Renewables unit operates wind and solar generation facilities across the U.S., as well as energy storage and microgrid projects.

Duke Energy is modernizing the energy grid, generating cleaner energy and expanding natural gas infrastructure to create a smarter energy future for the people and communities it serves. The Electric Utilities and Infrastructure unit's regulated utilities serve approximately 7.7 million retail electric customers in six states and the Gas Utilities and Infrastructure unit distributes natural gas to more than 1.6 million customers in five states.

FUEL CELLS FOR URBAN COMMUNITY

The Alhambra, a 40-acre mixed-use urban community area, located east of downtown Los Angeles, will be powered by fuel cells provided by Bloom Energy. The sleek fuel cells will generate clean, reliable electricity, on-site at The Alhambra campus with lower CO2 emissions than the local electrical grid, and with virtually no particulate emissions that cause smog and respiratory diseases. The Bloom Energy Servers were selected by The Alhambra's developer, the Ratkovich Company, a Los Angeles real estate development firm, as part of its ongoing strategy to transform the former engineering campus.

The new Bloom Energy Servers – the fourth generation of the company's technology – will generate up to 1 MW of power for the campus with expansion capabilities as the campus grows, meeting approximately 75% of its total energy demand. Higher efficiency electricity generation not only helps to lower costs to tenants at The Alhambra, it also reduces CO2 emissions and pollution. Bloom Energy Servers have the highest electrical efficiency of any commercial electric power system and removing particulate matter improves the health and wellbeing of the local community, and of air quality in Los Angeles overall.

WATER SAVING

The Bloom Energy Servers use virtually no water in normal operation, an important consideration in drought-prone California. By comparison, power plants supplying electricity to the California grid consume annually 150 million gallons more water per megawatt of electricity than Bloom Energy Servers.

AGILENT PRODUCING 3.5 MW POWER

Agilent Technologies, a global leader in life sciences, diagnostics, and applied chemical markets, recently installed Bloom Energy Servers capable of producing 3.5 megawatts of power, at its corporate headquarters in Santa Clara, California, and a business unit in Little Falls, Delaware.

As a result, Agilent will lower its carbon footprint by almost 4,000 metric tons of CO_2 each year. The 'Always On' Bloom Energy Servers will reduce net water use and improve air quality by replacing most of the power Agilent previously drew from the grid.

Bloom Energy Servers solid oxide fuel cells convert natural gas or biogas into electricity via an electrochemical process. Because the Energy Servers generate low-emission power 24 hours a day, 365 days per year, they reduce greenhouse-gas emissions by amounts comparable to zero-emission wind and solar power over the course of a year. The Bloom Energy Servers also generate virtually none of the smog-forming particulate emissions that cause air pollution and respiratory distress. This is an important consideration at the Agilent sites in Delaware and California, two states that rank among the bottom U.S. states for air pollution. Agilent has commissioned more than 18 energy and water-conservation projects at its sites around the world, leading to a potential annual energy saving of about 8,000-megawatt hours.

www.bloomenergy.com

THE FUTURE OF HYDROGEN

An important report has been published by the International Energy Agency (IEA) on the role of hydrogen in all energy sectors. As the world's leading energy authority covering all fuels and all technologies, the IEA is ideally placed to help to shape global policy on hydrogen.

Hydrogen is already used on an industrial scale around the world, but it is obtained mainly from fossil fuels and is used mostly in oil refining and for the production of fertilisers. Much of the refining and chemicals production that uses hydrogen is already concentrated in coastal industrial zones around the world, so the IEA proposes that industrial ports could become the nerve centres for scaling up the use of clean hydrogen.

The hydrogen trade's first international shipping routes should be started immediately in order to make an impact on global energy systems. Hydrogen can also be added to the natural gas infrastructure in millions of kilometres of pipelines. To make a real contribution to the clean energy transition hydrogen needs to be adopted in sectors such as transport, buildings and power generation.

World trade will benefit from common international standards for the safety of transporting and storing large volumes of hydrogen. Powering high mileage cars, trucks and buses to carry passengers and goods along popular routes can make fuel-cell vehicles more competitive.

Hydrogen can help to improve air quality and strengthen energy security. Despite very ambitious international climate goals, global energy-related CO2 emissions reached an all time high in 2018. Outdoor air pollution also remains a pressing problem, with around 3 million people dying prematurely each year. The IEA finds that the cost of clean hydrogen could fall as a result of the declining costs of renewables and the scaling up of hydrogen production. Fuel cells, refuelling equipment and electrolysers can all benefit from mass manufacturing. www.iea.org

NEW HYDROGEN STUDY

ITM Power, Ørsted and Element Energy have been awarded a contract by the UK Government for a gigastack feasibility study. www.itm-power.com

NET ZERO GREENHOUSE GAS EMISSIONS

UK COMMITTEE ON CLIMATE CHANGE

The Committee on Climate Change (CCC) has outlined a series of actions which would enable the UK to have net-zero greenhouse gas (GHG) emissions by 2050. Carbon dioxide and other long-lived GHGs must be reduced to net zero. Despite only making up 1% of global population, 2-3% of human-induced global warming to date has resulted from GHG emissions in the UK. A net-zero target would imply that the UK will be actively reducing its large historical contribution to global warming. The UK also has a significant carbon footprint attached to imported products, for which the emissions are counted in other countries. If our net-zero target is replicated across the world this would deliver a greater than 50% chance of limiting the global temperature increase to 1.5ºC.

Action must progress with far greater urgency. By 2030 or 2035 all new cars and vans should be electric or hydrogen powered. The costs for renewable electricity have reduced in larger production, but we must also decarbonise heating. Other possibilities include limiting aviation demand growth, using technologies which will extract C02 direct from the air, or developing carbon neutral synthetic fuels produced from algae or renewable power. Biodegradable waste must no longer be sent to landfill and combustion of non bio waste must be limited.

By 2050 a new low carbon industry is needed, with UK hydrogen production capacity of comparable size to the UK's current fleet of gas-fired power stations. Carbon Capture Use and Storage (CCUS) is crucial to reaching net zero. Annual capture and storage of 75 – 175 MtC02 in 2050 would require a major C02 transport and storage infrastructure. GHG emissions from international aviation and shipping can no longer be ignored.

A fifth of our agricultural land must shift to alternative uses that support emissions reduction. Enabled by healthier diets and reductions in food waste, our scenarios involve a fifth of UK agricultural land shifting to tree planting, energy crops and peatland restoration. Where there are remaining emissions these must be fully offset by removing C02 from the atmosphere and permanently sequestering it, for example by using sustainable bioenergy in combination with CCUS.

Government policies must be fully funded and implemented across all sectors of the economy to drive the necessary innovation, market development and consumer take-up of low carbon technologies, and to positively influence societal change. Global average temperature has already risen 1ºC from pre-industrial levels and climate risks are increasingly apparent. Investors could be encouraged to prioritise low carbon investments. There should be mandatory disclosure of how their portfolios are consistent with a transition to net-zero emissions across the economy.

www.theccc.org.uk

The UK Government's chief environment scientist, Prof Sir Ian Boyd, has warned that the public has little idea of the scale of the challenge from the net zero emissions target. Emissions won't be reduced to Net Zero while ministers are focussed on economic growth measured by GDP, instead of environmental security and a relatively stable climate.

FUEL CELLS ACHIEVE NET ZERO EMISSIONS

Fuel cells of all types are becoming available to meet the requirements of communities, industries and individuals. They can be powered by natural gas, hydrogen or biomass, depending upon what resources are to hand. They will help to meet international demands for energy, as the electrochemical process is two or three times more efficient than combustion. Fuel cells can separate carbon dioxide for recycling and their only other emission is potable water.

Hydrogen is a useful store of intermittent renewable energy from solar, wind or marine sources. It can be used to power fuel cells and can also be added to natural gas. Fuel cells powered by natural gas are providing combined heat and power with up to 90% efficiency. The carbon dioxide is separated and recycled for use by industry and agriculture. Fuel cells can also be powered by anaerobic digester gas obtained from wastewater treatment plants and landfills. A Gasified Anaerobic Digester (GAD™) has been developed which provides a liquid to replace fossil fuels in the existing transport infrastructure. The separated carbon dioxide can be stored as a carbonate. Some fuel cells have been developed to scrub carbon dioxide from the ambient air and this can also be stored as a carbonate for recycling.

EVENTS

17th March 2020
16th International Conference on Hydrogen and Fuel Cells.
Hydrogen and Fuel Cells - Coming of Age
The Conference, Exhibition and Partnering Event will be held in Birmingham, UK
www.climate-change-solutions.co.uk

20th –24th April 2020
Group Exhibit Hydrogen + Fuel Cells
Hannover Fair, Germany. Includes Europe's largest hydrogen and fuel cells exhibition www.h2fc-fair.com

30th June - 3 July 2020
14th European SOFC and SOE Forum
Lucerne, Switzerland www.efcf.com

Fuel Cell Power's Blog covers all types of fuel cells and their applications in distributed power generation, portable power, CHP and transport. For millennia, energy has been obtained by burning fuels, which is changing the chemistry of the atmosphere and the oceans. Cleanly, quietly and efficiently the electrochemical conversion of fuels is now becoming a practical alternative to combustion. Fuel cells utilize fossil fuels or energy from waste efficiently. They can equally be powered by hydrogen which can be generated from intermittent renewable energy sources. Articles and features in Fuel Cell Power will help individuals, businesses and communities to plan for 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,
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