

FUEL CELL POWER

*The transition from combustion to clean
electrochemical energy conversion*



HEADLINE NEWS

The world's first hydrogen fuel cell double decker buses have been delivered to the City of Aberdeen. Wrightbus is following this up with orders from several UK cities.

The Scottish Government is supporting the move to zero emission transport prior to the meeting of COP26 in Glasgow later this year.

The United Nations states that the world is nowhere close to the level of action needed to stop dangerous climate change. 2021 is a make or break year to deal with the global climate emergency.

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HYDROGEN FUEL CELL BUSES IN UK CITIES

WORLD'S FIRST HYDROGEN FUEL CELL DOUBLE DECKER BUS IN ABERDEEN

The first customer for the Wrightbus hydrogen fuel cell double decker is the City of Aberdeen. The arrival of the first of the zero emission buses shows the City's commitment to the transition to green energy from oil and gas as part of their Net Zero Vision.

Councillor Douglas Lumsden is seen on left, with Councillor Jenny Laing and Jo Bamford, of Wrightbus and Ryse Hydrogen.

The hydrogen fuel cell buses are as efficient as battery electric equivalents. Refuelling takes less than 10 minutes and they offer a greater range. Water is the only emission from the vehicles which reduces carbon emissions. The new buses continue to contribute to the city's commitment to tackling air pollution.

The UK's first hydrogen production and bus refuelling station was opened in Aberdeen in 2015, as part of a £19million green transport demonstration project. The Aberdeen City Council-led project tested the economic and environmental benefits of hydrogen transport and aims to drive the development of hydrogen technologies. In addition to funding from the European Union, the new £8.3million project reported here has been funded by Aberdeen City Council and the Scottish Government with a total investment of about £500,000 per vehicle.

Councillor Jenny Laing said: "The new buses come with even more advanced technology which pushes established hydrogen boundaries and greatly assists us

in tackling air pollution in the city." Councillor Douglas Lumsden added: "It is fantastic to see the world's first hydrogen-powered double decker bus arrive in Aberdeen. These buses will complement the existing fleet that the City of Aberdeen already has. These include a range of hydrogen and electric vans, road sweepers, and cars in a car share scheme. We are responding as a world leader in the energy sector as an economic driver for the city, region, Scotland and the UK."

First Aberdeen, part of the multinational company *First Group* which originated in Aberdeen, is to run the 15 buses along one of its most popular service routes.

David Phillips, Operations Director for *First Aberdeen*, said: "We are delighted to be operating these state-of-the-art double decker hydrogen buses in partnership with Aberdeen City Council. *First Aberdeen* are committed to working with local stakeholders to accelerate our drive for a zero emission fleet across our entire network by 2035."

GREEN HYDROGEN PRODUCTION

Scottish energy firm Hy2Go is developing a plant which will harness solar and wind power to produce green hydrogen. They aim to have the facility partially up and running later in 2021 in time to provide Scottish hydrogen fuel to transport COP26 delegates around Glasgow.

The plant in Lanarkshire will have its own wind turbines and solar panels which will feed a 9MW hydrogen electrolyser, with the capacity to increase the electrolyser size to 20MW. The facility will initially produce 800,000 kg of hydrogen per annum, with production eventually increasing to 1 million kg per annum.

The hydrogen fuel cell double decker buses have been manufactured by Wrightbus in Northern Ireland. They are seen here on the assembly line at the Wrightbus factory.

Jo Bamford of Wrightbus and Ryse Hydrogen said: "These buses represent the start of what could be a world-leading hydrogen economy. Our buses hold the title of being the world's first zero-emission hydrogen fuel-cell double deckers and emit only water vapour."

The vehicles will be part funded by the European Union's Joint Initiative for Hydrogen Vehicles across Europe (JIVE) project, which aims to aid the commercialisation of hydrogen

buses through joint procurement between cities. The first cities using these buses include Aberdeen, London and Birmingham, with Dundee and Brighton and Hove being lead partners in JIVE2.

20 HYDROGEN FUEL CELL DOUBLE DECKER BUSES FOR BIRMINGHAM

Birmingham City Council has purchased 20 hydrogen double decker buses from Wrightbus, as part of their Clean Air Hydrogen Bus Pilot. These buses are the world's first zero-emission hydrogen fuel-cell double deckers. The pilot project aims to 'kick-start' the market for hydrogen as a viable zero-emission fuel. The buses will be introduced with National Express West Midlands from April 2021.

It is intended that the pilot project will be the catalyst for the development of the next generation of hydrogen buses, hydrogen production and re-fuelling infrastructure. The Council have also collaborated with ITM Power, who will be producing and dispensing the hydrogen from the new re-fuelling hub at Tyseley Energy Park.



Hydrogen fuel cell buses consume less fuel than standard diesel buses. They cover 300 miles on a single tank and can be refuelled within 7-10 minutes. They only emit water vapour, so no carbon dioxide or other harmful gases are being pumped into the air. Hailed as another solution to tackling the city's poor air quality and a key step towards achieving the council's net zero carbon target, each bus is expected to save up to 80 tons of carbon dioxide emissions per annum.

Jo Bamford of Wrightbus said: "We're incredibly proud that these buses hold the title of being the world's first zero-emission hydrogen fuel-cell double deckers, and we're delighted that Birmingham City Council has recognised the benefits that this technology can bring to the city. We have an opportunity with hydrogen-powered transport to make a huge difference to air quality. This fleet of buses also represents the start of what could be a world-leading UK hydrogen economy which will bring with it multi-million-pound investments and tens of thousands of jobs."

Tom Stables of National Express UK said: "National Express West Midlands announced earlier this year that our entire bus fleet will be zero-emission by 2030 and we are already operating 29 fully electric buses in Birmingham, Solihull and Coventry."

By operating hydrogen double deckers in service in Birmingham, we will learn which routes lend themselves to hydrogen buses and what the mix of vehicles in our fleet should be going forward. These new buses will be fitted out in our top-spec Platinum range, so customers will also benefit from free Wi-Fi, USB chargers and extra legroom. Because there is no engine, they are super-quiet, and of course, all that comes out of the exhaust is water vapour."

The development will see the start of fuel cell technology supply chains within the region and will help to support a brand-new service and maintenance apprenticeship programme. In addition to the European Union it is funded by OLEV (Office for Low Emission Vehicles) and the Greater Birmingham & Solihull Local Enterprise Partnership and Birmingham City Council.

RYSE HYDROGEN'S CLEAN ENERGY TRENDS FOR 2021

Ryse Hydrogen has always championed a mix of renewable energy sources if we are to reach our emissions targets. Most of the world's hydrogen being made and used now is 'grey'. This is the cheapest option, a by-product of natural gas. However, as renewable energy and clean hydrogen technology prices fall, and with gas prices forecast to rise this is the decade that will see green hydrogen production rise significantly, playing a key role in the clean energy landscape.

The UK Government's 10 point green recovery plan proposes to generate 5GW of low carbon hydrogen production capacity by 2030. This will provide enough to power about 1.5 million homes and also be used to reduce carbon emissions from transport, industry, and heating. The Government needs to release a UK Hydrogen Strategy, along with a deeper commitment to hydrogen generally. Countries like Australia, Germany, Norway and Japan have had their strategies underway for some time.

Ryse Hydrogen is building the U.K.'s first network of green hydrogen production plants. Ryse supplies organisations operating heavy duty and long range fleets, seeking a simple and affordable conversion to green hydrogen. We can obtain green hydrogen from several sources.

Tidal power is hugely underdeveloped in the UK. The UK's coastlines have 35% of Europe's wave energy and 50% of its tidal energy. The global market could grow to £76 billion by 2050 if the UK grasped the natural benefits of being surrounded by ocean. By nature, both wave and tidal are predictable and consistent power sources that can help balance other intermittent renewable energy generators.

30% of the UK's electricity was generated by wind power in the first quarter of 2020. The Prime Minister recently committed £160 million towards wind power and pledged that offshore wind will be powering every home in the country within a decade. This commitment however is insignificant considering the private investments pushing wind to the top of the energy generation pile in the UK. More than £20bn has gone into offshore wind in the UK since 2016. This represents massive progress towards net zero energy stability.

Bioenergy made up 11.3% of UK power generation in 2019 and 16.7% of capacity according to the Department of Business Energy and Industrial Strategy. After wind power bioenergy is the second biggest clean power generator in the UK. As part of the effort to reach net zero by 2050 bioenergy will therefore be crucial.

The UK is the sixth largest worldwide solar power generator. Private investors continue to grow the industry as solar has not received much government support. As solar technology continues to advance rapidly it will become less expensive and more efficient. Hydropower is reliable, cost-efficient and clean and is an important contributor to the UK's clean energy mix. Around 5% of renewable electricity generation in 2018 was attributed to hydro. www.ryse.team

ZEROAVIA'S FUEL CELL POWERED PASSENGER PLANE FLIGHT

ZeroAvia, the leading innovator in decarbonising commercial aviation, has completed the world's first hydrogen fuel cell powered flight of a commercial-grade aircraft. The flight took place at the company's R&D facility in Cranfield, England, with the Piper M-class six-seat plane completing taxi, takeoff, a full pattern circuit, and landing.

ZeroAvia's achievement is the first step to realising the transformational possibilities of moving from fossil fuels to zero-emission hydrogen as the primary energy source for commercial aviation. Eventually, and without any new fundamental science required, hydrogen-powered aircraft will match the flight distances and payload of the current fossil fuel aircraft.

This major milestone on the road to commercial zero-emission flight is part of the HyFlyer project, a sequential R&D programme supported by the UK Government. ZeroAvia will now turn its attention to the final stage of its six-seat development program - a 250-mile zero emission flight out of an airfield in Orkney. The demonstration of this range is roughly equivalent to busy major routes such as London to Edinburgh.

Val Miftakhov, CEO, ZeroAvia commented: "While some experimental aircraft have flown using hydrogen fuel cells as a power source, the size of this commercially available aircraft shows that paying passengers could be boarding a truly zero-emission flight very soon. All of the team at ZeroAvia and at our partner companies can be proud of their work getting us to this point, and I want to also thank our investors and the UK Government for their support."

Aviation Minister Robert Courts said: "ZeroAvia's fantastic technology takes us all one step closer to a sustainable future for air travel. Through our ground-breaking

Jet Zero partnership we are working with industry to drive innovation in zero carbon flight, and we look forward to seeing the sector go from strength to strength." Prime Minister, Boris Johnson, has invited ZeroAvia to join the UK's JetZero Council, in order to help lead the UK towards the goal of achieving the first zero emission long haul passenger flight.

ZeroAvia's innovation programme in the UK is part-funded through the UK Government's Aerospace Technology Institute (ATI) Programme. Through the HyFlyer project, ZeroAvia is working with key partners, the European Marine Energy Centre (EMEC) and Intelligent Energy, to decarbonise medium-range small passenger aircraft by demonstrating powertrain technology to replace conventional engines in propeller aircraft. Intelligent Energy will optimise its high power fuel cell technology for application in aviation whilst EMEC, producers of green hydrogen from renewable energy, will supply the hydrogen required for flight tests and develop a mobile refuelling platform compatible with the plane.

In addition to the work on the aircraft ZeroAvia and EMEC have developed the Hydrogen Airport Refuelling Ecosystem at Cranfield Airport. This is a microcosm of what the hydrogen airport ecosystem will look like in terms of green hydrogen production, storage, refuelling and fuel cell powered flight. This also marks another world's first - a fully operational hydrogen production and refuelling airport facility for commercial aircraft propulsion.

The Piper M-class plane was illustrated in the *Fuel Cell Power* winter 2019 issue. A video of the first hydrogen fuel cell flight can be seen on ZeroAvia's website.

www.zeroavia.com

INTELLIGENT ENERGY'S FUEL CELL INTEGRATED INTO LATEST UAV FROM ISS AEROSPACE

Intelligent Energy, the market leader for lightweight Fuel Cell Power Modules, welcomes the news that its 2.4kW fuel cell has been integrated into UK-based ISS Aerospace's heavy lift fuel cell powered unmanned aerial vehicle (UAV), which has achieved a flight time of 100 minutes.



Intelligent Energy offers the lightest and most power dense, certified products available on the market. As well as their compact design, the products offer many advantages for commercial and military UAV users, including providing a solution to the current issue of endurance for companies that need longer flight times, like inspection services, parcel delivery and military applications.

ISS Aerospace identified Intelligent Energy's fuel cells as being the ideal power product to improve UAV operator efficiency by significantly extending flight duration compared to that offered by Lithium Polymer (LiPo) batteries.

Ryan Kempley of ISS commented: "We were excited to be one of the development partners in the 2.4 kW project as Intelligent Energy's hydrogen fuel cells have been a game changer achieving impressive gains in endurance, with 100 minutes of continuous flight time carrying an 8kg payload.

We were only able to achieve 25 to 40 minutes using LiPo batteries. Having the ability to fly for such a considerable amount of time opens up many possibilities for wide area and extensive operations.

We have found the refuelling process of the hydrogen cylinders to be simple and quick, meaning we can be back up in the air in the matter of a few minutes rather than experiencing the lengthy re-charge times that you get with batteries."

Intelligent Energy's new regulator valve enables unmanned aerial vehicles (UAVs) to transport full hydrogen cylinders and is certified for use in Europe and the US. Without this valve the transportation of full, UAV compatible, hydrogen cylinders is not permitted, which in turn has a significant impact on the time and cost required to complete an operation.

Andy Kelly, Head of UAV Product Development at Intelligent Energy said "This high-pressure valve has been developed by Pressure Tech specifically to requirements set out by Intelligent Energy and its customers." www.intelligent-energy.com

BLOOM ENERGY ANNOUNCES STRATEGY FOR HYDROGEN

Bloom Energy is entering the commercial hydrogen market by introducing hydrogen-powered fuel cells and electrolyzers that produce renewable hydrogen. Bloom has improved the efficiency and reduced the cost of its products and expects this trend to continue. This, combined with the rapidly reducing cost of bulk solar and wind power, should make the hydrogen generated with Bloom electrolyzers reach the U.S. Department of Energy's goal of gasoline price parity faster than other technologies.

Professor Jack Brouwer, director of the National Fuel Cell Research Center at the University of California, Irvine said: "Generating low-cost hydrogen from intermittent renewables is a *sine qua non* for decarbonization. Solid oxide electrolyzers hold the greatest potential to generate low-cost green hydrogen because of their superior efficiency, rapidly declining costs, and scalability. Achieving zero emissions in many sectors will depend upon making massive amounts of renewable hydrogen."

SOCALGAS POWERING TWO LOS ANGELES FACILITIES WITH BLOOM ALWAYS ON MICROGRIDS

In the Los Angeles area the Southern California Gas Company (SoCalGas) has begun powering two of its largest facilities with Bloom Energy solid oxide fuel cells. The switch to fuel cells will reduce greenhouse gas emissions, air pollutants and the cost of power, as well as provide reliable electricity independent of the power grid.

The company selected the fuel cells for its Monterey Park and Pico Rivera facilities because of their superior resiliency. To produce electricity, Bloom Energy's fuel

cells can use natural gas, renewable natural gas, or hydrogen. Bloom Energy Servers can operate at 60% efficiency and are considered one of the most efficient power solutions currently available. Maryam Brown, president of SoCalGas said: "These onsite generation systems will provide clean, affordable and resilient energy to key facilities so that we can ensure safe and reliable service to our 22 million customers." The Bloom Energy Servers at each of SoCalGas' facilities total 950 kilowatts in size. They replace over 90% of the baseload power that would otherwise come from the grid.

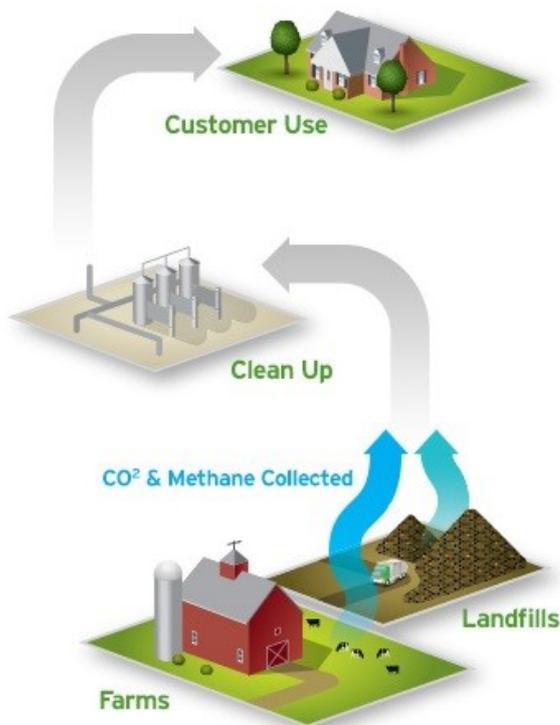
In addition to providing cost savings and improving reliability of power, the fuel cells will lead to a reduction in carbon emissions of 683 metric tons per year compared to the current grid profile. Because no fuel is burned to produce the electricity, smog-forming pollutants and particulate matter are reduced by more than 99%. Because they virtually eliminate all combustion-related pollutants, the California Air Resources Board has certified the Bloom Energy Servers as a Distributed Generation Technology that does not require a generation permit, a designation given only to the cleanest technologies in the state.

Adoption of distributed power generation solutions is a growing trend in the U.S. These solutions can combine environmental benefits and the ability to provide uninterrupted power in the event of natural disasters or outages. The Servers are configured as AlwaysON Microgrids operating alongside the main grid and operating independently during an outage. Bloom Energy has deployed its Servers at 600 sites globally, and more than 85 of those are microgrids, which have provided power through more than 1,500 outages.

The environmental benefits of switching to fuel cells at these facilities are part of SoCalGas' vision to support a 21st century energy system that provides clean, affordable, resilient and integrated energy. As part of its vision, the utility last year committed to replacing five percent of natural gas supplies to its core customers with renewable natural gas from sources like dairies, wastewater treatment plants and landfill by 2022 and 20% by 2030.

RECYCLED NATURAL GAS IS CARBON NEUTRAL

Renewable natural gas is a carbon neutral fuel because it comes from organic sources that once absorbed carbon dioxide from the atmosphere during photosynthesis. It has even greater benefits when it is produced from organic waste that would otherwise decay and emit greenhouse gas emissions into the atmosphere. By capturing more greenhouse gases than it emits, this gas can be considered carbon neutral.



Courtesy American Gas Association

HYDROGEN FORWARD COALITION

A coalition of eleven companies have partnered to form Hydrogen Forward, an initiative focused on advancing hydrogen development in the United States. The founding members – Air Liquide, Anglo American, Bloom Energy, CF Industries, Chart Industries, Cummins Inc., Hyundai, Linde, McDermott, Shell and Toyota – are united under a shared belief in the environmental and economic benefits of hydrogen technologies. These companies believe that accelerating investment in hydrogen will help the U.S. deliver on its climate goals while creating a stronger economy.

Produced domestically with low or no carbon footprint, hydrogen can help decarbonize large segments of the economy, including shipping and transportation, power generation, refining, steelmaking, chemical production, mining, manufacturing and other industries.

From the manufacturing and sale of hydrogen fuel cell electric vehicles (FCEVs) to supporting the fuelling stations that keep FCEVs moving, Hydrogen Forward members are on the leading edge of transportation innovation. Likewise, the hydrogen storage solutions of member companies and their partnerships with local utility companies are helping to harness renewable energy and decarbonize the power generation sector. While Europe and East Asia have committed to investing hundreds of billions of dollars into hydrogen solutions, the U.S. is the only major market without a national hydrogen strategy.

“We must embrace hydrogen if we are to meet our ambitious decarbonization goals” said K R Sridhar of Bloom Energy. Jillian Evanko of Chart Industries added: “Chart Industries has been producing hydrogen-related equipment for over 50 years, and we are continuing to discover its many applications as a safe, reliable and versatile fuel.”

BLOOM ENERGY DEPLOYING MULTI-MEGAWATT SOFC FUEL CELLS IN SOUTH KOREA

In 2019 the Government of South Korea released a Hydrogen Economy Roadmap calling for 15,000 megawatts of stationary fuel cells, 6.2 million hydrogen vehicles and 1,200 hydrogen charging stations to be in operation by 2040. This Bloom Energy power plant is a 19.8 MW Energy Server deployed in the historic city of Hwasung,



This is the largest Bloom Energy fuel cell system in South Korea to date and the company's second largest in the world.

The solid oxide fuel cell (SOFC) provides a new source of electricity to meet growing energy demand. This facility alone is designed to generate enough electricity to power approximately 43,000 homes in the area. Another plant is an 8.1 megawatt deployment of Bloom Energy Servers in the City of Paju. This is designed to power nearly 18,000 homes in the area with clean and reliable energy.

This is just the beginning. South Korea has introduced several initiatives to increase power generation from renewable and new technologies. Bloom Energy's partner is SK Engineering and Construction (SK E&C) which is an affiliate of the SK Group, the leading oil and gas provider in Korea with 3,400 gas companies. They won a competitive RE100 contract to supply SOFC powered by 100 percent hydrogen to the industrial complex in Changwon. RE100 is a global renewable energy initiative led by the Climate Group to accelerate the move toward zero-carbon electricity grids.

The Changwon RE100 proposal is aimed at identifying and selecting partners to contribute to a fully renewable ecosystem in Korea. Bloom Energy will supply 1.8 megawatts of hydrogen-powered fuel cells which will be the cornerstone of a microgrid that also includes onsite solar and battery storage.

In addition, Bloom Energy intends to supply its solid oxide electrolyzer cells (SOEC) to this site in 2022. These will be capable of producing green hydrogen from solar energy which can be stored in batteries as needed. The green hydrogen produced by the SOEC is created through electrolysis of water by using the renewable electricity. This hydrogen will be used to power the hydrogen SOFC. There are no carbon emissions.

Jason Ahn of SK E&C said: "SK E&C and Bloom Energy are paving the way towards a zero-carbon energy future. With a projected domestic deployment of 8.4 gigawatts of stationary fuel cells, coupled with an additional 6.6 gigawatts for international export, Korea is trailblazing the hydrogen economy."

KRAFT GROUP ACHIEVES SUSTAINABILITY AT GILLETTE STADIUM

The Kraft Group is providing sustainable energy at Gillette Stadium with fuel cells from Bloom Energy. Gillette Stadium is the premier sports and entertainment venue in New England. The stadium attracts summer concerts, hosts an array of sporting events and operates with office and function space that is utilized year-round.

Bloom Energy Servers provide the stadium with two megawatts of power, supplying nearly 50 percent of the 65,878-seat stadium's energy needs. The use of Bloom Energy solid oxide fuel cells is expected to reduce the emission of nearly 1,500 metric tons of CO₂ each year.

Dan Middleton of Bloom Energy said "Professional sports teams have the ability to leverage their visibility and following to drive social impact in the communities that support them. The Kraft Group is leading the charge for sustainability, minimizing its own environmental impact by utilizing all available technologies, and serving as a role model for other organizations to follow." "Good business and sustainability go hand in hand," said Jim Nolan of Gillette Stadium. "The addition of Bloom Energy Servers provides power that is not only clean, but also reliable and always-on for stadium-goers and the community."

The Bloom Energy Servers were installed in a microgrid-ready configuration, allowing the stadium to easily upgrade to a microgrid that can disconnect from the traditional grid to operate autonomously. Bloom's AlwaysON Microgrid provides enhanced resiliency in the face of grid outages and extreme weather events, along with predictable energy costs.

Planning for the future in this way aligns with the Kraft Group's goal for Gillette Stadium to be the first stadium in the world to operate independently of the traditional electric grid.

www.bloomenergy.com

NEWS

FUEL CELLS POWER NATIONAL GRID LINK

Danish electricity operator, Energinet, will build a 1.4 GW high voltage electricity interconnector to the National Grid's UK Viking Link construction site in Lincolnshire. Siemens Energy and partner GeoPura are installing a zero-emission hydrogen fuel cell to provide off grid power to the project's construction site.

The hydrogen fuel cell will provide the electricity and heat for around 20 cabins across the construction area. These will be used by Siemens Energy employees and contractors, as works start on the converter station. The fuel cell system is based on a 20ft shipping container which houses the equipment needed to convert the hydrogen into electricity and heat.

The development of the fuel cell was undertaken at Siemens Energy's site in Newcastle by GeoPura. It uses state of the art Siemens Energy monitoring and control for critical power applications and is now able to be manufactured in Newcastle in greater quantity. www.siemens.com

HYDROFLEX TRIALS ON MAINLINE RAILWAY

HydroFLEX, Britain's first hydrogen powered train, has started operational trials on the mainline railway. This is the culmination of two years development work and more than a million pounds investment in HydroFLEX by both Porterbrook and the University of Birmingham. Porterbrook has also announced plans to start putting HydroFLEX into production, in response to customer demand. The production version will be configured for operation using both overhead-electric-wires and hydrogen for non-electrified routes. This will make HydroFLEX particularly attractive to regions and routes where there is only partial electrification of the network. www.porterbrook.co.uk

HYDROGEN STORED AS MAGNESIUM HYDRIDE PASTE

There is great potential for hydrogen to replace gasoline and diesel in order to meet climate change targets. Most hydrogen fuel cell vehicles are equipped with a reinforced tank that is fuelled at a pressure of 700 bar. In the case of passenger cars, this technology is well advanced, with several hundred hydrogen-powered automobiles already in operation on German roads. At the same time, the network of hydrogen stations in Germany is projected to grow from 100 to 400 over the next three years. However, hydrogen is not currently an option for small vehicles such as electric scooters and motorcycles because the pressure surge during refilling would be too great.

Researchers from the Fraunhofer Institute in Dresden have now come up with a hydrogen-based fuel that is ideal for small vehicles. Dr. Marcus Vogt, research associate at Fraunhofer said: "POWERPASTE, which is based on solid magnesium hydride, stores hydrogen in a chemical form at room temperature and atmospheric pressure to be then released on demand." Given that the paste only begins to decompose at temperatures of around 250 °C, it remains safe even when an e-scooter stands in the baking sun for hours. Moreover, refuelling is extremely simple as riders only have to replace an empty cartridge with a new one and then refill a tank with mains water. This can be done either at home or during the journey.

Magnesium is one of the most abundant and easily available elements. Magnesium powder is combined with hydrogen to form magnesium hydride in a process conducted at 350 °C and five to six times atmospheric pressure. Onboard the vehicle, the paste is released from a cartridge by means of a plunger.

When water is added from an onboard tank, the ensuing reaction generates hydrogen gas in a quantity dynamically adjusted to the actual requirements of the fuel cell.

In fact, only half of the hydrogen originates from the paste; the rest comes from the added water. "POWERPASTE thus has a huge energy storage density," says Vogt. "It is substantially higher than that of a 700 bar high-pressure tank. Compared to batteries, it has ten times the energy storage density." This means that the paste offers a range comparable to or even greater than gasoline and also provides a higher range than compressed hydrogen at a pressure of 700 bar.

With its huge energy storage density, this paste is an interesting option for cars, delivery vehicles and range extenders in battery-powered electric vehicles. It could also significantly extend the flight time of large drones, which would thereby be able to fly for several hours rather than a mere 20 minutes. This would be especially useful for survey work, such as the inspection of forestry or power lines.

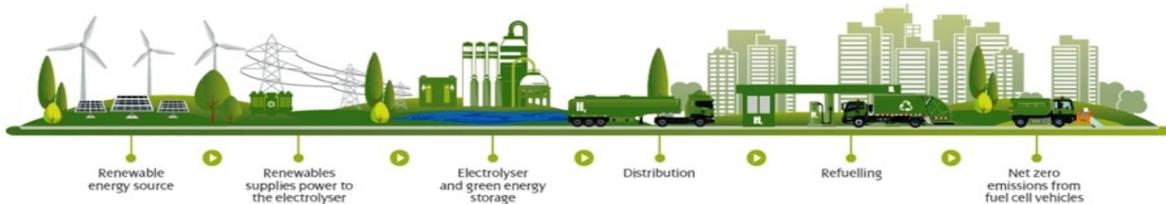
Unlike gaseous hydrogen, POWERPASTE does not require a costly infrastructure. This makes it ideal for use in places where there are no hydrogen stations. Regular filling stations could sell the paste in cartridges or canisters. This would cost much less than the equipment required to pump hydrogen at high pressure. The paste is also cheap to transport because no costly high-pressure tanks are involved nor the use of extremely cold liquid hydrogen.

The Fraunhofer Institute is currently building a production plant for POWERPASTE which is scheduled to go into operation in 2021 and will be able to produce up to four tons of paste per year.

www.ifam-dd.fraunhofer.de

ITM EXPANDING LOCAL PRODUCTION OF ZERO CARBON HYDROGEN

GREEN HYDROGEN FOR SCOTLAND



A partnership of ScottishPower Renewables, BOC (a Linde company) and ITM Power has been set up to create new green hydrogen production facilities with clusters of refuelling stations across Scotland. The partnership will provide facilities for producing renewable energy, electrolysis for producing hydrogen, storing and distributing the hydrogen and providing it for use in zero emission fuel cell vehicles. The partnership's first project 'Green Hydrogen for Glasgow' is designed to provide carbon-free transport and clean air for communities across the city. Glasgow City Council is committed to creating a zero emissions vehicle fleet, using only electric and hydrogen powered vehicles by the end of 2029.

Hydrogen is particularly suitable for larger vehicles, such as buses and trucks. It offers a much better vehicle power-to-weight ratio than batteries, which makes it possible to travel long distances without significantly increasing vehicle weight. The new facilities planned by 'Green Hydrogen for Scotland' will ensure the zero emission fuel is readily available to organisations such as local authorities and others with fleets of heavy duty vehicles.

www.itm-power.com

GIGAFACTORY AT SHEFFIELD UK

ITM is making a step change in manufacturing volumes as they move into their 1 GW (1,000MW) per annum electrolyser production facility. The Gigafactory has large stack manufacturing and production areas and a dedicated ATEX safety rated space for factory acceptance testing of products. The Gigafactory houses the 24hour remote and technical monitoring centre that will support ITM Power's after-sales services. There is also a Hydrogen Academy to support the training of apprentices, local engineers and customers. The Gigafactory delivers a blueprint for a high capacity, semi-automated PEM electrolyser manufacturing facility, which can be readily replicated, enabling a local facility to be planned and rapidly deployed in response to large order volumes.



ALSTOM HYDROGEN FUEL CELL TRAINS

SIX FUEL CELL TRAINS FOR ITALY

Alstom will supply six hydrogen fuel cell trains, with the option for eight more, to Ferrovie Nord Milano, the main transport and mobility group in the Italian region of Lombardy,

The new hydrogen trains will be based on Alstom's Coradia Stream regional train, which is already being produced for Italy. It will be equipped with the same fuel cell

propulsion technology that was introduced to the world by the Coradia iLint.

The hydrogen Coradia will maintain the high standards of comfort already appreciated by passengers of its electric version and will match the operational performance of diesel trains, including their range.

These trains, together with the Coradia iLint that have already proven themselves in commercial service in Germany, represent another major step in the transition towards global sustainable transport systems.

The Coradia iLint is the world's first passenger train powered by a hydrogen fuel cell, which produces electrical power for traction. This zero-emission train emits low levels of noise, with exhaust being only steam and condensed water. The iLint is special for its combination of different innovative elements: clean energy conversion, flexible energy storage in batteries, and smart management of traction power and available energy. Specifically designed for operation on non-electrified lines, it enables clean, sustainable train operation with high levels of performance.



FIRST HYDROGEN FILLING STATION FOR TRAINS IN HESSE

From December 2022 the first hydrogen filling station for passenger trains in Hesse and the second worldwide, will supply the world's largest fuel cell train fleet for passenger traffic. Alstom is supplying the fuel cell trains that the Rhein-Main Transport Association will use, while Infracore Höchst, the operator of the local industrial park, is building and operating the filling station.

State Secretary Deutschendorf said "Hesse is a pacemaker on the way to climate and environmentally friendly mobility. In 2022 pollutant-free fuel cell trains will replace the old diesel vehicles there - an electric operation without overhead lines, which could also be an interesting alternative for other regions. I would like to thank Rhein-Main Transport and Industriepark Höchst for their courage in realizing this innovative project."

For the Rhine-Main transport association, the project has a very special significance. "With Alstom's fuel cell trains, we are opening up a new chapter of emission-free mobility," said Managing Director Prof. Knut Ringat. "With the 27 vehicles, we are setting a world record: nowhere else is there such a large fuel cell fleet in local public transport."

This heralds a new era in emission-free rail traffic in the Rhine-Main region. Thanks to a range of up to 1,000 kilometres, the Coradia iLint can travel an entire day replacing diesel-powered locomotives. The world's first passenger train powered by a hydrogen fuel cell runs completely emission-free, is quiet and emits only water vapor and condensation. Infraserb Höchst has been active in hydrogen and fuel cell technology for many years, with their first hydrogen filling station for cars operating since 2006.

SUCCESSFUL EVALUATION OF HYDROGEN FUEL CELL TRAIN IN THE NETHERLANDS

The Province of Groningen has published a report outlining the results of the Coradia iLint tests performed on the 65 kilometers of line between Groningen and Leeuwarden in the north of the Netherlands. The tests aimed to investigate whether a hydrogen fuel cell train could be a fully sustainable alternative to the diesel trains currently running in the northern part of the country.

Alstom's hydrogen train has been extensively tested with the Province of Groningen operator Ariva, the Dutch railway infrastructure manager ProRail and the energy company Engie. DEKRA, an independent testing inspection and certification company, was the test leader.



The report states that Alstom's hydrogen train has successfully met the four objectives of the test frame:

- 1) authorisation by the Dutch National Safety Assessor to run on the Dutch railway network
- 2) fully zero emissions
- 3) perfectly fitting the commercial service of the current timetable, with quick and easy refuelling
- 4) familiarising local people with hydrogen mobility.

Bernard Belvaux, Managing Director, Alstom Benelux said: "After Germany, the Netherlands is the second country in Europe where Alstom's hydrogen train has proven itself a unique emissions-free solution for non-electrified lines. The tests have demonstrated how our hydrogen train is mature in terms of availability and reliability, providing the same performance as diesel equipment, and with the benefit of low noise and zero emissions. The Coradia iLint hydrogen train supports the transition towards global sustainable transport systems."

There were no problems with the supply and use of hydrogen, infrastructure compatibility, acceleration, braking, docking, maximal speed, or the performance of the auxiliaries. The Dutch drivers found the train comfortable, smooth and easy to drive. Refuelling with green hydrogen went faster than expected and was performed safely. Moreover, this zero-emission train is significantly quieter than the current diesel trains. This was confirmed during the tests and is a significant benefit for the passengers and inhabitants near the line. The report concludes that the goals have all been achieved and that the hydrogen train is a fully viable alternative to diesel equipment.

HYDROGEN FUEL CELL TRAINS FOR AUSTRIA

Alstom's Coradia iLint has just completed three months of successful test operation on the Austrian Federal Railways' regional lines. This comes just after it received official approval from the highest railway authority in the country, the Austrian Federal Ministry for Climate Protection, Mobility and Innovation.

These important milestones make Austria the second country in Europe, after Germany, to fully approve the Coradia iLint as an emission-free alternative to diesel trains. Alstom once again underlines its world-leading position in hydrogen mobility by rail. No other train manufacturer can currently offer a proven, tested hydrogen train ready for series production.

The Coradia iLint has proven that it is suitable for all service routes. During the three months of testing on four demanding routes in southern Lower Austria, Vienna and eastern Styria, Austrian Federal Railways and its passengers witnessed the operability and performance of the new drive technology based on fuel cells, including on some steep track sections and under the most varied climatic conditions.

They are very positive about the hydrogen train and the test run.

ALSTOM'S LEADING EFFORTS ON CLIMATE CHANGE

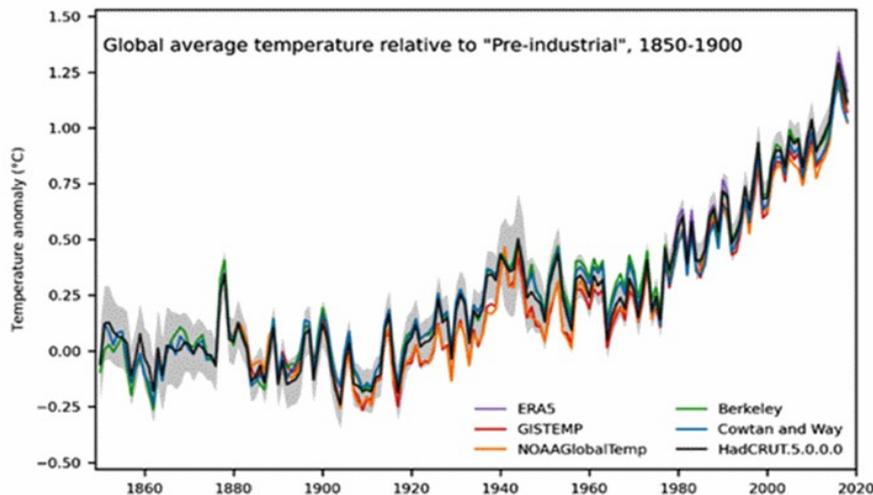
Alstom has attained the highest possible score of "A" in the 2020 annual assessment for transparency and leadership on climate issues, run by the global environmental non-profit organisation cdp, formerly known as the Carbon Disclosure Project. Cecile Texier, Alstom's vice president of sustainability said: "As we mark the fifth anniversary of the Paris Agreement, this outcome demonstrates our sustained commitment and strong performance when it comes to energy and climate challenges. Supporting energy transition and decarbonisation in transport is at the heart of everything we do at Alstom". Alstom's strategy sets ambitious environmental objectives for 2025, including a 25 % reduction in energy consumption, supplying 100% of the company's electricity consumption from renewable sources, and for all newly developed solutions to be eco-designed.

The cdp runs the global disclosure system for investors, companies, cities, states and regions to measure and manage their environmental impacts. A detailed and independent methodology is used by cdp to assess companies, allocating a score of A to D. This score is based on their comprehensiveness of disclosure, awareness and management of climate risks and demonstration of best practices associated with environmental leadership. In 2020, over 9,600 companies disclosed these details through the cdp platform. www.alstom.com



ZERO CARBON ENERGY FOR EMERGING WORLD MARKETS

The Met Office and the University of East Anglia have announced the latest data from their long-running global temperature data set, HadCRUT, which contains data stretching back to 1850.



Global average temperature (°C) relative to the average for 1850-1900, computed from a range of global temperature data sets.

The results provide very similar estimates of overall warming with those from the National Oceanic and Atmospheric Administration (NOAA) and the National Aeronautics and Space Administration (NASA) and reinforce the fact that the world has warmed considerably since the mid nineteenth century.

The UN Secretary General, Antonio Guterres said that the UN's central objective is to build a global coalition to reduce greenhouse gas emissions to net zero by 2050. Unless the world cuts fossil fuel production by 6% every year between now and 2030, things will get much worse. We may be headed for a catastrophic three to five-degree temperature rise this century. The impact is already being felt around the world. Apocalyptic fires and floods, cyclones and hurricanes are the new normal. Biodiversity is collapsing and deserts are spreading.

In their recent report Portfolio Earth said that in 2019 the world's largest banks Invested more than \$2.6trillion in sectors which governments and scientists agree

are the primary drivers of biodiversity destruction. Banks must stop finance for new fossil fuels, deforestation and ecosystem destruction. The Green Innovation Policy Commission is bringing together progressive businesses and leading academics to identify how policy can best support green innovation. They will focus on hard-to-reach sectors including road freight, buildings and industry. A report in Science Magazine entitled Granular Technologies explains that currently one unit of energy saved through end use efficiency avoids the need for 3.2 units of primary energy resource. Portfolios of granular technologies throughout the global energy system could limit warming to 1.5C without relying on large carbon capture and storage infrastructure. Careful attention must be placed on material efficiency, life-cycle design, product durability, modularity and reparability. Small scale fabrication units can 3D print locally adapted products using standardized design data.

Using data provided by the International Energy Agency (IEA), Carbon Tracker estimates that although developed countries

will reduce their use of oil for transport by nearly 3 million barrels per day by 2030, emerging markets in developing countries will significantly increase their demands by 4 million barrels per day. The IEA has recently set up a global commission to lead the change to clean energy. The development of advanced fuel cells has been undertaken by members of the IEA's Technology Collaboration Programme, which states that fuel cells could enable a switch to renewable biofuels as well as hydrogen and are therefore a key instrument to achieving the Paris Agreement targets.

COST EFFECTIVE FUEL CELLS FOR EMERGING MARKETS

The electrochemical conversion of fuel is two or three times more efficient than combustion, so developing countries will require less investment in their new zero emission energy systems. There will also be much less investment in infrastructure as fuel cells could be powered by hydrogen from onsite wind or solar energy or by energy recycled from food waste and sewage.

The electrochemical conversion of renewable and recycled organic fuels can help to restore the natural balance. Scientists and engineers have been working on fuel cell development for decades but progress has been unnecessarily slow. Established industries, backed by the Government, do not want competitors entering their markets. Some fuel cell engineers concerned about air pollution and climate change have continued their work, largely on a voluntary basis.

Fuel cell technology could be made available to people around the world who cannot afford the large infrastructures required to transport electricity, heat, transport fuels, waste or for carbon capture and storage. Emerging markets are projected to increase their use of fossil fuels instead of meeting the requirements of the Paris Agreement. Advanced nations are providing more renewable energy to provide their electricity but are only making incremental changes with existing industries.

The use of fuel cells could enable farmers in developing countries to provide their electricity heat and transport fuels at up to 90% efficiency. This substantially reduces the amount of primary fuel required. Fuel cell technology can also be used as an electrolyser to provide hydrogen which enables onsite storage of surplus wind and solar energy. Communities would be able to make their own fuel cells with the help of computer aided design. A Gasified Anaerobic Digester (GAD™) produces electricity, heat and valuable by-products from recycled organic waste.

There would be large residues of organic fertiliser which can replace the chemical fertilisers which are adding to global warming gases. The other by-product of electrochemical conversion is potable water. Combustion joins oxygen with nitrogen to form NOx but electrochemical conversion only joins the oxygen with the hydrogen in the fuel to form H₂O. The use of the organic waste avoids the emission of methane from landfill sites. At present large areas of land are being used for obtaining fuel from crops or forests or for storing waste in landfill sites. The requirement for land will reduce as recycled energy is used efficiently so more areas could revert to sustainable use.

The recycled organic fuel contains carbon, but engineers have developed materials to store the carbon, which could be recycled for use by farmers or industrialists. The carbon can be used in greenhouses in both urban and rural areas or for replacing in the soil. The fuel cell also captures carbon from the ambient air so the whole process can be carbon negative.

Based upon decades of work developing materials for Dr Francis Bacon's alkaline fuel cell, engineers at Fair Air Limited could provide zero emission systems for London Taxis. These fuel cells can be powered by green hydrogen or recycled energy from organic waste. The fuel cell systems could be licensed to users around the world to provide fuel for transport and industry or combined heat and power for buildings.

www.fairair.london

NEL BUILDING HYDROGEN INFRASTRUCTURE

HYDROGEN STATIONS FOR FUEL CELL VEHICLES

Nel Hydrogen Fueling has received a purchase order for multiple H2Station™ units for fueling light-duty vehicles in California from Iwatani Corporation of America. Iwatani and Toyota selected Nel's H2Station™ hydrogen fueling station solutions for strengthening the hydrogen infrastructure in Southern California.

The stations will serve existing as well as new fuel cell vehicles, such as the next generation Toyota Mirai, with zero-emission fuel, at the same convenience as conventional fuels. The value of the purchase order was in excess of 150 million Norwegian krone. It includes 14 H2Station™ which will be installed in 2021 on 7 sites in California for fuelling vehicles.

Nel Korea Co., Ltd., a subsidiary of Nel ASA, has received a purchase order worth around 4million euros from Hydrogen Energy Network Co., Ltd. (HyNet) for three additional H2Station® hydrogen fueling stations in Korea. HyNet is a special purpose company established to roll out 100 hydrogen fueling stations in Korea by 2022. It is part of the national ambition in Korea to have more than 300 hydrogen refuelling stations operational by then.

Nel Hydrogen Fueling has received a purchase order from ZE PAK SA, the leading energy company in Poland, for H2Station™ hydrogen fueling stations which will be used to fuel passenger vehicles and buses. The value of the purchase order is around EUR 3.2 million, and the stations are scheduled to be delivered in 2021.

ADVANCES WITH PEM ELECTROLYSER

Proton Energy Systems, Inc., a wholly owned subsidiary of Nel ASA, has been awarded a \$4.4 million grant by the US Department of Energy (DOE) for development of advanced components and manufacturing methods to enable low cost hydrogen from electrolysis. Kathy Ayers, Vice President R&D of Nel Hydrogen US, said that this award from the DOE enables continuing progress on their technology strategy to decrease the cost of proton exchange membrane electrolysis.

The purpose of the project is to leverage the DOE National Lab capabilities to develop advanced cell configurations which optimize interactions between components, such as flow and conductivity, and translate those configurations to low cost manufacturing methods in collaboration with project partners. These advancements will not only reduce the cost of the components being developed, but also the adjacent parts through this optimization. The project is funded by the Hydrogen and Fuel Cell Technologies Office (HTFO) within DOE's Office of Energy Efficiency and Renewable Energy. It will enable hydrogen to provide improved efficiency and resiliency in multiple sectors including transportation and industry.

Nel Hydrogen US, a subsidiary of Nel ASA, has received a purchase order for a containerized 2.5 megawatt Proton PEM® electrolyzer from a customer in Europe. The value of the purchase order is in excess of USD 3 million, and the electrolyser is scheduled to start producing green hydrogen in the spring of 2021.

Raymond Schmid, Market Development Director, Nel Hydrogen Electrolyser, said that the containerized electrolyser would produce green hydrogen for mobility applications in Europe.

NORWAY FUNDING ALKALINE ELECTROLYSER

Nel Hydrogen Electrolyser, a division of Nel ASA, has been awarded a grant of 16 million Norwegian krone by the Research Council of Norway for a project to further improve the efficiency and cost of Nel's next generation, pressurized alkaline electrolyser platform.

Nel's next generation alkaline electrolyser already represents a novel stack design within the field of electrolysis. Improvements are expected to further support realization of large-scale electrolyser opportunities through lower total cost of ownership for Nel's customers. Nel will collaborate with Norwegian research and development partners on the project to reduce both capital and operating costs significantly.

Marius Bornstein, Technology Manager in Nel Hydrogen Electrolyser said that this will contribute to reduction of the cost of green hydrogen and stimulate on-site hydrogen generation from renewables to be used in both the industry and transport sectors.

Nel is a global hydrogen company, delivering optimal solutions to produce, store, and distribute hydrogen from renewable energy. Nel ASA was founded in 1927 in Norway and since then they have been developing and improving hydrogen technologies. Today they are enabling industries to transition to green hydrogen and providing fuel cell electric vehicles with the same fast fuelling and long range as fossil-fuelled vehicles - without the emissions.

Nel has signed a letter of intent with Statkraft to develop a large-scale alkaline electrolyser plant of 40-50 MW with superior performance compared to today's. The green hydrogen produced by the plant will be used in a production process of steel reinforcing products as an alternative to fossil fuels and hence lower the carbon footprint of the process.

Nikola Corporation in Phoenix, Arizona has signed a purchase order with Nel ASA for 85-megawatt alkaline electrolyzers. The systems will be delivered from the new electrolyzer mega-factory currently under development in Norway. The first purchase order will support Nikola's initial stations with 8 tons per day hydrogen production capacity. Trevor Milton, Chairman of Nikola, said: "These electrolyzers will support five heavy duty hydrogen stations which will cover multiple states and trucking routes. The future of clean transportation is here, and fleets are lining up to be part of the transition."

RENEWABLE HYDROGEN FOR INDUSTRY AND TRANSPORT

Jon Andre Lokke of Nel said; "Green renewable hydrogen is set to outcompete fossil alternatives, and Nel is placed in the centre of this transition. We're today launching our target which should enable our customers in certain markets to produce green renewable hydrogen from a large-scale Nel facility at 1.5 USD/kg from low cost renewable power, already within 2025. Achieving this would allow green hydrogen to start to reach fossil parity, representing one of the most significant achievement for zero-emission solutions and a carbon neutral planet. The growth will not only come from industrial applications, but also from transforming the current diesel-based heavy-duty transportation to run on zero-emission and cost-efficient green hydrogen. These developments require low-cost electrolysis and ultra-fast fueling."

www.nelhydrogen.com

AUSTRALIA'S NATIONAL HYDROGEN STRATEGY

The Australian Government's Energy Council has set a vision for a clean, innovative, safe and competitive hydrogen industry that benefits all Australians and is a major global player by 2030. They have established a Hydrogen Working Group, chaired by Australia's Chief Scientist, Dr Alan Finkel, to develop a National Hydrogen Strategy that can achieve this vision. Australia has some of the world's best solar and wind resources, especially on the southern and western coastlines. Based on the quality of wind, solar and hydro resources alone, Geoscience Australia estimates that about 11% of Australia (872,000 square kilometres) could be highly suitable for renewable hydrogen production. However, producing hydrogen also requires water. Using desalinated seawater or waste water, if available, may be the most feasible approach.

These resources will enable Australia to take advantage of the increasing global momentum for clean hydrogen and make it their next energy export. They can integrate more low-cost renewable generation, reduce dependence on imported fuels, and help reduce carbon emissions in Australia and around the world. A key element of Australia's approach will be to create hydrogen hubs – clusters of large-scale demand. These may be at ports, in cities, or in regional or remote areas, and will provide the industry with its springboard to scaling up. Hubs will make the development of infrastructure more cost-effective and promote efficiencies from economies of scale. These will be complemented by other early steps to use hydrogen in transport, industry, gas distribution networks and electricity systems.

HYDROGEN FUEL CELLS FOR TRANSPORT

Hydrogen can power fuel cell electric cars, trucks, buses and trains. The advantages of

hydrogen powered vehicles compared to battery electric vehicles are faster refuelling times and the ability to travel longer distances carrying larger loads before refuelling. Refuelling hydrogen vehicles requires a network of refuelling stations, similar to what exists for petrol and diesel.

The Queensland Government is planning to trial a fleet of fuel cell electric vehicles. The Australian Capital Territory (ACT) Government is preparing a hydrogen mobility project which includes refuelling infrastructure and the integration of 20 fuel cell vehicles into the ACT Government fleet. In Victoria, Toyota is building the first commercial-scale station for refuelling hydrogen fuel cell vehicles. In Tasmania, renewable hydrogen is being integrated into a range of domestic end-users. Fuel cells are powering light vehicles, buses, trucks and passenger ferries. In areas where renewable energy varies with the seasons, hydrogen can be produced during times of plentiful supply and fuel cells can then be used to generate electricity in times of limited supply. Australia's potential to produce clean hydrogen does not just support carbon emissions reduction. Its potential as an industrial and transport fuel provides a pathway to eliminate the nitrous oxides and particulate pollution caused by burning fossil fuels, which are associated with much ill health.

RELIABILITY AND SUSTAINABILITY

Australia is setting clear regulatory frameworks and ensuring that development has a positive influence on energy prices and energy security. They will work with other countries to develop a scheme to track and certify the origins of internationally traded clean hydrogen. They will work constructively to shape international markets and open new frontiers for trade.

The growth of clean hydrogen will be achieved without compromising safety, cost of living, water availability, access to land or environmental sustainability.

The Strategy identifies joint actions which are the first steps towards national coordination. They will develop production capacity and ensure responsive regulation. They will support innovation and research and development (R&D) and ensure the development of workforce skills.

HYDROGEN RENEWABLES AUSTRALIA

Hydrogen Renewables Australia (HRA) Pty Ltd is proposing to develop a large scale (up to 5,000 MW) combined wind and solar farm to produce low-cost renewable hydrogen. The project would create enough 'green hydrogen' to ultimately meet the growing demands of the Asian energy market.

Green hydrogen (or renewable hydrogen) is the term commonly used for hydrogen which is produced using purely renewable energy.

The Murchison Renewable Hydrogen Project is proposed to be developed in stages. Firstly, a demonstration phase providing hydrogen for transport fuels. Secondly an expansion to blend with natural gas in the nearby Dampier to Bunbury pipeline. Thirdly, a large expansion to produce hydrogen for the Asian markets, notably Japan and Korea.

The location of Murchison has an ideal combination of wind and solar capable of delivering the low-cost electricity needed to power electrolyzers to achieve competitive-priced green hydrogen for local and international markets. HRA has been established by experienced renewable energy developers, working in collaboration with Siemens Limited who are world leaders in electrolyser technology. Through the process of electrolysis, the electrolyser uses electricity and water to produce hydrogen.

The project has received a favourable response from local communities who are involved in the planned programmes. HRA believes that this project will contribute significantly to the objectives of national, state and local communities for new investment, new jobs, renewable energy sources and new export markets.



The Murchison Renewable Hydrogen Project is proposed to be located on Murchison House Station, just north of Kalbarri in Western Australia.

www.coagenergycouncil.gov.au

www.hydrogenrenewablesaustralia.com

BALLARD PROGRESSING INTERNATIONAL PROGRAMMES

FIRST COMMERCIAL ZERO EMISSION FUEL CELL TO POWER MARINE VESSELS



Ballards's FCWave™ fuel cell provides megawatts of power for marine vessels, in 200 kilowatt increments.

The fuel cell module can be scaled in series up to the multi-megawatt (MW) power level. It provides primary propulsion power for marine vessels, such as passenger and car ferries, river push boats and fishing boats.

It also provides stationary electrical power to support hotel and auxiliary loads on cruise ships and other vessels while docked at port.

Rob Campbell of Ballard said that they are focused on heavy and medium duty motive power applications, particularly where extended range and rapid refueling are required. This is backed up by more than 50 million kilometers of operational experience in thousands of road vehicles. Ballard intends to build on their leading position with zero-emission fuel cells to address global efforts to decarbonize maritime activities with FCwave™.

"The United Nations International Maritime Organization (IMO) has set aggressive targets for reduction of CO₂ emissions in the marine sector, including 50% lower emissions by 2050," said Jesper Thomsen of Ballard Power Systems Europe. "At Ballard we have recognized this important market and launched a Marine Center of Excellence in Denmark.

This center will focus on engineering, manufacturing and servicing the developing marine market with our FCwave™ product."

FCwave™ offers compelling benefits to maritime customers, including:

- industry-leading durability, with greater than 30,000 hours expected operating lifetime;
- high system efficiency of more than 55%;
- light weight at 4.4 kilograms/kW;
- flexibility through modular components for scalable power;
- extended range, limited only by the volume of hydrogen fuel stored onboard;
- reliable performance;
- safe operation;
- and a proven service model.

BALLARD AND AUDI DEVELOP HIGH POWER DENSITY FUEL CELLS FOR VEHICLES

Ballard has announced the launch of its FCgen® a high-performance, zero-emission, proton exchange membrane (PEM) fuel cell stack, to provide propulsion for a range of light, medium and heavy-duty vehicles. The FCgen® has an industry-leading volumetric high-power density of 4.3 kilowatts per litre. This marks another power density milestone for Ballard over decades of PEM fuel cell product innovation.



The FCgen® was designed and developed by Ballard to stringent automotive standards in the company's technology solutions program with Audi AG. Ballard holds the right to use the FCgen® for all applications, including commercial trucks, passenger cars, bus, rail, marine, mining, construction and aerospace vehicles, along with stationary power applications.

In addition to its leading high-power density, the FCgen® delivers a combination of impressive performance metrics, including a high power output of up to 140kW.

The number of fuel cell stacks can be increased or decreased depending upon expected power demand. Up to 95°C maximum operating temperature allows for more efficient and smaller cooling systems. It has rugged cold weather capabilities with a minus 28°C freeze start capability with a fast power ramp.

Randy MacEwen of Ballard said "While governments across the planet are increasingly declaring green hydrogen to play a major role in the path towards net zero carbon, there is also a growing recognition that zero-emission fuel cell systems are well suited to decarbonize a range of motive applications that have historically been difficult to abate. This is

true for buses, commercial trucks, trains, and marine vessels where there is a requirement for heavy payload, extended range and rapid refuelling. These uses typically feature return-to-base depot refuelling, which reduces the challenge of scaling up the hydrogen refuelling infrastructure. The FCgen® adds an important high-power density fuel cell stack to Ballard's current product line-up, supporting our efforts to penetrate these large markets, while also improving our long-term position for future motive applications, including passenger cars."

Dr. Kevin Colbow of Ballard said: "The FCgen® delivers significant value through advancements made by Ballard in membrane electrode assemblies, or MEAs, and carbon bipolar plates. While the FCgen® establishes a new industry standard for power density, we continue to move the yard sticks at Ballard on stack design, with continuous improvements on power density, durability, operating parameters, freeze start capabilities, efficiency and total lifecycle costs. At Ballard, we believe we have industry-leading talent to design PEM fuel cell stacks and systems that offer best performance and value for our markets."

BALLARD AND MAHLE COLLABORATE ON FUEL CELL PROPULSION FOR TRUCKS

Ballard has made an agreement to collaborate with MAHLE, a leading international development partner and Tier 1 supplier to the commercial vehicle and automotive industry. The aim is to collaborate on the development and commercialization of zero-emission fuel cell systems to provide primary propulsion power in various classes of commercial trucks.

Founded in Germany in 1920 the MAHLE Group employs approximately 77,000 people working at 160 production locations and 16 research and development centers around the globe and generates annual sales of approximately €12 billion. MAHLE's commercial vehicle division supplies a broad range of products to truck and other original equipment manufacturers (OEMs), including power cells, valves and camshafts, engine cooling components, fuel and oil management systems, electronics and mechatronics. MAHLE components are present in half of all the vehicles on the world's roads.

MAHLE has been a series supplier for fuel cell vehicles for over a decade. The technology group holds a particularly strong position in the complex air intake system and in the temperature control of fuel cell systems, as well as air filter solutions for fuel cells. MAHLE is developing components for fuel cell systems in commercial vehicles. Dr. Jörg Stratmann of MAHLE said, "Hydrogen and fuel cells are a cornerstone of CO₂-neutral mobility, particularly with regard to road transport. This collaboration brings together our vast expertise in the fuel cell periphery with Ballard's industry leadership in PEM fuel cell technology and systems."

Randy MacEwen of Ballard added: "We are excited to be working with MAHLE, a global leader in automotive product supply, service and support.

Together with Ballard's experience powering vehicles for over 50 million kilometers, our unparalleled proven product durability, and our intellectual property and know-how around high-power density fuel cell stacks, we are very confident in our ability to effectively address the \$100 billion annual total market for commercial truck engines."

During the initial development phase, Ballard has prime responsibility for system design and the fuel cell stack sub-system, while MAHLE's scope of responsibility includes balance-of-plant components, thermal management and power electronics for the complete fuel cell system, as well as system assembly.

BALLARD WELCOMES CHINA'S NEW OFFICIAL POLICY TO SUPPORT FUEL CELL VEHICLES

Ballard has noted that China's government has announced a new official policy on fuel cell electric vehicles (FCEVs), which is expected to support the adoption of FCEVs in selected demonstration regions in China.

Randy MacEwen of Ballard said "With a target to achieve 1 million fuel cell electric vehicles on China's roads by 2030, this new fuel cell policy sets a framework for the scaled adoption of FCEVs. We believe this new policy signifies the strategic importance China places on FCEVs, both from a decarbonization perspective, as well as a competitive industrial perspective.

The new policy comes just as the Weichai-Ballard joint venture has been commissioned in Shandong Province with annual manufacturing capacity in excess of 1 gigawatt of fuel cell stacks. We believe the Weichai-Ballard joint venture is well positioned to become a leading fuel cell stack and module platform in China – the world's largest market for commercial trucks and buses."

He continued "We are increasingly transitioning to a carbon-regulated world. With 66 countries announcing net zero carbon targets for 2050, there are now about 20 countries – collectively representing approximately 70% of global GDP – that have announced hydrogen strategies or roadmaps as key planks of their decarbonization plans. As part of this movement policymakers and industry are prioritizing the decarbonization of medium and heavy duty motive applications, including bus, truck, rail and marine. Fuel cell technology offers a zero-emission technology pathway for these hard-to-abate mobility uses that feature heavy payload and have requirements for long range and fast refuelling. We are pleased to see China's priority on stimulating the adoption of zero-emission commercial vehicles, including buses and trucks, using fuel cell technology. We are also pleased that the policy framework is set for the next four years."

Ballard's technology enjoys a significant share of the approximately 7,200 FCEVs deployed in China to date. Ballard has been executing an aggressive market strategy since closing a strategic collaboration agreement with Weichai Power Co. Ltd in November 2018. This agreement included the establishment of a joint venture – owned 51% by Weichai and 49% by Ballard – for the production and assembly of Ballard's next-generation fuel cell stacks and modules for use in China's bus, truck and forklift markets. Weichai also made an equity investment in Ballard, taking a 19.9% ownership position at that time. The joint venture is located in a newly constructed Weichai facility and has a staff of approximately 180 employees.

www.ballard.com
www.mahle.com

[https://
en.weichai.com](https://en.weichai.com)

FUEL CELLS FOR BUSES, TRAINS AND INDUSTRY

Ballard is continuing to supply fuel cells for European bus fleets. Ten more fuel cell modules have been ordered by Van Hool for fleets in the Netherlands. The Van Hool A330 fuel cell bus carries up to 74 people and has a range of up to 400 kilometers powered by green hydrogen. Solaris Bus & Coach has also ordered more fuel cell modules to power buses in The Netherlands. In the UK, Arcola Energy has ordered a Ballard fuel cell to power Scotland's first fuel cell train. The passenger train will be demonstrated in Glasgow during COP 26 in November this year.

Ballard has signed a Memorandum of Understanding with Chart Industries, a global manufacturer of highly engineered equipment for the industrial gas and clean energy industries. They will jointly develop integrated systems that include a fuel cell with onboard liquid hydrogen storage for the transportation industry, with a focus on heavy-duty applications including buses, trucks, rail and marine vessels. Both Ballard and Chart have provided hydrogen solutions and equipment to industry for multiple decades. This collaboration of two industry veterans is targeted to enable accelerated adoption of hydrogen in heavy-duty transport applications requiring long range, rapid refuelling and lowest total cost of ownership of the vehicle.



Van Hool A330 Fuel Cell Bus powered by Ballard

FUELCELL ENERGY ANNOUNCES US DEPARTMENT OF ENERGY AWARD

FuelCell Energy has been selected by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy for an \$8.0 million funding award to support the design and manufacture of a SureSource electrolysis platform capable of producing hydrogen. FuelCell Energy has previously demonstrated multi-stack solid oxide power generation systems at both the 50kW and 200kW output levels. This project will be the first multi-stack electrolysis system produced with the Company's solid oxide technology. The system will be equipped with an option to receive thermal energy, thus increasing the electrolysis electrical efficiency to over 90%.

Following the design, manufacture and testing of the system by FuelCell Energy the electrolysis system will be delivered to Idaho National Laboratories, where it will undergo rigorous testing to confirm the electrical efficiency, as well as the ability to utilize nuclear power plant waste heat to obtain higher efficiencies of up to 100%. This project represents a key step in FuelCell Energy's path to commercialize its high efficiency solid oxide electrolysis technology. The multi-stack module that forms the core of the system is scalable for larger systems. The solid oxide electrolysis technology has the potential to be an economical, near-term solution for energy and environmental needs that simultaneously supports the advancement of nuclear plant utilization.

Electrolysis technology can support the hydrogen economy by providing carbon-free, clean hydrogen for transportation, power generation, agricultural uses, and a host of other industrial applications.

AWARDS FOR FUELCELL ENERGY RESCINDED

FuelCell Energy, the Connecticut-based manufacturer of clean energy fuel cells announced in December 2020 that state

regulators have improperly rescinded three fuel cell awards which have now been given to solar development projects. Jason Few of FuelCell Energy said: "This illuminates the fact that the processes of the Department of Energy Protection (DEEP) and the Public Utilities Regulatory Authority (PURA) lack integrity. Unless the original awards were honoured they will have to re-evaluate their in state growth prospects. The fuel cell industry urges the state of Connecticut's policy leaders to speak with one voice and act quickly to reverse this irregular action that works against its own policy goals."

Michelle Cook, Deputy Speaker of the House said "It is difficult to hear Connecticut's energy regulators are re-evaluating clean energy bids that were awarded to multiple fuel cell companies, including FuelCell Energy. Reversing the awards will have detrimental effects on these companies, ratepayers, and our state as it seeks to build a more resilient energy grid."

FUEL CELL ENERGY JOINS HYDROGEN EUROPE

FuelCell Energy has joined Hydrogen Europe, the leading European association representing the interests of the hydrogen and fuel cell industry and its stakeholders. They are joining a community of major companies working to significantly advance and accelerate the hydrogen economy.

Jason Few of FuelCell Energy said: "We bring over 50 years of experience of developing, commercializing, manufacturing and operating commercial scale fuel cell power platforms for the growing hydrogen markets."

FuelCell Energy, while headquartered in the United States, operates a manufacturing and service centre in Germany.

www.fuelcellenergy.com

ZERO EMISSION RAPID RESPONSE OPERATIONS AMBULANCE

ULEMCo, the UK hydrogen fuel pioneer, and their partners have delivered the first milestone to creating the zero emission ambulance of the future ZERRO.



The project for the Zero Emission Rapid Response Operations (ZERRO) ambulance, is funded by the Office for Zero Emission Vehicles (OZEV) and aims to deliver a prototype ambulance for the London Ambulance Service NHS Trust later this year.

ULEMCo and partners have agreed the design for the hydrogen powered ambulance. The prototype build stage incorporates a hydrogen fuel cell range extender with an electric drive and low frame chassis. The bespoke lightweight ambulance body was designed and manufactured by the Woodall Nicholson Group. Innovations include a low access floor that removes the need for patient lifting equipment, and a frame-based body that ensures that the overall weight of the vehicle can meet the payload requirements of the service.

Amanda Lyne, Managing Director of ULEMCo, said: "Given the energy need of the NHS ambulance duty cycle, it seems clear that hydrogen fuel is needed to

provide both the range and vehicle availability for emergency response requirements. Working with the Woodall Nicholson Group we have the advantage of a bespoke ambulance based on their current battery technology vehicle platform. This has enabled us to apply our capability in integrating hydrogen fuel cell range extension systems, and to prove that this will be a really viable and practical solution for NHS fleets across the UK."

Chris Rutherford of London Ambulance Service added: "This project is a key part of our strategy for a zero emission fleet, to support the NHS aim to be the world's first net zero national health service, and to meet or exceed the clean air requirements in London."

"Hydrogen continues to play an increasingly important role in the energy mix," said Dr Francesca Ludicello of Innovate UK. "We look forward to seeing the benefits of zero emission vehicles with a high readiness for service."

www.ulemco.com

ADELAN FUEL CELLS IN UK GOVERNMENT PROGRAMME

The Government's UK Research and Innovation (UKRI) programme has awarded funds to help the Midlands achieve net zero emissions. The programme aims to deploy technologies like hydrogen-ready fuel cells in a bid to establish the world's first net zero industrial cluster by 2040. In the first phase a £1million grant will help businesses to develop plans for decarbonising an industrial cluster. Adelan's solid oxide fuel cell (SOFC) is one of the technologies being considered as a solution to decarbonise the transport, heat and power demands of the cluster.

The six winners are now able to compete for a total of up to £131 million for phase two of the competition to deliver significant emissions reductions in a UK industrial cluster by 2030. The project aims to agree a roadmap for securing significant commercial funding and investment to support clean industrial growth within the region and establish affordable net zero carbon energy. This consortium of partners will identify the best ways to deliver zero carbon power to local businesses using local resources.

Commenting on the UKRI funding, Dr Michaela Kendall of Adelan said that as a Birmingham-based energy technology innovation company they were proud to contribute to the clean energy transition in their home region and across the world. Hydrogen-ready fuel cells have a key role to play in tackling climate change and improving air quality. Adelan's microtubular fuel cells can provide clean, quiet and reliable energy for remote, mobile and other applications.

The pioneering fuel cell company Adelan is keeping Birmingham's rich engineering heritage alive and well with its remarkable energy technology innovation. Fuel cells are already known as the cleanest possible technology for dependable and reliable electricity generation. Adelan's unique microtubular solid oxide fuel cell (mSOFC)

delivers key advantages over other types of fuel cell system.

The Adelan fuel cells run on gas and are ideal as a diesel replacement: they are much cheaper to run and are less polluting. Unlike other kinds of fuel cell which require pure hydrogen fuel, Adelan's quiet, compact and efficient fuel cells use readily available fuels such as LPG or propane. As a result, the company's mSOFC technology can act as a stepping stone towards the low-carbon and clean hydrogen economy of the future.

In addition to its ability to operate on hydrocarbon fuels such as natural gas – as well as hydrogen if it is available – efficient generation of heat and power, quick start times and quiet low-emission operation make Adelan's mSOFCs especially competitive.

The Adelan mSOFC system is stackable and scalable from small light-weight, portable applications like battery chargers right up to grid-connected power stations. Unmanned airborne vehicles, recreational vehicles, portable power, electric vehicles, remote power and micro combined heat and power (mCHP) have all emerged in recent years as strong growth markets for Adelan.

Adelan's core microtubular solid oxide fuel cell (mSOFC) technology was patented by Prof Kevin Kendall FRS and Dr Michaela Kendall in 1992. They attracted significant inward investment from global markets such as the US, China and Europe, which are looking to develop new clean, green energy markets. Adelan was a founding member of the European Industry Grouping for the Fuel Cell and Hydrogen Joint Undertaking (FCH JU). A key market for Adelan is the rapidly expanding decentralised power sector which is driven by worldwide issues such as climate change and urban air quality.

www.adelan.co.uk

WILHELMSSEN HySHIP FOR ZERO EMISSION SHIPPING



The HySHIP project embraces 14 European partners collaborating on the design and construction of a new demonstration vessel running on liquid green hydrogen (LH2). The ship will be operated by Norwegian maritime industry group Wilhelmsen and will distribute LH2 to hydrogen hubs along the Norwegian coast from 2024.

The project aims to lower the development and operational cost of a wider move to LH2 for ship propulsion throughout Europe. The EU's Fuel Cells and Hydrogen Joint Undertaking (FCH2 JU) is allocating EUR 8m funding. Enova SF which is owned by the Norwegian Ministry of Climate and Environment has also contributed 219 million Norwegian krone.

Going under the concept name "Topeka", the vessel will provide a two-in-one solution: it will sail on a fixed schedule carrying both coastal customer cargo and containerized LH2 to the bunkering hubs. Norway's west coast is dotted with bases serving offshore industries, with base-to-base transport representing a heavy-duty transport route eminently suited to LH2. The bunkering hubs will in the future supply LH2-powered vessels including ferries and seagoing tonnage.

Per Brinchmann of Wilhelmsen said "Hydrogen as a fuel enables low, or zero-emission shipping. We shall create a full LH2 infrastructure and commercial ecosystem, while at the same time removing yearly some 25,000 trucks from the roads." Bart Biebuyck of FCH2 JU added: "Maritime is a large contributor of global GHG emissions and thus a priority sector to decarbonize. Hydrogen and fuel cells have the potential to propel vessels in a zero-emission fashion and various ship types are starting to integrate them."

The Topeka vessel will have a combination of 1,000 kWh battery capacity and a three-megawatt PEM (proton exchange membrane) hydrogen fuel cell. Hydrogen will be sourced from the new LH2 production plant planned outside Bergen by BKK, Equinor and Air Liquide. HySHIP will also conduct three replicator studies, including a smaller 1MW tanker barge for use on inland waterways, a 3MW fast ferry and a scaling-up study on a larger, 20MW energy system for deep sea vessels using a bulk carrier. In time they will be able to support the entire maritime industry with zero emission fuel alternatives.

www.wilhelmsen.com



www.yachtingworld.com

Photo: Olivier Blanchet

Yachting World shows how hydrogen fuel cells could provide a truly clean energy source for yachts. Offshore solo racer Phil Sharp is seen here on his yacht OceansLab on which the onboard electricity is generated by hydrogen fuel cell technology. Currently a litre of hydrogen is more expensive than a litre of diesel but it contains three times more useable energy than a litre of diesel. Sharp will start production of his hydrogen fuel cell system in La Rochelle this year and has the facilities to quickly scale up production.

EVENTS

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

www.fuelcellpower.wordpress.com

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

Information can be obtained from: Jean Aldous, Editor, Fuel Cell Power,
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