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ALTERNATIVE DRIVE

A one-off special looks at the next-generation technologies bringing fresh, low-emission options to the powertrain space

THINK AGAIN

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FIRST PRINCIPLES

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FULL FORCE

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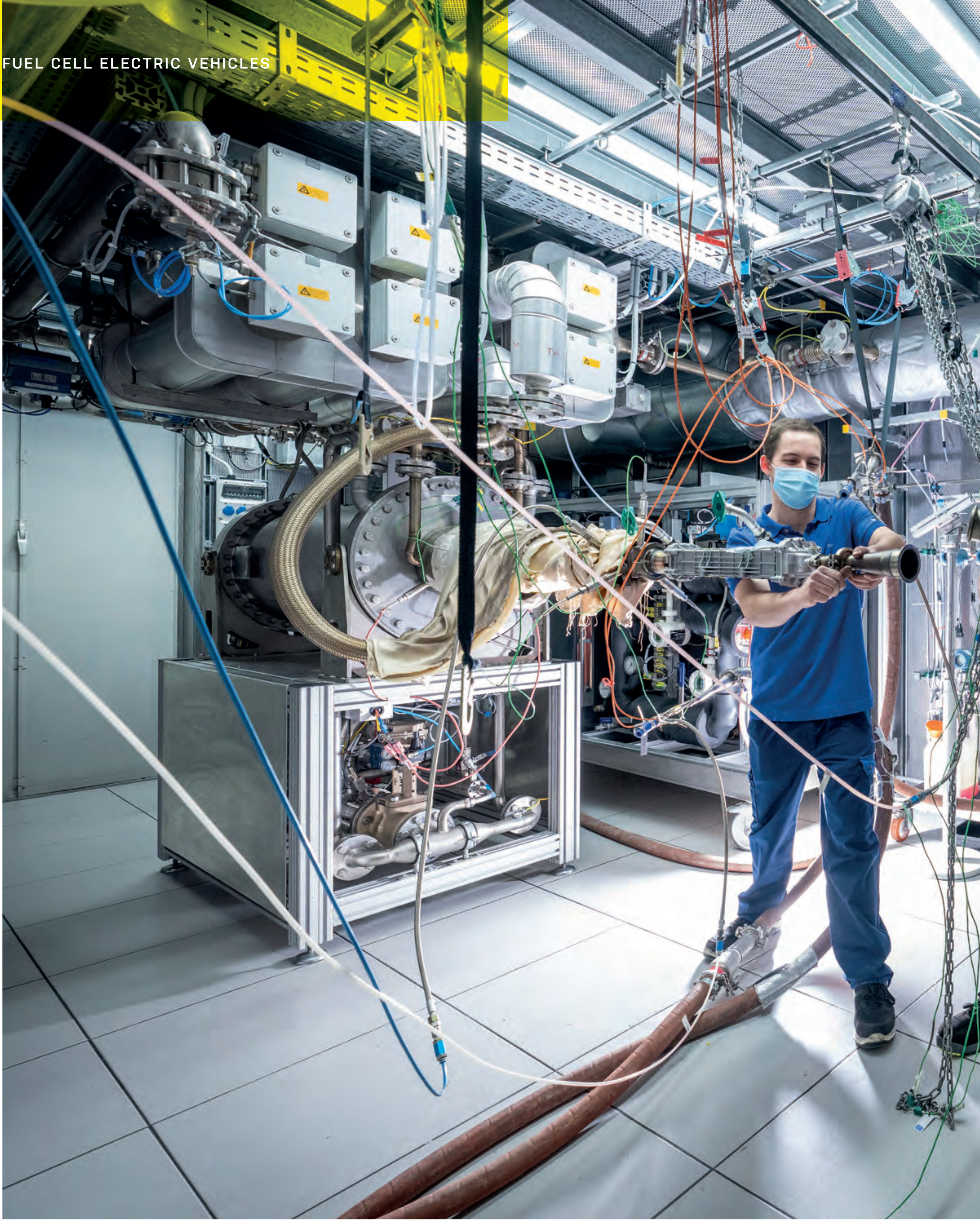
ALTERNATIVE DRIVE



Energy boost

AS THE RACE TO DECARBONIZE CONTINUES, HYDROGEN FUEL CELL ELECTRIC VEHICLES ARE CHASING BEVS. *ETi* LOOKS AT WHETHER FCEV TECHNOLOGY CAN LIVE ALONGSIDE OTHER ZERO-EMISSION OPTIONS

Words: Richard Gooding

Hydrogen is an energy carrier of almost limitless potential: the most abundant element in the universe, the basis for not one but several zero-emission powertrain technologies, and offering the highest energy content per unit mass of any fuel. Yet, in 2022, there is an increasing number of questions over the technology – and, in particular, hydrogen fuel cells.

OEMs have been keen to highlight their dedication to pure battery-electric drive solutions and they continue to aggressively pursue development in this area, while hydrogen combustion has taken center stage when it comes to recent headlines.

Yet the heavy-duty vehicle and long-haul transportation sectors are continuing to put their faith in the potential of FCEVs. "A key advantage that FCEV currently has is the speed of 'refill'," explains Zemo Partnership's chief executive, Andy Eastlake. However, he fully appreciates how precarious this position is in a fast-moving industry: "We do need to be aware that the potential for megawatt charging systems will erode the advantage that we have," he says.

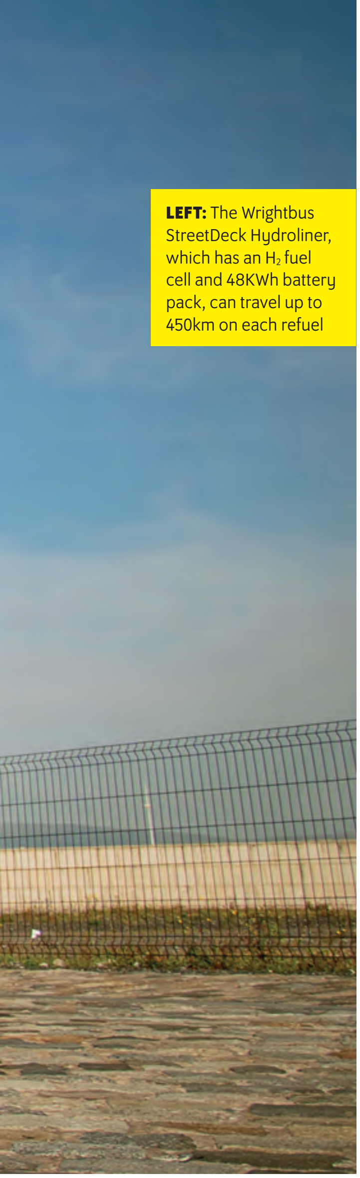
"A key advantage that FCEV currently has is the speed of 'refill'"

Andy Eastlake, chief executive, Zemo Partnership

According to many experts in the industry, pure battery technology isn't yet feasible for larger or greater-distance vehicles without significant changes in how the vehicle is operated. "The criteria for choice are both range and utilization," says Hugo Spowers, Riversimple's chief engineer and founder. "It's easy enough to make a battery-electric HGV if you're happy to do 80km a day, but that's not what HGVs do. We need hydrogen because of range and uptime; HGVs don't have the downtime for charging.

"There are road transportation niches where hydrogen may provide a solution that batteries currently constrain," Spowers notes.

RIGHT: Riversimple's Rasa pairs a fuel cell electric powertrain with supercapacitors and in-wheel e-motors. Hugo Spowers, chief engineer and founder of Riversimple (pictured), unveiled the first Rasa prototype back in 2016



LEFT: The Wrightbus StreetDeck Hydroliner, which has an H_2 fuel cell and 48KWh battery pack, can travel up to 450km on each refuel

"Emergency vehicles, and large-scale remote construction activity where a significant amount of energy is needed for plant and/or equipment, are situations where hydrogen may have a role."

MATERIAL WORLD

Fuel cell systems still face notable challenges though, especially when it comes to material supply. The demand for platinum currently threatens to outstrip the supply, and FCEVs typically use significantly more than is found in the aftertreatment system of an internal combustion engine vehicle.

However, Spowers believes that the situation is manageable: "Because the vehicle efficiency drops off with range, the battery material content of BEVs goes up more than pro rata with range," he says. "Platinum is a tiny portion of the fuel cell. Riversimple fuel cells have jut 5g platinum – a typical catalytic converter has between 3g and 7g. And unlike in catalytic converters, from our fuel cells it's 100% recoverable."

The issue with material supply may well be entirely solvable, but reaching a level of efficiency that is comparable to that of BEV systems isn't so simple. Fuel cell electric vehicle skeptics point out that the technology will never match the powertrain efficiency of a BEV. "Looking purely at efficiency, BEVs are far more efficient than FCEVs," notes Jo Bamford, executive chairman of Wrightbus and Ryze Hydrogen. "The balance starts to shift when you start to look at operational efficiency, due to the significant difference in charge times, though."

"The lower onboard efficiency is one downside – only around 50% of the energy stored in the hydrogen can be delivered to the drive motors. So, they're better than combustion-fueled engines but worse than energy stored in a battery," adds Eastlake. "When energy is on board, around 90% is available from a battery to the EV motor. For an FCEV, there's the added step of converting hydrogen into electricity in the fuel cell, which may be 50-55% efficient. An FCEV uses almost double the energy of a BEV."

INCREMENTAL IMPROVEMENT

Nonetheless, there are gains to be made with the fuel cells and their associated hardware, particularly with regard to power density and reliability. Companies such as Siemens PLM are finding incremental improvements through 3D CFD, looking at how the water is distributed inside the fuel cell along with the internal gradients that are closely related to reliability. Siemens PLM is also using 1D simulation to improve dynamic response through pedal input tweaks.

Another key area of development is onboard storage. The volume of the tanks means that they have to be very light, while

Forward thinking

Will BEV tech block FCEV progress?

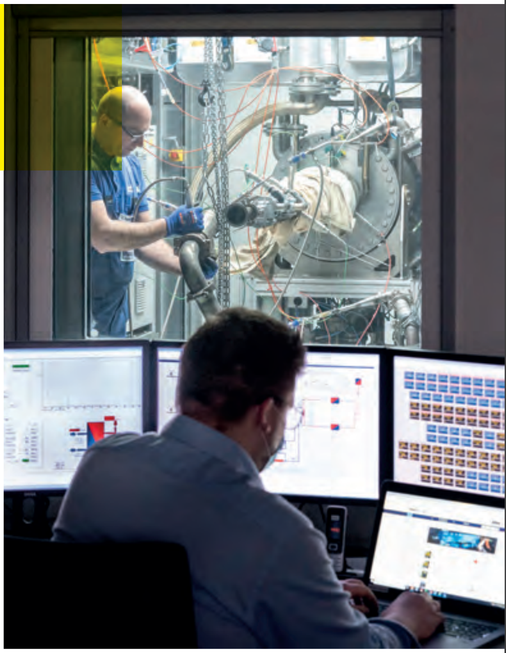
It seems as though BEVs have raced ahead of hydrogen fuel cell technology, with a number of OEMs including Audi, for example, devoting themselves to an electric-only future. However, battery-electric progress could prove mutually beneficial for FCEVs and BEVs.

"I see no reason why FCEV and BEV technologies shouldn't exist together," says IAAPS's Sam Akehurst. "There's an infrastructure requirement for both that relies on green electricity, but I don't see why one should prevent the other."

If further developed, parked and grid-connected hydrogen FCEVs have the potential to allow a transition to a balanced, 100% renewable energy system. On average, cars are used for driving less than 10% of the time, suggesting that the fuel cells in the car could be used over 90% of the time surplus energy to the grid and relieve pressure.

Zemo's Andy Eastlake notes "The challenge has moved to energy and its efficient generation, transmission, stora and use. Batteries and hydrog have advantages and disadvan but they will both contribute."

RIGHT: Mahle has invested US$2.1m in a test facility dedicated to hydrogen applications. The new $1,400m^2$ site is in Stuttgart, Germany



internal pressures (~700 bar) and the risk of crash loads mean that they also have to be very strong. This typically means that the tanks are carbon fiber, which considerably limits cost savings.

Infrastructure challenges also remain. If nothing else, producing green hydrogen requires considerable amounts of renewable electricity that few regions globally are equipped to produce at present. In the USA, for instance, 95% of hydrogen is produced by steam methane reforming, which uses fossil fuels and produces substantial quantities of CO_2. The technology exists to capture hydrogen without any emissions (typically by the electrolysis of water) but this is only done on a relatively small scale.

"In July 2021, the European Commission put forward a set of legislative proposals (Fit for 55) that could make or break renewable hydrogen uptake in all sectors of the EU's economy," says Hydrogen Europe's mobility policy manager, Viktor Borecky. "Hydrogen Europe's priority is to facilitate development of sufficient infrastructure. The Alternative Fuels Infrastructure Regulations (AFIR) would ensure the deployment of refueling stations at every 150km as a minimum."

So, is a wider hydrogen ecosystem needed to enable the FCEV transition? The reality is that while hydrogen fuel cells may yet form an essential part of the net zero transition, their role in transportation is yet to be fully mapped out. "It needs to go beyond the car world," says Spowers. "Hydrogen can be generated relatively directly from any energy source, like electricity. If we have a sustainable energy system and our grids are good for renewables, it will transition from a distribution system to a balancing system."

Hydrogen fuel cells face a 'chicken and egg' situation. Consumers are reluctant to commit to the technology while there is so little infrastructure in place. Yet there's little incentive to expand the H_2 infrastructure – and limited scope to reduce the costs – while production levels remain low.

Sam Akehurst, professor of advanced powertrain systems and deputy academic director at the Institute for Advanced Automotive Propulsion Systems (IAAPS), an institute of the University of Bath, notes, "If you build demand, the solution will come along. Equally, if you build a fuel solution, the demand will build up."

NEXT STEP

The potential in hydrogen fuel cell tech is there. It offers greater range than a BEV and provides a cleaner alternative than traditional combustion systems. But determining the target sector is now the most vital step.

"If the construction and long-haul sectors emerge as the most realistic uses for FCEV, then the industry should focus on delivering those systems and not try to force FCEV into the car sector to create volume," notes Eastlake. "This is where initiatives like the Zero Emission Road Freight Trials (ZERFT) program are critical – to establish how we will move HGVs to zero emissions and meet the UK's challenging 2040 targets."

For now, heavy-duty and long-haul vehicles are a focus point for fuel cell system development. That doesn't mean passenger vehicle integration won't come in the future. BMW is planning to use a common platform architecture for its X5 models with different powertrain options, including FCEV.

"There are [feasible] applications on the heavy end of the passenger car market," notes Akehurst. "But there's still a challenge for vehicles powered on hydrogen around storage and most of these vehicles will still require a degree of electrification."

For many OEMs, the goal is to offer a wide range of clean solutions to help decarbonize mobility. Consumers will then decide which technology best fits their needs based on range, infrastructure availability and grid flexibility. So, FCEV has a future, although certain questions remain unanswered. ⦿

Engineering parallels

Can ICE experience aid FCEV design?

As manufacturers and suppliers look for major gains in fuel cell powertrain performance, there are correlations between ICEs and FCEVs that can aid fuel cell development and scale-up. Mahle, in collaboration with Bramble Energy, for example, updated a light commercial FCEV to use Bramble's Printed Circuit Board Fuel Cell (PCBFC) technology.

"One of the interesting things we did find was when you're looking at all the equipment that goes around a fuel cell, there are a lot of similarities to the engineering that we carry out on ICEs, such as air path design," says Jonathan Hall, head of research projects at Mahle Powertrain.

The similarities found by Mahle's engineering team included the air compressor, which features tech comparable to the electric supercharger that the company has used on previous ICE projects. Mahle also found that existing skills in ICE thermal management were transferable when it came to working on the Bramble FCEV project.

"Analysis tools and techniques are similar and the fuel cell controller for the Bramble project is an adaptation of an engine controller we developed," says Mike Bassett, head of research at Mahle Powertrain. "It was quite reassuring." Hall adds, "It was really interesting to be able to draw on our previous experience."