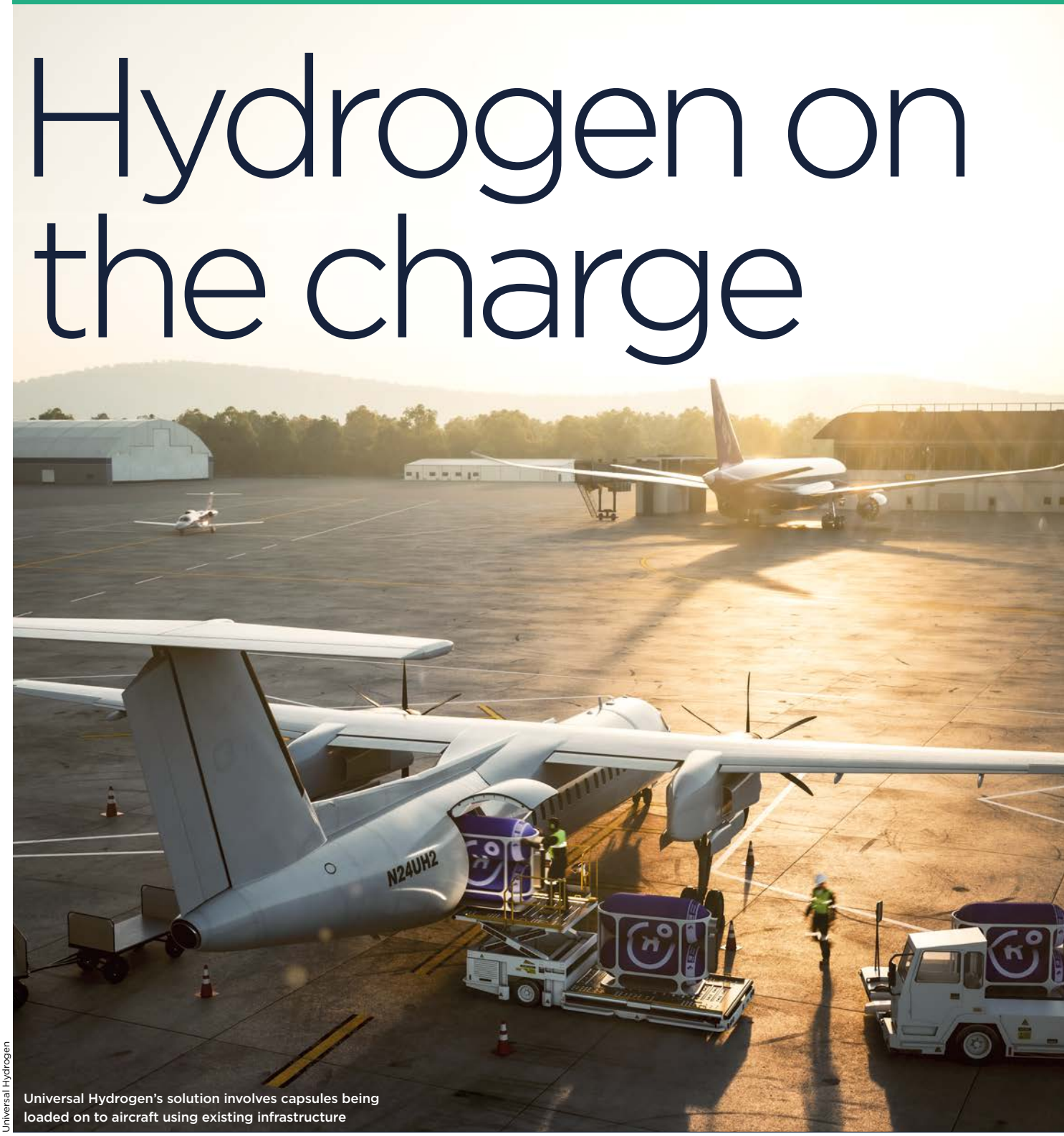
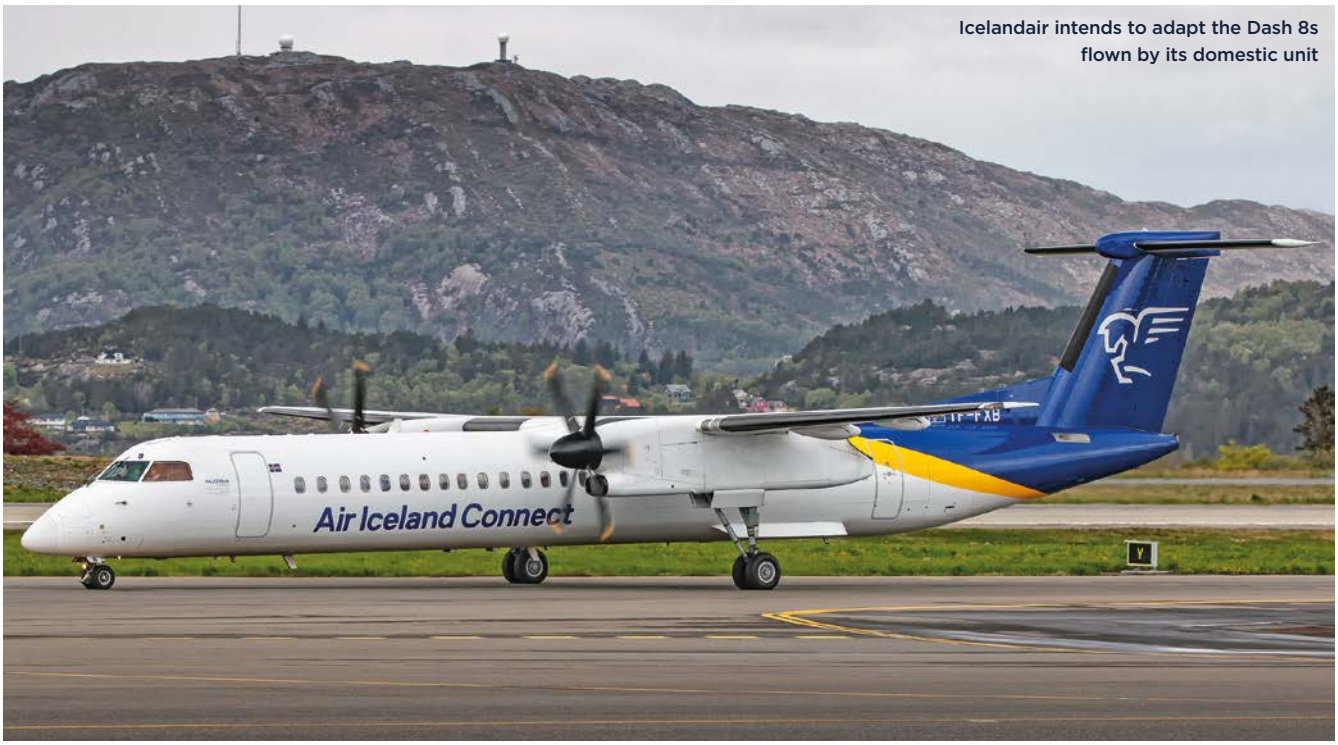
Airlines and lessors have been lining up in recent months to buy kits to convert their turboprops to new sources of power. Are their hopes justified? And could the technology work on larger aircraft?

Hydrogen on the charge



Universal Hydrogen

Universal Hydrogen's solution involves capsules being loaded on to aircraft using existing infrastructure



Icelandair intends to adapt the Dash 8s flown by its domestic unit

AirTeamImages

Mark Pilling London

Having taken his forward-thinking plans to them, Dave Andrew, the chief executive of cargo airline operator and lessor ASL Aviation Holdings, has found his group's private equity owners extremely supportive in his early bet to fully explore the potential of hydrogen-electric-powered turboprops. "We see exponential development in these technologies and have signed up to net-zero emissions by 2050," he explains.

There is also a hard commercial edge to ASL's move. In late 2020, the company created a forum called ASL CargoVision, then invited customers and potential new technology innovators to join, to understand and promote sustainability and innovations for air cargo operations.

"In the cargo world we need cost-effective freighters, which means aircraft converted from passenger operations," says Andrew. "If we wait for solutions to come to us, we won't be ahead of the curve."

Commercial necessity

Like others interviewed for this article, Andrew anticipates environmental legislation on the horizon that will push up costs for airlines through taxes and the purchase of carbon credits. This will make low-emission fuels more attractive purely on commercial grounds. In addition, moving to a fuel that is environmentally friendly – the claims are that hydrogen-powered aircraft offer the prospect of emitting zero greenhouse gases – will become a necessity.

"At some point, if you are not operating a zero-emissions aircraft you will be told you are not allowed at an airport," believes Andrew, drawing a comparison with the ban of noisy aircraft. "My biggest issue is about protecting and sustaining our existing business. If we wait, we will not be on it," he says.

ASL has signed deals with two of the main conversion kit players: Universal Hydrogen, and ZeroAvia, and is in talks to supply an ATR 72 to them as a cargo test and certification aircraft.

ASL is not waiting – and nor are Air Nostrum, Icelandair or Ravn Alaska, among others, who were the first to sign up for hydrogen conversion kits in July 2021. The kits will replace the Pratt & Whitney Canada PW100 turboprop engines on either 50-seat de Havilland Canada Dash 8-300s or the 70-seat ATR 72, but not the heavier 78-seat Dash 8-400 yet.

The three start-ups leading the development of hydrogen power for turboprops are H2FLY of Germany, California-based Universal Hydrogen, and UK-based ZeroAvia – which has major research and development centres in the UK and the USA. These firms have plenty in common – pioneering founders, experienced management teams, big-name advisers – and have attracted a hatful of heavyweight investors.

The increasing attention paid to hydrogen as a clean fuel for aviation over the past year has propelled this technology from an academic curiosity to an industry front-runner.

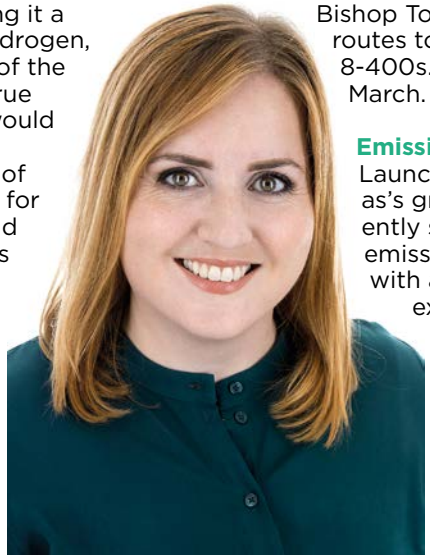
"We are pushing at an open door," says Rod Williams, an ex-Bombardier executive, who joined Universal Hydrogen as chief commercial officer in

> "At some point, if you are not operating a zero-emissions aircraft you will be told you are not allowed at an airport"
>
> **Dave Andrew Chief executive, ASL Aviation Holdings**

January 2021. "There is inherent interest in and demand for a true zero-emissions solution in aviation and in particular in the regional turboprop sector."

For Icelandair, the motivation to be at the forefront of sustainable aviation comes from a combination of factors, explains Heida Gudbrandsdottir, deputy chief operating officer. "There is a desire to accelerate emissions reductions between now and 2030 as part of an early push to meet the industry's commitment for net zero by 2050, the fact that Iceland has an abundance of green energy making it a perfect location to produce green hydrogen, and the possibility of becoming one of the first airlines in the world to achieve true zero emissions for domestic flights would be a huge advantage," she says.

Last July, Icelandair signed a letter of intent (LOI) with Universal Hydrogen for conversion kits to adapt its Air Iceland Connect fleet of Dash 8s, and if this is successful a long-term fuel services contract to supply green hydrogen to the airline. It currently operates three 37-seat Dash 8-200s and two 76-seat Dash 8-400s on its domestic network. The carrier is also interested in a pure electric aircraft solution and has an LOI with Heart Aerospace to explore opportunities regarding its full-electric 19-seat ES-19.



Icelandair

Heida Gudbrandsdottir says Iceland is the perfect location to produce green hydrogen

Gudbrandsdottir says that the turboprop conversion plan, where an existing aircraft is modified and certificated via a supplemental type certificate (STC), is a well-established path for both operators and regulatory authorities such as the European Union Aviation Safety Agency and the US Federal Aviation Administration (FAA).

"This approach helps build our confidence and the way the technology is presented builds trust to begin with," she adds. "Coupled with the research work being done, the ambitious timeline and the stakeholders behind it make a persuasive case.

"We recognise it is still in the early stages, but based on what we have seen the operational feasibility and costs look promising. Now we are digging deeper, seeking to understand the actual costs involved and the impact it would have on our operation."

Industry veteran John Thomas, who has a stint as chief executive of Virgin Australia Airlines on his CV, runs an FAA Part 135 jet charter operation in Boston, and is planning hydrogen-electric-powered aircraft as soon as he can get them for his start-up, Connect Airlines. "We plan to be the first zero-emissions airline in the US," he says.

The airline plans to operate initially from Billy Bishop Toronto City airport in Canada on routes to Chicago and Philadelphia with Dash 8-400s. It is aiming to begin services in late March.

Emissions advantage

Launching with turboprops meets Thomas's green ambitions, as the type is inherently superior in terms of carbon dioxide emissions compared with regional jets, with about a 35% carbon advantage, he explains. Thomas has signed an LOI with Universal Hydrogen to acquire 12 Dash 8-300 hydrogen kits when the technology is ready, plus purchase rights for 12 more kits of other types, which will mean the airline lowering its emissions even further and transitioning to all hydrogen at some point.

Early adopters such as Thomas are building sustainability into their business model, and his business is so enthusiastic about the Universal Hydrogen solution that it participated in the firm's recent $62 million financing round.

All three of the main players are developing hydrogen-electric powertrains to replace turboprop engines. Renewable hydrogen, stored in tanks on the aircraft, is converted to electricity in flight using a fuel cell. These cells power the electric motors. Hydrogen-electric powertrains offer higher specific power and higher energy density compared with lithium-ion batteries, which have been used for smaller electric aircraft, to get 30-plus-seaters into the air.

This technology is not new, with H2FLY having flown its first manned hydrogen-electric aircraft,

> "It is still in the early stages, but based on what we have seen the operational feasibility and costs look promising. Now we are digging deeper, seeking to understand the actual costs"
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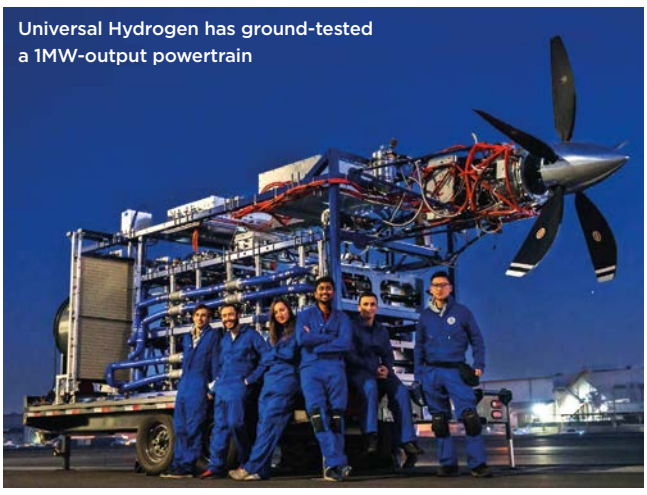
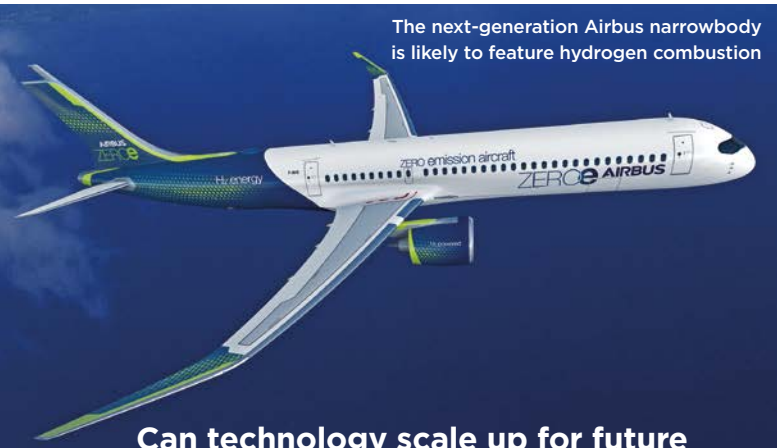
> **Heida Gudbrandsdottir**
> **Deputy chief operating officer, Icelandair**



Universal Hydrogen

Universal Hydrogen has ground-tested a 1MW-output powertrain



The next-generation Airbus narrowbody is likely to feature hydrogen combustion

Airbus

Can technology scale up for future narrowbodies?

By the mid-2020s, as hydrogen-electric-powered turboprop conversions come to market, the conversation around hydrogen as a fuel that could power the next generation of narrowbody aircraft will become more positive, according to Val Miftakhov, chief executive of ZeroAvia.

"If successful in the regional segment we see a hydrogen single-aisle as a probability," he said during a McKinsey webinar on the subject in January. "The long game is the single-aisle, and the timing is kind of perfect, as there is likely to be a new single-aisle from Airbus and Boeing for entry into service in the mid-2030s."

One of the key questions for this potential aircraft is the form of the hydrogen fuel and thus the engine. The turboprop conversion world is starting with gaseous hydrogen for fuel cells, moving on to liquid hydrogen as that technology matures.

However, while fuel cell development appears to be moving at pace, it is unlikely to be mature in time, and the power delivered at system level will not be great enough for a next-generation narrowbody, according to the industry players. Therefore, the successors to the Airbus A320 and Boeing 737 are likely to feature a hydrogen combustion architecture, believes Paul Eremenko, chief executive of Universal Hydrogen.

The downside on the emissions front is that "direct-burn hydrogen" may produce zero carbon, but residual non-carbon emissions such as nitrogen oxides remain. There is also the possibility of creating contrails and the climate warming effects they can exhibit (*see p57*).

the Antares DLR-H2, in 2009. "There is a realistic chance to bring megawatt-scale hydrogen fuel cells into aviation. They will not only be functional, but we can get them qualified," Josef Kallo, the founder and chief executive of H2FLY, told a McKinsey webinar on the subject in January. "In the last 15 years we have gone from small aircraft to larger powertrains as we upscale the systems."

H2FLY has partnered with Deutsche Aerospace to prepare a 30-seat Dornier 328 demonstrator with a hydrogen-electric powertrain aimed at delivering 1.5MW of power for its first flight in 2025, with a commercial version to be ready three years later, says Kallo. Universal Hydrogen has a memorandum of understanding with Deutsche Aerospace to evaluate the incorporation of its capsule technology in Deutsche's aircraft designs.

The ability to deliver 1.5MW of power is the sweet spot for a fuel cell – enough to power a Dash 8-300, ATR 72 or Dornier 328. Universal Hydrogen's goal is to conduct its first flight of a Dash 8-300 with the powertrain by the end of this year. The target is to gain a STC in 2025 and deliver to customers soon afterwards, says Williams.

Hardware tests

"Our real hardware tests and demonstrations have really helped ignite our conversations with customers," says Val Miftakhov, the founder and chief executive of ZeroAvia. The company flew its Piper M350 six-seater equipped with a hydrogen powertrain in September 2020, although this testbed was destroyed during a landing mishap last April. It began ground tests on its Dornier 228 test aircraft at the end of 2021 and ZeroAvia's roadmap sees certification flights beginning by late 2022 or early 2023, with service entry of a 19-seater with a 300nm (555km) range in 2024, he says.

"In parallel we have kicked off our larger engineering programme for Dash 8s and ATRs, with ground tests slated for the first half of this year. The aim is for Dash 8-300s and ATR 72-sized aircraft [to enter] into commercial service in 2026," Miftakhov says. These will have a range of 1,000nm. The next step will see fuel cells delivering 2.5MW of power – sufficient for the heavier Dash 8-400.

ZeroAvia is developing its own powertrain while working with fuel-cell makers on that technology and collaborating with airports on zero-emissions hydrogen production and refuelling infrastructure.

Universal Hydrogen describes itself as a system integrator and is working with Seattle-based Magnix to provide the electric power units and with US firm Plug Power for the fuel cells. "We are creating two completely different value chains, firstly to create the aircraft solution and secondly to create the hydrogen logistics and infrastructure solution," Williams says.

> "The only way to make hydrogen viable is to find a way where you don't change the infrastructure at airports"
>
> **John Thomas Chief executive, Connect Airlines**

The solutions that both Universal Hydrogen and ZeroAvia are pursuing for aircraft in the 20- to 50-seat class see compressed gaseous hydrogen stored in tanks on board the aircraft. "But hydrogen is not the problem; the problem is that there is no fuel supply," says Paul Eremenko, the founder and chief executive of Universal Hydrogen.

Replicating the global installed infrastructure that delivers Jet A-1 fuel at airports is a monumental task. "We honed in on this as the problem and our approach is that we already have a way

of delivering the fuel – and that is to make hydrogen compatible with the intra-modal freight network," Eremenko said during the McKinsey webinar.

Universal Hydrogen is patenting a special hydrogen delivery system, effectively shipping hydrogen directly to airports to load on to aircraft as "espresso-style" capsules. "This is at the core of our business model and eliminates the need to build an airport hydrogen infrastructure," explains Williams. The firm is also developing a cryogenic liquid hydrogen capsule. It will supply the hydrogen to customers as part of the product and has already signed offtake agreements with green hydrogen manufacturers to ensure it has the fuel available when needed, Williams says.

Connect Airlines

John Thomas: 'Canisters are used in trucks, so we are not creating a new technology'

Refuelling facility

ZeroAvia has built the world's first hydrogen airport refuelling facility at its UK base to demonstrate how the fuel delivery cycle will work, and is partnering with several energy companies, including investor Shell, to gain access to green hydrogen, says Miftakhov. Its model is likely to see the aircraft with hydrogen tanks mounted on the fuselage and fuelled from a truck.

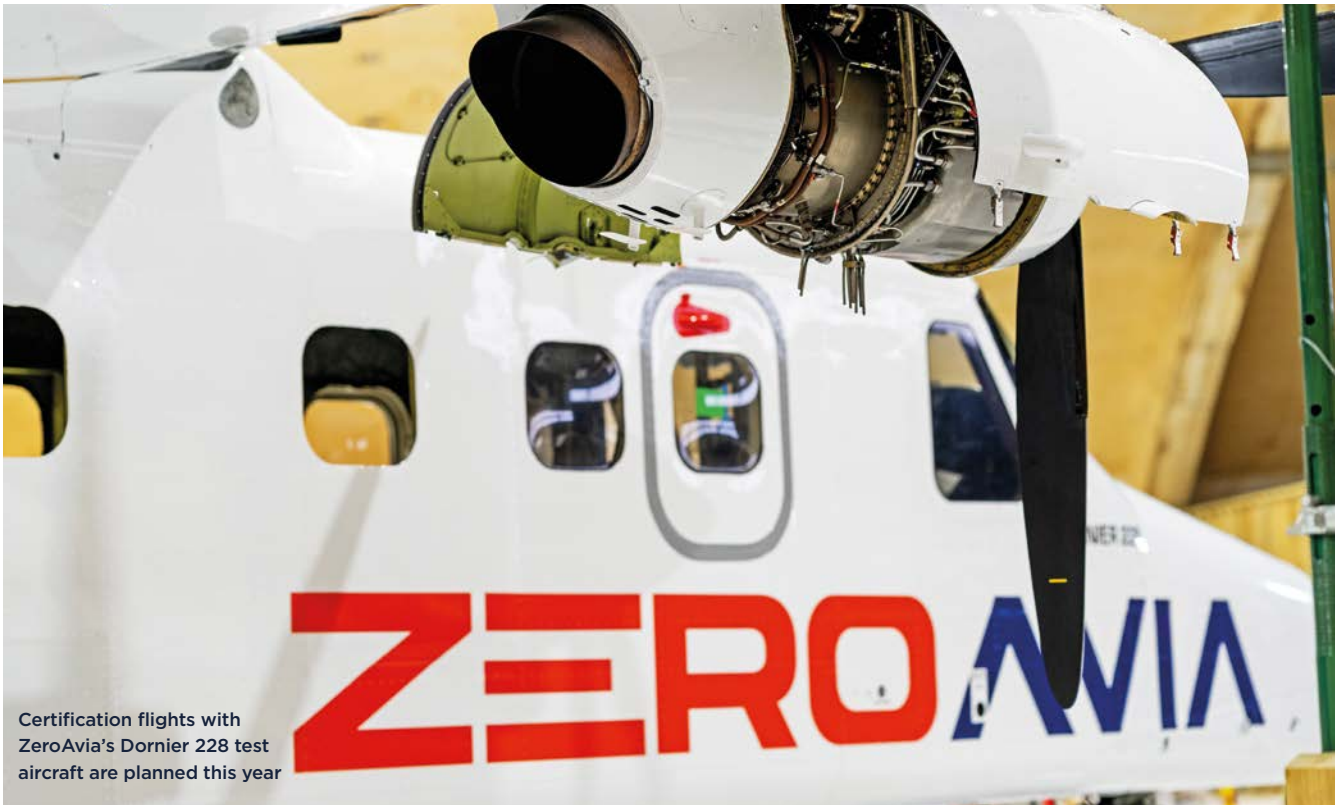
"Airports make a great deal of sense as hydrogen production hubs," Miftakhov says. "There is going to be a massive demand for green hydrogen for propulsion, and that demand enables a supply that supports other use cases for decarbonisation through hydrogen, including ground operations, onward transport links and nearby industry. The initial capex spend will ultimately be dwarfed by fuel savings as green hydrogen costs continue to fall."

"The only way to make hydrogen viable is to find a way where you don't change the infrastructure at airports," Thomas says. "The key is the containerisation of the hydrogen. These canisters are already used in trucks, so we are not creating a new technology."

However, the storage space needed for the capsules in the Universal Hydrogen solution will mean a Dash 8-300 losing about eight seats and an ATR 72 losing up to 2t of cargo capacity. By placing the fuel in outboard tanks, ZeroAvia's concept will not have a space penalty – nor will it introduce a major drag penalty for smaller aircraft.

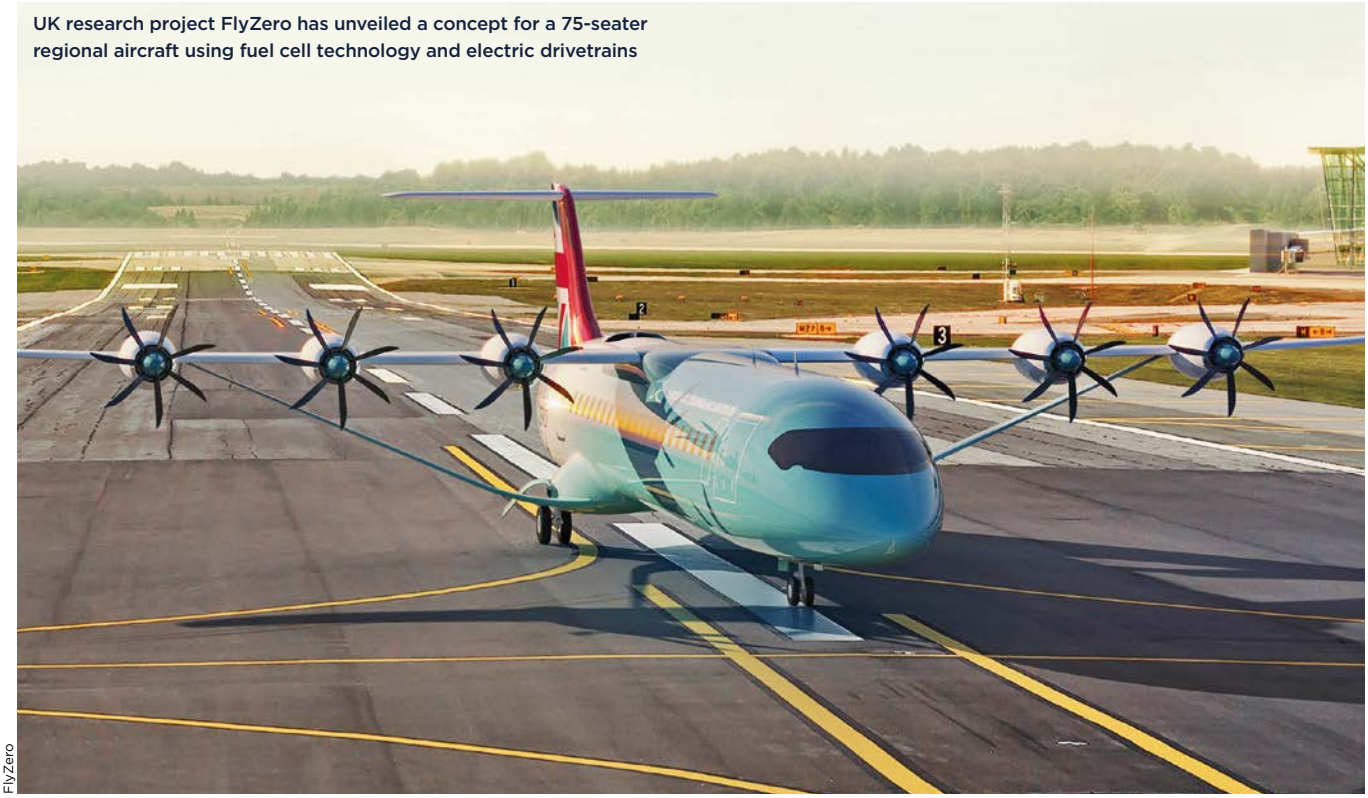
Putting a detailed business plan around a hydrogen-electric aircraft operation is not possible right now, says Thomas, because there is too much uncertainty about the aircraft's performance, fuel prices and environmental legislation. But the early adopters are convinced that being first is an advantage.

"The key for us is we don't want to be reacting to the market, we want to be in a leading position," explains Sameer Adam, senior vice-president commercial at ACIA Aero Leasing. At the Dubai air show last November, ACIA signed an LOI with Universal Hydrogen to buy up to 30 ATR 72 conversion kits.



Certification flights with ZeroAvia's Dornier 228 test aircraft are planned this year

ZeroAvia



UK research project FlyZero has unveiled a concept for a 75-seater regional aircraft using fuel cell technology and electric drivetrains

FlyZero

> "The biggest challenge in this whole game is putting the powertrain through certification in the timeframe we are targeting"
>
> **Val Miftakhov Chief executive, ZeroAvia**

According to Miftakhov: "We are going to get to cost parity at launch on a seat mile basis [for a hydrogen-electric aircraft compared with a turboprop-powered version] before you add in the incentives that will come in [for operating a low-emissions aircraft]. We know the economics will be there."

The entrepreneurs developing hydrogen-electric solutions acknowledge there are plenty of misconceptions about the technology – primarily around the safety of hydrogen itself, the cost of the fuel, the technical challenge of developing fuel cells powerful enough for larger aircraft, and that of certification. They are working through the challenges with the support of their airline partners and the regulatory bodies are engaged.

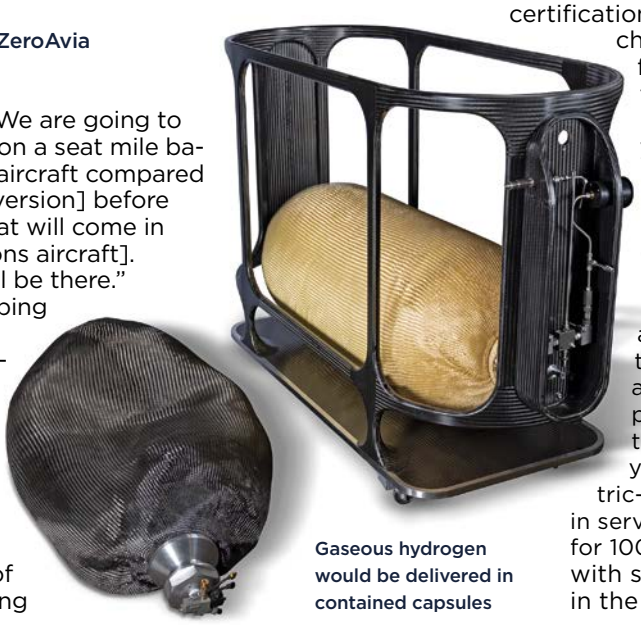
"The biggest challenge in this whole game is putting the powertrain through certification in the timeframe we are targeting," says Miftakhov. This involves building new certification guidelines. ZeroAvia already has a team of six people working full-time on certification at its R&D base in the UK.

Regulatory support

"The FAA and the CAA [UK Civil Aviation Authority] are actively supporting partners like us to create certification roadmaps," Alex Ivanenko, chief executive of hydrogen fuel cell developer HyPoint, told the McKinsey webinar.

"If you had told me five years ago we would be talking now about a hydrogen aircraft proposal, I would not have imagined it," says Gudbrandsdottir.

It is a technology that has many questions to answer, and many millions of dollars to be found and man-hours to absorb, but there are entrepreneurs and backers willing to stump up. In five more years, 50-seat hydrogen-electric-powered turboprops could be in service, becoming the trailblazers for 100-plus-seat airliners powered with some form of hydrogen fuel in the 2030s.



Universal Hydrogen

Gaseous hydrogen would be delivered in contained capsules