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Rolls-Royce pilot project on stationary fuel cell systems supported by Mercedes-Benz's Lab1886

Rolls-Royce and Lab1886, the innovation lab within Mercedes-Benz, have taken the first step in cooperation on the use of automotive PEM fuel cells for stationary power generation. The partners aim to develop a holistic concept for future sustainable and independent, emergency power supply in the coming months.

A pilot project has been agreed between Lab1886 and the business unit Rolls-Royce Power Systems AG, which produces solutions under the MTU brand name. Rolls-Royce will develop an integrated MTU solution for sustainable off-grid generation of continuous and emergency power using automotive fuel cells, focused on safety-critical applications such as data centres. The project is already in development; construction of the pilot plant is planned to begin in early 2020, for an emergency power plant at Rolls-Royce's data centre in Friedrichshafen, in southern Germany.

Data centres are among the biggest energy consumers, but fuel cells are now a feasible proposition for carbon-neutral generation of emergency and continuous power to keep data centres running [*e.g. FCB, August 2017, p1 and October 2017, p1*]. Few energy technologies offer the same level of reliability and modular scalability, yet include the benefits of renewable energy. Synergies can also be exploited for cooling, since the outlet temperature of the computer system coolant corresponds to the inlet temperature of the fuel cell coolant.

MTU generator sets from Rolls-Royce are already in service at many data centres worldwide, providing emergency power to safeguard global internet traffic. Thus far, these generator sets have been diesel-engine based, but fuel cells could be a valid alternative.

The pilot plant will be based on PEM fuel cell modules built by Mercedes-Benz Fuel Cell GmbH, which in 2012 opened the world's first automated facility dedicated to automotive fuel cell stack production, in Canada [*July 2012, p7*]. Mercedes-Benz has substantial expertise through its work on many generations of hydrogen fuel cell electric vehicles, including through NuCellSys [*February 2019, p12*], while Rolls-Royce has long-standing experience in fuel cell systems using other technologies, in particular solid oxide fuel cells.

Rolls-Royce is also researching the manufacture of hydrogen and other synthetic fuels using renewable energy sources – including for use in fuel cells. 'Used in this combination, fuel cells promise to make an even bigger contribution to the energy turnaround,' says Dr Martin Teigeler, Executive VP of R&D for Rolls-Royce Power Systems. 'We're confident that Mercedes-Benz fuel cell modules have the potential to open up new application possibilities in stationary power generation as well.'

Two years ago Lab1886 and Mercedes-Benz Fuel Cell extended their development portfolio to include stationary fuel cell systems, in cooperation with Mercedes-Benz Research and Development North America [*see the News Focus in December 2017*]. Together with Hewlett Packard Enterprise, Power Innovations, and the National Renewable Energy Laboratory (NREL) in the US, the company is testing automotive fuel cells in stationary energy supply systems for emergency power supply in computer centres, reinforcing the potential of hydrogen and fuel cells within the framework of a future sustainable overall energy system.

Rolls-Royce Power Systems' product portfolio includes MTU-brand engines and propulsion systems, as well as diesel and gas systems and battery containers for mission-critical, standby and continuous power, combined heat and power generation, and microgrids. The company traded as Tognum between 2006 and 2014 [*June 2011, p1 and May 2012, p1*], and before that the core company – MTU Friedrichshafen GmbH – was a constituent of DaimlerChrysler Powersystems Off-Highway.

Rolls-Royce Power Systems: www.rrpowersystems.com
Lab1886: www.lab1886.com

Contents

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Hyundai NEXO:
www.hyundai.com/worldwide/en/eco/nexo

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to retailer utilising zero-emission fleet technology, in its hometown of St Louis, Missouri.

A Nikola hydrogen-electric truck picked up the load of beer, and delivered it to Anheuser-Busch's local wholesaler partner, Lohr Distributors – the first commercial delivery onboard a Nikola hydrogen-electric vehicle. Lohr then delivered the beer to the Enterprise Center, home of the St Louis Blues ice hockey team, on a BYD battery electric truck. In this way the beer reached its destination with zero transportation emissions.

The delivery builds on Anheuser-Busch's ongoing commitment to sustainability and existing partnerships with Nikola and BYD. Last year, Anheuser-Busch placed an order for up to 800 hydrogen-electric semi-trailer trucks from Nikola [*FCB, May 2018, p4*], as the brewer moves to transition its entire long-haul fleet to zero-emission vehicles.

'As the first commercial delivery of freight with our hydrogen-electric truck, this is an exciting time for both Nikola and Anheuser-Busch,' says Trevor Milton, CEO of Nikola. 'We are now preparing production vehicles for Anheuser-Busch, and plan on delivering the trucks as fast as possible.'

Arizona-based Nikola designs and manufactures hydrogen-electric vehicles, electric vehicle drivetrains, vehicle components, energy storage systems, and hydrogen refueling stations. The company unveiled its Nikola One™ semi-trailer truck, powered by lithium batteries recharged by a 200 kW hydrogen fuel cell, in late 2016 [*January 2017, p13*], and last autumn announced the Nikola Tre hydrogen-electric truck specifically for the European market [*December 2018, p4*]. Nikola currently has more than 14 000 Class 8 fuel cell heavy trucks on order, which will be manufactured in Coolidge, Arizona [*April 2019, p14*]; testing will begin on Arizona roads this year, with full production expected in late 2022.

Nikola Motor Company: www.nikolamotor.com

Anheuser-Busch: www.anheuser-busch.com

BYD Motors: www.byd.com

Horizon to deliver 370 kW PEMFC stacks for heavy-duty vehicles

Singapore-based Horizon Fuel Cell Technologies is installing volume production of its 150 kW PEM fuel cell stacks (generation VL-II) for heavy-duty trucks, and has released specifications for its next-generation (VL-III) high-power automotive fuel cells. These will produce 370 kW (500 hp), with power density exceeding 5 kW/L and 5 kW/kg, comfortably providing enough power to displace most large diesel engines.

Volume production of Horizon VL-II fuel cells for buses and medium- to heavy-duty trucks commenced earlier this year, serving customers around the world [*FCB, August 2019, p10*]. Horizon has a number of heavy truck platforms running on these fuel cells, up to 42 tonnes gross vehicle weight. Horizon says that even though its 150 kW (200 hp) module is the highest power automotive fuel cell being supplied today, heavy vehicle applications would benefit from even higher power fuel cells for optimal vehicle performance, reliability, and efficiency [*September 2019, p11*].

Horizon is now accepting orders for the 300 kW fuel cell powertrains, and expects to start shipping VL-III stacks and VLS-III complete powertrains from mid-2020. The first customers are expected to deploy the systems in long-haul heavy trucking applications, based on confidential discussions under way with Horizon. Long-haul heavy trucks are a particularly attractive application for hydrogen powered transport, but this has been difficult to validate given a shortage of suitable fuel cells to meet the market need. Horizon expects significant early interest from logistics operators and major retailers who are seeking to reduce their carbon footprint.

Horizon supplies a full range of fuel cell systems, from low-power air-cooled fuel cells to high-power automotive systems, as well as containerised stationary power plants [*May 2018, p7*]. Earlier this year it unveiled ultrathin bipolar plates that deliver high power density and offer significant cost reduction, in particular targeting automotive PEMFC stacks [*June 2019, p13*].

Horizon Fuel Cell Technologies: www.horizonfuelcell.com

MOBILE APPLICATIONS

Toyota, Fenix demo fuel cell electric utility tractor rig in California

Toyota Motor North America unveiled its first hydrogen fuel cell powered electric utility tractor rig (UTR), developed in collaboration with Fenix Marine Services, at the recent 2019 Fuel Cell Seminar & Energy Exposition in Long Beach, California.

EDITORIAL

Record-breaking is popular with many people and organisations around the world – there's something very appealing about doing better than anyone has ever done before. And it provides excellent publicity.

For example, Hyundai Motor Company's fuel cell electric vehicles have been involved in setting numerous records. In this issue we report on Swiss balloonist Bertrand Piccard driving 778 km (483.4 miles) in a Hyundai NEXO fuel cell SUV, claimed as breaking the world record for the **longest distance driven in a hydrogen powered vehicle on a single fueling** [*see page 2*]. Amazingly, the vehicle's display indicated up to 49 km (30 miles) of remaining range.

Last month we reported on another NEXO car setting what is believed to be a new **land speed record for the hydrogen fuel cell category** [*November 2019, p3*]. Hyundai engineering teams from the Hyundai America Technical Center, Hyundai Motor America, and the Korean parent company collaborated to achieve 106.160 mph (170.848 km/h) at the Bonneville Salt Flats in Utah.

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Specially designed fuel cell powered vehicles have also set records, such as students at Duke University in North Carolina last year setting a world record for **fuel efficiency in a hydrogen fuel cell car**, achieving the equivalent of 14 573 miles per gallon (6195 km per litre of gasoline equivalent) [*September 2018, p5*]. The car used less than 1g of pure hydrogen in travelling 8.5 miles (13.7 km) on a track.

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Horizon to deliver 370 kW PEMFC stacks for heavy-duty vehicles

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Volume production of Horizon VL-II fuel cells for buses and medium- to heavy-duty trucks commenced earlier this year, serving customers around the world [*FCB, August 2019, p10*]. Horizon has a number of heavy truck platforms running on these fuel cells, up to 42 tonnes gross vehicle weight. Horizon says that even though its 150 kW (200 hp) module is the highest power automotive fuel cell being supplied today, heavy vehicle applications would benefit from even higher power fuel cells for optimal vehicle performance, reliability, and efficiency [*September 2019, p11*].

Horizon is now accepting orders for the 300 kW fuel cell powertrains, and expects to start shipping VL-III stacks and VLS-III complete powertrains from mid-2020. The first customers are expected to deploy the systems in long-haul heavy trucking applications, based on confidential discussions under way with Horizon. Long-haul heavy trucks are a particularly attractive application for hydrogen powered transport, but this has been difficult to validate given a shortage of suitable fuel cells to meet the market need. Horizon expects significant early interest from logistics operators and major retailers who are seeking to reduce their carbon footprint.

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PowerCell Sweden: www.powercell.se

Havyard Group: www.havyard.com

Havila Kystruten: www.havilakystruten.no [in Norwegian]

H3 Dynamics delivers first hydrogen powered UAS for US Navy

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The UTR prototype, known as 'Uno', was imagined and developed by Toyota engineers, and deployed at the Fenix terminal in the Port of Los Angeles as a test of how zero-emissions container handling equipment could operate in a real-world, marine terminal environment. The Uno made its first productive moves around the Fenix container terminal in October, ahead of its formal unveiling to a crowd of officials, operators, industry experts, and supply chain innovators.

The Uno is powered by the same fuel cell module as in the Toyota *Mirai* passenger cars and Project Portal electric semi-trailer truck prototypes. The first Uno test cycle at Fenix ran for 2.5 h per trial on the rail, and consumed one fill of its two hydrogen tanks. Additional tanks can be added for the desired range and can be filled in around 3 minutes, allowing it to get back on the road quickly.

'We view the hydrogen fuel cell electric UTR Uno as an expansion of our Project Portal hydrogen fuel cell electric Class 8 heavy-duty truck development,' says Andrew Lund, Chief Engineer for Product Development at Toyota Motor North America Research and Development.

The Project Portal 'Alpha' truck began operation in April 2017, in real-world, zero-emissions drayage operations in and around the Ports of Long Beach and Los Angeles [*FCB, April 2017, p1 and November 2017, p3*], with the next-stage 'Project Portal 2.0' launched the following year [*July 2018, p1*].

'This deployment is hopefully the first of many zero- and near-zero emissions platforms throughout the facility,' comments Scott Schoenfeld, General Manager of Fenix's terminal development group. In the coming months Fenix will look at testing a Hydrogen Electric Hybrid Top Pick vehicle to assist with cargo movement through the terminal.

Toyota Motor Sales USA, *Mirai*: https://ssl.toyota.com/mirai

Fenix Marine Services: www.fenixmarineservices.com

Nedstack fuel cells for Ulstein SX190 offshore construction vessel

Nedstack fuel cell technology BV and Ulstein Design & Solutions BV in the Netherlands have collaborated on the development of the Ulstein SX190 Zero Emission DP2 construction support vessel. Ulstein's first hydrogen powered offshore vessel, which can serve a wide range of offshore support operations, features a PEM fuel cell system from Nedstack.

Ulstein says that its first hydrogen powered ship design, utilising Nedstack fuel cell power systems to offer zero-emission marine operations, is now market-ready. Sea trials of a new-build Ulstein SX190 Zero Emission vessel could begin as soon as 2022.

Using existing technology, the SX190 design is already capable of operating for four days in zero-emission mode. However, given ongoing rapid developments in fuel cells and hydrogen storage technologies, Ulstein is targeting a future zero-emission endurance of up to two weeks. For extended missions and capabilities, the vessel can fall back on its conventional diesel-electric system using low-sulfur marine diesel oil.

The Ulstein SX190 Zero Emission design is based on its existing SX190 vessel platform, and has a total installed power of 7.5 MW, of which 2 MW is generated by a fuel cell power system, typically Nedstack PEM fuel cells, which are located in a separate engine room. The 99 m (325 ft) long vessel has a maximum speed of 11 knots (20 km/h), and features 2 × 1280 kW propulsion thrusters and 2 × 750 kW tunnel thrusters.

Nedstack's PEM fuel cell systems have already been built and proven in the multi-MW power range [*see the Nedstack feature in FCB, August 2014, and the News Feature in November 2016*], and have now been marinised to meet the requirements of the maritime sector, including class requirements and supply chains. The company recently collaborated with OSD-IMT to develop a concept design for a 65 tonne bollard pull harbour tug powered by fuel cells [*June 2019, p6*], and has partnered with GE Power Conversion to develop fuel cell systems for powering cruise vessels, designing a concept 2 MW fuel cell power plant for an expedition vessel [*April 2019, p6*]. Nedstack is also participating in the FELMAR consortium in the Netherlands, which is developing fuel cell systems for zero-emission inland-sea and coastal vessels [*August 2018, p7*].

Nedstack: www.nedstack.com

Ulstein: www.ulstein.com

PowerCell, Havyard to develop maritime zero-emission solution

PowerCell Sweden has signed a contract with Norwegian ship technology company Havyard Group, to develop the design and technical specifications for a zero-emissions fuel cell system. The system will be installed onboard a vessel that will serve on shipping company Havila Kystruten's new long-distance route from Bergen to Kirkenes.

The one-year contract covers development of the design and technical specifications for a zero-emissions system fully classifiable and in conformity with International Maritime Organization (IMO) safety requirements. The system solution that PowerCell and Havyard will jointly design will be based on several marinised 200 kW fuel cell system modules, connected in parallel for a total power output of 3.2 MW.

Havila Kystruten's vessels will operate in Norwegian waters, where increasingly strict emissions regulations are being introduced. The company has been contracted to build four new ships that will be equipped with zero-emission solutions; the first ship will enter service in 2021.

'Fuel cells provide an optimal solution for this type of maritime applications, and is perfect for use in combination with battery solutions,' says Per Wassén, CEO of PowerCell. 'These vessels have the space available for storage of hydrogen, and can easily be refueled during one of their many stops. When entering the fjords, they can operate fully electric for a long time.'

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fuel cell powered rotary-wing UAS – from Singapore-based H3 Dynamics.

The Hycopter is manufactured by H3 Dynamics at its facility in Austin, Texas, whose team conducted the acceptance training and flight demonstration in Monterey. This particular UAS will be used to support a Naval Research Program project to study the feasibility of using compressed hydrogen as a power source onboard naval platforms. The Hycopter could also be used to support future research projects that require long-endurance aerial data collection. Hydrogen fuel cell technology offers a step change in UAS productivity, and widens the scope of applications that are currently limited by battery-based technologies.

The six-rotor Hycopter has a blade tip-to-tip diameter of 7 ft (2.1 m), a takeoff weight of about 35 lb (16 kg) with a 5 lb (2.3 kg) payload, and a flight duration of about 2.5 h. The all-electric platform is powered by an ultralight PEM fuel cell fed with compressed hydrogen gas. HES Energy Systems – the energy storage technology subsidiary of H3 Dynamics – says that the Hycopter's ultra-energy-efficient design and open-payload bay can fly many types of sensor packages for much longer than a conventional battery powered drone, making it ideal for use in large-scale industrial maintenance inspections.

HES unveiled the Hycopter unmanned aerial vehicle (UAV) in 2015 [*FCB, June 2015, p4*], with the commercial launch of the upgraded version a year ago [*December 2018, p5*]. The company recently partnered with EPH Engineering in Brazil to launch a turnkey dam inspection solution that combines artificial intelligence (AI)-enabled damage assessment and Hycopter hydrogen fuel cell drones capable of flying for 3.5 h [*September 2019, p1*].

H3 Dynamics: www.h3dynamics.com

HES Energy Systems: www.hes.sg

SMALL STATIONARY

SFC deal for German radio tower sites, telecom partnership for North America

SFC Energy in Germany has received a framework contract from cooperation partner adKor to deliver hydrogen fuel cells for emergency backup power for radio tower sites in several federal states. And its Canadian subsidiary Simark Controls has signed a partnership agreement with Axsera in Montreal, to commercialise EFOY Pro direct methanol fuel cell solutions for telecom applications across North America.

The **framework contract with adKor GmbH** runs to the end of 2021, and has a total order volume of €1.8–5.3 million (US$2–5.9 million), depending on installation and commissioning by the federal states. This is the first hydrogen fuel cell order for SFC Energy, a year after SFC and adKor signed a partnership agreement to jointly develop a new generation of powerful hydrogen fuel cell systems [*FCB, December 2018, p13*].

adKor and its system partners have already won tenders for emergency backup power equipment at more than 400 radio tower sites with hydrogen fuel cells in different federal states. For these radio tower site projects SFC will deliver the hydrogen fuel cell modules to adKor as a subcontractor.

At critical radio tower sites, operators have to ensure a minimum of 72 h power autonomy for their radio systems at any time, to safeguard radio communications for critical users during power blackouts. Earlier this year the Jupiter hydrogen fuel cell-based power solution developed by SFC Energy and adKor was extensively tested at the DLR German Aerospace Center, and technically accepted and qualified for outdoor use in telecom and BOS (public authorities and organisations with security tasks) digital radio systems [*May 2019, p1*].

Meanwhile in Canada, **Simark Controls has signed a partnership agreement with Axsera** – a provider of technical services, telecoms and remote power solutions, with an extensive industry network – for the commercialisation of EFOY Pro DMFC solutions for telecom applications across North America. Axsera will sell EFOY Pro solutions to provide highly reliable, fully autonomous power to critical off-grid telecom equipment in Canada and the US.

EFOY Pro solutions are used to ensure reliable operation of remote devices in any season and weather. In the context of the partnership agreement, Simark will integrate the robust EFOY Pro fuel cells into a wide variety of turnkey autonomous, fully automatic, and highly reliable EFOY Pro solutions for Axsera customers.

SFC Energy is a leading provider of direct methanol and hydrogen fuel cells for stationary and mobile hybrid power solutions, with more than 40 000 fuel cells sold worldwide [*see the SFC feature in January 2013*].

SFC Energy: www.sfc.com/en or www.efoy-pro.com

adKor GmbH: www.adkor.de/en

Simark Controls Ltd: www.simarkcontrols.com

Axsera Inc: www.axsera.com

IN BRIEF

Doosan FC, Hyundai Motor to develop hydrogen fuel cell distributed generation

In South Korea, Doosan Fuel Cell has signed a contract with Hyundai Motor Company [*see also page 2, and the Hyundai item below*] and Ulsan Techno Park to develop hydrogen fuel cell distributed power generation systems for micro grids. Doosan FC will manufacture phosphoric acid fuel cells and Hyundai Motor will manufacture PEM fuel cells, while Ulsan Techno Park will provide a demonstration site and supply hydrogen.

Doosan Fuel Cell was split off from Doosan Corporation on 1 October [*see also the Centrica–Doosan item on page 6, and the Doosan Mobility Innovation item below*], and launched as a separate company to enhance management efficiency and expertise in line with anticipated growth in the hydrogen fuel cell business.

Hyundai unveils fast police fuel cell bus

Hyundai Motor Company has unveiled a high-speed, hydrogen electric bus that will be deployed for police transportation in South Korea. The bus is based on the company's standard police bus, with an integrated fuel cell power system comprising two 95 kW stacks from the NEXO car [*see also page 2*] and a commercial hydrogen tank, mounted on the roof to secure sufficient cargo capacity for carrying police equipment. The bus can accommodate 29 people, including drivers, and is strengthened with a low body floor to suit domestic road conditions and high-speed driving.

Hyundai aims to provide two buses to the National Police Agency by the end of the year, and start mass production by 2021. The government plans to replace 800 police buses with hydrogen electric buses by 2028.

Doosan Mobility Innovation demos fuel cell drones in sea crossing, river patrol

South Korean company Doosan Mobility Innovation (www.doosanmobility.com) collaborated with Skyfire Consulting (www.skyfireconsulting.com), the US Department of Health and others for a 43 mile (69 km) open ocean drone crossing between the Caribbean islands of Saint Croix and Saint Thomas, in the US Virgin Islands. The Doosan DS30 fuel cell powered unmanned aerial vehicle (UAV) completed the flight in 1 h 43 min, and still had nearly 30 minutes' worth of hydrogen left in its tank.

DMI has also tested a fuel cell powered drone with Korea Water Resources Corporation in the Nakdong River Basin. The drone was flown for 20 km (12 miles), showcasing its capabilities for missions such as regional water resource management, emergency evacuation warning broadcasts, and transmission tower inspections.

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Ceres Power launches hydrogen-ready SOFC system at FC Seminar

UK-based Ceres Power has announced the successful development of its first zero-emission combined heat and power (CHP) system, designed exclusively for use with hydrogen. The first prototype system, featuring the company's low-cost, intermediate-temperature solid oxide fuel cell technology, was unveiled at the recent 2019 Fuel Cell Seminar & Energy Exposition in Long Beach, California.

The new system has been developed as part of Ceres' continuing product roadmap, with significant interest from customers seeking greater innovation to tackle climate change and air pollution. In initial testing, the hydrogen CHP system has achieved greater than 50% electrical efficiency, with an overall efficiency of 90% achievable in CHP mode. Ceres' hydrogen CHP is simpler than its existing fuel-flexible system, delivering an equivalent performance with fewer components, reduced size, and cost reduction of up to 40% against an existing Ceres system running on natural gas. The technology provides a zero emissions, highly efficient distributed power system that can be deployed in homes and businesses.

'Ceres' new hydrogen CHP technology runs on both green hydrogen and more widely available low-purity hydrogen from industrial sources,' says Dr Subhasish Mukerjee, Director of Fuel Cell and Stack Development at Ceres Power.

Ceres has already successfully developed and licensed its fuel-flexible IT-SOFC power systems to leading original equipment manufacturers (OEMs) including Bosch in Germany [*FCB, September 2018, p11*], Weichai Power in China [*October 2019, p4*], Miura in Japan [*July 2019, p4*], and Doosan in South Korea [*August 2019, p6*]. The current fuel-flexible system operates on any fuel, including natural gas with any ratio of hydrogen, making it an ideal technology to support the introduction of greater amounts of biogas and hydrogen as a path to decarbonising the existing gas grid infrastructure.

Ceres Power: www.cerespower.com

Fraunhofer IMM develops CHP system with reformer/fuel cell

The Fraunhofer Institute for Microengineering and Microsystems IMM in Mainz, Germany has developed a prototype reformer/fuel cell-based combined heat and power (CHP) system that produces 50 kW of electrical power. The prototype CHP system has been put into trial operation at the Fraunhofer IMM site.

CHP plants are typically comparatively compact, essentially comprising a motor, generator, and heat-exchanger. In Germany, tens of thousands of these combustion-based systems are currently in use, mainly running on natural gas or wood pellets/chips, and operating in a power range well below 50 kW.

Fraunhofer IMM scientists are now using a fuel cell in combination with a reformer, which achieves a highly dynamic system, allowing many start-stop cycles. The use of exclusively catalytic processes completely eliminates the pollutant emissions that come from internal combustion engines. However, this development is currently being driven mainly in Japan, and Japanese core components dominate the solutions available on the German market.

In the current phase of the Fraunhofer IMM system development, regular natural gas is supplied from the pipeline network, reformed into hydrogen in normal operation, and converted into electricity using the fuel cell. The electric power output of the system is up to 50 kW, plus up to 70 kW thermal output. An overall efficiency above 90% can be achieved by utilising the 'waste' heat generated by the fuel cell for hot water and heating. This can be taken a step further, achieving CO_2 neutrality by connecting to a biogas plant, where the CO_2 produced would be captured during biomass production.

The development was largely financed by the Ministry of Science, Further Education and Culture of the western federal state of Rhineland-Palatinate.

Last year PowerCell Sweden [*see also pages 4 and 13*] delivered two S2 PEM fuel cell stacks to Fraunhofer IMM, for use in CHP in a new extension building where hydrogen reformer technology is being developed [*FCB, October 2018, p7*].

Fraunhofer IMM: www.imm.fraunhofer.de/en.html

LARGE STATIONARY

Toshiba wins order for H2Rex hydrogen fuel cell unit at sports park

In Japan, Toshiba Energy Systems & Solutions (Toshiba ESS) has been awarded an order from Fukushima Prefecture, to install an H2Rex™ pure hydrogen fuel cell system at the Azuma Sports Park in Fukushima City.

The system will use hydrogen produced in the Fukushima Hydrogen Energy Research Field (FH2R), a hydrogen production project equipped with some of the world's largest hydrogen production equipment and using renewable energy, which is under construction in Namie Town [*FCB, September 2018, p9*]. Operation is scheduled to start in April 2020.

The system for Azuma Sports Park is rated at 100 kW output power, the largest system in the product range, and will be integrated by the locally based Toshiba ESS subsidiary Kitashiba Electric Co Ltd. It will be installed next to the gymnasium in the park, and provide part of the building's power supply, for lighting and air-conditioning, and the heat from power generation will be used for hot water supply.

The 100 kW system for Azuma Sports Park has been optimised to reduce weight by 30% and volume by 40% compared to the previous model, while maintaining its efficiency and longevity – its power generation efficiency is at least 50% (LHV). In addition, the system has a modular design that can increase (or reduce) the installed capacity in 100 kW units, and can be flexibly expanded to MW class according to customer needs.

Toshiba ESS has already delivered more than 100 H2Rex pure hydrogen fuel cell systems in Japan, including for the municipal wholesale flower and vegetable market in Shunan, Yamaguchi Prefecture [*May 2017, p7*], a 7-Eleven convenience store in Tokyo [*February 2018, p5*], and the Kawasaki King Skyfront Tokyu REI hotel in Kawasaki City, Kanagawa Prefecture [*June 2018, p3*]. The company recently signed its first hydrogen business partnership agreement in China, with More Hydrogen Energy Technology Co Ltd in Guangzhou, Guangdong Province, to develop fuel cell systems for the Chinese market [*November 2019, p14*].

Toshiba ESS, Hydrogen Energy: www.toshiba-energy.com/en/hydrogen/index.htm

Kitashiba Electric Co Ltd: www.kitashiba.co.jp/english

Centrica invests in Connecticut fuel cell park with Doosan tech

Centrica Business Solutions, part of UK-based global energy and services company Centrica Plc, has invested in the development of a 4.99 MW fuel cell facility in South Windsor, Connecticut.

The facility will deliver power to local utility Eversource Energy under a 20-year Power

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Toshiba ESS, Hydrogen Energy: www.toshiba-energy.com/en/hydrogen/index.htm

Kitashiba Electric Co Ltd: www.kitashiba.co.jp/english

Centrica invests in Connecticut fuel cell park with Doosan tech

Centrica Business Solutions, part of UK-based global energy and services company Centrica Plc, has invested in the development of a 4.99 MW fuel cell facility in South Windsor, Connecticut.

The facility will deliver power to local utility Eversource Energy under a 20-year Power

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Ceres Power launches hydrogen-ready SOFC system at FC Seminar

UK-based Ceres Power has announced the successful development of its first zero-emission combined heat and power (CHP) system, designed exclusively for use with hydrogen. The first prototype system, featuring the company's low-cost, intermediate-temperature solid oxide fuel cell technology, was unveiled at the recent 2019 Fuel Cell Seminar & Energy Exposition in Long Beach, California.

The new system has been developed as part of Ceres' continuing product roadmap, with significant interest from customers seeking greater innovation to tackle climate change and air pollution. In initial testing, the hydrogen CHP system has achieved greater than 50% electrical efficiency, with an overall efficiency of 90% achievable in CHP mode. Ceres' hydrogen CHP is simpler than its existing fuel-flexible system, delivering an equivalent performance with fewer components, reduced size, and cost reduction of up to 40% against an existing Ceres system running on natural gas. The technology provides a zero emissions, highly efficient distributed power system that can be deployed in homes and businesses.

'Ceres' new hydrogen CHP technology runs on both green hydrogen and more widely available low-purity hydrogen from industrial sources,' says Dr Subhasish Mukerjee, Director of Fuel Cell and Stack Development at Ceres Power.

Ceres has already successfully developed and licensed its fuel-flexible IT-SOFC power systems to leading original equipment manufacturers (OEMs) including Bosch in Germany [*FCB, September 2018, p11*], Weichai Power in China [*October 2019, p4*], Miura in Japan [*July 2019, p4*], and Doosan in South Korea [*August 2019, p6*]. The current fuel-flexible system operates on any fuel, including natural gas with any ratio of hydrogen, making it an ideal technology to support the introduction of greater amounts of biogas and hydrogen as a path to decarbonising the existing gas grid infrastructure.

Ceres Power: www.cerespower.com

Fraunhofer IMM develops CHP system with reformer/fuel cell

The Fraunhofer Institute for Microengineering and Microsystems IMM in Mainz, Germany has developed a prototype reformer/fuel cell-based combined heat and power (CHP) system that produces 50 kW of electrical power. The prototype CHP system has been put into trial operation at the Fraunhofer IMM site.

CHP plants are typically comparatively compact, essentially comprising a motor, generator, and heat-exchanger. In Germany, tens of thousands of these combustion-based systems are currently in use, mainly running on natural gas or wood pellets/chips, and operating in a power range well below 50 kW.

Fraunhofer IMM scientists are now using a fuel cell in combination with a reformer, which achieves a highly dynamic system, allowing many start-stop cycles. The use of exclusively catalytic processes completely eliminates the pollutant emissions that come from internal combustion engines. However, this development is currently being driven mainly in Japan, and Japanese core components dominate the solutions available on the German market.

In the current phase of the Fraunhofer IMM system development, regular natural gas is supplied from the pipeline network, reformed into hydrogen in normal operation, and converted into electricity using the fuel cell. The electric power output of the system is up to 50 kW, plus up to 70 kW thermal output. An overall efficiency above 90% can be achieved by utilising the 'waste' heat generated by the fuel cell for hot water and heating. This can be taken a step further, achieving CO_2 neutrality by connecting to a biogas plant, where the CO_2 produced would be captured during biomass production.

The development was largely financed by the Ministry of Science, Further Education and Culture of the western federal state of Rhineland-Palatinate.

Last year PowerCell Sweden [*see also pages 4 and 13*] delivered two S2 PEM fuel cell stacks to Fraunhofer IMM, for use in CHP in a new extension building where hydrogen reformer technology is being developed [*FCB, October 2018, p7*].

Fraunhofer IMM: www.imm.fraunhofer.de/en.html

LARGE STATIONARY

Toshiba wins order for H2Rex hydrogen fuel cell unit at sports park

In Japan, Toshiba Energy Systems & Solutions (Toshiba ESS) has been awarded an order from Fukushima Prefecture, to install an H2Rex™ pure hydrogen fuel cell system at the Azuma Sports Park in Fukushima City.

The system will use hydrogen produced in the Fukushima Hydrogen Energy Research Field (FH2R), a hydrogen production project equipped with some of the world's largest hydrogen production equipment and using renewable energy, which is under construction in Namie Town [*FCB, September 2018, p9*]. Operation is scheduled to start in April 2020.

The system for Azuma Sports Park is rated at 100 kW output power, the largest system in the product range, and will be integrated by the locally based Toshiba ESS subsidiary Kitashiba Electric Co Ltd. It will be installed next to the gymnasium in the park, and provide part of the building's power supply, for lighting and air-conditioning, and the heat from power generation will be used for hot water supply.

The 100 kW system for Azuma Sports Park has been optimised to reduce weight by 30% and volume by 40% compared to the previous model, while maintaining its efficiency and longevity – its power generation efficiency is at least 50% (LHV). In addition, the system has a modular design that can increase (or reduce) the installed capacity in 100 kW units, and can be flexibly expanded to MW class according to customer needs.

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The fuel cell manufacturer and long-term operations and maintenance provider for the project is Doosan Fuel Cell America [*see also the In Brief item on page 5*]. Located less than 2 miles (3 km) from the South Windsor project, Doosan Fuel Cell America was established in Connecticut in 2014, following its acquisition of ClearEdge Power [*FCB, July 2014, p5*], focusing primarily on the stationary phosphoric acid fuel cell products (PureCell Model 400) that ClearEdge had previously acquired from UTC Power [*January 2013, p8, and see the PureCell feature in February 2012*].

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FuelCell Energy's proprietary technology uses MCFCs to efficiently capture and concentrate CO_2 streams from large industrial sources. Combustion exhaust is directed to the fuel cell, which produces power while capturing and concentrating CO_2 for permanent storage. The modular design enables the technology to be deployed at a wide range of locations, which could lead to a more cost-efficient path for large-scale deployment of carbon capture and sequestration (CCS).

'We have a great opportunity to scale and commercialise our unique carbon capture solution, one that captures about 90% of CO_2 from various exhaust streams, while generating additional power, unlike traditional carbon capture technologies which consume significant power,' says Jason Few, President and CEO of FuelCell Energy [*September 2019, p7*].

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FUELING

H_2 Mobility, BMVI sign MOU for further expansion of German hydrogen infrastructure

The German Federal Ministry of Transport and Digital Infrastructure (BMVI) and H_2 Mobility Deutschland GmbH have signed a Memorandum of Understanding on the further expansion of the national hydrogen infrastructure, such that by the end of 2021, more than 60 000 fuel cell cars and 500 commercial vehicles would be able to refuel in Germany.

The H_2 Mobility Deutschland joint venture was formed in 2015 to facilitate a staged nationwide expansion of hydrogen stations to serve fuel cell electric vehicles in Germany [*FCB, November 2015, p6*]. The first phase of its hydrogen infrastructure expansion will be completed by mid-2020 [*see also page 8*]. At that point, with 100 stations in seven metropolitan regions – Hamburg, Berlin, Rhine-Ruhr, Frankfurt, Nuremberg, Stuttgart, and Munich – as well as along the connecting arteries, Germany will have a public hydrogen infrastructure that will make possible hydrogen mobility with virtually no restrictions.

The new MOU – signed at the Stakeholder Conference on the National Hydrogen Strategy in Berlin in early November – will see the hydrogen refueling station network grow by up to 30 stations by the end of 2021. The new stations will be larger: while most hydrogen stations today have a capacity sufficient for refueling 40–50 cars per day, in future it will be possible to refuel up to three times as many FCEVs at one station. H_2 Mobility is thus not only preparing itself for the market ramp-up of hydrogen powered passenger cars, but is also making it possible to service light- and heavy-duty commercial vehicles at selected sites.

The first few manufacturers of FCEVs, including Hyundai [*see page 2*] and Toyota [*see page 2*], as well as the German companies StreetScooter and Faun [*November 2019, p12*], have already announced hydrogen powered models. Toyota will increase its production in the hydrogen passenger car sector 10-fold from 2020, and Hyundai has announced a similarly large scale-up. The new hydrogen stations will be set up in the regions with the greatest demand for hydrogen.

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

HyPort project supports hydrogen station, four buses at French airport

Toulouse–Blagnac Airport (Aéroport de Toulouse–Blagnac, ATB) in southern France will inaugurate a hydrogen production and refueling station in 2020, which will primarily be used to refuel four fuel cell buses used for passenger transport.

The airport will be the first in the world to introduce hydrogen-fueled transport in both the landside and airside areas. The hydrogen production and distribution station will refuel four fuel cell powered buses operated by public transport company Transdev. The station will be in a public zone and available to all users. The buses will operate on the runways, to transport passengers between the terminal and aircraft parked away from the building, and will also provide a shuttle service between the terminal and the remote car parks.

The buses will be provided by local bus manufacturer Safra, which in the summer unveiled its first fuel cell electric bus, fitted with a Michelin/Symbio fuel cell system [*FCB, July 2019, p3, and see the In Brief item on Symbio on page 15 in this issue*].

The initiative is supported by the HyPort project, which aims to make Toulouse–Blagnac Airport the world's first zero-emissions airport using hydrogen energy. HyPort is a company owned 51% by Engie Cofely – the energy efficiency and environmental services subsidiary of French electric utility Engie [*see also pages 9*

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Centrica acquired the project (South Energy Investments LLC) in March from a leading Massachusetts-based fuel cell development team. This investment is a part of Centrica's 'Ambition 2030' initiative, which outlines 15 long-term goals to reduce the company's emissions, and enable customers to use energy more sustainably.

The fuel cell manufacturer and long-term operations and maintenance provider for the project is Doosan Fuel Cell America [*see also the In Brief item on page 5*]. Located less than 2 miles (3 km) from the South Windsor project, Doosan Fuel Cell America was established in Connecticut in 2014, following its acquisition of ClearEdge Power [*FCB, July 2014, p5*], focusing primarily on the stationary phosphoric acid fuel cell products (PureCell Model 400) that ClearEdge had previously acquired from UTC Power [*January 2013, p8, and see the PureCell feature in February 2012*].

Centrica Business Solutions, North America: www.centricabusinesssolutions.com/us

Doosan Fuel Cell America: www.doosanfuelcellamerica.com

FCE and ExxonMobil expand agreement for carbon capture tech

In the US, FuelCell Energy and ExxonMobil have signed a new two-year, expanded joint development agreement to further enhance molten carbonate fuel cell technology for the large-scale capture of CO_2 from industrial facilities such as refineries and chemical plants.

FuelCell Energy [*see also page 13*] and ExxonMobil began working together in 2016, with a focus on better understanding the fundamental science behind molten carbonate fuel cells and how to increase efficiency in separating and concentrating CO_2 from the exhaust of natural gas-fueled power generation [*see the News Feature in FCB, May 2016, and November 2016, p4*]. The new agreement, worth up to $60 million, will focus efforts on optimising the core technology, overall process integration, and large-scale deployment of carbon capture solutions. ExxonMobil is exploring options to conduct a pilot test of this next-generation MCFC carbon capture solution at one of its operating sites.

FuelCell Energy's proprietary technology uses MCFCs to efficiently capture and concentrate CO_2 streams from large industrial sources. Combustion exhaust is directed to the fuel cell, which produces power while capturing and concentrating CO_2 for permanent storage. The modular design enables the technology to be deployed at a wide range of locations, which could lead to a more cost-efficient path for large-scale deployment of carbon capture and sequestration (CCS).

'We have a great opportunity to scale and commercialise our unique carbon capture solution, one that captures about 90% of CO_2 from various exhaust streams, while generating additional power, unlike traditional carbon capture technologies which consume significant power,' says Jason Few, President and CEO of FuelCell Energy [*September 2019, p7*].

FuelCell Energy: www.fuelcellenergy.com

ExxonMobil, Carbon Capture and Storage: https://tinyurl.com/exxonmobil-ccs

FUELING

H_2 Mobility, BMVI sign MOU for further expansion of German hydrogen infrastructure

The German Federal Ministry of Transport and Digital Infrastructure (BMVI) and H_2 Mobility Deutschland GmbH have signed a Memorandum of Understanding on the further expansion of the national hydrogen infrastructure, such that by the end of 2021, more than 60 000 fuel cell cars and 500 commercial vehicles would be able to refuel in Germany.

The H_2 Mobility Deutschland joint venture was formed in 2015 to facilitate a staged nationwide expansion of hydrogen stations to serve fuel cell electric vehicles in Germany [*FCB, November 2015, p6*]. The first phase of its hydrogen infrastructure expansion will be completed by mid-2020 [*see also page 8*]. At that point, with 100 stations in seven metropolitan regions – Hamburg, Berlin, Rhine-Ruhr, Frankfurt, Nuremberg, Stuttgart, and Munich – as well as along the connecting arteries, Germany will have a public hydrogen infrastructure that will make possible hydrogen mobility with virtually no restrictions.

The new MOU – signed at the Stakeholder Conference on the National Hydrogen Strategy in Berlin in early November – will see the hydrogen refueling station network grow by up to 30 stations by the end of 2021. The new stations will be larger: while most hydrogen stations today have a capacity sufficient for refueling 40–50 cars per day, in future it will be possible to refuel up to three times as many FCEVs at one station. H_2 Mobility is thus not only preparing itself for the market ramp-up of hydrogen powered passenger cars, but is also making it possible to service light- and heavy-duty commercial vehicles at selected sites.

The first few manufacturers of FCEVs, including Hyundai [*see page 2*] and Toyota [*see page 2*], as well as the German companies StreetScooter and Faun [*November 2019, p12*], have already announced hydrogen powered models. Toyota will increase its production in the hydrogen passenger car sector 10-fold from 2020, and Hyundai has announced a similarly large scale-up. The new hydrogen stations will be set up in the regions with the greatest demand for hydrogen.

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

HyPort project supports hydrogen station, four buses at French airport

Toulouse–Blagnac Airport (Aéroport de Toulouse–Blagnac, ATB) in southern France will inaugurate a hydrogen production and refueling station in 2020, which will primarily be used to refuel four fuel cell buses used for passenger transport.

The airport will be the first in the world to introduce hydrogen-fueled transport in both the landside and airside areas. The hydrogen production and distribution station will refuel four fuel cell powered buses operated by public transport company Transdev. The station will be in a public zone and available to all users. The buses will operate on the runways, to transport passengers between the terminal and aircraft parked away from the building, and will also provide a shuttle service between the terminal and the remote car parks.

The buses will be provided by local bus manufacturer Safra, which in the summer unveiled its first fuel cell electric bus, fitted with a Michelin/Symbio fuel cell system [*FCB, July 2019, p3, and see the In Brief item on Symbio on page 15 in this issue*].

The initiative is supported by the HyPort project, which aims to make Toulouse–Blagnac Airport the world's first zero-emissions airport using hydrogen energy. HyPort is a company owned 51% by Engie Cofely – the energy efficiency and environmental services subsidiary of French electric utility Engie [*see also pages 9*

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To support the deployment of the first five hydrogen buses (four of which will operate at the airport) and introduce decarbonised transport to the area, HyPort has also requested funding via the regional 'Occitanie Hydrogen Plan' and the ADEME French Environment and Energy Management Agency's 'Hydrogen Transport Ecosystems' call for projects. European funding is also being sought through the Joint Initiative for hydrogen Vehicles across Europe (JIVE 2) [*March 2018, p2*].

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Engie Cofely, HyPort: www.engie-cofely.fr/actualites/hyport [in French]

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H_2 Mobility opens first site in Lower Bavaria, station for Heidelberg

In Germany, H_2 Mobility Deutschland GmbH and its shareholders Shell and Air Liquide recently inaugurated a new hydrogen refueling station in Passau, the first such facility in the administrative district of Lower Bavaria. H_2 Mobility has also begun trial operation of a new OMV hydrogen station in Heidelberg, Baden-Württemberg.

The new facility at the Shell service station in **Passau** is located at Regensburger Strasse 68, close to the town centre as well as the A3 federal motorway and the B8 and B12 federal roads. The hydrogen dispensing technology has been supplied by Air Liquide, and the facility holds around 200 kg of hydrogen, enough to refuel 40–50 vehicles per day.

The owner/developer of the station is the H_2 Mobility joint venture, formed in 2015 to facilitate a staged nationwide expansion of hydrogen stations to serve fuel cell electric vehicles in Germany [*FCB, November 2015, p6, and see page 7 in this issue*]. The station is funded by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU) as part of the Hydrogen Mobility Europe (H2ME) project [*see the News Feature in October 2015, and June 2016, p1*].

There are already hydrogen refueling stations in 16 cities in Bavaria, including Munich [*e.g. September 2019, p7*], Regensburg, Ingolstadt, Augsburg and Nuremberg [*e.g. June 2019, p8*], and stations will open soon in Landshut and Irsching. The Passau station is the 77th hydrogen refueling station in Germany, and the 29th in the Shell network.

H_2 Mobility has also begun trial operation of a hydrogen station in **Heidelberg,** Baden-Württemberg, at the OMV filling station at Speyerer Strasse 20. The trial operation is a standard procedure that is carried out at all stations for four to six weeks. The official opening is expected in February 2020.

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The H_2 Kusatsu Farm station uses two separate methods to reliably supply hydrogen at 350 bar, regardless of the weather. The first utilises a water electrolysis unit that produces hydrogen using the power from solar panels. The other uses compact hydrogen production equipment in combination with a proven natural gas reforming process developed as part of the Ene-Farm residential fuel cell system operating on natural gas [*e.g. FCB, January 2013, p1*].

The station can produce enough hydrogen to operate two fuel cell powered forklifts, with refueling in just 3 min. These forklifts will carry finished products at the Ene-Farm factory. In this way Panasonic is accelerating the development of technology for hydrogen production equipment while verifying the stable operation and economic viability of hydrogen based energy.

Panasonic has been conducting continuous demonstrations of pure hydrogen fuel cell systems at the Yume Solar Hall Yamanashi in Yamanashi Prefecture and the Shizuoka Model Hydrogen Town project since 2012, and plans to commercialise a hydrogen fuel cell system around April 2021 in Japan. The company's hydrogen fuel cells and Ene-Farm systems will also be installed into the Harumi Flag urban redevelopment project in Harumi, Tokyo, the site of the Olympic Village for the 2020 Summer Olympics and Paralympics.

In 2009, Panasonic launched the world's first residential fuel cell system in Japan, under the government-supported Ene-Farm programme [*June 2008, p5*]. Since then, the company has worked towards much longer lifetime, higher efficiency, and smaller size. The company is now expanding its fuel cell business to Europe, targeting Germany, Austria, France, the UK, Luxembourg, Belgium, and the Netherlands.

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French-based industrial gases giant Air Liquide has signed a Memorandum of Understanding with Sinopec (China Petroleum & Chemical Corporation), to accelerate the deployment of hydrogen mobility solutions in China. The partners subsequently inaugurated two hydrogen refueling stations in Shanghai.

Air Liquide [*see also page 9*] and Sinopec will work to **develop a hydrogen mobility network**, and enhance the regulatory framework intrinsic to the development of hydrogen energy in China. Air Liquide will provide Sinopec with its hydrogen supply chain expertise, from production and storage to distribution, to provide competitive hydrogen supply solutions for Chinese clean mobility markets.

Sinopec is the world's largest refining company, and the second largest chemical and fuel retailer, with a network of more than 30 000 stations. In the summer it opened the first multi-fuel station in Foshan, Guangdong Province, offering public hydrogen refueling [*FCB, August 2019, p15*]. Air Liquide and Sinopec already have a long-term partnership, with three joint ventures supplying gases to Sinopec facilities. Air Liquide was a founding member of the Hydrogen Council [*January 2017, p1*], which Sinopec joined last year [*October 2018, p14*].

In mid-November, Sinopec and Air Liquide inaugurated **two hydrogen stations in Shanghai**, rebuilt from the original filling stations and equipped with state-of-the-art hydrogen equipment and technology from the Air Liquide–Houpu joint venture [*May 2019, p9*]. The JV opened its first station last month, in Jiashan, Zhejiang Province, also operated by Sinopec [*November 2019, p11*].

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Sinopec is the world's largest refining company, and the second largest chemical and fuel retailer, with a network of more than 30 000 stations. In the summer it opened the first multi-fuel station in Foshan, Guangdong Province, offering public hydrogen refueling [*FCB, August 2019, p15*]. Air Liquide and Sinopec already have a long-term partnership, with three joint ventures supplying gases to Sinopec facilities. Air Liquide was a founding member of the Hydrogen Council [*January 2017, p1*], which Sinopec joined last year [*October 2018, p14*].

In mid-November, Sinopec and Air Liquide inaugurated **two hydrogen stations in Shanghai**, rebuilt from the original filling stations and equipped with state-of-the-art hydrogen equipment and technology from the Air Liquide–Houpu joint venture [*May 2019, p9*]. The JV opened its first station last month, in Jiashan, Zhejiang Province, also operated by Sinopec [*November 2019, p11*].

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PEM electrolyser from Siemens for Salzgitter steelmaking hydrogen

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The plant, due to commence operation in Q4 of 2020, will cover SZFG's entire current demand for hydrogen [*FCB, December 2018, p12*]. The necessary electrical power will be generated by seven wind turbines with a total capacity of 30 MW, which will be erected by Avacon on the Salzgitter site and likewise enter service from 2020.

A containerised plant will be erected in Salzgitter, which at full capacity will produce 400 Nm^3/h of hydrogen. PEM technology is ideally suited to exploiting the variable generation of wind and solar power; its highly dynamic mode of operation allows the plants to respond to demands resulting from the rapidly fluctuating power supply.

'As our SALCOS project has demonstrated, we are technologically in a position to achieve significant reductions in CO_2 with the aid of hydrogen,' says Professor Heinz Jörg Fuhrmann, Chairman of the Executive Board for Salzgitter AG. 'The Salzgitter Wind Hydrogen project is an important building block on the way towards climate-friendly steel production.'

The cost of the project as a whole – including construction of the wind turbines and the hydrogen plant, and connecting these to the existing supply networks – amounts to around €50 million (US$55 million). Hydrogen has long played a role in steelmaking, in enhancing the quality of annealing processes. The gas is currently supplied by Linde, which will continue to safeguard Salzgitter's own production in future.

Salzgitter Flachstahl is also participating in the EU-funded GrinHy project, to demonstrate high-temperature electrolysis for hydrogen production using a solid oxide electrolysis cell (SOEC) supplied by Sunfire GmbH [*August 2016, p10 and July 2017, p12*].

Siemens, Hydrogen Solutions: http://tinyurl.com/siemens-silyzer

SALCOS project: https://salcos.salzgitter-ag.com/en

Salzgitter Hydrogen Project: www.windh2.de/en.html

Major cooperation deal signed for transport of hydrogen in Belgium

A partnership of seven major industrial players and public stakeholders in Belgium have signed a cooperation agreement, to bring their expertise together in a coordinated way and take steps towards establishing a Belgian hydrogen economy.

The target to reduce CO_2 emissions in Belgium by 80% by 2050 compared to 2005 levels is a major challenge, and hydrogen has an important role to play in the mix of solutions needed to achieve such a result. This is why the dredging and marine engineering company DEME, electric utility Engie Benelux [*see also pages 7 and 9*], shipping and energy supply chain company Exmar, natural gas transmission system operator Fluxys [*FCB, June 2018, p6*], Port of Antwerp, Port of Zeebrugge, and WaterstofNet [*July 2017, p3*] – a cross-border hydrogen initiative between the Flanders region in Belgium and the southern Netherlands – are joining forces.

The generation of sufficient renewable electricity for 'green' hydrogen production is crucial for the viability of a hydrogen economy. However, Belgium does not have extensive wind and solar energy resources, so some of the renewable energy required must be imported.

In the first phase, the partners will conduct a joint analysis of the entire hydrogen import and transport chain. The aim is to map the financial, technical, and regulatory aspects of the various components in the logistics chain: production, loading and unloading, and transport by sea and via pipelines. This analysis will create a roadmap that indicates the best way to transport hydrogen for the various applications in the energy and chemical sectors. The results of this analysis, which is expected to be ready in late 2020, will form the basis for real-world projects.

WaterstofNet: www.waterstofnet.eu/en

Hy2gen Canada in JV to produce green hydrogen in Quebec

Canada's largest ethanol producer, Greenfield Global Inc, and Hy2gen Canada, which specialises in commercial production and distribution of 'green' hydrogen, are creating a joint venture that will develop and operate a facility in Varennes, Quebec for industrial-scale production of green hydrogen and other zero-carbon energy products.

The 50:50 joint venture will build a facility in Varennes, adjacent to Greenfield's existing biorefinery, and use the latest electrolysis technologies powered by hydroelectricity. The final products – green hydrogen, biomethane, and biomethanol – will achieve zero carbon footprint and greenhouse gas (GHG) emissions by using the sustainably produced CO_2 from Greenfield's biorefinery. The JV facility will be built at 29 MW capacity and expanded to meet demand, with possible scale-up to 80 MW in 2024.

Green hydrogen can be used in the industrial, transportation, and mobility sectors, as well as energy storage solutions. The new Varennes facility will help deploy clean, sustainable hydrogen in Montreal, and position Quebec as a world leader in green hydrogen production.

Montreal-based Hy2gen Canada was founded in 2018, as a subsidiary of Hy2gen AG in Germany. It develops and operates large-scale alkaline and PEM electrolyser facilities for the production of green hydrogen and hydrogen-based feedstocks such as biomethanol and biomethane.

Hy2gen Canada: www.hy2gen.ca

Hy2gen AG: www.hy2gen.com

Greenfield Global Inc: www.greenfield.com

ITM Power, Iwatani in US collaboration deal for green hydrogen

UK-based ITM Power has signed a collaboration agreement with Iwatani Corporation of America (ICA), a subsidiary of Japanese energy company Iwatani Corporation, for the deployment of multi-MW, electrolyser-based hydrogen energy systems in North America.

ITM and ICA will offer renewably produced hydrogen to the transportation, energy storage, and renewable energy sectors in North America, with the aim of reducing pollutants and improving air quality. The collaboration agreement will enable the companies to share opportunities and, where a commercial case exists, work together on an exclusive basis to deploy ITM Power's state-of-the-art PEM electrolysers and Iwatani's market-leading gas handling and deployment solutions. The California hydrogen refueling station market is a particular area of interest, as well as large-scale liquid and gaseous renewable hydrogen production for domestic and export markets.

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The cost of the project as a whole – including construction of the wind turbines and the hydrogen plant, and connecting these to the existing supply networks – amounts to around €50 million (US$55 million). Hydrogen has long played a role in steelmaking, in enhancing the quality of annealing processes. The gas is currently supplied by Linde, which will continue to safeguard Salzgitter's own production in future.

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The generation of sufficient renewable electricity for 'green' hydrogen production is crucial for the viability of a hydrogen economy. However, Belgium does not have extensive wind and solar energy resources, so some of the renewable energy required must be imported.

In the first phase, the partners will conduct a joint analysis of the entire hydrogen import and transport chain. The aim is to map the financial, technical, and regulatory aspects of the various components in the logistics chain: production, loading and unloading, and transport by sea and via pipelines. This analysis will create a roadmap that indicates the best way to transport hydrogen for the various applications in the energy and chemical sectors. The results of this analysis, which is expected to be ready in late 2020, will form the basis for real-world projects.

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COMMERCIALISATION

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'This road map shows how critically important hydrogen is to achieve a lower-carbon energy mix, and with the right actions now, reinforce US energy leadership and strengthen our economy by generating $140 billion per year in revenue and 700 000 jobs by 2030, and $750 billion per year in revenue and 3.4 million jobs by 2050 in hydrogen,' says Morry Markowitz, President of the US Fuel Cell and Hydrogen Energy Association (FCHEA). 'In addition, if the right actions are taken now, a competitive hydrogen industry can meet 14% of US energy demand by 2050.'

The contributing companies shared and developed economic models as well as data on future energy needs and environmental expectations. Analytical support was provided by McKinsey, and the Electric Power Research Institute (EPRI) provided scientific observations and technical input.

Executive Summary: www.ushydrogenstudy.org

Fuel Cell and Hydrogen Energy Association: www.fchea.org

Blue World to supply methanol fuel cells to Chinese EV firm Aiways

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Later this year, Aiways will launch the battery electric version of its U5 SUV, and towards the end of 2021, the U5 will also be launched in a methanol fuel cell hybrid version. Blue World Technologies and Aiways are already developing the system design, to ensure easy integration into the existing platform, in addition to long range and fast refueling with liquid methanol. Blue World recently began construction of what it says will be the world's largest methanol fuel cell factory, with a production capacity of 750 MW per annum, equivalent to 50 000 fuel cell units, at the Port of Aalborg in Denmark [*FCB, October 2019, p9*].

In March, eight Chinese ministries – led by the Ministry of Industry and Information Technology (MIIT) – issued a Methanol Vehicle Policy, with the aim of deploying methanol fueled vehicles across China. The potential of producing methanol as a CO_2-neutral fuel with recycled CO_2 from a concentrated CO_2 source, or using direct air capture, was a key factor for Aiways in deciding to cooperate with Blue World Technologies.

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Later this year, Aiways will launch the battery electric version of its U5 SUV, and towards the end of 2021, the U5 will also be launched in a methanol fuel cell hybrid version. Blue World Technologies and Aiways are already developing the system design, to ensure easy integration into the existing platform, in addition to long range and fast refueling with liquid methanol. Blue World recently began construction of what it says will be the world's largest methanol fuel cell factory, with a production capacity of 750 MW per annum, equivalent to 50 000 fuel cell units, at the Port of Aalborg in Denmark [*FCB, October 2019, p9*].

In March, eight Chinese ministries – led by the Ministry of Industry and Information Technology (MIIT) – issued a Methanol Vehicle Policy, with the aim of deploying methanol fueled vehicles across China. The potential of producing methanol as a CO_2-neutral fuel with recycled CO_2 from a concentrated CO_2 source, or using direct air capture, was a key factor for Aiways in deciding to cooperate with Blue World Technologies.

The Gumpert Aiways Automobile GmbH joint venture presented the 'series production' version of its methanol fuel cell powered Nathalie supercar at CIIE 2019, with the first cars scheduled for delivery in 2020. The RG Nathalie was unveiled at the Beijing Motor Show 2018 early last year [*May 2018, p2*], and is claimed to offer a range of 1000 km (620 miles).

Blue World Technologies: www.blue.world

Aiways: www.ai-ways.eu

RG Nathalie supercar: www.rolandgumpert.com/en

Grove, FEV to develop hydrogen powertrain tech in mass production

The Chinese car manufacturer Grove Hydrogen Automobile Co Ltd has signed a cooperation agreement with FEV AG, a leading German automotive development company, to develop passenger car hydrogen fuel cell systems for mass production in Beijing. The partners will collaborate on manufacturing Grove products for the global fuel cell electric vehicle market.

Under the agreement, the companies will cooperate on vehicle system development, powertrain system integration, and vehicle electrical architecture platform construction around Grove's mass production vehicles. FEV will provide customised mass production development and engineering services based on the features of passenger car FCEVs.

Grove unveiled its first prototype car in March [*FCB, April 2019, p2*], and soon afterwards produced the first FCEVs at its new manufacturing facility in the central city municipality of Chongqing [*May 2019, p13*]. The company has also partnered with distributors in Australia and Brazil to serve those markets.

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'Iwatani Corporation is a recognised leader in the hydrogen industry, and we are delighted to be collaborating with the company in North America,' says Dr Graham Cooley, CEO of ITM Power. 'Transport refueling is just the tip of the iceberg for demand for hydrogen from renewable sources, and this partnership will be well positioned to participate in this exciting and rapidly growing industry.'

ITM Power manufactures integrated hydrogen energy solutions for grid balancing, energy storage, and the production of 'green' hydrogen for transport, renewable heat, and chemicals [*see the feature in FCB, January 2012*]. The company is in the process of moving to a new, larger site in Sheffield, which will have an annual production capacity of over 1000 MW per annum [*August 2019, p11*]. Industrial gases and engineering company Linde AG recently acquired a minority stake in the company, and will also form a joint venture to implement projects based on ITM's technology [*October 2019, p1*].

Iwatani is developing hydrogen refueling stations to support the widespread rollout of fuel cell electric vehicles, in Japan and now also in California [*May 2019, p10*].

ITM Power: www.itm-power.com

Iwatani Corporation of America: www.iwatani.com

Iwatani Corporation: www.iwatani.co.jp/eng

COMMERCIALISATION

Report offers road map to US leadership in hydrogen energy field

A coalition of major oil & gas, power, automotive, fuel cell, and hydrogen companies in the US have come together to develop a comprehensive road map that details how the US can expand its global energy leadership, by scaling up activity in the rapidly emerging and evolving hydrogen economy, as policy makers and industry work together and take the right steps.

The *Road Map to a US Hydrogen Economy* – with a freely available Executive Summary – stresses the versatility of hydrogen as an enabler of the renewable energy system, an energy vector that can be transported and stored, and a fuel for the transportation sector, heating of buildings, and providing heat and feedstock to industry. It can reduce both carbon and local emissions, increase energy security and strengthen the economy, as well as support the deployment of renewable power generation such as wind, solar and hydroelectric, as well as nuclear.

'This road map shows how critically important hydrogen is to achieve a lower-carbon energy mix, and with the right actions now, reinforce US energy leadership and strengthen our economy by generating $140 billion per year in revenue and 700 000 jobs by 2030, and $750 billion per year in revenue and 3.4 million jobs by 2050 in hydrogen,' says Morry Markowitz, President of the US Fuel Cell and Hydrogen Energy Association (FCHEA). 'In addition, if the right actions are taken now, a competitive hydrogen industry can meet 14% of US energy demand by 2050.'

The contributing companies shared and developed economic models as well as data on future energy needs and environmental expectations. Analytical support was provided by McKinsey, and the Electric Power Research Institute (EPRI) provided scientific observations and technical input.

Executive Summary: www.ushydrogenstudy.org

Fuel Cell and Hydrogen Energy Association: www.fchea.org

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AFC's partner De Nora [*September 2019, p13*] confirms that the AlkaMem performance 'exceeded internal expectations' following independent validation testing at its research facilities in Japan, endorsing the significant upside potential in alkaline water electrolysis applications. The AlkaMem membrane will come in three thicknesses (20, 40, and 100 µm), reflecting the needs of different applications, all based on the same technology and manufacturing process.

AFC Energy: www.afcenergy.com

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FuelCell Energy agrees new $200m strategic corporate loan facility

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This corporate and construction finance facility with Orion Energy will first be deployed towards current construction and engineering costs associated with several in-flight projects. These are the Connecticut Municipal Electric Energy Cooperative (CMEEC) molten carbonate fuel cell plant for the Naval Submarine Base New London in Groton, Connecticut [*FCB, November 2017, p7 and April 2019, p7*]; final construction costs associated with the Tulare BioMAT project in California [*July 2017, p6*], which will be commercially operable in mid-December; and the 5 MW unit for Bolthouse Farms in California [*March 2018, p1*]. The facility will also be used for future growth, including commencing construction of the first of three projects with the Long Island Power Authority (LIPA) [*August 2017, p6*].

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'Finding and accelerating adoption opportunities in the Spanish materials handling market is pivotal to the greater success of adopting clean energy mobility solutions,' says Andy Marsh, CEO of Plug Power. 'Our partnership is already providing fruitful work, and we look forward to finding areas of collaboration in the future.'

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The MS-100 hydrogen PEM fuel cell system has been developed for marine applications [*FCB, June 2018, p1, and see also page 4 in this issue*], as well as off-road applications such as construction and materials handling equipment [*February 2019, p4*], which demand reliable operation, high power output, and flexibility. The new version is designed to withstand vibrations to ensure a long service life while providing quick and smooth startup regardless of environmental conditions. It offers a maximum power output of 100 kW, and systems can be connected in series to achieve MW power levels.

The MS-100 system is based on the PowerCell S3 fuel cell stack, with its industry leading power density [*February 2016, p10*]. The S3 stack technology features compact metallic bipolar plates with large active area and state-of-the-art membrane-electrode assemblies (MEAs), to deliver a minimum operating lifetime of 20 000 h. The compact design – and a volume of only 276 litres (9.75 ft^3) – allows the system to be easily integrated and used in a wide range of applications. It is available in both vertical and horizontal positioning, which facilitates installation when space is limited.

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University of Delaware, Chemical and Biomolecular Engineering: http://cbe.udel.edu

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Increasing global demand for the company's test solutions for batteries and fuel cells, as well as its role as a 'global competence centre for fuel cells and batteries' within the Horiba Group, have led to substantial growth at Horiba FuelCon. The company has acquired the 2.9 ha (7 acre) site near the current building, and the planning application was initiated in early 2019. The aim is to receive the construction permit by the end of this year, so that construction work can start at the beginning of 2020.

Horiba FuelCon is a leading global supplier of test systems for fuel cells and batteries. Its test systems for fuel cells serve PEM or solid oxide technologies up to 250 kW, and it also offers systems for evaluating electrolysers.

The federal state of Saxony-Anhalt is providing financial support to facilitate a strong concentration of innovation and automotive competence at the Magdeburg-Barleben site. The close location of Horiba FuelCon, the Institute of Automotive Expertise (IKAM GmbH), the Innovation and Founders Centre (IGZ), and the planned Center for Method Development (CMD) of Otto von Guericke University Magdeburg will form a regional 'E-Mobility-Campus' that is attractive for companies and the region's skilled workforce.

Horiba FuelCon GmbH: www.horiba-fuelcon.com/en

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Pierburg develops new multi-purpose valve for automotive fuel cells

German-based Pierburg GmbH is applying its accumulated combustion engine expertise in pumps and valves to offer products specially developed for fuel cell electric vehicles. In addition to a leak-free control valve that meets the specific requirements of fuel cell systems, the company has developed a coolant pump and a hydrogen recirculation blower, both suitable for both low- and high-voltage vehicle electrical systems.

Automotive fuel cell systems are a challenging technology that, like combustion engines, requires sophisticated thermal management and supplies of air and fuel [*FCB, September 2019, p12*]. Pierburg's new Multi Purpose Valve (MPV) is particularly compact and lightweight, and is suitable for use on the cathode side of the fuel cell. It is resistant to deionised water and hydrogen, and allows precise control. It combines low leakage with both a high flow rate and low pressure loss. The valve operates as an air diverting or bypass valve for the air compressor, or can be used as a pressure control valve as well as an isolation or shutoff valve for the fuel cell stack.

Pierburg – a subsidiary of Rheinmetall Automotive AG – has also launched coolant pumps specifically developed for fuel cell applications, which are suitable for 400 V or up to 800 V operation. These high-voltage coolant pumps are driven by a brushless EC (electronic commutator) motor with sensorless control. They are equipped with LIN/CAN bus communication and corresponding diagnostic functions. The pumps are rated for up to 2.2 kW, and are suitable for use with deionised water and various coolants.

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Pierburg GmbH:
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RESEARCH

VTT's reversible fuel cell for highly efficient hydrogen production

The VTT Technical Research Centre of Finland has developed a mobile reversible solid oxide cell (rSOC) system, which can produce hydrogen by water electrolysis with an efficiency as high as 90%.

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The federal state of Saxony-Anhalt is providing financial support to facilitate a strong concentration of innovation and automotive competence at the Magdeburg-Barleben site. The close location of Horiba FuelCon, the Institute of Automotive Expertise (IKAM GmbH), the Innovation and Founders Centre (IGZ), and the planned Center for Method Development (CMD) of Otto von Guericke University Magdeburg will form a regional 'E-Mobility-Campus' that is attractive for companies and the region's skilled workforce.

Horiba FuelCon GmbH: www.horiba-fuelcon.com/en

Horiba Group: www.horiba.com

Pierburg develops new multi-purpose valve for automotive fuel cells

German-based Pierburg GmbH is applying its accumulated combustion engine expertise in pumps and valves to offer products specially developed for fuel cell electric vehicles. In addition to a leak-free control valve that meets the specific requirements of fuel cell systems, the company has developed a coolant pump and a hydrogen recirculation blower, both suitable for both low- and high-voltage vehicle electrical systems.

Automotive fuel cell systems are a challenging technology that, like combustion engines, requires sophisticated thermal management and supplies of air and fuel [*FCB, September 2019, p12*]. Pierburg's new Multi Purpose Valve (MPV) is particularly compact and lightweight, and is suitable for use on the cathode side of the fuel cell. It is resistant to deionised water and hydrogen, and allows precise control. It combines low leakage with both a high flow rate and low pressure loss. The valve operates as an air diverting or bypass valve for the air compressor, or can be used as a pressure control valve as well as an isolation or shutoff valve for the fuel cell stack.

Pierburg – a subsidiary of Rheinmetall Automotive AG – has also launched coolant pumps specifically developed for fuel cell applications, which are suitable for 400 V or up to 800 V operation. These high-voltage coolant pumps are driven by a brushless EC (electronic commutator) motor with sensorless control. They are equipped with LIN/CAN bus communication and corresponding diagnostic functions. The pumps are rated for up to 2.2 kW, and are suitable for use with deionised water and various coolants.

Pierburg has also developed a hydrogen recirculation blower (HRB), for unused hydrogen on the anode side, based on a side-channel blower and without dynamic sealing elements, to ensure hydrogen tightness over its lifetime. The HRB is rated at 0.7–2 kW for the high-voltage variant, and up to 400 W in the low-voltage version.

Pierburg GmbH:
www.rheinmetall-automotive.com/en/brands/pierburg

Rheinmetall Automotive:
www.rheinmetall-automotive.com/en

RESEARCH

VTT's reversible fuel cell for highly efficient hydrogen production

The VTT Technical Research Centre of Finland has developed a mobile reversible solid oxide cell (rSOC) system, which can produce hydrogen by water electrolysis with an efficiency as high as 90%.

The VTT team used solid oxide cell (SOC) technology, which they say offers a much higher hydrogen production efficiency than alkaline or PEM electrolysers, which achieve

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Delaware startup W7energy wins $3.4m in ARPA-E funding

Delaware-based startup W7energy has been awarded $3.4 million in new funding from the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E), to advance and commercialise a new class of polymer membranes that are expected to make fuels cells much more economical. The company has also received a $1 million private investment, and a $100 000 Delaware Division of Small Business EDGE grant.

W7energy grew out of technology developed at the University of Delaware, in the lab of Professor Yushan Yan in Chemical and Biomolecular Engineering [*FCB, October 2016, p11*]. The startup is developing technology to manufacture a class of hydroxide exchange membranes (HEMs) that efficiently transport hydroxide ions, which are negatively charged molecules that typically make a solution alkaline (i.e. pH > 7). Advanced polymer design and engineering by Yan's team at UD has resulted in innovative HEM membranes, which are chemically stable, ionically conductive and mechanically robust, making them a superior choice for hydrogen or ammonia fuel cells. W7energy adds that the technology is projected to be one-third less expensive than traditional fuel cell systems, since it uses less expensive catalysts such as nickel or silver.

W7energy is now working to optimise the membrane processes, so that they provide superior performance in ways that are scalable for mass production. The research team also plans to expand work in the lab to include in-house characterisation and testing of new membrane materials in functional fuel cells and water-splitting electrolysers – an additional capability that will set W7energy apart from its competitors.

W7energy: www.w7energy.com

University of Delaware, Chemical and Biomolecular Engineering: http://cbe.udel.edu

New building planned for Horiba FuelCon

German-based Horiba FuelCon GmbH has confirmed that it will go ahead with the construction of a new building close to its current facility in Magdeburg-Barleben, with completion expected in 2021.

Horiba FuelCon – acquired last year by Japanese company Horiba Automotive Test Systems [*FCB, September 2018, p12*] – will invest up to €30 million (US$33 million) in its 'Factory 2021' project, which was announced in the spring [*May 2019, p15*]. The new building, in the nearby Technologiepark Ostfalen, will have 7000 m² (75 000 ft^2) of production and commissioning space and 3000 m² (32 000 ft^2) of office space, and accommodate up to 360 employees, including some 250 new jobs.

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RESEARCH

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efficiencies of about 60%. 'Solid oxide cell technology and its required operating temperature of 700°C allow extremely high efficiency in hydrogen production,' says Dr Ville Saarinen, research scientist in VTT's fuel cell team. 'We can reach 80–90% with it.'

In addition, unlike a PEM fuel cell, VTT's rSOC technology can also directly utilise fuels other than hydrogen, such as natural gas or biogas (i.e. methane). Fuel flexibility could be a key factor in the gradual transition to a zero-emissions energy system over the next 20 years.

'The device can be installed, for example, in connection with a wind farm, making it possible to store environmentally friendly wind power as hydrogen, and convert it back into electricity during peaks in consumption,' adds Saarinen. 'The device fits in a 10 ft (3 m) shipping container, and can easily be transported to a vehicle refueling station or connected to a chemical industry process that uses hydrogen as a raw material. The device can be implemented on a usable scale.'

Hydrogen production using SOC technology is currently primarily hindered by its high price. Although SOCs do not use expensive platinum catalysts, like PEM cells, the production of ceramic electrolytes and cells assembled from them is technically demanding.

The rSOC system has been developed as part of the three-year, EU-supported BALANCE project, which ended in November. The other partners are the Technical University of Denmark (DTU), CEA French Alternative Energies and Atomic Energy Commission, ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development, the University of Birmingham's Centre for Fuel Cell & Hydrogen Research in the UK, Delft University of Technology (TU Delft) in the Netherlands, EPFL École Polytechnique Fédérale de Lausanne in Switzerland, and the Institute of Power Engineering in Poland.

BALANCE project: www.balance-project.org

VTT, Fuel Cells and Hydrogen: http://tinyurl.com/vtt-fuelcells-h2

German KWK.NRW 'virtual institute' launches CHP projects

The Virtual Institute KWK.NRW 4.0 combined heat and power joint project in Germany has been awarded a total of €9 million (US$10 million) in funding by the state government of North Rhine-Westphalia (NRW) and the European Regional Development Fund (ERDF), which has allowed it to launch the subprojects 'Demo Hybrid SOFC' and 'iFlex CHP 4.0'.

The Virtual Institute KWK.NRW, established in 2014, is a research network of competencies and infrastructures across the state, to create cooperation with the highest level of expertise in combined heat and power (CHP, or cogeneration). The latest version, KWK.NRW 4.0, has added another partner, the Chair of Energy Economics (EWL) at the University of Duisburg-Essen. The existing members are the Gas- und Wärme-Institut Essen (Gas and Heat Institute, GWI), which acts as the coordinator, the Chairs of Energy Technology (LET) and Environmental Process Engineering & Plant Design (LUAT) at the University of Duisburg-Essen, and the Hydrogen and Fuel Cell Center ZBT GmbH in Duisburg.

KWK.NRW 4.0 aims to develop and demonstrate flexible CHP concepts, looking in particular at the potential for CO_2 reduction with CHP systems and fuel cells. In the 'iFlex CHP 4.0' project, the research partners are developing flexible CHP supply concepts for commercial and industrial consumers as well as neighbourhoods. At ZBT, the project will expand the existing phosphoric acid fuel cell (PAFC) and combine it with an absorption chiller. The simulation and analysis of systemic, ecological and economic effects – by LET, LUAT, and EWL – are as much a part of the project as the construction and operation of the innovative demonstration systems.

At the same time, the 'Demo Hybrid SOFC' project will install the first hybrid solid oxide fuel cell-micro gas turbine (SOFC-MGT) system in Europe, at the GWI site in Essen. This will create a unique research platform to demonstrate the highly efficient and flexible generation of electricity, heat, and cooling.

Virtual Institute KWK.NRW: www.vi-kwk.nrw [in German]

Gas- und Wärme-Institut Essen: www.gwi-essen.de/en

University of Duisburg-Essen, Energy Economics: www.ewl.wiwi.uni-due.de/en

UDE, Energy Technology: www.uni-due.de/energietechnik [in German]

UDE, Environmental Process Engineering & Plant Design: www.uni-due.de/luat/index_en

Hydrogen and Fuel Cell Center ZBT GmbH: www.zbt.de/en

IN BRIEF

Faurecia and Michelin formalise Symbio joint venture to lead in hydrogen mobility

Michelin (www.michelin.com/en) and Faurecia (www.faurecia.com/en) have formalised the creation of Symbio, A Faurecia Michelin Hydrogen Company (www.symbio.one/en), as an equally owned joint venture that combines all of their hydrogen fuel cell dedicated activities [*FCB, March 2019, p1*]. The JV will develop, produce and market hydrogen fuel cell systems for light vehicles, commercial vehicles and trucks, and other electromobility sectors.

Michelin and Faurecia will initially invest €140 million (US$155 million) in the joint venture in order to accelerate the development of new-generation fuel cells, launch mass production, and increase business in Europe, China, and the US. The JV will eventually have three sites supplying the European, Asian, and US automotive markets.

FCH2 JU programme review report 2018

The *Programme Review Report 2018* of the EU-supported Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU, www.fch.europa.eu) [*and see the item below*], prepared by the European Commission's Joint Research Centre (JRC), has just been released [https://tinyurl.com/fchju-prog-rev-2018]. This comprehensive report reviews the activities supported by FCH2 JU, paying particular attention to the added value, effectiveness and techno-economic efficiency of FCH2 JU projects, assigned to six review panels under two main pillars – Transport and Energy – as well as Support for Market Uptake.

Two Transport panels reviewed trials and deployment of fuel cell applications, and the next generation of products; three Energy panels reviewed trials and deployment of fuel cell applications, next generation of products, and hydrogen for sectorial integration; and the Support for Market Uptake panel reviewed crosscutting activities such as standards and consumer awareness. The report includes poster presentations with details of 85 projects.

E4tech analyses hydrogen, fuel cells value

E4tech (https://tinyurl.com/e4tech-fch) has just published an analysis of the potential economic value of European fuel cell and hydrogen (FCH) manufacturing and supply (www.fch.europa.eu/page/FCH-value-chain). The study was commissioned by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU) [*see also the above item*] and carried out in partnership with Ecorys (www.ecorys.com) and Strategic Analysis Inc (www.sainc.com).

Three study reports are available: Summary (https://tinyurl.com/fch-valuechain1), Evidence (https://tinyurl.com/fch-valuechain2), and Findings (https://tinyurl.com/fch-valuechain3).

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to retailer utilising zero-emission fleet technology, in its hometown of St Louis, Missouri.

A Nikola hydrogen-electric truck picked up the load of beer, and delivered it to Anheuser-Busch's local wholesaler partner, Lohr Distributors – the first commercial delivery onboard a Nikola hydrogen-electric vehicle. Lohr then delivered the beer to the Enterprise Center, home of the St Louis Blues ice hockey team, on a BYD battery electric truck. In this way the beer reached its destination with zero transportation emissions.

The delivery builds on Anheuser-Busch's ongoing commitment to sustainability and existing partnerships with Nikola and BYD. Last year, Anheuser-Busch placed an order for up to 800 hydrogen-electric semi-trailer trucks from Nikola [*FCB, May 2018, p4*], as the brewer moves to transition its entire long-haul fleet to zero-emission vehicles.

'As the first commercial delivery of freight with our hydrogen-electric truck, this is an exciting time for both Nikola and Anheuser-Busch,' says Trevor Milton, CEO of Nikola. 'We are now preparing production vehicles for Anheuser-Busch, and plan on delivering the trucks as fast as possible.'

Arizona-based Nikola designs and manufactures hydrogen-electric vehicles, electric vehicle drivetrains, vehicle components, energy storage systems, and hydrogen refueling stations. The company unveiled its Nikola One™ semi-trailer truck, powered by lithium batteries recharged by a 200 kW hydrogen fuel cell, in late 2016 [*January 2017, p13*], and last autumn announced the Nikola Tre hydrogen-electric truck specifically for the European market [*December 2018, p4*]. Nikola currently has more than 14 000 Class 8 fuel cell heavy trucks on order, which will be manufactured in Coolidge, Arizona [*April 2019, p14*]; testing will begin on Arizona roads this year, with full production expected in late 2022.

Nikola Motor Company: www.nikolamotor.com

Anheuser-Busch: www.anheuser-busch.com

BYD Motors: www.byd.com

Horizon to deliver 370 kW PEMFC stacks for heavy-duty vehicles

Singapore-based Horizon Fuel Cell Technologies is installing volume production of its 150 kW PEM fuel cell stacks (generation VL-II) for heavy-duty trucks, and has released specifications for its next-generation (VL-III) high-power automotive fuel cells. These will produce 370 kW (500 hp), with power density exceeding 5 kW/L and 5 kW/kg, comfortably providing enough power to displace most large diesel engines.

Volume production of Horizon VL-II fuel cells for buses and medium- to heavy-duty trucks commenced earlier this year, serving customers around the world [*FCB, August 2019, p10*]. Horizon has a number of heavy truck platforms running on these fuel cells, up to 42 tonnes gross vehicle weight. Horizon says that even though its 150 kW (200 hp) module is the highest power automotive fuel cell being supplied today, heavy vehicle applications would benefit from even higher power fuel cells for optimal vehicle performance, reliability, and efficiency [*September 2019, p11*].

Horizon is now accepting orders for the 300 kW fuel cell powertrains, and expects to start shipping VL-III stacks and VLS-III complete powertrains from mid-2020. The first customers are expected to deploy the systems in long-haul heavy trucking applications, based on confidential discussions under way with Horizon. Long-haul heavy trucks are a particularly attractive application for hydrogen powered transport, but this has been difficult to validate given a shortage of suitable fuel cells to meet the market need. Horizon expects significant early interest from logistics operators and major retailers who are seeking to reduce their carbon footprint.

Horizon supplies a full range of fuel cell systems, from low-power air-cooled fuel cells to high-power automotive systems, as well as containerised stationary power plants [*May 2018, p7*]. Earlier this year it unveiled ultrathin bipolar plates that deliver high power density and offer significant cost reduction, in particular targeting automotive PEMFC stacks [*June 2019, p13*].

Horizon Fuel Cell Technologies: www.horizonfuelcell.com

MOBILE APPLICATIONS

Toyota, Fenix demo fuel cell electric utility tractor rig in California

Toyota Motor North America unveiled its first hydrogen fuel cell powered electric utility tractor rig (UTR), developed in collaboration with Fenix Marine Services, at the recent 2019 Fuel Cell Seminar & Energy Exposition in Long Beach, California.

EDITORIAL

Record-breaking is popular with many people and organisations around the world – there's something very appealing about doing better than anyone has ever done before. And it provides excellent publicity.

For example, Hyundai Motor Company's fuel cell electric vehicles have been involved in setting numerous records. In this issue we report on Swiss balloonist Bertrand Piccard driving 778 km (483.4 miles) in a Hyundai NEXO fuel cell SUV, claimed as breaking the world record for the **longest distance driven in a hydrogen powered vehicle on a single fueling** [*see page 2*]. Amazingly, the vehicle's display indicated up to 49 km (30 miles) of remaining range.

Last month we reported on another NEXO car setting what is believed to be a new **land speed record for the hydrogen fuel cell category** [*November 2019, p3*]. Hyundai engineering teams from the Hyundai America Technical Center, Hyundai Motor America, and the Korean parent company collaborated to achieve 106.160 mph (170.848 km/h) at the Bonneville Salt Flats in Utah.

Last year the NEXO's predecessor, the Hyundai ix35 (or Tucson) Fuel Cell, was used to set a world record for electric driving, when a Dutch team achieved **2888 km (1795 miles) in 24 hours** [*April 2018, p2*]. This even exceeded the world record for a battery electric vehicle, of 2424 km (1506 miles) set in 2016 in a Tesla car in Germany.

Specially designed fuel cell powered vehicles have also set records, such as students at Duke University in North Carolina last year setting a world record for **fuel efficiency in a hydrogen fuel cell car**, achieving the equivalent of 14 573 miles per gallon (6195 km per litre of gasoline equivalent) [*September 2018, p5*]. The car used less than 1g of pure hydrogen in travelling 8.5 miles (13.7 km) on a track.

Record breakers are also busy in the aerial sector, where long flight times are a key achievement, especially for unmanned aerial vehicles (UAVs, or drones). For example, MMC's new Griflion H hydrogen-powered vertical take-off and landing (VTOL) drone has demonstrated a record-breaking **15h flight time** [*October 2019, p7*]. And earlier this year Intelligent Energy was involved in two projects that broke different records for hydrogen fuel cell powered, multirotor drones. Project Rachel in the UK beat its test flight target of **60 min with a 5 kg payload**, while South Korean company MetaVista demonstrated a **10 h 50 min test flight** using Intelligent Energy's Fuel Cell Power Module [*February 2019, p5*].

Steve Barrett

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fuel cell powered rotary-wing UAS – from Singapore-based H3 Dynamics.

The Hycopter is manufactured by H3 Dynamics at its facility in Austin, Texas, whose team conducted the acceptance training and flight demonstration in Monterey. This particular UAS will be used to support a Naval Research Program project to study the feasibility of using compressed hydrogen as a power source onboard naval platforms. The Hycopter could also be used to support future research projects that require long-endurance aerial data collection. Hydrogen fuel cell technology offers a step change in UAS productivity, and widens the scope of applications that are currently limited by battery-based technologies.

The six-rotor Hycopter has a blade tip-to-tip diameter of 7 ft (2.1 m), a takeoff weight of about 35 lb (16 kg) with a 5 lb (2.3 kg) payload, and a flight duration of about 2.5 h. The all-electric platform is powered by an ultralight PEM fuel cell fed with compressed hydrogen gas. HES Energy Systems – the energy storage technology subsidiary of H3 Dynamics – says that the Hycopter's ultra-energy-efficient design and open-payload bay can fly many types of sensor packages for much longer than a conventional battery powered drone, making it ideal for use in large-scale industrial maintenance inspections.

HES unveiled the Hycopter unmanned aerial vehicle (UAV) in 2015 [*FCB, June 2015, p4*], with the commercial launch of the upgraded version a year ago [*December 2018, p5*]. The company recently partnered with EPH Engineering in Brazil to launch a turnkey dam inspection solution that combines artificial intelligence (AI)-enabled damage assessment and Hycopter hydrogen fuel cell drones capable of flying for 3.5 h [*September 2019, p1*].

H3 Dynamics: www.h3dynamics.com

HES Energy Systems: www.hes.sg

SMALL STATIONARY

SFC deal for German radio tower sites, telecom partnership for North America

SFC Energy in Germany has received a framework contract from cooperation partner adKor to deliver hydrogen fuel cells for emergency backup power for radio tower sites in several federal states. And its Canadian subsidiary Simark Controls has signed a partnership agreement with Axsera in Montreal, to commercialise EFOY Pro direct methanol fuel cell solutions for telecom applications across North America.

The **framework contract with adKor GmbH** runs to the end of 2021, and has a total order volume of €1.8–5.3 million (US$2–5.9 million), depending on installation and commissioning by the federal states. This is the first hydrogen fuel cell order for SFC Energy, a year after SFC and adKor signed a partnership agreement to jointly develop a new generation of powerful hydrogen fuel cell systems [*FCB, December 2018, p13*].

adKor and its system partners have already won tenders for emergency backup power equipment at more than 400 radio tower sites with hydrogen fuel cells in different federal states. For these radio tower site projects SFC will deliver the hydrogen fuel cell modules to adKor as a subcontractor.

At critical radio tower sites, operators have to ensure a minimum of 72 h power autonomy for their radio systems at any time, to safeguard radio communications for critical users during power blackouts. Earlier this year the Jupiter hydrogen fuel cell-based power solution developed by SFC Energy and adKor was extensively tested at the DLR German Aerospace Center, and technically accepted and qualified for outdoor use in telecom and BOS (public authorities and organisations with security tasks) digital radio systems [*May 2019, p1*].

Meanwhile in Canada, **Simark Controls has signed a partnership agreement with Axsera** – a provider of technical services, telecoms and remote power solutions, with an extensive industry network – for the commercialisation of EFOY Pro DMFC solutions for telecom applications across North America. Axsera will sell EFOY Pro solutions to provide highly reliable, fully autonomous power to critical off-grid telecom equipment in Canada and the US.

EFOY Pro solutions are used to ensure reliable operation of remote devices in any season and weather. In the context of the partnership agreement, Simark will integrate the robust EFOY Pro fuel cells into a wide variety of turnkey autonomous, fully automatic, and highly reliable EFOY Pro solutions for Axsera customers.

SFC Energy is a leading provider of direct methanol and hydrogen fuel cells for stationary and mobile hybrid power solutions, with more than 40 000 fuel cells sold worldwide [*see the SFC feature in January 2013*].

SFC Energy: www.sfc.com/en or www.efoy-pro.com

adKor GmbH: www.adkor.de/en

Simark Controls Ltd: www.simarkcontrols.com

Axsera Inc: www.axsera.com

IN BRIEF

Doosan FC, Hyundai Motor to develop hydrogen fuel cell distributed generation

In South Korea, Doosan Fuel Cell has signed a contract with Hyundai Motor Company [*see also page 2, and the Hyundai item below*] and Ulsan Techno Park to develop hydrogen fuel cell distributed power generation systems for micro grids. Doosan FC will manufacture phosphoric acid fuel cells and Hyundai Motor will manufacture PEM fuel cells, while Ulsan Techno Park will provide a demonstration site and supply hydrogen.

Doosan Fuel Cell was split off from Doosan Corporation on 1 October [*see also the Centrica–Doosan item on page 6, and the Doosan Mobility Innovation item below*], and launched as a separate company to enhance management efficiency and expertise in line with anticipated growth in the hydrogen fuel cell business.

Hyundai unveils fast police fuel cell bus

Hyundai Motor Company has unveiled a high-speed, hydrogen electric bus that will be deployed for police transportation in South Korea. The bus is based on the company's standard police bus, with an integrated fuel cell power system comprising two 95 kW stacks from the NEXO car [*see also page 2*] and a commercial hydrogen tank, mounted on the roof to secure sufficient cargo capacity for carrying police equipment. The bus can accommodate 29 people, including drivers, and is strengthened with a low body floor to suit domestic road conditions and high-speed driving.

Hyundai aims to provide two buses to the National Police Agency by the end of the year, and start mass production by 2021. The government plans to replace 800 police buses with hydrogen electric buses by 2028.

Doosan Mobility Innovation demos fuel cell drones in sea crossing, river patrol

South Korean company Doosan Mobility Innovation (www.doosanmobility.com) collaborated with Skyfire Consulting (www.skyfireconsulting.com), the US Department of Health and others for a 43 mile (69 km) open ocean drone crossing between the Caribbean islands of Saint Croix and Saint Thomas, in the US Virgin Islands. The Doosan DS30 fuel cell powered unmanned aerial vehicle (UAV) completed the flight in 1 h 43 min, and still had nearly 30 minutes' worth of hydrogen left in its tank.

DMI has also tested a fuel cell powered drone with Korea Water Resources Corporation in the Nakdong River Basin. The drone was flown for 20 km (12 miles), showcasing its capabilities for missions such as regional water resource management, emergency evacuation warning broadcasts, and transmission tower inspections.

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efficiencies of about 60%. 'Solid oxide cell technology and its required operating temperature of 700°C allow extremely high efficiency in hydrogen production,' says Dr Ville Saarinen, research scientist in VTT's fuel cell team. 'We can reach 80–90% with it.'

In addition, unlike a PEM fuel cell, VTT's rSOC technology can also directly utilise fuels other than hydrogen, such as natural gas or biogas (i.e. methane). Fuel flexibility could be a key factor in the gradual transition to a zero-emissions energy system over the next 20 years.

'The device can be installed, for example, in connection with a wind farm, making it possible to store environmentally friendly wind power as hydrogen, and convert it back into electricity during peaks in consumption,' adds Saarinen. 'The device fits in a 10 ft (3 m) shipping container, and can easily be transported to a vehicle refueling station or connected to a chemical industry process that uses hydrogen as a raw material. The device can be implemented on a usable scale.'

Hydrogen production using SOC technology is currently primarily hindered by its high price. Although SOCs do not use expensive platinum catalysts, like PEM cells, the production of ceramic electrolytes and cells assembled from them is technically demanding.

The rSOC system has been developed as part of the three-year, EU-supported BALANCE project, which ended in November. The other partners are the Technical University of Denmark (DTU), CEA French Alternative Energies and Atomic Energy Commission, ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development, the University of Birmingham's Centre for Fuel Cell & Hydrogen Research in the UK, Delft University of Technology (TU Delft) in the Netherlands, EPFL École Polytechnique Fédérale de Lausanne in Switzerland, and the Institute of Power Engineering in Poland.

BALANCE project: www.balance-project.org

VTT, Fuel Cells and Hydrogen: http://tinyurl.com/vtt-fuelcells-h2

German KWK.NRW 'virtual institute' launches CHP projects

The Virtual Institute KWK.NRW 4.0 combined heat and power joint project in Germany has been awarded a total of €9 million (US$10 million) in funding by the state government of North Rhine-Westphalia (NRW) and the European Regional Development Fund (ERDF), which has allowed it to launch the subprojects 'Demo Hybrid SOFC' and 'iFlex CHP 4.0'.

The Virtual Institute KWK.NRW, established in 2014, is a research network of competencies and infrastructures across the state, to create cooperation with the highest level of expertise in combined heat and power (CHP, or cogeneration). The latest version, KWK.NRW 4.0, has added another partner, the Chair of Energy Economics (EWL) at the University of Duisburg-Essen. The existing members are the Gas- und Wärme-Institut Essen (Gas and Heat Institute, GWI), which acts as the coordinator, the Chairs of Energy Technology (LET) and Environmental Process Engineering & Plant Design (LUAT) at the University of Duisburg-Essen, and the Hydrogen and Fuel Cell Center ZBT GmbH in Duisburg.

KWK.NRW 4.0 aims to develop and demonstrate flexible CHP concepts, looking in particular at the potential for CO_2 reduction with CHP systems and fuel cells. In the 'iFlex CHP 4.0' project, the research partners are developing flexible CHP supply concepts for commercial and industrial consumers as well as neighbourhoods. At ZBT, the project will expand the existing phosphoric acid fuel cell (PAFC) and combine it with an absorption chiller. The simulation and analysis of systemic, ecological and economic effects – by LET, LUAT, and EWL – are as much a part of the project as the construction and operation of the innovative demonstration systems.

At the same time, the 'Demo Hybrid SOFC' project will install the first hybrid solid oxide fuel cell-micro gas turbine (SOFC-MGT) system in Europe, at the GWI site in Essen. This will create a unique research platform to demonstrate the highly efficient and flexible generation of electricity, heat, and cooling.

Virtual Institute KWK.NRW: www.vi-kwk.nrw [in German]

Gas- und Wärme-Institut Essen: www.gwi-essen.de/en

University of Duisburg-Essen, Energy Economics: www.ewl.wiwi.uni-due.de/en

UDE, Energy Technology: www.uni-due.de/energietechnik [in German]

UDE, Environmental Process Engineering & Plant Design: www.uni-due.de/luat/index_en

Hydrogen and Fuel Cell Center ZBT GmbH: www.zbt.de/en

IN BRIEF

Faurecia and Michelin formalise Symbio joint venture to lead in hydrogen mobility

Michelin (www.michelin.com/en) and Faurecia (www.faurecia.com/en) have formalised the creation of Symbio, A Faurecia Michelin Hydrogen Company (www.symbio.one/en), as an equally owned joint venture that combines all of their hydrogen fuel cell dedicated activities [*FCB, March 2019, p1*]. The JV will develop, produce and market hydrogen fuel cell systems for light vehicles, commercial vehicles and trucks, and other electromobility sectors.

Michelin and Faurecia will initially invest €140 million (US$155 million) in the joint venture in order to accelerate the development of new-generation fuel cells, launch mass production, and increase business in Europe, China, and the US. The JV will eventually have three sites supplying the European, Asian, and US automotive markets.

FCH2 JU programme review report 2018

The *Programme Review Report 2018* of the EU-supported Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU, www.fch.europa.eu) [*and see the item below*], prepared by the European Commission's Joint Research Centre (JRC), has just been released [https://tinyurl.com/fchju-prog-rev-2018]. This comprehensive report reviews the activities supported by FCH2 JU, paying particular attention to the added value, effectiveness and techno-economic efficiency of FCH2 JU projects, assigned to six review panels under two main pillars – Transport and Energy – as well as Support for Market Uptake.

Two Transport panels reviewed trials and deployment of fuel cell applications, and the next generation of products; three Energy panels reviewed trials and deployment of fuel cell applications, next generation of products, and hydrogen for sectorial integration; and the Support for Market Uptake panel reviewed crosscutting activities such as standards and consumer awareness. The report includes poster presentations with details of 85 projects.

E4tech analyses hydrogen, fuel cells value

E4tech (https://tinyurl.com/e4tech-fch) has just published an analysis of the potential economic value of European fuel cell and hydrogen (FCH) manufacturing and supply (www.fch.europa.eu/page/FCH-value-chain). The study was commissioned by the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH2 JU) [*see also the above item*] and carried out in partnership with Ecorys (www.ecorys.com) and Strategic Analysis Inc (www.sainc.com).

Three study reports are available: Summary (https://tinyurl.com/fch-valuechain1), Evidence (https://tinyurl.com/fch-valuechain2), and Findings (https://tinyurl.com/fch-valuechain3).

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Patents

System and method for storing and releasing energy, e.g. hydrogen generation using SOECs, storage in liquid organic hydrogen carriers (LOHCs), use with PEMFCs

Assignee: **Hydrogenious Technologies GmbH, Germany**
Inventors: A. Bosmann et al.
Patent number: US 10396388
Published: 27 Aug. 2019 (Filed: 19 Nov. 2014)

SOFC stack with heat-exchanger between two power generation cells, which can be effectively cooled by causing fuel gas to flow through heat-exchanger

Assignee: **NGK Spark Plug Co Ltd, Japan**
Inventors: S. Tsuga et al.
Patent number: US 10396389
Published: 27 Aug. 2019 (Filed: 5 Feb. 2014)

Automotive PEMFC stack with effective discharge of fuel gas leaking out into stack casing

Assignee: **Honda Motor Co, Japan**
Inventor: H. Naito
Patent number: US 10396390
Published: 27 Aug. 2019 (Filed: 22 Feb. 2017)

Corrosion-resistant catalyst support of TiO_2 doped with metals, for enhanced stability and performance in PEM or DMFC

Assignee: **National Taiwan University of Science and Technology, Taiwan**
Inventors: V.T.T. Ho et al.
Patent number: US 10403904
Published: 3 Sep. 2019 (Filed: 16 Aug. 2017)

Structures and simple preparation methods for CCMs with improved mechanical strength for PEMFCs, no need to use solid polymer sheets

Assignees: **Daimler, Germany** *and* **Ford, USA**
Inventors: Y. Zou et al. [AFCC, Canada]
Patent number: US 10403905
Published: 3 Sep. 2019 (Filed: 12 Dec. 2016)

Fabrication of porous carbon support for Pt or Pt alloy catalyst in PEM or PAFC electrode, with low gas diffusion resistance

Assignees: **Toyota Motor Corporation, Japan** *and* **Nippon Steel Chemical & Material Co Ltd, Japan**
Inventors: Y. Itoh et al.
Patent number: US 10403906
Published: 3 Sep. 2019 (Filed: 6 Dec. 2017)

PEMFC separator with two same-thickness plates with protrusions, improves production efficiency by adopting self-aligning structure

Assignees: **Hyundai Motor Company, Korea** *and* **Kia Motors Corporation, Korea**
Inventors: S.J. Lim et al.
Patent number: US 10403907
Published: 3 Sep. 2019 (Filed: 29 June 2017)

SOFC stack structure with stable electrical contact between separator plates, configured to allow easy replacement of defective cell(s)

Assignee: **MiCo Co Ltd, Korea**
Inventors: S.J. Choi et al.
Patent number: US 10403908
Published: 3 Sep. 2019 (Filed: 21 Nov. 2013)

Corrugated PEMFC bipolar plates with multiple coplanar fluid flow channels, for reduced thickness with high power, cooling capacity

Assignee: **Intelligent Energy, UK**
Inventors: P.D. Hood et al.
Patent number: US 10403909
Published: 3 Sep. 2019 (Filed: 18 Dec. 2013)

Manufacturing automotive PEMFC stack with varied diffusion channel height to uniformly distribute reactant, improving efficiency by reducing differential pressure

Assignees: **Hyundai Motor Company, Korea** *and* **Kia Motors Corporation, Korea**
Inventors: S.M. Jin et al.
Patent number: US 10403910
Published: 3 Sep. 2019 (Filed: 17 Nov. 2015)

Anode discharge valve to prevent overpressure in hydrogen recirculation line in automotive (PEM) fuel cell system

Assignee: **Hyundai Motor Company, Korea**
Inventors: B.K. Kwon et al.
Patent number: US 10403912
Published: 3 Sep. 2019 (Filed: 19 Sep. 2016)

PEMFC device and operating method with water-transfer anode gas path, e.g. to ensure sufficient humidification when hot-restarting

Assignee: **Audi, Germany**
Inventors: M. Arendt et al.
Patent number: US 10403913
Published: 3 Sep. 2019 (Filed: 18 June 2015)

Integrated automotive PEMFC control system to remove noise between controllers and reduce costs, operating method

Assignee: **Hyundai Motor Company, Korea**
Inventors: J.T. Kim et al.
Patent number: US 10403914
Published: 3 Sep. 2019 (Filed: 30 Sep. 2016)

Technique for reducing power consumption due to purging when stopping automotive PEMFC stack

Assignee: **Toyota Motor Corporation, Japan**
Inventors: H. Saito et al.
Patent number: US 10403915
Published: 3 Sep. 2019 (Filed: 1 June 2017)

Determining PEMFC condition by calculating impedance response across frequency range

Assignee: **University of Cape Town, South Africa**
Inventor: C. De Beer
Patent number: US 10403916
Published: 3 Sep. 2019 (Filed: 24 June 2015)

Automotive PEMFC system with ammonia pump to reduce amount of ammonia in fuel gas supply, suppressing increase in pressure loss of fuel gas supplied to pump

Assignee: **Toyota Motor Corporation, Japan**
Inventor: M. Matsusue
Patent number: US 10403917
Published: 3 Sep. 2019 (Filed: 27 Nov. 2017)

Heated catalytic oxidiser for use with (PEM) fuel cell in enclosed humid environment such as UUV

Assignee: **Hamilton Sundstrand Corp, USA**
Inventors: D.G. Converse et al.
Patent number: US 10403918
Published: 3 Sep. 2019 (Filed: 1 June 2017)

PEMFC with reduced absorption of water discharged from manifold by porous body between MEA and separator, for improved drainage

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Assignee: **Toyota Motor Corporation, Japan**
Inventor: Y. Watanabe
Patent number: US 10403920
Published: 3 Sep. 2019 (Filed: 29 Oct. 2015)

SOFC stack with gas diffusion plates curved at ends to embed cell(s), with fast startup and resistant to thermal cycling

Assignee: **CEA, France**
Inventor: J. Vulliet
Patent number: US 10403921
Published: 3 Sep. 2019 (Filed: 15 Dec. 2015)

PEM with hydrophilic-hydrophobic phase separation structure controlled to form hydrophilic channel, high proton conductivity

Assignee: **LG Chem, Korea**
Inventors: E. Kang et al.
Patent number: US 10407521
Published: 10 Sep. 2019 (Filed: 4 Dec. 2015)

PEM with excellent proton conductivity, durability and acid resistance, for use in PEMFC or redox flow battery

Assignee: **LG Chem, Korea**
Inventors: S. Jung et al.
Patent number: US 10407545
Published: 10 Sep. 2019 (Filed: 28 Oct. 2015)

Highly porous cathode catalyst layer structures for flexible SOFC applications in vehicles, with mesoporous nanoionic catalyst in interconnected fibrous network

Assignee: **Nissan North America, USA**
Inventors: C. Gumeci et al.
Patent number: US 10411267
Published: 10 Sep. 2019 (Filed: 27 Nov. 2017)

PEMFC electrode catalyst layer comprising catalyst metal (e.g. Pt) particles and metal oxide spacers for enhanced ORR activity

Assignees: **Nissan Motor Co Ltd, Japan** *and* **Ishifuku Metal Industry Co Ltd, Japan**
Inventors: A. Ohma et al.
Patent number: US 10411268
Published: 10 Sep. 2019 (Filed: 10 May 2017)

Gas diffusion electrode substrate highly resistant to flooding, and to drying out at high temperature, for use in PEMFC MEA

Assignee: **Toray Industries, Japan**
Inventors: Y. Tanimura et al.
Patent number: US 10411269
Published: 10 Sep. 2019 (Filed: 17 Feb. 2015)

Bus plate unit for automotive (PEM) fuel cell system, with thin plate to reduce separation cavity and increase contact area, improving stack output density

Assignees: **Hyundai Motor Company, Korea** *and* **Kia Motors Corporation, Korea**
Inventors: D.W. Kim et al.
Patent number: US 10411270
Published: 10 Sep. 2019 (Filed: 30 Aug. 2016)

Automotive PEMFC system with separator support to ensure insulation between casing and separator even when external load is applied to casing

Assignee: **Honda Motor Co, Japan**
Inventors: S. Goto et al.
Patent number: US 10411271
Published: 10 Sep. 2019 (Filed: 15 Feb. 2018)

Optimisation of tunnel location for uniform contact pressure distribution in bipolar plate for (PEM) fuel cell

Assignee: **General Motors, USA**
Inventors: X. Yang et al.
Patent number: US 10411272
Published: 10 Sep. 2019 (Filed: 21 Oct. 2016)

PEMFC single cell structure comprising MEA with low-rigidity frame that prevents blockage of reactant gases even when frame is deformed, for more robust stack

Assignee: **Nissan Motor Co, Japan**
Inventors: K. Ichihara et al.
Patent number: US 10411273
Published: 10 Sep. 2019 (Filed: 6 Nov. 2015)

Electrochemical cell with cost-effective, automated production of joining and contact elements, for planar SOFC or SOEC stacks

Assignee: **Fraunhofer-Gesellschaft, Germany**
Inventors: S. Megel et al. [Fraunhofer IKTS]
Patent number: US 10411274
Published: 10 Sep. 2019 (Filed: 23 Mar. 2016)

Automotive PEMFC cooling system with novel structure for improved radiator heat dissipation and cathode air humidification

Assignees: **Hyundai Motor Company, Korea** *and* **Kia Motors Corporation, Korea**
Inventor: H.R. Kwon
Patent number: US 10411275
Published: 10 Sep. 2019 (Filed: 4 Dec. 2017)

SOFC with monitoring element short-circuited by bridging device, for continuous operation without interrupting cathode air flow

Assignee: **Hexis AG, Switzerland**
Inventors: R. Denzler et al.
Patent number: US 10411276
Published: 10 Sep. 2019 (Filed: 4 Nov. 2015)

Gas circuit for SOFC system, to facilitate recirculation of anode exhaust gas without significant rise in pressure in anode gas space

Assignee: **ThyssenKrupp Marine Systems GmbH, Germany**
Inventor: P. Nehter
Patent number: US 10411277
Published: 10 Sep. 2019 (Filed: 15 Dec. 2014)

Control method for anode exhaust gas recirculation in automotive PEMFC system, for efficient startup in freezing conditions

Assignee: **Nissan Motor Co, Japan**
Inventor: K. Hoshi
Patent number: US 10411279
Published: 10 Sep. 2019 (Filed: 16 June 2015)

Shutdown method for automotive PEMFC system, to stop generating power if abnormality occurs during oxygen consumption process

Assignee: **Honda Motor Co, Japan**
Inventors: K. Ojima et al.
Patent number: US 10411280
Published: 10 Sep. 2019 (Filed: 24 May 2017)

Thermally integrated SOFC system with tubular fuel reformer-combustor module wrapped around heat extractor, itself around stack

Assignee: **Precision Combustion Inc, USA**
Inventors: S. Vilekar et al.
Patent number: US 10411281
Published: 10 Sep. 2019 (Filed: 12 Feb. 2018)

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Inhibited formation of microcracks close to surface in SOFC cathode

Assignee: **NGK Insulators Ltd, Japan**
Inventor: M. Ohmori
Patent number: US 10411282
Published: 10 Sep. 2019 (Filed: 19 Dec. 2017)

PEM with hydrophilic channel, for excellent proton conductivity, durability and acid resistance in PEMFC or redox flow battery

Assignee: **LG Chem, Korea**
Inventors: Y. Kim et al.
Patent number: US 10411283
Published: 10 Sep. 2019 (Filed: 4 Dec. 2015)

Ion-exchanger that maintains ion removal efficiency in ion-exchange resin, in cooling circuit for automotive fuel cell system

Assignee: **Toyota Boshoku KK, Japan**
Inventor: J. Ohira
Patent number: US 10413897
Published: 17 Sep. 2019 (Filed: 12 July 2017)

Method for determining critical operating states in PEMFC stack

Assignee: **AVL List GmbH, Austria**
Inventors: P. Prenninger et al.
Patent number: US 10416240
Published: 17 Sep. 2019 (Filed: 18 Oct. 2018)

Highly anion resistant, non-noble metal electrocatalysts (e.g. $Fe_xN_yC_z$ in MOFs) for oxygen depolarised cathodes in PAFCs, synthesis

Assignee: **Northeastern University, USA**
Inventors: U. Tylus et al.
Patent number: US 10418639
Published: 17 Sep. 2019 (Filed: 7 Jan. 2014)

Method of manufacturing dry-laid precursor substrates with carbon fibres, for PEM and PAFCs

Assignee: **Audi, Germany**
Inventor: R.D. Breault [ClearEdge Power, USA]
Patent number: US 10418640
Published: 17 Sep. 2019 (Filed: 9 Dec. 2013)

Device and method for bonding GDL to both sides of MEA in PEMFC, preventing shrinkage deformation due to evaporation of water in MEA matrix

Assignees: **Hyundai Motor Company, Korea** *and* **Kia Motors Corporation, Korea**
Inventors: Y.G. Kim et al.
Patent number: US 10418642
Published: 17 Sep. 2019 (Filed: 18 July 2017)

Metallic bipolar plate with electrically conductive reduced graphene oxide (rGO) coating for HT-PEMFCs and electrolysis cells

Assignee: **Forschungszentrum Juelich GmbH, Germany [Jülich]**
Inventors: V. Weissbecker et al.
Patent number: US 10418643
Published: 17 Sep. 2019 (Filed: 17 Sep. 2015)

Composite bipolar plate fabricated using lamellar graphite and thermoplastic polymer, for PEM or DMFC

Assignee: **CEA, France**
Inventors: P. Buvat et al.
Patent number: US 10418644
Published: 17 Sep. 2019 (Filed: 27 May 2015)

Magnesium phosphate cement based composite material for corrosion-resistant PEMFC bipolar plates with high flexural strength

Assignee: **Nano and Advanced Materials Institute Ltd, Hong Kong**
Inventors: Z. Li et al.
Patent number: US 10418645
Published: 17 Sep. 2019 (Filed: 24 Aug. 2017)

Composite membrane containing ion transfer polymer for use in fuel cell or redox flow battery

Assignee: **LG Chem, Korea**
Inventors: S. Moon et al.
Patent number: US 10418646
Published: 17 Sep. 2019 (Filed: 23 Sep. 2015)

Production of DMFC bipolar plate by removing scrap material from electrically conductive plate

Applicant: **EnergyOr Technologies, Canada**
Inventor: T. Jones
Patent number: US 10418648
Published: 17 Sep. 2019 (Filed: 16 May 2016)

Seal plate for PEMFC stack, avoids need to discard functioning cell module when bead gasket degrades

Assignee: **Nissan Motor Co, Japan**
Inventors: Y. Numao et al.
Patent number: US 10418649
Published: 17 Sep. 2019 (Filed: 7 Mar. 2013)

Protecting sealing of separator in PEMFC, better gasket durability

Assignee: **Toyota Motor Corporation, Japan**
Inventors: T. Kurihara et al.
Patent number: US 10418650
Published: 17 Sep. 2019 (Filed: 17 Oct. 2014)

Plate-membrane humidifier for transferring water vapour between gas streams in automotive PEMFC

Assignee: **Dana Canada Corp, Canada**
Inventor: D. Vanderwees
Patent number: US 10418651
Published: 17 Sep. 2019 (Filed: 6 July 2017)

PEMFC with movable MEA to allow variable volume of anode and cathode spaces, to control pressure

Assignees: **Tsinghua University, China** *and* **Hon Hai Precision Industry Co, Taiwan**
Inventors: L.-N. Zhang et al.
Patent number: US 10418652
Published: 17 Sep. 2019 (Filed: 27 Feb. 2017)

Ventilation systems for air-cooled fuel cell systems, directing reaction exhaust away from cabinet door when it is open

Assignee: **Bloom Energy Corporation, USA**
Inventors: D. Trevisan et al.
Patent number: US 10418654
Published: 17 Sep. 2019 (Filed: 7 Sep. 2016)

PEMFC cathode catalyst layer containing heat-treated ordered mesoporous carbon, manufacturing method, use in MEA

Assignee: **Kolon Industries, Korea**
Inventors: Y.S. Kim et al.
Patent number: US 10418655
Published: 17 Sep. 2019 (Filed: 25 May 2016)

Compound comprising aromatic ring with sulfonamide and ion transport group, use in PEM for fuel cell or redox flow battery

Assignee: **LG Chem, Korea**
Inventors: Y.J. Jang et al.
Patent number: US 10418656
Published: 17 Sep. 2019 (Filed: 26 Jan. 2016)

Formation of SOFC anode, electrolyte and cathode layers by atomising slurries for spraying

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onto metal or metal oxide support, which is later removed

Assignee: **Phillips 66 Company, USA**
Inventors: Y. Liu et al.
Patent number: US 10418657
Published: 17 Sep. 2019 (Filed: 6 Oct. 2014)

Resin composition for PEMFC sealing material with suppressed detachment and deterioration

Assignee: **PANAC Co Ltd, Japan**
Inventor: S. Motoike
Patent number: US 10421828
Published: 24 Sep. 2019 (Filed: 17 Nov. 2015)

Coating polymer and inert particles on fibres in nonwoven carbon fibre network of substrate, for PEMFC gas diffusion substrate with improved corrosion resistance

Assignee: **Technical Fibre Products Ltd, UK**
Inventors: J.M. Cash et al.
Patent number: US 10424795
Published: 24 Sep. 2019 (Filed: 4 Feb. 2015)

Suppressing excessive drying of cells in automotive PEMFC system by controlling temperature increase

Assignee: **Toyota Motor Corporation, Japan**
Inventors: S. Hasegawa et al.
Patent number: US 10424796
Published: 24 Sep. 2019 (Filed: 30 June 2017)

Dynamically estimating RH and condensed water in automotive (PEM) fuel cell system, to control condensed water drain in anode

Assignees: **Hyundai Motor Company, Korea** *and* **Kia Motors Corporation, Korea**
Inventors: S.I. Jeon et al.
Patent number: US 10424798
Published: 24 Sep. 2019 (Filed: 13 Apr. 2016)

Control method to suppress drying of automotive PEMFC during continuous high-load operation

Assignee: **Toyota Motor Corporation, Japan**
Inventors: H. Imanishi et al.
Patent number: US 10424799
Published: 24 Sep. 2019 (Filed: 5 Nov. 2015)

Process for making reinforced membrane-seal assembly for PEMFC or electrolyser

Assignee: **Johnson Matthey Fuel Cells, UK**
Inventor: L.A. Sweetland
Patent number: US 10424800
Published: 24 Sep. 2019 (Filed: 8 Sep. 2016)

Cell structure for SOFC with high power generation performance and durability, manufacturing method

Assignee: **Sumitomo Electric Industries Ltd, Japan**
Inventors: T. Higashino et al.
Patent number: US 10424801
Published: 24 Sep. 2019 (Filed: 20 Oct. 2015)

Compact rechargeable device with integrated electrolyser, hydrogen storage and fuel cell functions, can be recharged using battery charger or supplying hydrogen

Assignee: **NEMESYS Srl, Italy**
Inventors: M. Matteini et al.
Patent number: US 10424802
Published: 24 Sep. 2019 (Filed: 11 Apr. 2017)

Preventing moisture from condensing inside stack housing for automotive PEMFC system

Assignees: **Hyundai Motor Company, Korea** *and* **Kia Motors Corporation, Korea**
Inventors: J.H. Yu et al.
Patent number: US 10424807
Published: 24 Sep. 2019 (Filed: 29 Aug. 2017)

Highly active, less expensive electrocatalyst for PEMFC, with Pt shell and two-layer core containing oxide with defects, manufacturing

Assignees: **Toyota Motor Corp, Japan** *and* **University of Miyazaki, Japan**
Inventors: G. Sakai et al.
Patent number: US 10431831
Published: 1 Oct. 2019 (Filed: 13 Apr. 2017)

Stainless-steel foil coated with metal strike and Sn alloy layers, for excellent corrosion resistance and adhesion in PEMFC separator

Assignee: **JFE Steel Corporation, Japan**
Inventors: T. Yano et al.
Patent number: US 10431832
Published: 1 Oct. 2019 (Filed: 29 Jan. 2015)

Coatings for metal interconnects to reduce SOFC degradation, plasma spraying air side of interconnect with $(Mn, Cr, Co)_3O_4$ spinel coating

Assignee: **Bloom Energy Corporation, USA**
Inventors: J. Wilson et al.
Patent number: US 10431833
Published: 1 Oct. 2019 (Filed: 1 Mar. 2012)

Automotive PEMFC system with improved valve control, with valve element pressed against valve seat

Assignee: **Toyota Motor Corporation, Japan**
Inventors: T. Yamanaka et al.
Patent number: US 10431834
Published: 1 Oct. 2019 (Filed: 16 June 2017)

Control of fuel cell and battery power output and charging in automotive PEMFC system, for improved overall power efficiency

Assignee: **Honda Motor Co, Japan**
Inventor: S. Kazuno
Patent number: US 10431836
Published: 1 Oct. 2019 (Filed: 8 Mar. 2017)

MEA with low sensitivity to RH variations, via different substrate and microporous coatings on anode and cathode GDLs, for improved water management in PEMFC

Assignee: **SGL Carbon, Germany**
Inventor: R.-B. Schweiss
Patent number: US 10431837
Published: 1 Oct. 2019 (Filed: 2 July 2015)

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EVENTS CALENDAR

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

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

4–5 March 2020
4th ACI Hydrogen & Fuel Cells Energy Summit 2020
Lisbon, Portugal
More information: www.wplgroup.com/aci/event/hydrogen-fuel-cells-energy-summit

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

1–2 April 2020
f-cell + HFC Vancouver 2020, The Hydrogen and Fuel Cell Event [and see f-cell 2020 on 29–30 September in Stuttgart, Germany]
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 extended: 20 December 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

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

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

25–27 May 2020
9th Meeting of Electrochemistry in Nanoscience, ElecNano9: Electrochemistry for Nano & Nano for Electrochemistry
Paris, France
More information:
http://elecnano.univ-paris-diderot.fr

14–17 June 2020
33rd World Electric Vehicle Symposium & Exposition, EVS33
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

28 June–2 July 2020
17th International Symposium on Polymer Electrolytes, ISPE-17
Niagara-on-the-Lake, Ontario, Canada
Email: ISPE17.2019@gmail.com

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

5–9 July 2020
23rd World Hydrogen Energy Conference (WHEC 2020), including 11th International Conference on Hydrogen Production (ICH2P-2020)
Istanbul, Turkey
More information: www.whec2020.org

25–26 July 2020
Gordon Research *Seminar* on Fuel Cells: Experimental and Theoretical Characterization of Fuel Cell Materials and Electrodes
Bryant University, Rhode Island, USA
More information:
www.grc.org/fuel-cells-grs-conference/2020
Abstract deadline: 25 April 2020

26–31 July 2020
Gordon Research *Conference* on Fuel Cells: Integrating Theory, Synthesis, Characterization and Validation for the Advancement of Fuel Cell Research
Bryant University, Rhode Island, USA
More information:
www.grc.org/fuel-cells-conference/2020

30 August–4 September 2020
71st Annual Meeting of the International Society of Electrochemistry, including Symposium 9: Fuel Cells and Electrolysis: Promising Energy for the Future
Belgrade, Serbia
More information:
https://annual71.ise-online.org

23–25 September 2020
Electrochemistry 2020: At the Interface between Chemistry and Physics
Berlin, Germany
More information: https://veranstaltungen.gdch.de/tms/frontend/index.cfm?l=9169
Abstract deadline: 12 April 2020

29–30 September 2020
f-cell 2020: The Impulse Summit for Hydrogen and Fuel Cells [and see f-cell + HFC Vancouver on 1–2 April, in Canada]
Stuttgart, Germany
More information: www.f-cell.de

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