# HYDROGEN?

## "IT'S NOT SCIENCE FICTION"

Significant changes to GreenGT's experimental racecar underpin ACO president Pierre Fillon's confidence that hydrogen is viable for the 2024 Le Mans 24 Hours. By **Chris Pickering**

OF all the technologies vying to become the power source of the future, hydrogen fuel cells represent perhaps the biggest shift.

Engineering a car around one of these miniature onboard power stations is a huge mountain to climb – especially if you're building it to lap one of the world's most demanding race circuits for 24 hours at a time.

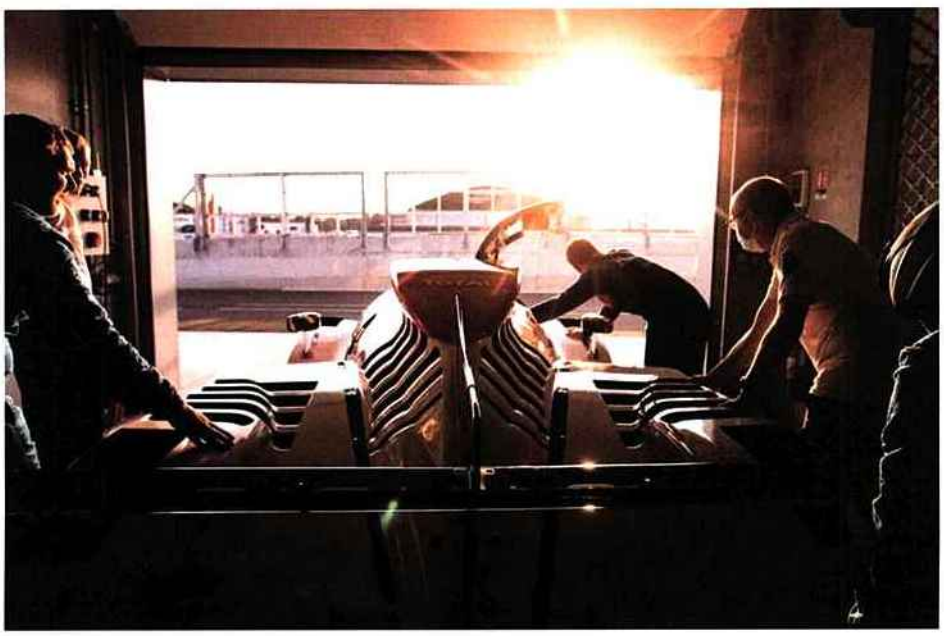
By any normal standards, the GreenGT H24 has been a long time coming. It's the third in a line of experimental prototypes that dates back to 2012, and despite some high-speed practice laps, the team has yet to compete in a race. But you'd be wrong to underestimate the importance of this car. It's a world away from the heavy and ungainly GreenGT H2 that set the first ever hydrogen-fuelled lap of Le Mans in 2016, and a significant stepping stone towards the ACO's goal of having fuel cell vehicles competing in 2024.

In between we've had the LMPH2G, which carried out a series of demonstration runs at Spa and a parade lap at this year's Le Mans 24 Hours. Like that car, the H24 is built around a modified LMP3 tub from ADESS, but pretty much everything on it is new or revised.

"The LMPH2G was mostly about testing the fuel cell," explains Hugues Lardy, technical coordinator for GreenGT. "We've focused a lot more on performance gains with the H24."

You can tell just by looking at it. This may still be an experimental vehicle rather than a true competition car, but its deeply chiselled nose, giant splitter and biplane winglets scream intent. GreenGT has yet to release any performance figures, but the eventual hope is that this car will be able to lap Le Mans at a similar rate to a GT3 machine and capable of 45-minute stints between fuel stops.

The new bodywork is linked to significant changes to the car's packaging, Lardy explains: "Last year



**LEFT** The switch from four motors to two has enabled the team to revise the rear suspension system and reduce the height of the rear bodywork


All photos: Mission H24

we had the fuel cell radiators mounted on the nose – that freed up space at the back of the car, but it wasn't ideal for cooling, and more importantly it meant that we couldn't optimise the flow around the front splitter. We also had some heat exchangers for the ancillaries that were mounted under the rear wing, which compromised the aerodynamics in that area. With that in mind, we decided to move all the heat exchangers towards the middle of the car, into the space between the front and rear wheels. This helps to clean up the air flow right back to the rear wing and the diffuser."

Look closely at the sidepods and you can make out the slightly bulbous shape of the hydrogen tanks that sit either side of the monocoque (with a third tank behind the driver). The large air intakes for these radiators sit just above the rear of these pods, while the heat exchangers themselves have been enlarged to allow for extra cooling capacity as the powertrain evolves.

Under the skin, the most significant change is the switch from four motors to two. This has allowed the development of a far more compact transmission design, with each rear wheel powered by its own motor, through a single-speed gearbox. As before, the internals for these units come from French transmission specialist Sadev, while the casing has been designed in-house by GreenGT. These smaller transmission units have led GreenGT to design a revised rear suspension system, which in turn allowed the height of the rear bodywork to be reduced, enabling some of ▸

**ABOVE** The aggressive new bodywork is enabled by significant changes to the car's packaging

> ***"Developing a fuel cell-powered racecar really is a leap into the unknown"***

**RIGHT** The LMPH2G laps Le Mans ahead of this year's race

**BELOW** The H24 (right) is 150 kg lighter than its predecessor, the LMPH2G (left), and for the first time features a greater focus on aero efficiency

the bodywork changes.

Stepping from four motors down to two also halves the number of DC-DC converters and reduces the amount of wiring, setting off a chain reaction of weight reduction throughout the powertrain. Likewise, bringing the radiators into the centre of the car significantly reduces the length (and mass) of the cooling circuits. GreenGT has also worked with ADESS to reduce the weight in the suspension and driveshafts. The dampers are off-the-shelf items from French firm PKM Consulting, but these too have been revised for the new car.

This all adds up to a reduction of around 150 kg, bringing the total weight of the H24 down to just under 1,400 kg. That's still relatively heavy by motorsport standards, but it puts it within 150 kg or so of a typical GT3 car. Where the H24 should make up for that extra mass is its LMP-style aerodynamics package and the use of a sophisticated torque vectoring system.

## FUELLED FOR SUCCESS

As on the LMPH2G, the fuel cell is mounted at the rear of the car, behind the third fuel tank. It's a new design that has been developed with Symbio – a joint venture between Michelin and Faurecia. This acts as an onboard generator, supplying electricity to a bank of lithium ion cells from Saft – a battery specialist that's been involved in Formula 1 since the days of KERS.

Unlike the previous battery, which sat behind the driver, this one is mounted in the passenger compartment, which helps to improve the weight distribution. This has been achieved without any changes to the monocoque, although it has required a new mounting system, which was tested along with the new battery itself at the CSI laboratory in Milan under the watchful eye of the FIA.

As we speak to the GreenGT engineers, the ACO is in the process of laying down the rules for its forthcoming hydrogen racing category. The H24's primary role is to serve as a testbed, building up data that will help to set the technical regulations for the class. It's also being used to assess the requirements for the circuit, including new hydrogen refuelling facilities that the ACO plans to install at Le Mans as part of a new pit complex due in 2023.

"We can refill the hydrogen tanks far quicker than it would be possible to recharge a battery, but at present it's still slower than refuelling a combustion- ▶


engined car," says Lardy. "Part of the challenge is that filling the tanks increases the temperature of the hydrogen, while emptying them (as the fuel cell consumes the gas) reduces it. Our tanks can operate over a range of +80 to -35 deg C, which limits how fast we can refill the system. We're working with Total on how we can optimise that process."

Currently the team is refuelling at 450 bar, but they're working with new sponsors Plastic Omnium on revised tanks that are rated to 700 bar. The target is to refuel in a similar duration to a combustion-engined car, which will feed directly into the plans for the new pit facilities.

The exact format of the new hydrogen category has yet to be finalised, but it's likely to follow a similar concept to Formula E, with teams free to develop parts of the car around a shared chassis. "We're looking to determine things like the best size for the buffer battery, the size of the fuel cell," comments Lardy. "Once this is done we will be able to give the chassis manufacturer [for the 2024 cars] the packaging volumes that they need to know."

## FOUR-WHEEL DRIVE?

The requirements for the fuel cell will be driven partly by the car's ability to harvest energy through its regenerative braking system. At present, the car only has motors on the rear. A four-wheel drive configuration with motors on both ends would allow it to harvest more energy under braking, which Lardy says is likely to be a prerequisite for competing successfully in 2024. Already, a lot of work has gone into the H24's brake-by-wire system, which combines regenerative braking with carbon discs and pads from Brembo.

"Managing the energy is really important," says Lardy. "We want the brake-by-wire system to be seamless to the driver. The brake pressure at the front is always directly proportional to the pedal input. At the back, we give priority to the regenerative braking whenever possible, and then we use the mechanical braking on top of that to maintain the same overall brake balance front-to-rear."

It sounds simple in theory, but the reality soon becomes complex. For a start, the amount of regenerative braking that you can extract is limited by available battery capacity; if the buffer battery is completely full, then it's not possible to provide any regenerative braking at all. To complicate matters, ▶

**ABOVE** Mounting the battery in the passenger compartment, rather than behind the driver, has improved the weight distribution

**BELOW** The sidepods reveal the slightly bulbous shape of the hydrogen tanks either side of the monocoque. A third sits behind the driver

## What they said

**Pierre Fillon**
*President of the Automobile Club de l'Ouest, co-President of MissionH24*
"By launching MissionH24 in 2018, our ambition was to show step by step that hydrogen technology was not science fiction, but a concrete efficient promising solution, and above all a guarantor of competition and zero emission mobility.

"We've been following this road map as we've already concretised different stages. First of all with the LMPH2G, the first electric-hydrogen racing prototype of its kind, then with the first H2 Mobile station by Total, and finally this weekend at Le Mans the presentation of the H24, the fruit of valuable testing carried out with the LMPH2G, and also the arrival of new partners, Plastic Omnium and Richard Mille, alongside Total and Michelin-Symbio: each in its own sphere of activity, is going to contribute to the pursuit of MissionH24 and its objective – a dedicated hydrogen category at the 2024 24 Hours of Le Mans."

**Jean-Michel Bouresche**
*MissionH24 Operations Manager and Team Principal of the H24Racing team*
"This weekend at Le Mans and the LMPH2G's lap of the track mark the end of a cycle. Since the launch of the MissionH24 project at Spa two years ago, this prototype has covered almost 10,000 km in private testing and during race weekends. In the coming weeks the H24 will take over.

"Our aim? To do more running at higher speeds for longer periods and then test this level of performance again in competition. Our new partners, Richard Mille and Plastic Omnium, which are joining Total and Michelin-Symbio in the programme, share the same ambition: namely, to show together with us that electric-hydrogen is a tangible solution for motor sport in endurance and beyond that for mobility." RT


**LEFT** The ACO believes 2024 is a viable start date for hydrogen competition

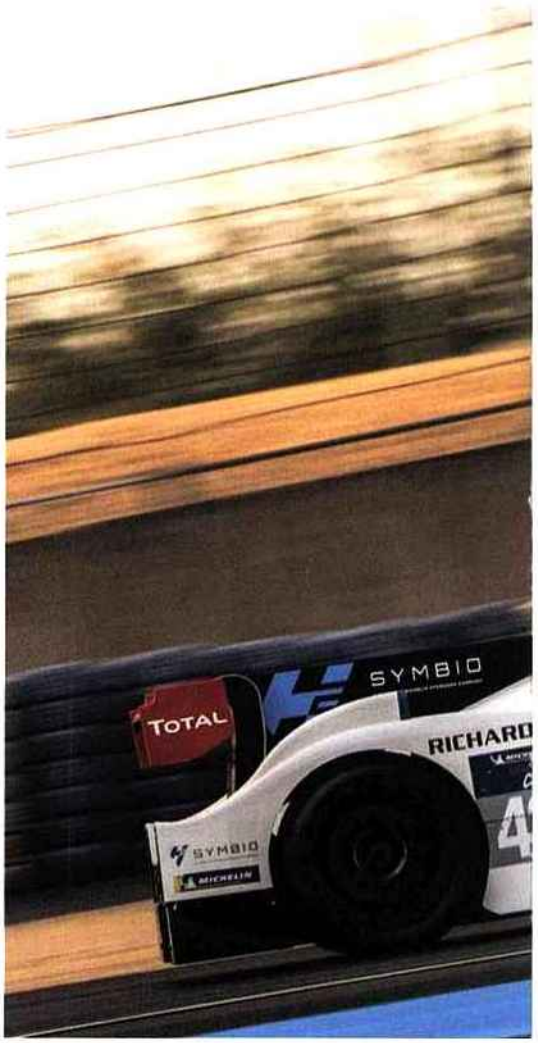

**LEFT** FIA President Jean Todt was among those taking a close interest at Le Mans

the friction coefficient of the brake material varies with temperature. The GreenGT engineers have mapped this on a test rig, but they also use infrared sensors to provide real-time feedback.

The battery itself is also heavily temperature dependent. As the temperature increases, the amount of brake regeneration will have to be reduced. Plus, there's always the possibility that regenerative system may fail, which means that the car needs to be able to stop safely on mechanical braking alone.

It's a tricky balancing act to manage, Lardy explains: "The strategy will vary from corner to corner. For example, if you're at Le Mans, you'll use up all of your buffer battery between Mulsanne and Indianapolis, so you will want to regenerate as much as possible. But you won't have time to empty the buffer battery on the short run down to Arnage, so you will have to use more mechanical braking."

It's theoretically possible that the cars could use GPS as one of the inputs to this



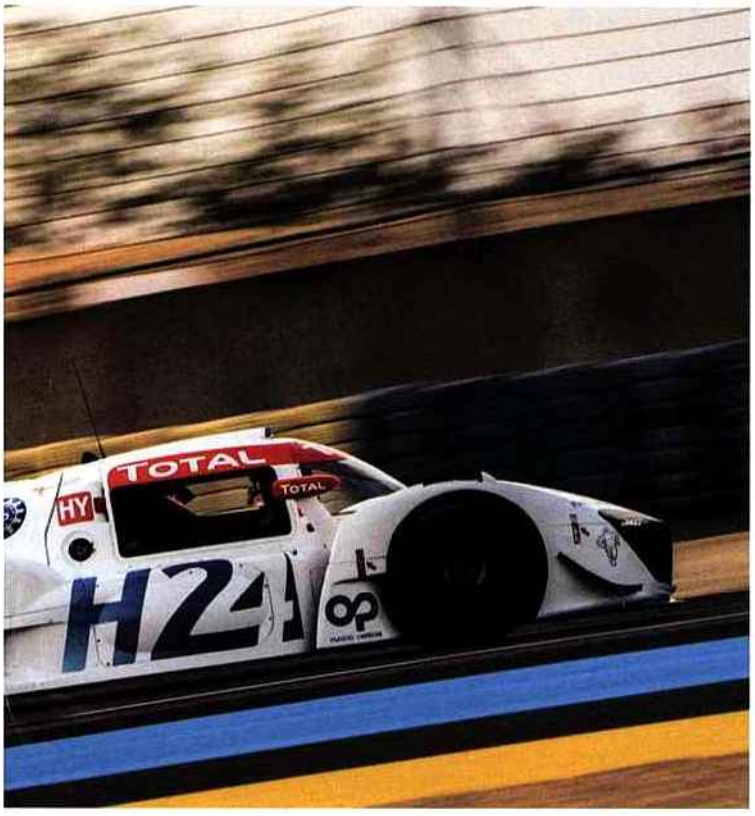
system. GreenGT has no plans at present to do so (and the technology is currently banned in other categories) but it's not out of the question. During the GT1 era, some cars used corner-specific traction control settings governed by GPS, so the technology does exist. However, it would still have to be balanced against other data, such as battery temperature.

"As well as variations from one section of the track to another, the temperature of the battery and the brakes will vary during the course of the race," Lardy points out. "At Le Mans, it could be less than 10 deg C at night, whereas the same location could be 40 deg C during the day. That means on the same braking zone you might be restricted by the battery temperature during the day but not during the night."

**RIGHT** The target is to refuel in a similar duration to a combustion-engined car

**BELOW** The ambition is that the LMPH2G's successors will lap Le Mans at a similar rate to a GT3 machine and be capable of 45-minute stints between fuel stops

> ***"Stepping from four motors down to two, sets off a chain reaction of weight reduction throughout the powertrain"***




GreenGT has another trick up its sleeve in the form of torque vectoring. With no physical differential between the two wheels, some degree of torque management is essential. Plus, this is another area where the hydrogen vehicles could potentially offset their greater mass compared to the combustion-engined cars.

## TORQUE VECTORING

"We started looking into torque vectoring with the LMPH2G," says Lardy. "That proved its potential, and I think it's going to need to be used, along with traction control, to improve performance. One of the things we're looking at is the possibility of using sensors within the driveshafts to give more accurate information on the wheel torque."

This technology is a world away from the Group C prototypes that Lardy began his career working on in the 1980s. As one of the most experienced engineers in the business, there's not much he hasn't come across, but developing a fuel cell-powered racecar really is a leap into the unknown. "It's a very exciting project to work on," he says. "There are a lot of things that we wouldn't encounter in a traditional racecar, like the energy management with the fuel cell and the torque vectoring system."

And yet for all the questions that still surround hydrogen racing, it's clear that progress is being made. As an experimental prototype, the H24 might never actually race, but it may still prove to be a landmark achievement.