ELSEVIER

fuelCELLS BULLETIN

ISSN 1464-2859 October 2019

www.fuelcellsbulletin.com

Linde acquires stake in ITM Power, agrees JV

Industrial gases and engineering company Linde AG has acquired a minority stake in ITM Power, a UK-based manufacturer of PEM water electrolysers. Linde will also form a joint venture with ITM Power to implement projects based on ITM's technology.

The **investment transaction**, completed on 22 October, provides Linde with a strategic investment in a leading manufacturer of integrated hydrogen energy solutions. ITM is running a fundraising programme to raise at least £52 million (US$67 million), with Linde investing £38 million ($49 million) for a 20% stake in its enlarged share capital. The remainder will come from a proposed Firm Placing of £14 million ($18 million) with certain existing and new institutional investors, as well as an Open Offer of up to £6.8 million ($8.7 million).

The net proceeds will be utilised to facilitate ITM's move to its new, larger Bessemer Park facility in Sheffield, with an annual production capacity of over 1000 MW per annum [*FCB, August 2019, p11*]. It will also fund and resource development of a 5 MW electrolyser module [*September 2019, p10*], enhance product standardisation, and meet initial funding requirements for the JV.

The **50:50 joint venture** will bring together ITM Power's expertise in PEM electrolysis [*see the Feature in January 2012, and the SWIFTH$_2$ item on page 6 in this issue*] and Linde's engineering procurement and construction experience [*see the Feature in September 2014*], to focus on delivering 'green' hydrogen to large-scale industrial projects, principally those with an installed electrolyser capacity of 10 MW and above, and particularly in the metals and glass, electronics, refinery, chemistry, and steel industries. In addition to opening new commercial opportunities, the joint venture is expected to create capacity to deliver a higher volume of projects, shorten lead times, improve project execution, and reduce costs.

'The major strategic investment from Linde cements a five-year relationship between us, and provides ITM Power with a world leading partner that brings deep expertise in engineering, procurement and construction, and a global customer base,' says Dr Graham Cooley, CEO of ITM Power. 'The joint venture will enable us to focus on our core competency of the development and sale of electrolysers, and with Linde as our partner to deliver green hydrogen at scale.'

ITM Power: www.itm-power.com

Linde: www.linde.com

Umicore opens Korea catalyst production plant

Belgium-based materials technology company Umicore has opened its new South Korean fuel cell catalysts production facility in Songdo, Incheon City, southwest of the capital Seoul. The new production plant, close to the company's catalyst technology development centre, will support the growth of Hyundai Motor Group as well as other automotive customers.

The facility, announced at the end of last year [*FCB, January 2019, p13*], is expected to ramp up production in 2020, and can expand further in the future. This new production capability in Korea and the existing production capacity in Hanau, Germany mean that Umicore is well placed to serve the growing demand for fuel cell catalysts from its global automotive customers.

Umicore has a competitive product portfolio with a strong R&D pipeline, and has entered into close collaboration agreements with Hyundai Motor Group and other leading car OEMs.

Umicore has been developing fuel cell catalysts for a broad range of PEM fuel cell technologies, with catalysts designed for superior performance and durability in fuel cell electric vehicles, PEM electrolysis, and other fuel cell applications.

Umicore, Automotive Catalysts: https://pmc.umicore.com/en/markets/automobile

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The companies signed a product development partnership agreement in 2016, and since then have been collaborating on future generations of fuel cell drive systems and on scalable, modular components for FCEVs. In January 2017 they were among the founding members of the Hydrogen Council, a global initiative with the long-term ambition of a hydrogen fueled energy revolution [*January 2017, p1*].

BMW, Electro-mobility:
https://tinyurl.com/bmw-e-mobility

Freudenberg Sealing Technologies, FlixBus developing fuel cells for long-distance buses

In Germany, Freudenberg Sealing Technologies is collaborating with FlixBus, the largest European operator of long-distance bus travel, in a project to put fuel cell powered buses on the road for long-distance, zero-carbon transit operations. The companies will extend their partnership in the near future with the participation of a bus manufacturer, and are currently holding talks to finalise the project parameters.

Initially, a representative fleet of 30 buses will be equipped with a hybrid fuel cell-battery powertrain to validate system performance. The partners are also aiming for public funding under the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP).

In early 2018, Freudenberg Sealing Technologies strengthened its fuel cell expertise by acquiring Munich-based fuel cell manufacturer Elcomax (Elcore), and expanded its battery technology expertise by acquiring a minority interest in US battery manufacturer XALT Energy (subsequently built into a majority stake).

These strategic acquisitions have solidified Freudenberg Sealing Technologies' position as a provider of fuel cell and electric battery powertrain solutions. The company is pursuing integrated battery-fuel cell hybrid systems that address power, baseload, and the unique operating cycles in a range of heavy-duty applications, including truck, bus, commercial marine, and rail transportation. Through unique vertical integration, FST will become a single-source supplier of complete battery, fuel cell, and hybrid energy systems that include all the necessary components, modules, and subsystems.

This will give FST expertise ranging from separators to cells to complete battery systems, and from gas diffusion layers to membrane-electrode assemblies and stacks to complete fuel cells. The modular systems can be customised to accommodate different performance requirements that offer customers better efficiency, value, and total cost of ownership for their specific needs.

Freudenberg Sealing Technologies:
www.fst.com/press/2019/freudenberg-flixbus-press

FlixBus: https://global.flixbus.com

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The buses are co-funded by the 3Emotion project of the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), which is deploying 21 new fuel cell buses and extending the use of eight existing buses along with the required refueling infrastructure in Versailles and Pau in France, London (UK), Rotterdam (Netherlands), and Aalborg (Denmark) [*FCB, February 2015, p1*].

They refuel at Air Liquide's Loges-en-Josas station [*April 2018, p7*], which can fully refuel a bus in just 20 minutes. The bus can hold 39 kg of hydrogen, giving it a range of 300 km (185 miles). All the drivers have received training on the specifics of using a hydrogen station.

The hydrogen for the Loges-en-Josas station is produced by Air Liquide [*see also page 8*] at its Port-Jérôme-sur-Seine site in Normandy, under the CertifHy Guarantee of Origin platform [*May 2018, p10*]. This facility uses the Cryocap™ carbon capture technology, which captures up to 90% of the CO_2 emitted during steam methane reforming (SMR) to produce hydrogen; the CO_2 is then liquefied and purified to be utilised in various applications.

Van Hool, Fuel Cell Buses:
https://tinyurl.com/vanhool-fuelcell

Air Liquide, Hydrogen Energy:
http://tinyurl.com/hydrogen-energy-airliquide

3Emotion project: www.3emotion.eu

Hamburg to test M-B articulated bus with fuel cell range-extender

Hamburger Hochbahn, the public transport company in the northern German city-state of Hamburg, has agreed to field-test the next-generation Mercedes-Benz eCitaro G articulated bus featuring a fuel cell range-extender, with two buses scheduled for delivery during 2021.

The all-electric battery eCitaro was unveiled in late 2018, with Mercedes-Benz delivering to Hamburger Hochbahn the first of an order of 20 of these new buses. In 2020 a next-generation battery will bring a significant increase in capacity and range. Then the eCitaro G articulated bus will be rolled out, followed by the eCitaro G with a fuel cell range-extender.

'We anticipate a number of advantages to arise from the new development of the fuel cell bus based on the purely electric vehicle, especially when it comes to covering greater ranges,' says Henrik Falk, Chair of the Board of Hamburger Hochbahn, who signed the Letter of Intent with Till Oberwörder, Head of Daimler Buses.

The Mercedes-Benz eCitaro city bus features modular battery packs with a total capacity up to 292 kWh, giving it a system-relevant range of around 170 km (105 miles) under all weather conditions. With a fuel cell range-extender, the eCitaro is anticipated to achieve a system-relevant range of up to 400 km (250 miles), depending on the vehicle configuration and equipment.

Hamburger Hochbahn first deployed Daimler/Mercedes-Benz Citaro fuel cell electric buses in 2003 [*FCB, November 2003, p2*], and in 2011 took delivery of a fleet of Citaro FuelCELL Hybrid buses [*August 2011, p1*]. Hamburg has also trialed Solaris Urbino articulated buses with fuel cell range-extenders [*January 2015, p2, and see also the next item*].

Hamburger Hochbahn:
www.hochbahn.de/hochbahn/hamburg/en

Mercedes-Benz eCitaro:
www.daimler.com/innovation/case/electric/ecitaro-2.html

Solaris Urbino 12 hydrogen bus being trialed across Europe

The Solaris Urbino 12 hydrogen fuel cell bus has been tested by transit operators in Austria, Italy, Germany and Poland over the past few weeks, following its première in June at the UITP Global Public Transport Summit 2019 in Stockholm, Sweden.

This new vehicle from Polish bus builder Solaris Bus & Coach has attracted huge interest among potential customers, as evidenced by the demand for bus tests in several European cities. In August, the bus was showcased in the Austrian cities of Graz and Klagenfurt, and then in the Italian city of Bolzano. In the following weeks, the vehicle went on to be tested in Germany, by public transport operators in Frankfurt, Cologne and Wuppertal. The bus was then presented to the municipal operator Miejskie Przedsiębiorstwo Komunikacyjne in Poznań, close to the Solaris headquarters.

Immediately after the vehicle's unveiling during the UITP Summit in June, representatives of Solaris and Régie Autonome des Transports Parisiens (RATP) signed a contract to lease and

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Buses are again a key topic in this issue, in particular in Europe but also in China, California, and for the first time in New Zealand.

In Germany, **Freudenberg Sealing Technologies and FlixBus** are collaborating in a project to deploy fuel cell powered buses for long-distance transit, and are looking to bring in a bus manufacturer to equip a fleet of 30 buses with a hybrid fuel cell-battery powertrain [*page 2*].

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Hamburger Hochbahn in Hamburg will field-test the next-generation Mercedes-Benz eCitaro G articulated bus featuring a fuel cell range-extender, with two buses scheduled for delivery in 2021 [*page 3*].

Polish bus builder **Solaris Bus & Coach** has been trialing its new Solaris Urbino 12 hydrogen fuel cell bus with transit operators in Austria, Italy, Germany, and Poland [*page 3*]. The company has already contracted to lease the bus to RATP in Paris for trials next year, and has sold 12 buses to SASA in Bolzano, Italy.

Belgian bus builder **Van Hool** has unveiled its Exqui.City 18 Fuel Cell articulated bus, which will first be deployed in the French city of Pau [*page 4*]. This 'Fébus' initiative will be the world's first full Bus Rapid Transit system with 18 m articulated tram-buses.

UK-based **Ceres Power and Weichai Power** in China have developed a first prototype solid oxide fuel cell range-extender for Chinese electric buses, for demonstration in a city bus utilising CNG [*page 4*].

Meanwhile, **New Zealand** bus builder Global Bus Ventures will build a fuel cell bus for use in the Ports of Auckland hydrogen production and refueling system trial [*page 4*]. This will be the first NZ-built hydrogen fuel cell vehicle, and is expected to start trials next September.

In the US, the **California Fuel Cell Partnership** has released its second bus road map, calling for 11 essential actions and setting new industry targets needed to widely adopt fuel cell buses in the state [*page 10*].

And Northern Ireland bus builder **Wrightbus**, which collapsed into administration in September, has been acquired by Bamford Bus Company, owned by industrialist Jo Bamford, who also runs Ryse Hydrogen [*In Brief item on page 5*]. Ryse and Wrightbus are members of the H2Bus consortium, which plans to deploy 1000 fuel cell buses across Europe.

Steve Barrett

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In Germany, **Freudenberg Sealing Technologies and FlixBus** are collaborating in a project to deploy fuel cell powered buses for long-distance transit, and are looking to bring in a bus manufacturer to equip a fleet of 30 buses with a hybrid fuel cell-battery powertrain [*page 2*].

The **first fuel cell passenger bus route in France** has been commissioned, running between Versailles and Jouy-en-Josas to the west of Paris [*page 2*]. Two Van Hool buses are being refueled at the Air Liquide hydrogen station in Les Loges-en-Josas.

Hamburger Hochbahn in Hamburg will field-test the next-generation Mercedes-Benz eCitaro G articulated bus featuring a fuel cell range-extender, with two buses scheduled for delivery in 2021 [*page 3*].

Polish bus builder **Solaris Bus & Coach** has been trialing its new Solaris Urbino 12 hydrogen fuel cell bus with transit operators in Austria, Italy, Germany, and Poland [*page 3*]. The company has already contracted to lease the bus to RATP in Paris for trials next year, and has sold 12 buses to SASA in Bolzano, Italy.

Belgian bus builder **Van Hool** has unveiled its Exqui.City 18 Fuel Cell articulated bus, which will first be deployed in the French city of Pau [*page 4*]. This 'Fébus' initiative will be the world's first full Bus Rapid Transit system with 18 m articulated tram-buses.

UK-based **Ceres Power and Weichai Power** in China have developed a first prototype solid oxide fuel cell range-extender for Chinese electric buses, for demonstration in a city bus utilising CNG [*page 4*].

Meanwhile, **New Zealand** bus builder Global Bus Ventures will build a fuel cell bus for use in the Ports of Auckland hydrogen production and refueling system trial [*page 4*]. This will be the first NZ-built hydrogen fuel cell vehicle, and is expected to start trials next September.

In the US, the **California Fuel Cell Partnership** has released its second bus road map, calling for 11 essential actions and setting new industry targets needed to widely adopt fuel cell buses in the state [*page 10*].

And Northern Ireland bus builder **Wrightbus**, which collapsed into administration in September, has been acquired by Bamford Bus Company, owned by industrialist Jo Bamford, who also runs Ryse Hydrogen [*In Brief item on page 5*]. Ryse and Wrightbus are members of the H2Bus consortium, which plans to deploy 1000 fuel cell buses across Europe.

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buses to be commissioned in France. Serving the 'Versailles Grand Parc' communities, they meet the region's energy transition objectives that aim for an entirely clean Île-de-France Mobilités bus fleet running in densely populated areas by 2025, and across the entire region by 2029.

The buses are co-funded by the 3Emotion project of the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), which is deploying 21 new fuel cell buses and extending the use of eight existing buses along with the required refueling infrastructure in Versailles and Pau in France, London (UK), Rotterdam (Netherlands), and Aalborg (Denmark) [*FCB, February 2015, p1*].

They refuel at Air Liquide's Loges-en-Josas station [*April 2018, p7*], which can fully refuel a bus in just 20 minutes. The bus can hold 39 kg of hydrogen, giving it a range of 300 km (185 miles). All the drivers have received training on the specifics of using a hydrogen station.

The hydrogen for the Loges-en-Josas station is produced by Air Liquide [*see also page 8*] at its Port-Jérôme-sur-Seine site in Normandy, under the CertifHy Guarantee of Origin platform [*May 2018, p10*]. This facility uses the Cryocap™ carbon capture technology, which captures up to 90% of the CO_2 emitted during steam methane reforming (SMR) to produce hydrogen; the CO_2 is then liquefied and purified to be utilised in various applications.

Van Hool, Fuel Cell Buses:
https://tinyurl.com/vanhool-fuelcell

Air Liquide, Hydrogen Energy:
http://tinyurl.com/hydrogen-energy-airliquide

3Emotion project: www.3emotion.eu

Hamburg to test M-B articulated bus with fuel cell range-extender

Hamburger Hochbahn, the public transport company in the northern German city-state of Hamburg, has agreed to field-test the next-generation Mercedes-Benz eCitaro G articulated bus featuring a fuel cell range-extender, with two buses scheduled for delivery during 2021.

The all-electric battery eCitaro was unveiled in late 2018, with Mercedes-Benz delivering to Hamburger Hochbahn the first of an order of 20 of these new buses. In 2020 a next-generation battery will bring a significant increase in capacity and range. Then the eCitaro G articulated bus will be rolled out, followed by the eCitaro G with a fuel cell range-extender.

'We anticipate a number of advantages to arise from the new development of the fuel cell bus based on the purely electric vehicle, especially when it comes to covering greater ranges,' says Henrik Falk, Chair of the Board of Hamburger Hochbahn, who signed the Letter of Intent with Till Oberwörder, Head of Daimler Buses.

The Mercedes-Benz eCitaro city bus features modular battery packs with a total capacity up to 292 kWh, giving it a system-relevant range of around 170 km (105 miles) under all weather conditions. With a fuel cell range-extender, the eCitaro is anticipated to achieve a system-relevant range of up to 400 km (250 miles), depending on the vehicle configuration and equipment.

Hamburger Hochbahn first deployed Daimler/Mercedes-Benz Citaro fuel cell electric buses in 2003 [*FCB, November 2003, p2*], and in 2011 took delivery of a fleet of Citaro FuelCELL Hybrid buses [*August 2011, p1*]. Hamburg has also trialed Solaris Urbino articulated buses with fuel cell range-extenders [*January 2015, p2, and see also the next item*].

Hamburger Hochbahn:
www.hochbahn.de/hochbahn/hamburg/en

Mercedes-Benz eCitaro:
www.daimler.com/innovation/case/electric/ecitaro-2.html

Solaris Urbino 12 hydrogen bus being trialed across Europe

The Solaris Urbino 12 hydrogen fuel cell bus has been tested by transit operators in Austria, Italy, Germany and Poland over the past few weeks, following its première in June at the UITP Global Public Transport Summit 2019 in Stockholm, Sweden.

This new vehicle from Polish bus builder Solaris Bus & Coach has attracted huge interest among potential customers, as evidenced by the demand for bus tests in several European cities. In August, the bus was showcased in the Austrian cities of Graz and Klagenfurt, and then in the Italian city of Bolzano. In the following weeks, the vehicle went on to be tested in Germany, by public transport operators in Frankfurt, Cologne and Wuppertal. The bus was then presented to the municipal operator Miejskie Przedsiębiorstwo Komunikacyjne in Poznań, close to the Solaris headquarters.

Immediately after the vehicle's unveiling during the UITP Summit in June, representatives of Solaris and Régie Autonome des Transports Parisiens (RATP) signed a contract to lease and

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European Class 3 materials handling equipment (MHE) has a small footprint of 210 mm battery width, according to DIN 43535, which has until now been a barrier to the integration of fuel cells. Recent changes from slow-charge lead-acid batteries to faster-charge lithium-ion batteries have brought an increased need for electrical power and substation capacity for sites, where the cost is usually charged to the site owner. In addition, battery powered MHE experiences a voltage reduction during operation, which impacts on performance and extends operational downtime due to recharging.

Currently, fuel cell powered MHE is successfully integrated into larger applications (with c.330 mm battery tanks) operating in US warehouses. In Europe, grocery warehouses rely on fleets of order pickers with a smaller battery space (210 mm width). Intelligent Energy's compact FCMs can be easily accommodated [*see also page 6*], and in providing 1.2 kW of power and operating in a temperature

test the hydrogen fuel cell electric bus in Paris, France [*FCB, July 2019, p3*]. In 2020, RATP will test the bus for several weeks in regular passenger service. The bus also drew its first buyer, SASA SpA-AG in Bolzano, which ordered 12 buses, with delivery planned at the end of 2021.

Solaris Bus & Coach: www.solarisbus.com

Van Hool unveils its Exqui.City 18 Fuel Cell bus, ready for Pau

Belgian bus builder Van Hool premiered its hydrogen powered Exqui.City 18 Fuel Cell articulated bus at the recent Busworld Europe 2019 exhibition in Brussels, the 18 m (60 ft) version of which will be deployed for the first time in the French city of Pau.

In 2017 Pau placed an order with Van Hool for eight Exqui.City 18 Fuel Cell single-articulated tram-buses, as part of the EU-funded 3Emotion project [*see the News Focus in FCB, September 2017*]. The 'Fébus' initiative will be the first hydrogen fuel cell electric articulated bus deployment in France, and a world-first for a full Bus Rapid Transit (BRT) system with 18 m articulated tram-buses [*April 2018, p5*].

The Exqui.City 18 Fuel Cell buses for Pau have a capacity of 125 passengers. The vehicle can be fully refueled in 10 minutes and has a range of approximately 300 km (190 miles), giving bus operators the highest level of operational flexibility and productivity. The PEM fuel cell power plants are supplied by Canadian-based Ballard Power Systems, with the drive motors and traction systems from Siemens.

Van Hool has also developed the 24 m (79 ft) Exqui.City 24 Fuel Cell double-articulated bus, although there is no word yet on availability or deployment [*see also page 2*].

Van Hool, Fuel Cell Buses: www.vanhool.be/en/public-transport/exquicity-brt/fuel-cell

3Emotion project: www.3emotion.eu

Fébus initiative: www.pau.fr/article/febus-revolutionne-nos-deplacements [in French]

Ceres, Weichai Power develop first range-extender bus prototype

UK-based Ceres Power and Weichai Power, one of the leading automobile and equipment manufacturing companies in China, have completed the development of a first prototype solid oxide fuel cell range-extender for Chinese electric buses.

Following a successful technology transfer and the licensing of system-level technology from Ceres to Weichai Power [*FCB, January 2019, p11*], the combined team has produced a first prototype 30 kW SteelCell® intermediate temperature SOFC range-extender system, which met the required technical performance criteria, for demonstration in an electric city bus utilising widely available compressed natural gas (CNG). This marks the completion of the initial Joint Development Agreement between Ceres and Weichai, the first step in the collaboration first announced in May 2018 [*June 2018, p10*], and cements a strong working relationship between the two companies.

Ceres and Weichai are now focused on developing the next stage system to go on bus field trials in 2020. Following these field trials, the partners intend to establish a fuel cell manufacturing joint venture in Shandong Province in 2020, to manufacture SteelCell IT-SOFC systems.

In other news, **Dr Mark Selby, Chief Technology Officer** at Ceres Power, has been elected as a Fellow by the Royal Academy of Engineering, the UK's highest national honour for engineers. Mark is well known internationally for his work on establishing Ceres Power as a global technology leader in the fuel cell industry, with responsibility for leading on all aspects of the company's technology strategy and delivering SteelCell technology development.

Ceres Power: www.cerespower.com

Weichai Power: http://en.weichaipower.com

GBV building New Zealand's first fuel cell bus for Auckland

New Zealand bus builder Global Bus Ventures has been awarded a contract with Auckland Transport to supply a three-axle hydrogen fuel cell electric bus, to be used as part of the Ports of Auckland hydrogen production and refueling system trial. This will be the first NZ-built hydrogen fuel cell vehicle for use in New Zealand.

The bus will be 13.5 m (44 ft) long with three axles, and carry up to 78 passengers. It is expected to start trials from September 2020. Auckland Transport will trial hydrogen fuel cell buses in partnership with bus operators and Ports of Auckland Ltd (POAL), which is building a hydrogen production and refueling facility at its Waitematā port, another first for Auckland [*FCB, January 2019, p8*].

'We are committed to a low-emission future, and hydrogen could be one of the best ways to deliver it, as it has the potential to address the range anxiety associated with batteries on long and high-frequency bus routes,' says Darek Koper, AT's Bus Services Manager.

'AT's decision to select GBV for the first hydrogen bus project is an important step in growing high-tech bus manufacturing in New Zealand,' adds Mike Parker, Executive VP of Christchurch-based GBV.

Global Bus Ventures: www.globalbusventures.co.nz

Auckland Transport: www.at.govt.nz

MOBILE APPLICATIONS

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A U-30 aircraft tow tractor retrofitted with hydrogen fuel cells was used to tow the 84 tonne aircraft on the flightline of Joint Base Pearl Harbor-Hickam and demonstrate the efficacy of the technology. According to the Hawaii Center for Advanced Transportation Technologies (HCATT), this is the first time that hydrogen fuel cell technology has been used to tow a large US Air Force aircraft. The demonstration was made possible through a collaborative effort by a consortium of public and private entities. The demonstration involved towing the Stratotanker from its normal parking area to a wash rack some 400 m away, to conduct its periodic corrosion prevention maintenance.

'We're very pleased about this first demonstration. We've worked with US Hybrid, TUG Technologies, and the Air Force Research Laboratory on this vehicle for three years, and have garnered a lot of technical knowledge along the way,' says retired Col. Dave Molinaro, HCATT project manager. The tug will be put through its paces for another two to three years while HCATT continues to collect data in an operational environment.

Working closely with the vehicle's original manufacturer, US Hybrid modified the diesel-based drive train with a 30 kW PEM fuel cell, two 5 kg hydrogen storage tanks, a 28 kWh Li-ion battery configuration, and a 240 kW AC induction motor linked to the transmission. Hydrogen for the U-30 tow tractor is produced using HCATT's electrolyser at Joint Base Pearl Harbor-Hickam.

Hawaii Center for Advanced Transportation Technologies: www.htdc.org/hcatt

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Bloom and Samsung Heavy Industries plan SOFCs for ship power

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SHI – part of the Samsung Group – aims to be the first shipbuilder to deliver a large cargo ship for ocean operation powered by fuel cells running on natural gas. This innovation would play a key role in helping the company beat the 50% emissions reduction target, compared to 2008 levels, that the International Maritime Organization (IMO) has mandated that all shipbuilders should achieve by 2050. Replacing combustion-based power generation from bunker oil with electrochemical conversion of liquefied natural gas (LNG) using fuel cells could have a profound impact on carbon emissions from marine transportation. Bloom Energy and SHI estimate that replacing oil-based power generation on large cargo ships, which each require up to 100 MW of power, could reduce annual GHG emissions from shipping by 45%.

The two companies have already taken an important first step towards commercialising the maritime use of fuel cells for propulsion and auxiliary power. At a ceremony in the SHI Geoje shipyard, Samsung Heavy announced that it has received Approval in Principle from DNV GL, the internationally accredited marine shipping registrar and classification society, in collaboration with Bloom Energy to proceed with a fuel cell-powered ship design for Aframax crude oil tankers (COTs).

Bloom Energy Servers operate on natural gas, biogas, or hydrogen [*FCB, July 2019, p5, and see the In Brief item on page 15 in this issue]*. Bloom and SHI envision onboard fuel cells being powered by natural gas, converted from LNG, which is already commonly transported by marine shipping worldwide. The system's modularity makes it well suited to the space constraints in ships, allowing deployment in increments down to 200 kW, and distributed throughout the vessel to optimise space utilisation. SHI sees Bloom Energy Servers displacing existing power generation sets, requiring no additional space

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Bloom Energy: www.bloomenergy.com

Samsung Heavy Industries: www.samsungshi.com/eng

SWIFTH$_2$ project for hydrogen powered ferries in Scotland

The Scottish Western Isles Ferry Transport using Hydrogen (SWIFTH$_2$) project has studied the feasibility of ferries serving the Western Isles and west coast of Scotland being powered by hydrogen produced using onshore island wind power.

SWIFTH$_2$ has been led by the Point and Sandwick Trust community renewable energy company, and part-funded by the Scottish Government's Low Carbon Infrastructure Transition Programme. The project team also includes ferry and port operator Caledonia Marine Assets Ltd (CMAL), shipbuilder Ferguson Marine Engineering, project and engineering coordinator Wood Plc, Siemens Gamesa Renewable Energy, electrolyser manufacturer ITM Power [*see also page 1, and the In Brief item on page 5*], energy services group Engie [*In Brief item on page 5*], and accountants Johnston Carmichael.

The study assessed the feasibility of deploying hydrogen-powered passenger ferries on nine Caledonian MacBrayne ferry routes serving the Western Isles. Various aspects including local available renewable energy resource, planning constraints, challenges associated with hydrogen production, and the refueling requirements of each ferry route were studied.

Of the nine routes analysed, the highest scoring route using a small ferry on a short crossing was from Barra to Eriskay, and the highest scoring route using a large ferry on a long crossing was from Stornoway to Ullapool. The annual hydrogen requirements would be 219 tonnes and 3676 tonnes, respectively. A single 4.3 MW wind turbine generator would be capable of supplying the required hydrogen for the Barra–Eriskay route, while 15 turbines would be required on the Isle of Lewis for the crossing to the mainland.

While the cost of using hydrogen would be more than the current price of marine oil, at 11–17p (US13–21¢) per kWh compared to 5p (6¢) for marine oil, the price gap is smaller than anticipated. The project team found that if hydrogen produced from renewable resources for marine transport were included in the UK government's Renewable Transport Fuel Obligation mechanism, that price gap could be narrowed further, falling to 9–12p (11–15¢) per kWh.

Point and Sandwick Trust: www.pointandsandwick.co.uk

SWIFTH$_2$ report (PDF): https://tinyurl.com/swifth2-report

thyssenkrupp Marine Systems unveils 4th-gen fuel cell system for submarines

German naval ship and submarine builder thyssenkrupp Marine Systems (TKMS) unveiled its 4th Generation Fuel Cell (FC4G) for submarine applications at the recent SubCon submarine conference in Kiel, after completing an extensive test programme with more than 70 000 operating hours in the real-world environment.

FC4G is designed to be a high-availability modular system, comprising redundant components to retain maximum performance at all times. As with previous generations, for hydrogen storage it relies on the proven and safe use of metal hydride cylinders. Since pure hydrogen is fed to the system, no chemical conversion is required, so the overall system efficiency remains very high. The only by-product is pure water, which is stored on board for weight compensation, while the thermal and acoustic signatures are kept to a minimum.

'These are the reasons why 38 systems were contracted so far with seven customer navies, another 10 systems presently being under negotiation,' comments Philipp Schön, Head of Product Sales Submarines.

TKMS's Howaldtswerke-Deutsche Werft (HDW) shipyard built the Type 214 submarines, which are powered by an air-independent propulsion (AIP) system using Siemens hydrogen PEM fuel cells [*see the Feature in FCB, June 2012*].

TKMS is also participating in the new MultiSchiBZ research project in Germany, which aims to significantly reduce the pollutants and greenhouse gases produced by shipping [*September 2019, p5*]. TKMS is steering a two-phase optimisation and design evolution process for the SchiBZ2 solid oxide fuel cell onboard power generation system, with the longer-term objective of launching commercial applications.

thyssenkrupp Marine Systems: www.thyssenkrupp-marinesystems.com

HyFlyer zero-emission aircraft testing set for Orkney with ZeroAvia

The UK government has awarded £2.7 million (US$3.5 million) in funding to the HyFlyer project to demonstrate hydrogen fuel cell powertrain technology for aviation, culminating in the demonstration of a zero-emission flight of ZeroAvia's Piper M-class six-seater aircraft out of Orkney, in northern Scotland.

The HyFlyer project aims to decarbonise medium-range small passenger aircraft by demonstrating hydrogen fuel cell electric powertrain technology with electric motors, replacing conventional piston engines in propeller aircraft. The government grant is part of the ATI programme, supported by the Department for Business, Energy & Industrial Strategy (BEIS), the Aerospace Technology Institute (ATI), and Innovate UK. The grant is being matched by the project participants, making the scope of the project some £5.3 million ($6.8 million).

The project is led by California-based ZeroAvia, and will demonstrate a phased approach from battery power to hydrogen power, integrating the new technology onboard a Piper M-class six-seater aircraft which will perform test flights out of Cranfield in England and Orkney in Scotland. HyFlyer represents a significant opportunity to decarbonise aviation in Orkney, since all flights from Kirkwall – the largest town – could potentially be serviced by this zero-emissions technology.

Intelligent Energy [*see also page 4*] will optimise its high-power PEM fuel cell technology for application in aviation, while EMEC Hydrogen, an initiative of the Orkney-based European Marine Energy Centre (EMEC) which produces 'green' hydrogen from renewable energy, will supply the hydrogen required for flight tests, and develop a mobile refueling platform compatible with the plane.

ZeroAvia has already demonstrated its technology in flight tests in the US [*FCB, September 2019, p6*], and recently established an office in Cranfield to work closely with Cranfield Aerospace Solutions (CAeS) on integrating and certifying the hydrogen powertrain technology and performing initial flight tests. The project will culminate in a 250–300 nautical mile (460–555 km) demonstration flight out of an airfield in Orkney.

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The study assessed the feasibility of deploying hydrogen-powered passenger ferries on nine Caledonian MacBrayne ferry routes serving the Western Isles. Various aspects including local available renewable energy resource, planning constraints, challenges associated with hydrogen production, and the refueling requirements of each ferry route were studied.

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The project is led by California-based ZeroAvia, and will demonstrate a phased approach from battery power to hydrogen power, integrating the new technology onboard a Piper M-class six-seater aircraft which will perform test flights out of Cranfield in England and Orkney in Scotland. HyFlyer represents a significant opportunity to decarbonise aviation in Orkney, since all flights from Kirkwall – the largest town – could potentially be serviced by this zero-emissions technology.

Intelligent Energy [*see also page 4*] will optimise its high-power PEM fuel cell technology for application in aviation, while EMEC Hydrogen, an initiative of the Orkney-based European Marine Energy Centre (EMEC) which produces 'green' hydrogen from renewable energy, will supply the hydrogen required for flight tests, and develop a mobile refueling platform compatible with the plane.

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MMC UAV: www.mmcuav.com

SMALL STATIONARY

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EFOY Hybrid power solutions are customisable, completely self-sufficient, off-grid power sources for industrial applications, comprising EFOY Pro direct methanol fuel cells from German parent company SFC Energy, in combination with solar photovoltaic (PV) modules [*see the Feature on SFC in FCB, January 2013*]. If inclement weather prevents the solar array from delivering sufficient power to maintain the batteries, the EFOY Pro fuel cell senses the voltage drop and automatically switches on, to keep the battery bank charged at all times. Once the battery bank is recharged, the fuel cell returns to standby mode.

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SFC Energy: www.sfc.com/en

Ensol Systems adds Sunfire SOFC tech to rugged power products

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Ensol Systems has extensive expertise in the design and integration of off-grid power systems for use in extreme weather conditions. The natural gas or liquefied petroleum gas (LPG) fueled systems are specially developed, built and tested for harsh Canadian winters, which can reach ambient temperatures as low as –40°C. Ensol decided to cooperate with the German manufacturer because of the proven use of Sunfire technology in other regions with similar operating conditions.

The Sunfire-Remote 400 with up to 400 W electric power is almost twice as efficient as a conventional gas or diesel generator. It can reliably generate power for months on end, to provide a self-sufficient, clean and quiet power supply. The technology offers a reliable power supply in particular for the oil & gas, security, and telecom industries.

Ensol is known for the development of reliable and robust clean energy systems, designed for autonomous and low-emission integration into new or existing installations. Sunfire is a leading supplier of solid oxide fuel cell and electrolysis technologies, and also manufactures residential SOFC systems which can be operated with natural or liquefied gas [*FCB, March 2019, p11, and see the Feature on Sunfire in March 2016*].

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Nedstack partners with Raak, H2-Tech to push on micro CHP systems

Dutch companies Nedstack, Raak Engineering, and H2-Tech have signed a strategic cooperation

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Ensol Systems adds Sunfire SOFC tech to rugged power products

German-based Sunfire GmbH is partnering with Ensol Systems, a leading Canadian manufacturer and supplier of off-grid power solutions, for the integration, distribution and service of Sunfire solid oxide fuel cells for the North American market.

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The Sunfire-Remote 400 with up to 400 W electric power is almost twice as efficient as a conventional gas or diesel generator. It can reliably generate power for months on end, to provide a self-sufficient, clean and quiet power supply. The technology offers a reliable power supply in particular for the oil & gas, security, and telecom industries.

Ensol is known for the development of reliable and robust clean energy systems, designed for autonomous and low-emission integration into new or existing installations. Sunfire is a leading supplier of solid oxide fuel cell and electrolysis technologies, and also manufactures residential SOFC systems which can be operated with natural or liquefied gas [*FCB, March 2019, p11, and see the Feature on Sunfire in March 2016*].

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Sunfire GmbH: www.sunfire.de

Nedstack partners with Raak, H2-Tech to push on micro CHP systems

Dutch companies Nedstack, Raak Engineering, and H2-Tech have signed a strategic cooperation

Orkney is home to several hydrogen and fuel cell projects, including Surf 'n' Turf [*see the News Focus in October 2017*] and BIG HIT [*News Feature in October 2016, and June 2018, p8*], as well as the recently launched Integrating Tidal Energy into the European Grid (ITEG) [*May 2019, p12*] and HySpirits projects [*September 2019, p5*].

EMEC Hydrogen: www.emec.org.uk/research/hydrogen-projects

HyFlyer project [EMEC Hydrogen]: www.hyflyer.co.uk

ZeroAvia: www.zeroavia.com

Intelligent Energy: www.intelligent-energy.com

Cranfield Aerospace Solutions: www.cranfieldaerospace.com

MMC unveils drone with record-breaking 15 h flight time demo

Chinese unmanned aerial vehicle (UAV) manufacturer MMC UAV launched its Griflion H hydrogen-powered vertical take-off and landing (VTOL) drone at the recent InterGEO 2019 expo and conference for geodesy, geoinformation and land management in Berlin, Germany, where it achieved a record-breaking 15 h flight time.

The highlight of the Griflion H 'hydrone' is the extended flight time, which is attributed to its hydrogen fuel cell featuring high-efficiency metal bipolar plates, along with a maximum hydrogen storage capacity of 27 litres. The 15 h flight time was reached without a payload; it can fly for 10 h with a 3 kg payload, compared with most commercially available drones that have a maximum 2 h flight time.

In mapping applications, the mission is usually interrupted by the need for multiple take-offs and landings in different spots, which results in lower efficiency. The extended flight time of the Griflion H thus greatly improves mission efficiency. Other features include convenient operation, high security, wide coverage, zero emissions, and low noise. Coupled with different payloads, it provides solutions for global customers in applications such as surveying and mapping, rescue, security & protection, border scouting, and forest scouting.

MMC UAV has in-house industrial chain integration and independent R&D capabilities, which it has used to develop its own hydrogen fuel cell and related products, including hydrogen cylinders, pressure reducing valves, booster bumps, and hydrogen production devices. In 2016 the company launched what it claimed was the world's first hydrogen-powered multirotor, the HyDrone 1800, offering a flight time of more than 4 h [*FCB, June 2016, p4*]. The following year it launched the second-generation H1-Fuel Cell, specifically designed to provide commercial UAVs with long-endurance operation [*August 2017, p5*].

MMC UAV: www.mmcuav.com

SMALL STATIONARY

Simark EFOY Hybrid solutions for reliable power in Canada's Yoho National Park

Canadian-based Simark Controls has received an order for turnkey EFOY Hybrid power solutions from Okanagan Aggregates Ltd, a leading western Canadian road and bridge construction & maintenance and land development contractor. The solutions provide clean, reliable power for LED lighting at roadside brake-check and chain-off areas along the Trans-Canada Highway in Yoho National Park, in southeastern British Columbia.

EFOY Hybrid power solutions are customisable, completely self-sufficient, off-grid power sources for industrial applications, comprising EFOY Pro direct methanol fuel cells from German parent company SFC Energy, in combination with solar photovoltaic (PV) modules [*see the Feature on SFC in FCB, January 2013*]. If inclement weather prevents the solar array from delivering sufficient power to maintain the batteries, the EFOY Pro fuel cell senses the voltage drop and automatically switches on, to keep the battery bank charged at all times. Once the battery bank is recharged, the fuel cell returns to standby mode.

The Yoho National Park application uses 500 W EFOY ProCabinet hybrid power solutions [*May 2014, p3*]. The weatherproof cabinet integrates a 500 W EFOY Pro fuel cell [*July 2015, p6*], 120 V_{ac} sine-wave inverter and 48–24 V DC-DC converter, in hybrid operation with solar modules, to power 12 Autobahn Series LED lighting arrays, rest-stop washroom lighting, and a small weather station at each of the roadside areas. The solution features remote monitoring and control capabilities and is designed to operate autonomously for more than 12 months, eliminating costly trips to remote sites in winter and simplifying site management logistics.

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For the verification tests, the electricity generated by the fuel cell generator will be used inside the Honsha Plant [*May 2018, p1*]; the generator will operate continuously for 24 hours per day, and generate a rated output of 100 kW. The energy efficiency, stability of the generated output, and durability and ease of maintenance will be verified and evaluated.

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Toyota *Mirai*: https://tinyurl.com/toyota-europe-mirai

FUELING

Germany opens station in Mönchengladbach, adds Hamburg Airport

In late September the H_2 Mobility Deutschland joint venture and its shareholders Shell and Air Liquide jointly opened the first hydrogen refueling station facility in Mönchengladbach, North Rhine-Westphalia – the 75th such facility in Germany. The JV has also announced a further location for a hydrogen station, at Hamburg Airport.

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The generator uses two each of the fuel cell system components equipped in the *Mirai*, including its stack, power control unit, secondary battery, and air compressor [*FCB, November 2014, p1*]. By using components from the *Mirai* FC system, Toyota aims to produce a high-performance generator at a reasonable price. Development of the generator was carried out jointly by Toyota and Toyota Energy Solutions Inc [*July 2018, p12*].

For the verification tests, the electricity generated by the fuel cell generator will be used inside the Honsha Plant [*May 2018, p1*]; the generator will operate continuously for 24 hours per day, and generate a rated output of 100 kW. The energy efficiency, stability of the generated output, and durability and ease of maintenance will be verified and evaluated.

Based on the results of the verification tests, Toyota intends to use fuel cell generators as onsite power generators in an increasing number of plants. The generators will be fueled by hydrogen emitted both during the production process for fuel cell system components, and during the evaluation and testing processes; in this way, Toyota intends to develop and implement technologies that make effective use of hydrogen. In 2015, Toyota announced its Toyota Environmental Challenge 2050, one of which was the Plant Zero CO_2 Emissions Challenge [*November 2015, p2*].

Toyota *Mirai*: https://tinyurl.com/toyota-europe-mirai

FUELING

Germany opens station in Mönchengladbach, adds Hamburg Airport

In late September the H_2 Mobility Deutschland joint venture and its shareholders Shell and Air Liquide jointly opened the first hydrogen refueling station facility in Mönchengladbach, North Rhine-Westphalia – the 75th such facility in Germany. The JV has also announced a further location for a hydrogen station, at Hamburg Airport.

The **Mönchengladbach facility** is located at the Shell station at Odenkirchener Strasse 160 in the Rheydt district, along the B230 federal highway and close to the A61, A44 and A46 motorways. The station's owner-developer is H_2 Mobility, which is establishing Germany's hydrogen infrastructure, while the hydrogen station technology for this facility comes from gas and technology company Air Liquide. The hydrogen station is funded by the EU-supported Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU) through the Hydrogen Mobility Europe (H2ME) project [*see the News Feature in FCB, October 2015, and June 2016, p1*].

The latest opening further increases the density of the hydrogen supply network in Germany. The northwestern state of North Rhine-Westphalia already has 17 operational hydrogen refueling stations, topping the list of federal states with such facilities, followed by Bavaria (16) and Baden-Württemberg (12). In addition to the 75 hydrogen stations in operation, a further 29 are being planned and built throughout Germany.

H_2 Mobility Deutschland has also announced that a hydrogen station will be built for **Hamburg Airport**, at Weg beim Jäger 193. The facility will be integrated into a Shell station, and feature technology from Air Liquide. The new station is supported by the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP) of the Federal Ministry of Transport and Digital Infrastructure (BMVI).

H_2 Mobility Deutschland: https://h2.live/en

Shell Global, Hydrogen: http://tinyurl.com/shell-h2

Air Liquide, Hydrogen Energy: http://tinyurl.com/hydrogen-energy-airliquide

Hydrogen Mobility Europe project: www.h2me.eu

Fuel Cells and Hydrogen Joint Undertaking: www.fch.europa.eu

National Innovation Programme Hydrogen and Fuel Cell Technology: http://tinyurl.com/nip-h2fc-tech

Hexagon ultra-high-pressure composite tanks for California

Hexagon Group has been granted approval for its ultra-high-pressure hydrogen ground storage composite tanks by the California Occupational Safety and Health Standards Board.

The Cal/OSHA approval allows Hexagon's 1034 bar (15 000 psi) composite pressure tanks to be used as hydrogen ground storage in California. These pressure vessels are typically used as the high-pressure bank in hydrogen refueling stations. After vehicles with 700 bar tanks are filled from the medium-pressure storage (~500 bar), the 1034 bar tanks will ensure top filling up to 700 bar.

These tanks have been in service as ground storage at hydrogen stations in Europe and Canada for several years. The Type 4 all-composite tank technology allows this approval to provide a 20-year tank life, with only one requalification test required at year 15. This

minimises operating costs and maximises uptime. Last autumn these pressure vessels were permitted by the US Department of Transportation for moving hydrogen at 950 bar (13 775 psi) on American roadways, making them a multi-application product [*FCB, January 2019, p9*].

'We are glad to see the supplier base of hydrogen ground storage equipment expanding, particularly for the California market,' says Tim Brown, Chief Operations Officer of FirstElement Fuel, leading operator of hydrogen refueling stations in North America [*see the In Brief item on p15*]. 'The introduction of such a lightweight product as this one can be especially useful in urban settings where equipment footprint is critical. Lightweight tanks can be installed above grade; for example, above the hydrogen compression equipment, above the convenience store, or above the gas island canopy, thus saving real estate.'

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Since Blue World Technologies was founded last autumn [*November 2018, p11*], the company has grown to a team of 37; by the time full production is reached in 2023–2024, it expects to have more than 500 staff. In March the company closed a successful seed-round investment [*April 2019, p12*], and expects to close the next investment round in the next couple of months.

The company's high-temperature PEM fuel cell (HT-PEMFC) technology, combined with integrated methanol reforming, will be used with a small battery pack in a hybrid setup. This acts as a range-extender with fast refueling. Using liquid methanol fuel provides the opportunity to reuse the existing fueling infrastructure, and when using 'green' methanol produced from renewable sources, the fuel will be CO_2-neutral from a well-to-wheel perspective.

Blue World is working closely together with R&D departments at automotive OEMs, and the first cars featuring its technology are expected to hit the roads for testing in the first half of 2020. The company is working in close collaboration with Chinese automaker Aiways – one of the new seed investors – to integrate the methanol fuel cell technology for the Aiways U5 SUV platform. It also recently announced a strategic collaboration with Aalborg University [*June 2019, p14*], and acquired a minority stake in membrane-electrode assembly (MEA) manufacturer Danish Power Systems [*September 2019, p12*].

Blue World Technologies: www.blue.world

Aiways, U5 SUV: www.ai-ways.eu

CaFCP road map for procurement of fuel cell buses in California

The California Fuel Cell Partnership has released its second bus road map, *Fuel Cell Electric Buses: Enable 100% Zero Emission Bus Procurement by 2029*, calling for 11 essential actions and setting new industry targets needed to widely adopt fuel cell electric buses (FCEBs) in the state.

In late 2018, the California Air Resources Board (CARB) mandated that California transit bus fleets must be zero-emission by 2040, requiring that all bus purchases in 2029 and after must be battery electric or fuel cell electric. If transit agencies are to meet this mandate, FCEBs will play an essential role, with long range, fast refueling, and other significant performance benefits that allow them to offer zero emissions with zero compromise. In addition to helping California achieve clean air goals through substantial reductions in greenhouse gas emissions and other pollutants, the volume of hydrogen required to fuel these buses will help drive down per-kg costs for all vehicle categories.

The bus road map, developed by CaFCP members, lists 11 essential actions considered crucial to realising CARB's 2029 milestone and 2040 target. The road map also envisions bus purchase targets, sets new technical and cost milestone targets for industry, and presents commercial sustainability goals.

The 11 essential actions are: CARB to mandate inclusion of FCEBs in transit agency rollout plans; transit agencies to include FCEBs in zero-emission bus (ZEB) feasibility studies and procurement; hydrogen infrastructure providers to promote 'starter kits' with clear costs; hydrogen suppliers to provide transit agencies with attractive hydrogen cost trajectory for fleets of 50+ FCEBs; counter-balancing the SB350 Transportation Electrification mandate supporting utility investments for medium- and heavy-duty charging infrastructure; hydrogen producers, fueling infrastructure providers, and FCEV providers continue to advance fueling protocols, safety standards, and practices; all stakeholders to conduct a highly visible public PR campaign; Governor to prioritise funding of heavy-duty hydrogen infrastructure and ZEBs; industry to provide turnkey bus and infrastructure packages; state agencies to support ZEB grass-roots training programmes; and a major evaluation of the transformation to zero-emissions transport, impact on the grid, and hydrogen's key role in facilitating decarbonisation.

CaFCP fuel cell electric buses road map (PDF): https://tinyurl.com/cafcp-buses-roadmap

Cummins completes Hydrogenics takeover, invests in Loop Energy

US power solutions company Cummins has completed its previously announced acquisition of Canadian-based Hydrogenics Corporation. Cummins has also invested in another Canadian company, Loop Energy, a leading provider of fuel cell electric range-extenders for medium- and heavy-duty transport applications.

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Cummins, Electrified Power: www.cummins.com/electrification

Hydrogenics Corporation: www.hydrogenics.com

Loop Energy: www.loopenergy.com

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The company's high-temperature PEM fuel cell (HT-PEMFC) technology, combined with integrated methanol reforming, will be used with a small battery pack in a hybrid setup. This acts as a range-extender with fast refueling. Using liquid methanol fuel provides the opportunity to reuse the existing fueling infrastructure, and when using 'green' methanol produced from renewable sources, the fuel will be CO_2-neutral from a well-to-wheel perspective.

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The bus road map, developed by CaFCP members, lists 11 essential actions considered crucial to realising CARB's 2029 milestone and 2040 target. The road map also envisions bus purchase targets, sets new technical and cost milestone targets for industry, and presents commercial sustainability goals.

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'In launching the new and larger NM12 platform, ElringKlinger has extended the scope of PEM stacks for applications requiring a high power density, thus meeting the requirements of current automotive systems,' comments Dr Stefan Wolf, CEO of ElringKlinger.

ElringKlinger also develops and produces fuel cell systems on the basis of proprietary PEM stack technology. 'Our fuel cell system brings together stack, hydrogen and air supply, cooling, and power electronics as well as a fuel cell control unit in a self-controlled, protected, and standardised package,' says Wolf.

A year ago ElringKlinger announced that it would concentrate on PEM fuel cell technology for mobile applications, and sold its stationary solid oxide fuel cell business, including its ownership of new enerday GmbH, to Dresden-based Sunfire GmbH [*FCB, October 2018, p13*].

ElringKlinger, Electromobility: www.elringklinger.de/en/products-technologies/electromobility

Euro hydrogen safety reference database, planning guidelines

The European Hydrogen Safety Panel (EHSP) discussed the lessons learnt from the Hydrogen Safety Reference Database at the recent 8th International Conference on Hydrogen Safety (ICHS 2019) in Australia, and also presented its Safety Planning Guidelines.

EHSP has undertaken an in-depth analysis of safety data and events contained in the updated European **Hydrogen Incidents and Accidents Database** (HIAD 2.0). In close collaboration with the European Commission's Joint Research Centre (JRC), EHSP members reviewed more than 250 events, and have released the lessons learned from this assessment. The new database version focuses on facilitating sharing of lessons learnt and other relevant information related to hydrogen technology; the database is publicly available, while the events are anonymised. It aims to contribute to improved hydrogen safety awareness, encouraging users to benefit from the experiences of others as well as sharing information from their own experiences.

EHSP also recently published a **Safety Planning Guidance** document for fuel cell and hydrogen projects and programmes in Europe. This first-of-its-kind guidance document aims to assist in identifying minimum safety requirements, hazards and associated risks when generating a quality safety plan. The document serves as an assisting guide for the inherently safer conduct of all work related to the development and operation of hydrogen and fuel cell systems and infrastructure in Europe.

The Fuel Cells and Hydrogen 2 Joint Undertaking launched the European Hydrogen Safety Panel initiative in 2017, to assist it at both programme and project level in ensuring that hydrogen safety is adequately managed, and to promote and disseminate hydrogen safety culture both within and beyond the FCH2 JU programme.

European Hydrogen Safety Panel: http://fch.europa.eu/page/european-hydrogen-safety-panel

Hydrogen Incidents and Accidents Database (HIAD 2.0): https://odin.jrc.ec.europa.eu/giada

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8th International Conference on Hydrogen Safety: https://hysafe.info/ichs2019

German FlyGo project on lower-cost metal plates in fuel cells for automotive, aerospace

The 'FlyGo – Fuel Cell Assisted Mobility for Green Vehicles and Aircraft' research project is a partnership of German companies and research centres working to reduce the currently high production costs of fuel cells, and open the way for mass production of hydrogen-electric drives for the automotive and aerospace industries.

The project partners are e.GO Mobile AG and the Fraunhofer Institute for Production Technology IPT in Aachen, KCS Europe GmbH in Monschau, PSL Technik GmbH in Oberhausen, and The Hydrogen and Fuel Cell Center ZBT GmbH in Duisburg, along with associate partner Air s.Pace GmbH in Aachen. The project is funded by the European Regional Development Fund (ERDF) and the state of North Rhine-Westphalia (NRW).

The aim is to significantly reduce fuel cell manufacturing costs through a large-scale production chain of the required components, in particular the bipolar plates. Fraunhofer IPT engineers aim to utilise localised heating to improve the formability of the sheet metal material titanium and stainless steel (1.4404, 1.4301), preventing cracks and thinning. The number of required processing steps and tool wear should also be reduced. Titanium, for example, is a light metal that can further reduce the weight of the fuel cell, but it is brittle, and difficult to reform at room temperature. Hot forming promises a new application of titanium as a sheet material for bipolar plates.

To ensure that the thin sheet metal plates do not break during processing, the forming process and heating system design are being examined. Initial results for the process design were provided by simulation of the forming processes being investigated: rubber forming, stamping, and hydroforming. The new concept for mass production covers the entire process chain from hot forming to welding, coating, and assembly.

In addition, the FlyGo project is developing a concept for integrating a fuel cell range-extender into a battery-powered electric vehicle, utilising a vehicle from e.GO Mobile [*FCB, November 2018, p3*]. The partners are also working on a gas-cooled hydrogen fuel cell in combination with a methanol electrolyser, which would have more power per mass than conventional fuel cell systems, allowing its use in short-haul aircraft and drones.

e.GO Mobile, FlyGo project: www.e-go-mobile.com/en/company/research/flygo

Fraunhofer IPT: www.ipt.fraunhofer.de/en.html

Bavarian hydrogen alliance founded, centre in Nuremberg

The Bavarian State Government in Germany has founded the Center for Hydrogen.Bayern (H2.B), to develop and implement the state's hydrogen strategy. The centre – to be built on the Energy Campus in Nuremberg – will bring together business, science and politics to accelerate the 'hydrogen economy', in particular hydrogen mobility, in the southeastern state.

Bavarian companies are well positioned to develop technologies and devices such as electrolysers and fuel cells to full market readiness and to produce them in high volumes for local and global use. In particular, mobility applications are of central importance for its concentration of leading vehicle manufacturers and suppliers.

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'In launching the new and larger NM12 platform, ElringKlinger has extended the scope of PEM stacks for applications requiring a high power density, thus meeting the requirements of current automotive systems,' comments Dr Stefan Wolf, CEO of ElringKlinger.

ElringKlinger also develops and produces fuel cell systems on the basis of proprietary PEM stack technology. 'Our fuel cell system brings together stack, hydrogen and air supply, cooling, and power electronics as well as a fuel cell control unit in a self-controlled, protected, and standardised package,' says Wolf.

A year ago ElringKlinger announced that it would concentrate on PEM fuel cell technology for mobile applications, and sold its stationary solid oxide fuel cell business, including its ownership of new enerday GmbH, to Dresden-based Sunfire GmbH [*FCB, October 2018, p13*].

ElringKlinger, Electromobility: www.elringklinger.de/en/products-technologies/electromobility

Euro hydrogen safety reference database, planning guidelines

The European Hydrogen Safety Panel (EHSP) discussed the lessons learnt from the Hydrogen Safety Reference Database at the recent 8th International Conference on Hydrogen Safety (ICHS 2019) in Australia, and also presented its Safety Planning Guidelines.

EHSP has undertaken an in-depth analysis of safety data and events contained in the updated European **Hydrogen Incidents and Accidents Database** (HIAD 2.0). In close collaboration with the European Commission's Joint Research Centre (JRC), EHSP members reviewed more than 250 events, and have released the lessons learned from this assessment. The new database version focuses on facilitating sharing of lessons learnt and other relevant information related to hydrogen technology; the database is publicly available, while the events are anonymised. It aims to contribute to improved hydrogen safety awareness, encouraging users to benefit from the experiences of others as well as sharing information from their own experiences.

EHSP also recently published a **Safety Planning Guidance** document for fuel cell and hydrogen projects and programmes in Europe. This first-of-its-kind guidance document aims to assist in identifying minimum safety requirements, hazards and associated risks when generating a quality safety plan. The document serves as an assisting guide for the inherently safer conduct of all work related to the development and operation of hydrogen and fuel cell systems and infrastructure in Europe.

The Fuel Cells and Hydrogen 2 Joint Undertaking launched the European Hydrogen Safety Panel initiative in 2017, to assist it at both programme and project level in ensuring that hydrogen safety is adequately managed, and to promote and disseminate hydrogen safety culture both within and beyond the FCH2 JU programme.

European Hydrogen Safety Panel: http://fch.europa.eu/page/european-hydrogen-safety-panel

Hydrogen Incidents and Accidents Database (HIAD 2.0): https://odin.jrc.ec.europa.eu/giada

Assessment and lessons learnt from HIAD 2.0 (PDF): https://tinyurl.com/ehsp-hiad2-lessons

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8th International Conference on Hydrogen Safety: https://hysafe.info/ichs2019

German FlyGo project on lower-cost metal plates in fuel cells for automotive, aerospace

The 'FlyGo – Fuel Cell Assisted Mobility for Green Vehicles and Aircraft' research project is a partnership of German companies and research centres working to reduce the currently high production costs of fuel cells, and open the way for mass production of hydrogen-electric drives for the automotive and aerospace industries.

The project partners are e.GO Mobile AG and the Fraunhofer Institute for Production Technology IPT in Aachen, KCS Europe GmbH in Monschau, PSL Technik GmbH in Oberhausen, and The Hydrogen and Fuel Cell Center ZBT GmbH in Duisburg, along with associate partner Air s.Pace GmbH in Aachen. The project is funded by the European Regional Development Fund (ERDF) and the state of North Rhine-Westphalia (NRW).

The aim is to significantly reduce fuel cell manufacturing costs through a large-scale production chain of the required components, in particular the bipolar plates. Fraunhofer IPT engineers aim to utilise localised heating to improve the formability of the sheet metal material titanium and stainless steel (1.4404, 1.4301), preventing cracks and thinning. The number of required processing steps and tool wear should also be reduced. Titanium, for example, is a light metal that can further reduce the weight of the fuel cell, but it is brittle, and difficult to reform at room temperature. Hot forming promises a new application of titanium as a sheet material for bipolar plates.

To ensure that the thin sheet metal plates do not break during processing, the forming process and heating system design are being examined. Initial results for the process design were provided by simulation of the forming processes being investigated: rubber forming, stamping, and hydroforming. The new concept for mass production covers the entire process chain from hot forming to welding, coating, and assembly.

In addition, the FlyGo project is developing a concept for integrating a fuel cell range-extender into a battery-powered electric vehicle, utilising a vehicle from e.GO Mobile [*FCB, November 2018, p3*]. The partners are also working on a gas-cooled hydrogen fuel cell in combination with a methanol electrolyser, which would have more power per mass than conventional fuel cell systems, allowing its use in short-haul aircraft and drones.

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Bavarian hydrogen alliance founded, centre in Nuremberg

The Bavarian State Government in Germany has founded the Center for Hydrogen.Bayern (H2.B), to develop and implement the state's hydrogen strategy. The centre – to be built on the Energy Campus in Nuremberg – will bring together business, science and politics to accelerate the 'hydrogen economy', in particular hydrogen mobility, in the southeastern state.

Bavarian companies are well positioned to develop technologies and devices such as electrolysers and fuel cells to full market readiness and to produce them in high volumes for local and global use. In particular, mobility applications are of central importance for its concentration of leading vehicle manufacturers and suppliers.

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The company, a subsidiary of Michelin [*FCB, June 2014, p9*] and part of a new joint venture with Faurecia [*March 2019, p1*], has identified the tasks to be completed to achieve this goal. It will help car manufacturers reduce the development time and cost of their hydrogen vehicles across several market segments at the same time (cars, vans, commercial vehicles), despite their varying degrees of maturity. And it will encourage market growth and work to avoid automakers waiting for a hydrogen refueling station network to be in place before they produce the vehicles, while fuel distributors wait for the need to be apparent.

Symbio offers a full, standardised product range to provide manufacturers with a quick turnaround and a short time to market. Its customisable products can be adapted to customer requirements, and a uniquely flexible, cost-effective setup enables production for several carmakers at the same time. The company has proven expertise in the development of hydrogen mobility in France and across Europe, such as the Zero Emission Valley project in Auvergne-Rhône-Alpes [*see the In Brief item on page 5*] and Hydrogen Mobility Europe [*see the News Feature in October 2015, and June 2016, p1*].

The StackPack comprises a hydrogen fuel cell and key components to prolong its lifetime and optimise both compactness and integration into vehicles. Symbio designs hydrogen fuel cell kits that can be incorporated into various types of electric vehicles (e.g. utility vehicles, buses, heavy goods vehicles) [*July 2018, p3*], and associated with a range of services (e.g. remote vehicle repairs, fleet management). There are several hundred of these vehicles on the road in France and across Europe, mostly light utility vehicles (vans) such as the Renault Kangoo ZE H2 [*July 2015, p2*].

Symbio: www.symbio.one/en

Nel grant to develop advanced electrolyser pilot production line

Norwegian-based Nel Hydrogen Electrolyser has been awarded a NOK9.25 million (US$1 million) grant by Enova SF, for engineering and design improvements relating to the establishment of what would be the world's largest, automated alkaline electrolyser production line at Herøya.

Nel has been working with Enova SF, a Norwegian public enterprise to promote environmentally friendly production and consumption of energy, to optimise the development of the manufacturing plant. The grant covers the first phase in the process of establishing a full-scale pilot production line at the company's new facility in Herøya Industrial Park, about 110 km (70 miles) southwest of the capital Oslo [*FCB, September 2019, p13*]. The engineering phase for the advanced pilot production line will last until the end of 2019, and if successful will continue into an execution phase, involving construction and operation of the production line from 2020 onwards.

'Over the last year we have been looking into several aspects of our plans to expand our alkaline electrolyser manufacturing capacity, and have decided to raise the ambitions, now exploring the possibilities for an even more advanced and larger production line than first envisioned,' says Erik-Løkke Øwre, VP Operations for Nel Hydrogen Electrolyser, a subsidiary of Nel ASA. 'The grant is also a strong signal from the government recognising hydrogen as an important zero-emission energy carrier for the future.'

The company recently launched its A1000 alkaline electrolyser, a medium-scale, 2 tonne/day addition to its range of large-scale alkaline electrolyser solutions for hydrogen generation [*August 2019, p10*].

Nel Hydrogen Electrolyser: www.nelhydrogen.com

Enova SF: www.enova.no/about-enova

Nikola receives almost $500m from three strategic investors

US-based hydrogen-electric truck maker Nikola Corporation has announced several major investments through its latest fundraising activities. CNH Industrial, the lead investor in its $1 billion Series D fundraising plan, is investing $250 million, while two strategic investors from prior funding rounds – Robert Bosch GmbH and Hanwha Group – have invested a total of $230 million, with at least $100 million each.

CNH Industrial is taking a $250 million strategic stake in Phoenix, Arizona-based Nikola as the lead Series D investor. Nikola anticipates raising over $1 billion in the D round, granting approximately 25% ownership to new investors and business partners, including CNHI. Iveco and FPT Industrial [*FCB, October 2018, p4*] – the commercial vehicle and powertrain brands, respectively, of CNH Industrial – will assist in engineering and manufacturing expertise to industrialise Nikola's fuel cell and battery electric trucks. This will benefit the Nikola One NAFTA-compliant Class 8 sleeper truck, the Nikola Two NAFTA-compliant Class 8 day-cab truck, and the Nikola Tre European-compliant cab-over heavy-duty truck [*December 2018, p4*].

Nikola will contribute technologies for a European joint venture with CNH Industrial that will include fuel cell expertise, e-axles, inverters, independent suspension, onboard hydrogen storage, over-the-air software update functionality, infotainment, vehicle controls, vehicle-to-station communication protocols, power electronics, and access to a hydrogen refueling network.

Strategic near-term project milestones include the industrialisation of the Nikola Two truck for the North American market, and the integration of Iveco S-Way truck technology into the battery-electric Nikola Tre cab-over model for both the North American and European markets. In the long term, a European joint venture will cover both battery electric and fuel cell electric vehicles launched by Q4 in 2022, with Nikola planning to leverage Iveco's sales, service and warranty channels to accelerate access to the European market.

German-based **Bosch** [*see also page 15*] has been an instrumental partner for Nikola in the development of its heavy-duty vehicle fuel cell system and battery technology [*October 2017,*

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The partners say that large industrial PEM fuel cells from Proton Motor will be integrated with Schäfer Elektronik's power electronics, battery and hydrogen storage into a plug-and-play-power unit. This unit will provide in excess of 1 MW of power to supply electric vehicle charging stations, and will be available either as a stand-alone or grid-connected unit, which would also be able to support the local grid if required [*FCB, September 2019, p12*].

NEXUS-e will be headed by Hansjürgen Schäfer, CEO of Schäfer Elektronik, and Manfred Limbrunner, Sales & Marketing Director at Proton Motor. The company expects support for the battery electric car industry across Europe to rapidly increase by 2021, leading to demand for EV charging stations. To achieve a zero-carbon footprint and avoid overloading the grid, these charging stations could well be powered by hydrogen fuel cells.

Proton Motor – a wholly owned subsidiary of UK-based Proton Power Systems Plc – has more than 20 years' experience in industrial fuel cells and hybrid systems [*see the Feature in May 2015*]. The company offers complete fuel cell and hybrid systems, from development and production to implementation of customised solutions, in automotive, maritime, and stationary applications.

Proton Motor Fuel Cell GmbH: www.proton-motor.de/gb

Schäfer Elektronik GmbH: www.schaeferpower.de/?lang=en

Valmet Automotive centre to accelerate fuel cell development

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Valmet Automotive has extensive expertise in battery electric vehicle development, and for the last three years has also been focusing on fuel cells. Earlier this year the company joined the fuel cell cluster in the German federal state of Baden-Württemberg, and in April it founded the Center of Competence Fuel Cell, to bring together the development work that had been spread across several engineering teams. The centre, headed by Jochen Ludescher, currently has 25 staff.

The most promising product in the pipeline of current in-house developments is a flat-membrane humidifier. In contrast to currently used hollow fibre membrane humidifiers, Valmet Automotive says that the design of the flat membrane humidifier is much more compact but with the same performance – which opens up very flexible application possibilities. The company now wants to work with partners to bring the product to production maturity, since the automotive industry is showing great interest.

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FCEVs need to store a large quantity of hydrogen at high pressure, and this requires the development of new vessel concepts, process sequences, and material systems to meet current market requirements.

'One of the greatest challenges of future vehicle concepts will be high-pressure vessels, which will be installed in FCEVs as hydrogen tanks, and represent one of the biggest cost drivers,' explains Dr Timo Huber, Vice President R&D at the HRC Group. 'More cost-effective solutions will allow new, more competitive applications on the market for fuel cell electric vehicles. Reducing process costs in combination with new vessel concepts is of decisive importance, and this forms the basis of the partnership between HRC and Voith.'

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These new powertrains are expected to be developed by combining Hyundai's hydrogen PEM fuel cell systems with Cummins' electric powertrain, battery, and control technologies. The initial development will be focused on the North American commercial vehicle market, including working with North American OEMs on the integration of these systems into their vehicles. The companies will also explore ways they can work together to develop next-generation fuel cell systems, and have both committed to assign a team to investigate and pursue other areas of collaboration.

The partnership provides a springboard for Hyundai Motor Company to increase its presence in the North American commercial vehicle market, and Cummins to enhance its electrified power product portfolio by adding Hyundai's fuel cell technologies.

The collaboration may extend beyond the commercial vehicle market, as the companies will also evaluate the development of fuel cell power generators. The availability of reliable backup power generation to prevent data loss in emergency situations is a business-critical requirement for many organisations, and fuel cell backup power generation is attractive for its reduced carbon footprint.

Hyundai Motor opened the world's first commercial production facility for fuel cell electric vehicles in 2013 [*FCB, March 2013, p2*], and unveiled the second-generation Hyundai NEXO FCEV in early 2018 [*January 2018, p2*]. The company is also part of the Hyundai Hydrogen Mobility (HHM) joint venture in Switzerland, which is working to accelerate a Swiss 'green' hydrogen ecosystem [*see page 9*].

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Plug Power partners with Engie, expands hydrogen supply chain with United Hydrogen

US-based Plug Power has signed a global agreement with French multinational electric utility Engie to accelerate the adoption of hydrogen and fuel cell systems in end-uses such as distribution centres, manufacturing facilities, and logistic equipment and vehicles for ports and airports in more than 50 countries. Plug Power is also expanding its hydrogen supply chain partner network with United Hydrogen Group, signing a three-year reserved product supply agreement that will augment Plug Power's hydrogen supplier network.

Plug Power and **Engie** will identify mutually beneficial markets and customers, and package Plug Power's PEM fuel cell technology with Engie's hydrogen infrastructure, renewable energy, and service programmes to deliver fully integrated, cost-effective hydrogen energy solutions [*see the Feature on Plug Power in FCB, December 2011, and page 13 in this issue*]. The partnership will allow global customers to easily implement hydrogen technology for forklifts in their operations and throughout their logistic chains, especially in distribution centres, ports, and airports.

Plug Power has also signed a new three-year reserved product **hydrogen supply agreement with United Hydrogen**, which will allow Plug Power to maintain competitive pricing for its current customer base, and provide for future growth. United Hydrogen will supplement Plug Power's hydrogen delivery operation with a dedicated supply of liquid hydrogen, facilitating a diversified supply chain and bolstering Plug Power's ability to seamlessly meet customer demand while increasing the amount of 'green' hydrogen supplied to its network.

United Hydrogen provides liquid hydrogen to industrial customers throughout the US, and supplies the developing fuel cell electric vehicle market in California. The company also delivers gaseous hydrogen to customers throughout the US Southeast and Midwest.

Plug Power: www.plugpower.com

Engie: www.engie.com/en

United Hydrogen Group: www.unitedhydrogen.com

PowerCell wins stack follow-on orders from automotive firms, Bosch unveils system

PowerCell Sweden has received a follow-on order for S3 fuel cell stacks from a global automotive OEM for additional testing, and a follow-on order for S2 stacks from a Chinese supplier to the automotive industry. And Robert Bosch GmbH unveiled a fuel cell system built around the PowerCell S3 stack at the recent IAA 2019 Frankfurt Motor Show in Germany.

The **global automotive OEM** has previously ordered PowerCell S3 stacks, and MS-100 fuel cell systems, for testing and evaluation [*FCB, June 2018, p11*]. The unnamed company now wants to expand its fuel cell testing, and has ordered additional S3 stacks. The order value is approximately SEK2.6 million (US$270 000), with delivery expected during Q4. The S3 is the most powerful PowerCell stack, combining compact design with low weight and high power density, and was specifically developed for automotive applications [*February 2016, p10*].

PowerCell has also received a follow-on order for S2 stacks from a **Chinese automotive industry supplier**. The SEK1.3 million ($135 000) order will be delivered during Q3. The unidentified customer develops and market products for the Chinese automotive industry, and supplies both the commercial vehicle and passenger car sectors. The stacks will be integrated into fuel cell systems for use in vehicles by one of the supplier's customers.

Meanwhile, **Bosch presented a fuel cell system** built around the PowerCell S3 stack at IAA 2019. The companies signed a joint development and licensing agreement in April regarding the S3 stack for the automotive segment, giving Bosch an exclusive, global right to produce and sell the S3 in fuel cell systems for automotive applications [*May 2019, p13*]. The agreement includes joint development of the PowerCell S3 stack prior to Bosch's own production of the stack, commencing by 2022. Bosch [*see also page 12*] paid PowerCell €50 million ($55.6 million) during Q2 for the exclusive licence; when production begins, Bosch will pay PowerCell a royalty fee for every product sold during the contract period.

PowerCell Sweden: www.powercell.se

Robert Bosch GmbH: www.bosch.com

IN BRIEF

Bloom SOFCs for Fordham in NYC, upgrade for Ramar Foods in California

California-based Bloom Energy (www.bloomenergy.com) has announced an Energy Server installation for the William D. Walsh Family Library at **Fordham University** (www.fordham.edu) in New York City. The 250 kW solid oxide fuel cell installation will generate clean electricity onsite and provide power directly to the five-storey library.

And in the summer **Ramar Foods** (www.ramarfoods.com) in Pittsburg, California took delivery of a new 200 kW Energy Server to provide primary power to one of its manufacturing plants. Ramar Foods – a leading Filipino food supplier in the San Francisco Bay Area – began operation of its original 200 kW Bloom system in 2013 [*FCB, December 2013, p6, and see page 5 in this issue*].

True Zero opens latest station in Oakland

The latest addition to the network of hydrogen refueling stations in California (https://cafcp.org/stationmap) has opened in Oakland. The True Zero (www.truezero.com) station, developed by First Element (www.firstelementfuel.com), is the 11th retail hydrogen station in the San Francisco Bay Area, with another one being upgraded and 10 more in development.

The station – at 350 Grand Avenue – will be supplied by liquid hydrogen, and have a capacity of more than 800 kg. This is the first of True Zero's larger capacity, liquid hydrogen stations, with more than triple the capacity of its existing retail stations [*FCB, December 2018, p11*].

DOE 2019 merit review, peer evaluation

The US Department of Energy's Hydrogen and Fuel Cells Program has released its 2019 Annual Merit Review and Peer Evaluation Report: www.hydrogen.energy.gov/annual_review19_report.html

The report summarises the comments of expert peer reviewers on presentations at the 2019 Annual Merit Review and Peer Evaluation Meeting (AMR), held 29 April–1 May in Crystal City, Virginia. The 2019 AMR Proceedings, with the presentations from the plenary and technical sessions, are also available: www.hydrogen.energy.gov/annual_review19_proceedings.html

The 2019 AMR Awards, recognising outstanding achievements and significant contributions to the programme, were announced at the time [*FCB, May 2019, p15*].

The Office of Fossil Energy's Solid Oxide Fuel Cell Program presentations and posters are available on the National Energy Technology Laboratory website: www.netl.doe.gov/events/conference-proceedings

The 2020 Annual Merit Review and Peer Evaluation Meeting is scheduled for 19–21 May 2020 [*see the Events Calendar on page 20*].

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Plug Power and **Engie** will identify mutually beneficial markets and customers, and package Plug Power's PEM fuel cell technology with Engie's hydrogen infrastructure, renewable energy, and service programmes to deliver fully integrated, cost-effective hydrogen energy solutions [*see the Feature on Plug Power in FCB, December 2011, and page 13 in this issue*]. The partnership will allow global customers to easily implement hydrogen technology for forklifts in their operations and throughout their logistic chains, especially in distribution centres, ports, and airports.

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Hyundai Motor Company: http://worldwide.hyundai.com

Cummins Inc: www.cummins.com/always-on

Plug Power partners with Engie, expands hydrogen supply chain with United Hydrogen

US-based Plug Power has signed a global agreement with French multinational electric utility Engie to accelerate the adoption of hydrogen and fuel cell systems in end-uses such as distribution centres, manufacturing facilities, and logistic equipment and vehicles for ports and airports in more than 50 countries. Plug Power is also expanding its hydrogen supply chain partner network with United Hydrogen Group, signing a three-year reserved product supply agreement that will augment Plug Power's hydrogen supplier network.

Plug Power and **Engie** will identify mutually beneficial markets and customers, and package Plug Power's PEM fuel cell technology with Engie's hydrogen infrastructure, renewable energy, and service programmes to deliver fully integrated, cost-effective hydrogen energy solutions [*see the Feature on Plug Power in FCB, December 2011, and page 13 in this issue*]. The partnership will allow global customers to easily implement hydrogen technology for forklifts in their operations and throughout their logistic chains, especially in distribution centres, ports, and airports.

Plug Power has also signed a new three-year reserved product **hydrogen supply agreement with United Hydrogen**, which will allow Plug Power to maintain competitive pricing for its current customer base, and provide for future growth. United Hydrogen will supplement Plug Power's hydrogen delivery operation with a dedicated supply of liquid hydrogen, facilitating a diversified supply chain and bolstering Plug Power's ability to seamlessly meet customer demand while increasing the amount of 'green' hydrogen supplied to its network.

United Hydrogen provides liquid hydrogen to industrial customers throughout the US, and supplies the developing fuel cell electric vehicle market in California. The company also delivers gaseous hydrogen to customers throughout the US Southeast and Midwest.

Plug Power: www.plugpower.com

Engie: www.engie.com/en

United Hydrogen Group: www.unitedhydrogen.com

PowerCell wins stack follow-on orders from automotive firms, Bosch unveils system

PowerCell Sweden has received a follow-on order for S3 fuel cell stacks from a global automotive OEM for additional testing, and a follow-on order for S2 stacks from a Chinese supplier to the automotive industry. And Robert Bosch GmbH unveiled a fuel cell system built around the PowerCell S3 stack at the recent IAA 2019 Frankfurt Motor Show in Germany.

The **global automotive OEM** has previously ordered PowerCell S3 stacks, and MS-100 fuel cell systems, for testing and evaluation [*FCB, June 2018, p11*]. The unnamed company now wants to expand its fuel cell testing, and has ordered additional S3 stacks. The order value is approximately SEK2.6 million (US$270 000), with delivery expected during Q4. The S3 is the most powerful PowerCell stack, combining compact design with low weight and high power density, and was specifically developed for automotive applications [*February 2016, p10*].

PowerCell has also received a follow-on order for S2 stacks from a **Chinese automotive industry supplier**. The SEK1.3 million ($135 000) order will be delivered during Q3. The unidentified customer develops and market products for the Chinese automotive industry, and supplies both the commercial vehicle and passenger car sectors. The stacks will be integrated into fuel cell systems for use in vehicles by one of the supplier's customers.

Meanwhile, **Bosch presented a fuel cell system** built around the PowerCell S3 stack at IAA 2019. The companies signed a joint development and licensing agreement in April regarding the S3 stack for the automotive segment, giving Bosch an exclusive, global right to produce and sell the S3 in fuel cell systems for automotive applications [*May 2019, p13*]. The agreement includes joint development of the PowerCell S3 stack prior to Bosch's own production of the stack, commencing by 2022. Bosch [*see also page 12*] paid PowerCell €50 million ($55.6 million) during Q2 for the exclusive licence; when production begins, Bosch will pay PowerCell a royalty fee for every product sold during the contract period.

PowerCell Sweden: www.powercell.se

Robert Bosch GmbH: www.bosch.com

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buses to be commissioned in France. Serving the 'Versailles Grand Parc' communities, they meet the region's energy transition objectives that aim for an entirely clean Île-de-France Mobilités bus fleet running in densely populated areas by 2025, and across the entire region by 2029.

The buses are co-funded by the 3Emotion project of the Fuel Cells and Hydrogen Joint Undertaking (FCH JU), which is deploying 21 new fuel cell buses and extending the use of eight existing buses along with the required refueling infrastructure in Versailles and Pau in France, London (UK), Rotterdam (Netherlands), and Aalborg (Denmark) [*FCB, February 2015, p1*].

They refuel at Air Liquide's Loges-en-Josas station [*April 2018, p7*], which can fully refuel a bus in just 20 minutes. The bus can hold 39 kg of hydrogen, giving it a range of 300 km (185 miles). All the drivers have received training on the specifics of using a hydrogen station.

The hydrogen for the Loges-en-Josas station is produced by Air Liquide [*see also page 8*] at its Port-Jérôme-sur-Seine site in Normandy, under the CertifHy Guarantee of Origin platform [*May 2018, p10*]. This facility uses the Cryocap™ carbon capture technology, which captures up to 90% of the CO_2 emitted during steam methane reforming (SMR) to produce hydrogen; the CO_2 is then liquefied and purified to be utilised in various applications.

Van Hool, Fuel Cell Buses:
https://tinyurl.com/vanhool-fuelcell

Air Liquide, Hydrogen Energy:
http://tinyurl.com/hydrogen-energy-airliquide

3Emotion project: www.3emotion.eu

Hamburg to test M-B articulated bus with fuel cell range-extender

Hamburger Hochbahn, the public transport company in the northern German city-state of Hamburg, has agreed to field-test the next-generation Mercedes-Benz eCitaro G articulated bus featuring a fuel cell range-extender, with two buses scheduled for delivery during 2021.

The all-electric battery eCitaro was unveiled in late 2018, with Mercedes-Benz delivering to Hamburger Hochbahn the first of an order of 20 of these new buses. In 2020 a next-generation battery will bring a significant increase in capacity and range. Then the eCitaro G articulated bus will be rolled out, followed by the eCitaro G with a fuel cell range-extender.

'We anticipate a number of advantages to arise from the new development of the fuel cell bus based on the purely electric vehicle, especially when it comes to covering greater ranges,' says Henrik Falk, Chair of the Board of Hamburger Hochbahn, who signed the Letter of Intent with Till Oberwörder, Head of Daimler Buses.

The Mercedes-Benz eCitaro city bus features modular battery packs with a total capacity up to 292 kWh, giving it a system-relevant range of around 170 km (105 miles) under all weather conditions. With a fuel cell range-extender, the eCitaro is anticipated to achieve a system-relevant range of up to 400 km (250 miles), depending on the vehicle configuration and equipment.

Hamburger Hochbahn first deployed Daimler/Mercedes-Benz Citaro fuel cell electric buses in 2003 [*FCB, November 2003, p2*], and in 2011 took delivery of a fleet of Citaro FuelCELL Hybrid buses [*August 2011, p1*]. Hamburg has also trialed Solaris Urbino articulated buses with fuel cell range-extenders [*January 2015, p2, and see also the next item*].

Hamburger Hochbahn:
www.hochbahn.de/hochbahn/hamburg/en

Mercedes-Benz eCitaro:
www.daimler.com/innovation/case/electric/ecitaro-2.html

Solaris Urbino 12 hydrogen bus being trialed across Europe

The Solaris Urbino 12 hydrogen fuel cell bus has been tested by transit operators in Austria, Italy, Germany and Poland over the past few weeks, following its première in June at the UITP Global Public Transport Summit 2019 in Stockholm, Sweden.

This new vehicle from Polish bus builder Solaris Bus & Coach has attracted huge interest among potential customers, as evidenced by the demand for bus tests in several European cities. In August, the bus was showcased in the Austrian cities of Graz and Klagenfurt, and then in the Italian city of Bolzano. In the following weeks, the vehicle went on to be tested in Germany, by public transport operators in Frankfurt, Cologne and Wuppertal. The bus was then presented to the municipal operator Miejskie Przedsiębiorstwo Komunikacyjne in Poznań, close to the Solaris headquarters.

Immediately after the vehicle's unveiling during the UITP Summit in June, representatives of Solaris and Régie Autonome des Transports Parisiens (RATP) signed a contract to lease and

EDITORIAL

Buses are again a key topic in this issue, in particular in Europe but also in China, California, and for the first time in New Zealand.

In Germany, **Freudenberg Sealing Technologies and FlixBus** are collaborating in a project to deploy fuel cell powered buses for long-distance transit, and are looking to bring in a bus manufacturer to equip a fleet of 30 buses with a hybrid fuel cell-battery powertrain [*page 2*].

The **first fuel cell passenger bus route in France** has been commissioned, running between Versailles and Jouy-en-Josas to the west of Paris [*page 2*]. Two Van Hool buses are being refueled at the Air Liquide hydrogen station in Les Loges-en-Josas.

Hamburger Hochbahn in Hamburg will field-test the next-generation Mercedes-Benz eCitaro G articulated bus featuring a fuel cell range-extender, with two buses scheduled for delivery in 2021 [*page 3*].

Polish bus builder **Solaris Bus & Coach** has been trialing its new Solaris Urbino 12 hydrogen fuel cell bus with transit operators in Austria, Italy, Germany, and Poland [*page 3*]. The company has already contracted to lease the bus to RATP in Paris for trials next year, and has sold 12 buses to SASA in Bolzano, Italy.

Belgian bus builder **Van Hool** has unveiled its Exqui.City 18 Fuel Cell articulated bus, which will first be deployed in the French city of Pau [*page 4*]. This 'Fébus' initiative will be the world's first full Bus Rapid Transit system with 18 m articulated tram-buses.

UK-based **Ceres Power and Weichai Power** in China have developed a first prototype solid oxide fuel cell range-extender for Chinese electric buses, for demonstration in a city bus utilising CNG [*page 4*].

Meanwhile, **New Zealand** bus builder Global Bus Ventures will build a fuel cell bus for use in the Ports of Auckland hydrogen production and refueling system trial [*page 4*]. This will be the first NZ-built hydrogen fuel cell vehicle, and is expected to start trials next September.

In the US, the **California Fuel Cell Partnership** has released its second bus road map, calling for 11 essential actions and setting new industry targets needed to widely adopt fuel cell buses in the state [*page 10*].

And Northern Ireland bus builder **Wrightbus**, which collapsed into administration in September, has been acquired by Bamford Bus Company, owned by industrialist Jo Bamford, who also runs Ryse Hydrogen [*In Brief item on page 5*]. Ryse and Wrightbus are members of the H2Bus consortium, which plans to deploy 1000 fuel cell buses across Europe.

Steve Barrett

range from –10°C to 40°C, they are ideal for European warehouses. The operating temperature can widen to –30°C with the use of an additional cold pack, a perfect solution for cold storage locations.

Intelligent Energy: www.intelligent-energy.com

FES Fahrzeug Entwicklung Sachsen GmbH: www.fes-aes.de/home-en

US military demos fuel cell tow tractor to tow refueling aircraft

The Hawaii Air National Guard demonstrated the use of a fuel cell powered tow tractor to tow a Boeing KC-135 Stratotanker aerial refueling aircraft in mid-July, at Joint Base Pearl Harbor-Hickam.

A U-30 aircraft tow tractor retrofitted with hydrogen fuel cells was used to tow the 84 tonne aircraft on the flightline of Joint Base Pearl Harbor-Hickam and demonstrate the efficacy of the technology. According to the Hawaii Center for Advanced Transportation Technologies (HCATT), this is the first time that hydrogen fuel cell technology has been used to tow a large US Air Force aircraft. The demonstration was made possible through a collaborative effort by a consortium of public and private entities. The demonstration involved towing the Stratotanker from its normal parking area to a wash rack some 400 m away, to conduct its periodic corrosion prevention maintenance.

'We're very pleased about this first demonstration. We've worked with US Hybrid, TUG Technologies, and the Air Force Research Laboratory on this vehicle for three years, and have garnered a lot of technical knowledge along the way,' says retired Col. Dave Molinaro, HCATT project manager. The tug will be put through its paces for another two to three years while HCATT continues to collect data in an operational environment.

Working closely with the vehicle's original manufacturer, US Hybrid modified the diesel-based drive train with a 30 kW PEM fuel cell, two 5 kg hydrogen storage tanks, a 28 kWh Li-ion battery configuration, and a 240 kW AC induction motor linked to the transmission. Hydrogen for the U-30 tow tractor is produced using HCATT's electrolyser at Joint Base Pearl Harbor-Hickam.

Hawaii Center for Advanced Transportation Technologies: www.htdc.org/hcatt

US Hybrid Corporation: www.ushybrid.com

Bloom and Samsung Heavy Industries plan SOFCs for ship power

US-based Bloom Energy is collaborating with South Korean shipbuilding giant Samsung Heavy Industries (SHI) to design and develop ships powered by Bloom Energy's solid oxide fuel cell technology, as part of a global move in the sector to significantly reduce greenhouse gas (GHG) emissions from marine transport.

SHI – part of the Samsung Group – aims to be the first shipbuilder to deliver a large cargo ship for ocean operation powered by fuel cells running on natural gas. This innovation would play a key role in helping the company beat the 50% emissions reduction target, compared to 2008 levels, that the International Maritime Organization (IMO) has mandated that all shipbuilders should achieve by 2050. Replacing combustion-based power generation from bunker oil with electrochemical conversion of liquefied natural gas (LNG) using fuel cells could have a profound impact on carbon emissions from marine transportation. Bloom Energy and SHI estimate that replacing oil-based power generation on large cargo ships, which each require up to 100 MW of power, could reduce annual GHG emissions from shipping by 45%.

The two companies have already taken an important first step towards commercialising the maritime use of fuel cells for propulsion and auxiliary power. At a ceremony in the SHI Geoje shipyard, Samsung Heavy announced that it has received Approval in Principle from DNV GL, the internationally accredited marine shipping registrar and classification society, in collaboration with Bloom Energy to proceed with a fuel cell-powered ship design for Aframax crude oil tankers (COTs).

Bloom Energy Servers operate on natural gas, biogas, or hydrogen [*FCB, July 2019, p5, and see the In Brief item on page 15 in this issue]*. Bloom and SHI envision onboard fuel cells being powered by natural gas, converted from LNG, which is already commonly transported by marine shipping worldwide. The system's modularity makes it well suited to the space constraints in ships, allowing deployment in increments down to 200 kW, and distributed throughout the vessel to optimise space utilisation. SHI sees Bloom Energy Servers displacing existing power generation sets, requiring no additional space

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Ryse and Wrightbus are members of the H2Bus consortium, which plans to deploy 1000 fuel cell buses across Europe [*FCB, July 2019, p2*]. In the summer Wrightbus won a contract to supply 20 fuel cell buses to Transport for London [*June 2019, p2*], which will be the world's first hydrogen powered double decker buses when they are introduced next spring. The company also received an order from Aberdeen in Scotland, as part of the Joint Initiative for hydrogen Vehicles in Europe (JIVE) [*July 2019, p1*].

In 2015 Jo Bamford acquired a strategic shareholding in UK electrolyser manufacturer ITM Power, through his company JCB Research [*April 2015, p12*], making it ITM's largest shareholder [*see also page 1*].

Hyundai unveils generator at IAA 2019

Hyundai Motor Company [*see also page 9*] launched the Hyundai Generator, a portable fast-charging station for electric vehicles, at the recent IAA 2019 Frankfurt Motor Show. The Hyundai Generator consists of two fuel cell stacks – as used in the Hyundai NEXO fuel cell electric vehicle – allowing simultaneous charging for two EVs. Hyundai will provide the Hyundai Generator as a recharging system for all the cars in the 2020 Electric Touring Car Racing (ETCR) championship.

First station opens in Clermont-Ferrand

The first hydrogen refueling station has been inaugurated in the central French city/metropole of Clermont-Ferrand, as part of the Zero Emission Valley (ZEV) project (https://trimis.ec.europa.eu/project/zero-emission-valley), which aims to make the Auvergne-Rhône-Alpes region the leading European hydrogen region by 2023. The Clermont-Ferrand facility is the second station in Auvergne-Rhône-Alpes, which plans to open 20 stations, utilising 15 onsite electrolysers to produce hydrogen, and deploy a fleet of 1000 fuel cell electric vehicles.

Auvergne-Rhône-Alpes has committed to hydrogen alongside Michelin [*see the Symbio item on page 12*] and Engie [*see page 15*]. Behind this commitment is the joint venture Hympulsion, which combines public partners with industry partners including Michelin, Engie, and Crédit Agricole [*FCB, June 2019, p12*]. Hympulsion is responsible for deploying and installing the electrolysers and the hydrogen refueling stations.

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Robert Bosch GmbH: www.bosch.com

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Research Trends

Securing PGMs for the transport low-carbon transition
H. Hao et al.: *One Earth* **1**(1) (20 September 2019) 117–125.
https://doi.org/10.1016/j.oneear.2019.08.012

Electrochemical oxidation of phenyl group causes permanent performance loss in AEMFCs
S. Maurya et al.: *J. Power Sources* **436** (1 October 2019) 226866.
https://doi.org/10.1016/j.jpowsour.2019.226866

Effect of carbon-covering layer on catalyst layer in PEMFC under low relative humidity
S. Jang et al.: *J. Power Sources* **436** (1 October 2019) 226823.
https://doi.org/10.1016/j.jpowsour.2019.226823

Raising maximum power density of nanoporous catalyst film-based PEMFCs by laser micro-machining of GDL
J. Iglesia et al.: *J. Power Sources* **436** (1 October 2019) 226886.
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In situ NAP-XPS reveals surface composition of operating NBC oxide SOFC cathodes
B. Bozzini et al.: *J. Power Sources* **436** (1 October 2019) 226815.
https://doi.org/10.1016/j.jpowsour.2019.226815

Nano-fibrous SCY-Ni anode functional layer for proton-conducting SOFCs
K.-R. Lee et al.: *J. Power Sources* **436** (1 October 2019) 226863.
https://doi.org/10.1016/j.jpowsour.2019.226863

Porous membranes based on poly(ionic liquid) with quaternary ammonium and tertiary amine head groups for AEMFCs
F. Xie et al.: *Solid State Ionics* **338** (1 October 2019) 58–65.
https://doi.org/10.1016/j.ssi.2019.04.028

Composite membranes based on sulfonated PSF and PPSF via controlled atom-transfer radical polymerisation, for PEMFCs
L. Yu et al.: *Solid State Ionics* **338** (1 October 2019) 103–112.
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Chitosan/sulfonated graphene oxide/silica nanocomposite membranes for DMFCs
M. Ranjani et al.: *Solid State Ionics* **338** (1 October 2019) 153–160.
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Coupled stress–strain and transport in PEMFC with metallic bipolar plates
H. Zhang et al.: *Applied Energy* **251** (1 October 2019) 113316.
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Integrated direct hybridisation of PEMFC and supercapacitor by materials design
T. Kadyk: *Electrochimica Acta* **319** (1 October 2019) 323–330.
https://doi.org/10.1016/j.electacta.2019.06.172

Electrochemical impedance spectroscopy of LSCF nanofibre cathodes for IT-SOFCs
P. Costamagna et al.: *Electrochimica Acta* **319** (1 October 2019) 657–671.
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Gold nanoparticles and fullerene-C_{60} nanocomposite film at glassy carbon electrode as electrocatalyst for methanol oxidation in DMFCs
K.S. Bhavani et al.: *Int. J. Hydrogen Energy* **44**(47) (4 October 2019) 25863–25873
https://doi.org/10.1016/j.ijhydene.2019.08.005

LiI and KI with low melting temperature for electrolyte replenishment in MCFCs
J.K. Bae et al.: *Int. J. Hydrogen Energy* **44**(47) (4 October 2019) 25930–25938
https://doi.org/10.1016/j.ijhydene.2019.08.050

Spatial and temporal optimisation of hydrogen fuel supply chain for light-duty passenger vehicles in British Columbia
H. Talebian et al.: *Int. J. Hydrogen Energy* **44**(47) (4 October 2019) 25939–25956.
https://doi.org/10.1016/j.ijhydene.2019.07.218

ORR mechanism of PBSCF@LN core-shell structure SOFC cathode
J. Li et al.: *Int. J. Hydrogen Energy* **44**(48) (8 October 2019) 26489–26497.
https://doi.org/10.1016/j.ijhydene.2019.08.064

Fast startup system for microfluidic DMFCs
J. Massing et al.: *Int. J. Hydrogen Energy* **44**(48) (8 October 2019) 26517–26529.
https://doi.org/10.1016/j.ijhydene.2019.08.107

High-performance anode for solid acid fuel cells prepared by mixing carbon with anode catalysts
S. Tada et al.: *Int. J. Hydrogen Energy* **44**(48) (8 October 2019) 26545–26553.
https://doi.org/10.1016/j.ijhydene.2019.08.100

Perovskite oxide SFCN as cathode for room-temperature direct ammonia fuel cell
P. Zou et al.: *Int. J. Hydrogen Energy* **44**(48) (8 October 2019) 26554–26564 [Open Access].
https://doi.org/10.1016/j.ijhydene.2019.08.097

Poly(arylene ether)s-based anion-exchange membranes bearing pendant N-spirocyclic quaternary ammonium for AEMFCs
C. Lin et al.: *Int. J. Hydrogen Energy* **44**(48) (8 October 2019) 26565–26576.
https://doi.org/10.1016/j.ijhydene.2019.08.092

Heat release rate and thermal fume behaviour estimation of FCEVs in tunnel fires
M. Seike et al.: *Int. J. Hydrogen Energy* **44**(48) (8 October 2019) 26597–26608.
https://doi.org/10.1016/j.ijhydene.2019.08.099

High performance of Pd and PdAg nanoparticles with well defined facets in direct ethylene glycol microfluidic fuel cells
A. López–Coronel et al.: *Electrochimica Acta* **320** (10 October 2019) 134622.
https://doi.org/10.1016/j.electacta.2019.134622

High-durability PEMFC cathodes obtained from cobalt MOFs
A.K. Díaz-Duran et al.: *Electrochimica Acta* **320** (10 October 2019) 134623.
https://doi.org/10.1016/j.electacta.2019.134623

Distribution of relaxation times analysis and interfacial effects of LSCF fired at different temperatures, in SOFCs

G. DiGiuseppe et al.: *Int. J. Hydrogen Energy* **44**(49) (11 October 2019) 27067–27078.
https://doi.org/10.1016/j.ijhydene.2019.08.160

Direct ethylene glycol fuel cell stack as air-independent power sources for underwater and outer space applications

Z. Pan et al.: *J. Power Sources* **437** (15 October 2019) 226944.
https://doi.org/10.1016/j.jpowsour.2019.226944

Commercial PGM-free cathode electrocatalysts for high-performance DMFC applications

C. Lo Vecchio et al.: *J. Power Sources* **437** (15 October 2019) 226948.
https://doi.org/10.1016/j.jpowsour.2019.226948

Planar-distributed wettability of MPL in PEMFC to improve cold-start performance

G. Wang et al.: *J. Power Sources* **437** (15 October 2019) 226930.
https://doi.org/10.1016/j.jpowsour.2019.226930

Design guidelines for manufacturing of electrode-electrolyte interface in SOFCs

C.-C. Chueh et al.: *J. Power Sources* **437** (15 October 2019) 226888.
https://doi.org/10.1016/j.jpowsour.2019.226888

Ex situ experiment benchmarking of SOFC metal interconnects

M. Bianco et al.: *J. Power Sources* **437** (15 October 2019) 226900 [Open Access].
https://doi.org/10.1016/j.jpowsour.2019.226900

Durability of metal-supported SOFCs with infiltrated electrodes

E. Dogdibegovic et al.: *J. Power Sources* **437** (15 October 2019) 226935.
https://doi.org/10.1016/j.jpowsour.2019.226935

Lanthanum gallate based SOFCs with LCNF cathodes and SNMM anode

A.R. Gilev et al.: *Solid State Ionics* **339** (15 October 2019) 115001.
https://doi.org/10.1016/j.ssi.2019.115001

Perovskite-type oxides for proton-conducting SOFCs

K. Singh et al.: *Solid State Ionics* **339** (15 October 2019) 114951.
https://doi.org/10.1016/j.ssi.2019.04.014

Experimental performance of metal-foam flow-fields in PEMFC

Y. Awin et al.: *Applied Energy* **252** (15 October 2019) 113458.
https://doi.org/10.1016/j.apenergy.2019.113458

Review of advances in PEMFCs in dead-end anode operation

J.C. Kurnia et al.: *Applied Energy* **252** (15 October 2019) 113416.
https://doi.org/10.1016/j.apenergy.2019.113416

Cost competitiveness of electrolytic hydrogen

O.J. Guerra et al.: *Joule* **3**(10) (16 October 2019) 2425–2443.
https://doi.org/10.1016/j.joule.2019.07.006

Efficient direct ammonia fuel cell for affordable carbon-neutral transportation

Y. Zhao et al.: *Joule* **3**(10) (16 October 2019) 2472–2484.
https://doi.org/10.1016/j.joule.2019.07.005

Nanocomposite membrane electrolyte of PABS-SWCNT with sPEEK for DMFC

A. Shukla et al.: *Int. J. Hydrogen Energy* **44**(50) (18 October 2019) 27564–27574.
https://doi.org/10.1016/j.ijhydene.2019.08.189

Mn-rich SBCM double perovskite cathode material for SOFCs

A. Olszewska et al.: *Int. J. Hydrogen Energy* **44**(50) (18 October 2019) 27587–27599.
https://doi.org/10.1016/j.ijhydene.2019.08.254

Sulfur diffusion of H_2S contaminants to cathode in micro-tubular SOFC

D.-W. Choi et al.: *Electrochimica Acta* **321** (20 October 2019) 134713.
https://doi.org/10.1016/j.electacta.2019.134713

Highly stable MEA using ether-linkage-free SBF-based aromatic PEMs for direct formate solid alkaline fuel cells

H. Kuroki et al.: *J. Power Sources* **438** (31 October 2019) 226997.
https://doi.org/10.1016/j.jpowsour.2019.226997

Silica decorated carbon/Pt catalyst synthesis via single-step polyol method for superior PEMFC performance, durability and stack operation under low RH

P. Dhanasekaran et al.: *J. Power Sources* **438** (31 October 2019) 226999.
https://doi.org/10.1016/j.jpowsour.2019.226999

Anion-exchange membranes with 'rigid-side-chain' symmetric piperazinium structures for AEMFC with high power density

L. Gao et al.: *J. Power Sources* **438** (31 October 2019) 227021.
https://doi.org/10.1016/j.jpowsour.2019.227021

Performance enhancement of HT-PEMFCs using Pt pulse electrodeposition

D.-K. Kim et al.: *J. Power Sources* **438** (31 October 2019) 227022.
https://doi.org/10.1016/j.jpowsour.2019.227022

Functionality of $Ca_3Co_4O_{9+\delta}$ oxygen electrode for rSOCs based on proton-conducting electrolytes

E. Pikalova et al.: *J. Power Sources* **438** (31 October 2019) 226996.
https://doi.org/10.1016/j.jpowsour.2019.226996

Interface and grain boundary degradation in LSM-YSZ composite SOFC cathodes operated in humidified air

Y. Chen et al.: *J. Power Sources* **438** (31 October 2019) 227043.
https://doi.org/10.1016/j.jpowsour.2019.227043

Surface degradation of Sr-based perovskite electrodes for SOFCs

N.K. Patel et al.: *J. Power Sources* **438** (31 October 2019) 227040.
https://doi.org/10.1016/j.jpowsour.2019.227040

Review on sintering technology of proton-conducting $BaCeO_3$-$BaZrO_3$ perovskite oxide materials for protonic ceramic fuel cells

F.J.A. Loureiro et al.: *J. Power Sources* **438** (31 October 2019) 226991.
https://doi.org/10.1016/j.jpowsour.2019.226991

Patents

SOFC in which holes in interconnect are blocked with sealant to prevent gas leakage, use in stack, module and system

Assignee: **Kyocera Corporation, Japan**
Inventors: Y. Hori et al.
Patent number: US 10367220
Published: 30 July 2019 (Filed: 10 Mar. 2017)

Automotive PEMFC stack with alternating recesses and reinforcing ribs in contact surface of resin fluid manifold, reduces thickness, weight

Assignee: **Honda Motor Co, Japan**
Inventors: M. Takahashi et al.
Patent number: US 10367223
Published: 30 July 2019 (Filed: 1 Nov. 2016)

Hydrogen fuel cell powered electric multirotor VTOL aircraft for personal air transportation and manned or unmanned operation

Assignee: **Alakai Technologies Corporation, USA [Alaka'i]**
Inventor: B.D. Morrison
Patent number: US 10370088
Published: 6 Aug. 2019 (Filed: 25 Aug. 2017)
[*see the Alaka'i item in FCB, June 2019, p6*]

Poly(phenylene)-based anion-exchange polymers, for AEMFCs

Assignees: **National Technology & Engineering Solutions of Sandia LLC, USA [Sandia National Labs]** *and* **Triad National Security LLC, USA [Los Alamos National Lab]**
Inventors: Y.S. Kim et al.
Patent number: US 10370483
Published: 6 Aug. 2019 (Filed: 18 July 2018)

PEMFC bipolar plate with optimised hydraulic cross-section to reduce pressure loss of reactants, homogeneous pressure distribution

Assignee: **Audi, Germany**
Inventors: B. Andreas-Schott et al. [Volkswagen]
Patent number: US 10374237
Published: 6 Aug. 2019 (Filed: 2 Apr. 2015)

Automotive PEMFC stack which suppresses pressure loss in pipes, to allow smooth fluid flow

Assignee: **Honda Motor Co, Japan**
Inventor: K. Sasamoto
Patent number: US 10374238
Published: 6 Aug. 2019 (Filed: 8 June 2017)

Power generator with fuel cell and membrane conduits, for recharging handheld mobile devices from chemical hydride storage

Assignee: **Honeywell International, USA**
Inventor: S.J. Eickhoff
Patent number: US 10374240
Published: 6 Aug. 2019 (Filed: 22 Feb. 2017)

Automotive SOFC system in which first fuel cell in series suppresses reaction of methane in reformed fuel for cells in subsequent stages

Assignee: **Nissan Motor Co, Japan**
Inventors: T. Yaguchi et al.
Patent number: US 10374241
Published: 6 Aug. 2019 (Filed: 8 July 2015)

Automotive SOFC system with vaporiser unit to inject liquid diesel into recirculated anode exhaust gas, which is vaporised for supply to reformer

Assignee: **AVL List GmbH, Austria**
Inventors: J. Rechberger et al.
Patent number: US 10374242
Published: 6 Aug. 2019 (Filed: 4 Feb. 2014)

Porous current collector for SOFC, with high-performance fuel gas reforming and durability

Assignee: **Sumitomo Electric Industries Ltd, Japan**
Inventors: T. Higashino et al.
Patent number: US 10374243
Published: 6 Aug. 2019 (Filed: 23 Feb. 2015)

Fluorine-based nanocomposite membrane comprising polyhedral oligomeric silsesquioxanes with proton donor and acceptor, for PEM or DMFC

Assignee: **Sogang University, Korea**
Inventors: H. Rhee et al.
Patent number: US 10374244
Published: 6 Aug. 2019 (Filed: 15 Mar. 2016)

Method and apparatus for manufacturing reinforced PEMs

Assignee: **Toyota Motor Corporation, Japan**
Inventors: H. Kitoh et al.
Patent number: US 10374245
Published: 6 Aug. 2019 (Filed: 15 May 2014)

Ion-exchange membrane comprises crosslinked sulfonated triblock copolymer and CNT, for use in redox flow battery, PEM or DMFC

Assignee: **Hyundai Electric & Energy Systems Co Ltd, Korea**
Inventors: J.H. Kong et al.
Patent number: US 10374246
Published: 6 Aug. 2019 (Filed: 25 Nov. 2014)

Porous support comprising web of nanofibres for excellent air and water permeability, use in reinforced membrane for PEMFC

Assignee: **Kolon Fashion Material Inc, Korea**
Inventors: H.R. Oh et al.
Patent number: US 10374247
Published: 6 Aug. 2019 (Filed: 24 Feb. 2015)

Ionic and electronic conducting binder comprising single- or multi-sulfonic acid polymer and EDOT analogue monomer, for PEMFCs

Assignee: **Nissan North America, USA**
Inventor: R. Yadav
Patent number: US 10377849
Published: 13 Aug. 2019 (Filed: 13 Nov. 2017)

PEMFC electrodes including phospholipid with soluble oxygen to improve oxygen transport to active catalyst material, preparation

Assignee: **Nissan North America, USA**
Inventors: C. Gumeci et al.
Patent number: US 10381652
Published: 13 Aug. 2019 (Filed: 7 Mar. 2017)

PEMFC electrode mudcrack mitigation at low Pt loading

Assignee: **General Motors, USA**
Inventors: R.J. Koestner et al.
Patent number: US 10381653
Published: 13 Aug. 2019 (Filed: 2 Mar. 2017)

Preparing electrodes with targeted oxygen transport, GDL configured to concentrate gas distribution to detected active catalyst particles

Assignee: **Nissan North America, USA**
Inventor: T. Joshi

Patent number: US 10381654
Published: 13 Aug. 2019 (Filed: 3 Feb. 2017)

Fabrication of highly controlled barrier coatings on SOFC cathode powders, to reduce migration of cations to sintered cathode surface

Assignee: **Sonata Scientific LLC, USA**
Inventors: J.F. Roeder et al.
Patent number: US 10381655
Published: 13 Aug. 2019 (Filed: 13 July 2016)

Nanocomposite electrode material for proton-conducting SAFC

Assignee: **University of Tennessee, USA**
Inventors: A.B. Papandrew et al.
Patent number: US 10381656
Published: 13 Aug. 2019 (Filed: 19 Nov. 2015)

PEMFC bipolar plate with fibre reinforcement containing thermo-plastically bonded carbon fibres

Assignee: **Rochling Automotive, Germany**
Inventors: F. Chini et al.
Patent number: US 10381657
Published: 13 Aug. 2019 (Filed: 12 Feb. 2016)

Improved manufacturing method to minimise force required to efficiently assemble PEMFC stacks

Assignee: **Plug Power, USA**
Inventors: C.R. Elder et al.
Patent number: US 10381658
Published: 13 Aug. 2019 (Filed: 22 Dec. 2016)

PEMFC with increased reactant flow through porous ribs, improves oxygen diffusion into catalyst layer and reduces resistance overvoltage to increase cell voltage

Assignee: **Nissan Motor Co, Japan**
Inventor: K. Yoshizawa
Patent number: US 10381659
Published: 13 Aug. 2019 (Filed: 17 Nov. 2011)

PEMFC separator that restrains warping and distortion, in which recess in wall of protrusion forms trap in gas passage

Assignee: **Toyota Boshoku KK, Japan**
Inventor: K. Hirata
Patent number: US 10381660
Published: 13 Aug. 2019 (Filed: 13 Feb. 2015)

PEMFC MEA with resin frame, to prevent stress concentration in PEM due to cracks in electrode catalyst layer, suppress deformation

Assignee: **Honda Motor Co, Japan**
Inventors: S. Ohmori et al.
Patent number: US 10381661
Published: 13 Aug. 2019 (Filed: 12 July 2016)

PEMFC separator, manufacturing method to reduce burrs generated in die-casting rubber moulded body

Assignees: **Toyota Motor Corporation, Japan** *and* **Sumitomo Riko Co Ltd, Japan**
Inventors: H. Kadono et al.
Patent number: US 10381662
Published: 13 Aug. 2019 (Filed: 6 Nov. 2015)

Hollow fibre membrane cartridge-type humidification module with greater capacity and efficiency for use with PEMFC, reduced manufacturing time and cost

Assignee: **Kolon Industries, Korea**
Inventors: K.K. Kim et al.
Patent number: US 10381663
Published: 13 Aug. 2019 (Filed: 17 Dec. 2015)

PEMFC water transport plate with select cooling capacity distribution

Assignee: **Audi, Germany**
Inventors: S.S. Bhadange et al.
[UTC Power, USA]
Patent number: US 10381664
Published: 13 Aug. 2019 (Filed: 30 Aug. 2012)

Device and method to heat SOFC stack, in system with separated stacks to avoid heat transfer, and individually heated outlet manifolds

Assignee: **SK Innovation Co Ltd, Korea**
Inventors: Y.D. Kim et al.
Patent number: US 10381665
Published: 13 Aug. 2019 (Filed: 14 June 2017)

Automotive PEMFC system with control device that can use result of abnormality determination of pressure sensor for startup

Assignee: **Toyota Motor Corporation, Japan**
Inventors: Y. Ohkuwa et al.
Patent number: US 10381666
Published: 13 Aug. 2019 (Filed: 18 Dec. 2017)

Control of automotive PEMFC system operation, based on present and startup temperatures

Assignee: **Toyota Motor Corporation, Japan**
Inventors: Y. Naganuma et al.
Patent number: US 10381668
Published: 13 Aug. 2019 (Filed: 22 Oct. 2015)

Steam reformer for in-block SOFC reforming, method to control volumetric ratio of reformate and unreformed hydrocarbon fuel

Assignee: **LG Fuel Cell Systems Inc, USA**
Inventors: G.D. Agnew et al.
[Rolls-Royce Fuel Cell Systems Ltd, UK]
Patent number: US 10381669
Published: 13 Aug. 2019 (Filed: 13 July 2016)

Method for removing pentavalent antimony contaminants in water, using fuel cell utilising self-generated electrical energy

Assignee: **PowerChina Huadong Engineering Corporation Ltd, China**
Inventors: G. Zhou et al.
Patent number: US 10381671
Published: 13 Aug. 2019 (Filed: 13 June 2017)

Reinforced composite PEM, with porous support of 3D irregular and discontinuous polymer nanofibres, for improved impregnation of ionic conductors

Assignee: **Kolon Industries, Korea**
Inventors: M.S. Lee et al.
Patent number: US 10381672
Published: 13 Aug. 2019 (Filed: 27 Dec. 2013)

EVENTS CALENDAR

3–8 November 2019
15th International Conference on Electrified Interfaces, ICEI 2019
Valdivia, Chile
More information: www.deq.cl/icei2019

5–6 November 2019
5. HYPOS-Forum, Annual Meeting of the HYPOS Consortium [in German]
Dresden, Germany
More information: www.hypos-eastgermany.de/nc/blog/events/5-hypos-forum-save-the-date

5–7 November 2019
2019 Fuel Cell Seminar & Energy Exposition
Long Beach, California, USA
More information: www.fuelcellseminar.com

19–21 November 2019
Fuel Cells and Hydrogen Joint Undertaking: Programme Review Days [19–20 November], and Stakeholder Forum [21 November]
Brussels, Belgium
More information: www.fch.europa.eu

19–21 November 2019
Motorship Propulsion & Future Fuels Conference 2019
Hamburg, Germany
More information:
www.propulsionconference.com

26–27 November 2019
FC^3 Fuel Cell Conference Chemnitz [in German]
Fraunhofer IWU, Chemnitz, Germany
More information:
www.hzwo.eu/veranstaltungen/fc3

27 November 2019
Final Conference of the High V.LO-City project: Towards Zero Emission Public Transport with Fuel Cell Buses
Groningen, The Netherlands
More information: www.fuelcellbuses.eu/public-transport-hydrogen/high-vlo-city-final-conference

9–11 December 2019
8th European Fuel Cell Technology & Applications Piero Lunghi Conference, EFC19
Naples, Italy
More information: www.europeanfuelcell.it

12–13 December 2019
2nd International Symposium on Hydrogen Energy and Energy Technologies, HEET 2019
Osaka, Japan
More information: http://heet-18.org

2020

28–30 January 2020
SAE Hybrid and Electric Vehicle Technologies Symposium
Pasadena, California, USA
More information: www.sae.org/attend/hybrid

12–14 February 2020
2nd Congress of the Italian Chemical Society, Interdivisional Group on Chemistry for Renewable Energy, EnerCHEM 2
Padua, Italy
More information:
https://enerchem-2.icmate.cnr.it
Abstract deadline: 27 November 2019

25 February 2020
8th International Fuel Cell Meeting, Fuel Cell Development Information Center (FCDIC) [before FC EXPO]
Tokyo, Japan
More information: www.fcdic.com/infometion

26–28 February 2020
FC EXPO 2020, 16th International Hydrogen & Fuel Cell Expo, within World Smart Energy Week 2020
Tokyo, Japan
More information: www.fcexpo.jp/en-gb.html

1–4 March 2020
The International Coalition for Energy Storage and Innovation Conference, ICESI 2020
Sydney, Australia
More information: www.icesi2020.com
Abstract deadline: 1 December 2019

10–12 March 2020
14th International Renewable Energy Storage Conference (IRES 2020), with Energy Storage Europe International Trade Fair
Düsseldorf, Germany
More information: www.eseexpo.com
www.energystorageconference.org

17 March 2020
16th UK Hydrogen and Fuel Cell Conference: Hydrogen & Fuel Cells – Coming of Age, CCSHFC2020
NEC, Birmingham, UK
More information:
www.climate-change-solutions.co.uk/events

25–26 March 2020
Hydrogen & Fuel Cells for Heavy Duty Transport Conference [site visit to E-Trucks Europe on 24 March]
Brussels, Belgium
More information: www.h2-transport.com

29 March–2 April 2020
2020 AIChE Spring Meeting, including Topical Conferences on Emerging Technologies in Clean Energy, and Hydrogen Safety
Houston, Texas, USA
More information: www.aiche.org/spring
Abstract deadline: 22 November 2019

1–2 April 2020
f-cell + HFC Vancouver 2020, The Hydrogen and Fuel Cell Event
Vancouver, BC, Canada
More information: www.hyfcell.com

20–24 April 2020
Hydrogen+Fuel Cells Europe 2020, within Hannover Messe 2020
Hannover, Germany
More information: www.h2fc-fair.com

21–23 April 2020
SAE 2020 WCX
Detroit, Michigan, USA
More information:
www.sae.org/attend/wcx

3–6 May 2020
HYPOTHESIS XV Cape Town 2020 South Africa, HYdrogen POwer THeoretical & Engineering Solutions International Symposium
Cape Town, South Africa
More information: www.hypothesis.ws
Abstract deadline: 31 October 2019

10–13 May 2020
5th Green and Sustainable Chemistry Conference
Bonn, Germany
More information: www.elsevier.com/events/conferences/green-and-sustainable-chemistry-conference
Abstract deadline: 4 December 2019

10–15 May 2020
237th ECS Meeting, The Electrochemical Society
Montreal, Canada
More information: www.electrochem.org/237
Abstract deadline: 15 November 2019

13–14 May 2020
All-Energy Exhibition & Conference 2020
Glasgow, Scotland, UK
More information: www.all-energy.co.uk

19–21 May 2020
US DOE Hydrogen and Fuel Cells Program 2020 Annual Merit Review and Peer Evaluation Meeting
Crystal City, Virginia, USA
More information:
www.annualmeritreview.energy.gov

21–22 May 2020
27th Fuel Cell Symposium, Fuel Cell Development Information Center (FCDIC)
Tokyo, Japan
More information: www.fcdic.com/infometion
Abstract deadline: 31 October 2019

14–17 June 2020
EVS33, 33rd World Electric Vehicle Symposium & Exposition
Portland, Oregon, USA
More information: https://evs33portland.org

14–18 June 2020
12th European Symposium on Electrochemical Engineering, Electrochemistry for Electrification and Energy Transition Toward a Sustainable Future
Leeuwarden, The Netherlands
More information:
www.electrochemical-engineering.eu/2020
Abstract deadline: 15 January 2020

30 June–3 July 2020
14th European SOFC & SOE Forum, EFCF 2020, Featuring Solid Oxide Technologies: Fuel Cells, Electrolysers & Membrane Reactors, CO_2 Emission Reduction & Reuse
Lucerne, Switzerland
More information: www.efcf.com
Abstract deadline: 30 November 2019