June 2021 boatinternational.com

THE OCEANS ISSUE

BOAT

tional

HYDROGEN VS HYBRID

WHAT WILL POWER YOUR NEXT PROJECT?

THE 2021 OCEAN AWARDS

CELEBRATE THE HEROES SAVING OUR SEAS

ALL DECKED OUT

THE ITALIAN EXPLORER PREPPED FOR ADVENTURE

Exclusive

Ben Ainslie on his new bid for America's Cup glory

FROM SALVADOR DALI TO PRINCESS GRACE: RESCUING THE YACHT THAT SEDUCED THE STARS

£7.00

06

9 770264 913125

"EVERY MORNING WE WOKE UP SURROUNDED BY 20 OR 30 CANOES"

Off-grid cruising in Papua New Guinea

FUTURE FUEL

For years the yachting industry has got by with conservative tweaks to diesel-based engines, but now, says *Cecile Gauert*, time is up. She outlines the options facing builders and owners today in the face of tough new emissions targets

The yachting industry needs a revolution. It's currently attached to the status quo – twin diesel engines, shafts and propellers (and variations thereof) are still the norm. Why? Diesel is a widely available fuel that packs the most bang for its buck, and private yachts use some of the "cleanest" diesel available in finely tuned engines, is a typical answer. Is it true? Essentially yes, says Martin Richter, Ship Type Expert, Yacht, for classification society DNV GL. "These are cleaner solutions and state-of-the-art engines – [although] they still burn conventional fossil fuels."

But better naval architecture, increased efficiency and finely tuned engines won't suffice to meet decarbonisation goals. "To comply with the IMO's level of emissions, improving efficiency will not be enough. We will have to go through a propulsion revolution, which means new fuels," says Lorenzo Pollicardo, technical & environmental director for the Superyacht Builders Association (SYBAss).

Among problematic emissions, including carbon dioxide (CO_2) and sulphur oxides (SOx), nitrogen oxides (NOx) have been in the forefront in recent years because of a 2021 deadline that mandated the maritime industry come up with solutions to reduce NOx output.

"Yachts don't emit a lot of sulphur, but that leaves other emissions," says Robert van Tol, executive director of the Water Revolution Foundation, which is attempting to provide the first comprehensive guide that defines the yachting sector's environmental impact. "The SCR [selective catalytic reduction] system – which injects a urea solution into exhaust – is trying to tackle NOx." However, it's bulky, cumbersome and only effective at high temperatures, so the industry is looking for other solutions that will help meet regulations without reinventing the engine room.

Another reason for conservative thinking is safety. "Naval architects are risk-averse," says Jorden Kemper, founding partner at Zero Emission Advisors, a consulting company based in San Francisco that advises industries on hydrogen solutions. "[They are about] safety engineering and compliance." And they are not the only ones. Classification societies, brokers and buyers also gravitate toward proven solutions. Finally, for builders and shipyards it makes sense financially to choose incremental

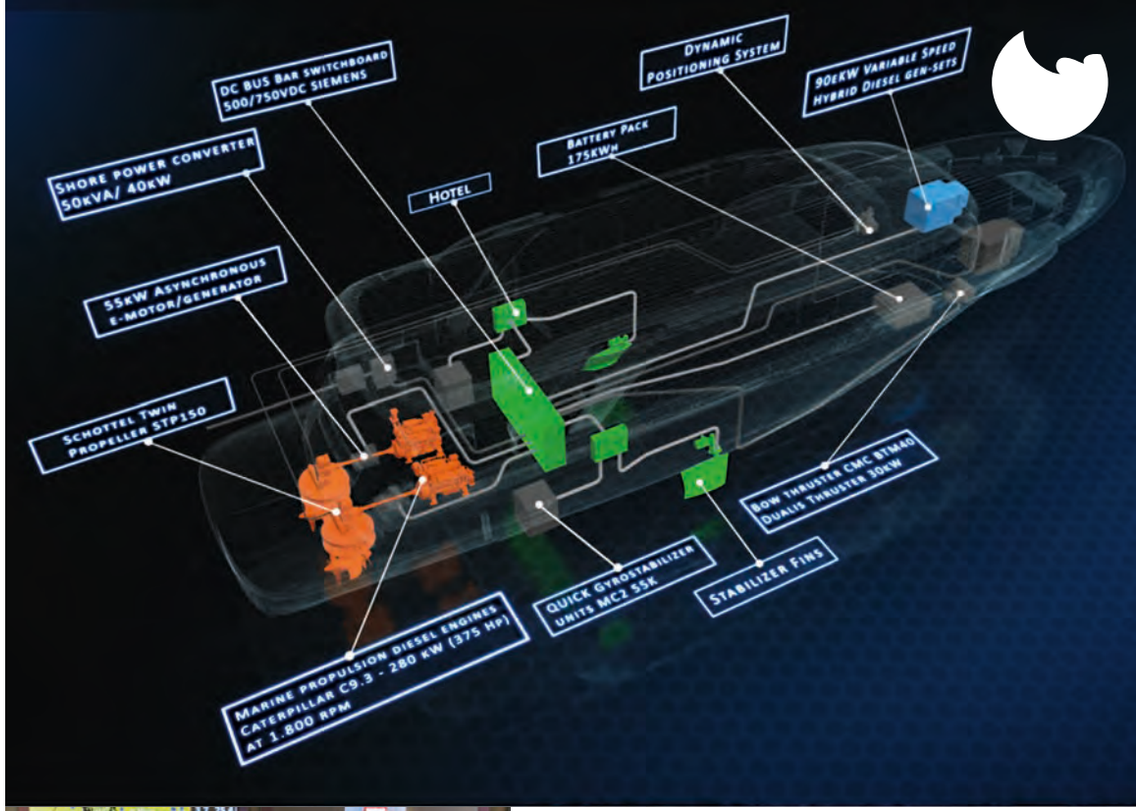
improvements (for example, better engines, variable-speed generators, heat recovery systems, batteries for peak shaving or better stabilisers) over radical changes. "Manufacturers have billions of dollars-worth of production lines based on the conventional system. Will they simply dump their investments? I don't think so," offers a naval architect and engineer working in Turkey.

Improvements are possible, including in the yacht's most fundamental characteristic, its naval architecture – especially since computational fluid dynamics (CFD) analysis has made the modelling of hulls quicker and more affordable. Take the Hull Vane, an underwater appendage that acts a bit like a spoiler on a car to improve efficiency. Heesen's first installation on 42-metre *Alive* yielded a 20 per cent fuel saving in "the yacht's useful speed range". This result is consistent with a case study on a 52-metre offshore patrol boat retrofit. Fuel consumption was reduced by 18 to 27 per cent, depending on speed. Increased stability and less fuel also mean fewer emissions (and increased comfort).

FUEL FOR THOUGHT

Although seldom discussed in yachting circles, bio and synthetic fuels offer great benefits because they work with current combustion engines and have far fewer emissions. In the US, Gevo makes fuel, essentially, from carbohydrates. It currently focuses on jet fuel and gasoline (Isobutanol made from corn), which the National Marine Manufacturers Association (NMMA) has endorsed for use as a blend in boat engines in the US. If the demand is there, Gevo can also produce biodiesel for maritime use.

Rolls-Royce (which owns engine maker MTU) sees these types of fuels as a good transition solution. "Short- to medium-term options are synthetic diesel fuels, [such as] the second generation of bio-based fuel like HVOs [hydrotreated vegetable oils], and in the longer term we believe there will be a transition to e-fuels [synthetic fuels produced by electrolysis]," says Daniel Chatterjee, head of Exhaust Gas After-treatment & Green & High-Tech Programme at Rolls-Royce Power Systems. "Our modelling sees that the major take-up for renewable fuels made from electricity will be after 2030. Until then, we will see those bio-based fuels." Because engines can work with synthetic and conventional diesel indiscriminately, availability will not be a problem, even for long-distance cruises, making them an attractive intermediate solution.



Above and right: E-Motion created a hybrid propulsion system for the 42m Perini Navi Evolution. *Bottom right: E-Motion's drawing for electric engines and batteries set up on the Sanlorenzo 86*

WHY WON'T INCREMENTAL CHANGES SUFFICE?

For better or worse, large yachts are considered part of the maritime community and have to comply with international conventions, says Pollicardo. Driving change in the maritime world is the IMO's 2018 adoption of greenhouse gas emission reduction targets. "The real objective is to reduce the total greenhouse gas emissions by at least 50 per cent by 2050," he says, with full decarbonisation by 2100.

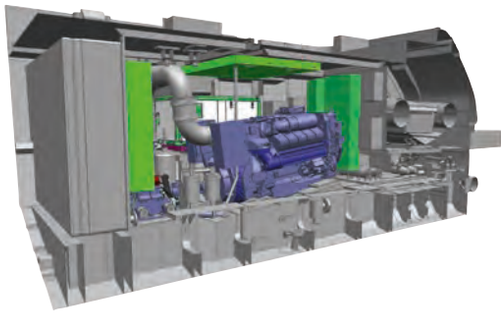
Combustion engines have had more than 100 years of refinements and are very good at converting fuel into mechanical energy. "[But] when you are at 40, 45, 50 per cent (thermal) efficiency, you reach a point where you can't make the engine significantly more efficient," says Kristian Holmefjord, executive vice president and project director–fuel cells for Corvus Energy (*see overleaf*).

IMO's 2018 resolution also implemented an Energy Efficiency Design Index (EEDI) that requires a minimum energy efficiency level per capacity mile for new ships, and Pollicardo says it's essential for the yachting industry to come up with facts and figures relevant to private yachts to help tailor these regulations. For instance, ships have regular routes and predictable

<50%
Proportion of large yachts that will be built to use conventional diesel by 2035

60%
The percentage rise of CO_2 emissions by 2040 with no mitigation

50%
The amount battery costs could drop in the next few years



>>

PHOTOGRAPHY: COURTESY OF E-MOTION; COURTESY OF BAGLIETTO. SOURCES: ROLLS-ROYCE; MAGNUS EIDE; DNV GL; REMI ERIKSEN

speed and behaviour, while SYBAss has calculated that yachts operate an average of 400 to 500 hours a year. This means that solutions devised for the shipping industry will not necessarily translate to yachts, and vice versa. Besides, "There is no comparison between the economic model of yachts and the shipping industry," says Laurent Perignon, who advises Energy Observer Developments (EODev), an R&D firm working on speeding up the energy transition.

There is also the matter of public image. Who wants to be seen as having wanton disregard for a global environmental problem? Yacht owners don't. Lennart Pundt, head of project development for Lürssen, sees a parallel between new designs that place the lifestyle close to the water and an "increased awareness and care about environmental responsibility. The mindset is changing," he says.

76%
The additional volume required for diesel fuel alternatives for the same energy content

20-30°C
The temperature at which batteries operate most efficiently – the same as humans

1839
The year of the first known electric boat, which carried 14 passengers at three knots

WHAT ARE THE CURRENT OPTIONS?

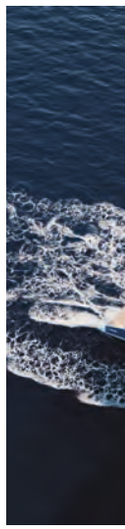
The time has not yet come to ditch the combustion engine. It will play a role for up to 50 years, Homelfjord says, but a transition is happening with many taking a look at re-emerging fuels (for instance, hydrogen, ammonia or synthetic diesel) and new power conversion solutions. A common thread is electrification through fuel cell and battery technologies.

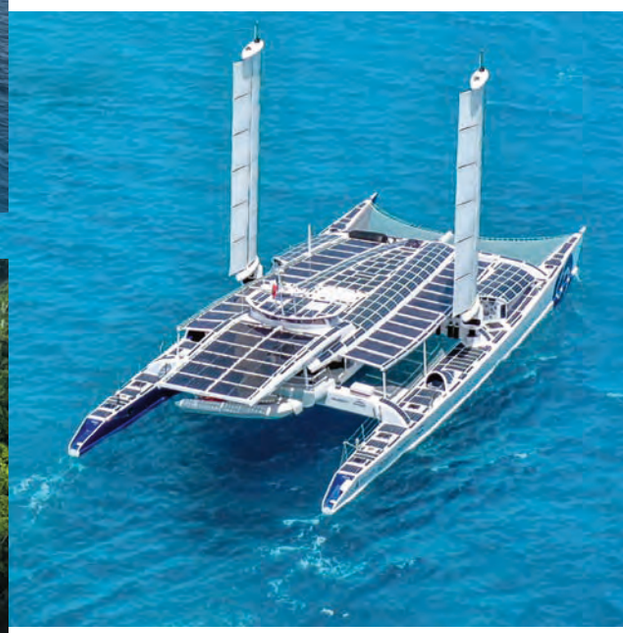
1: HYBRID

"There are currently more than 500 hybrid or purely electric ships of all kinds either in service or under construction. What is truly impressive about this number is the fact that it has grown from practically zero over as little as five years," says DNV's Richter.

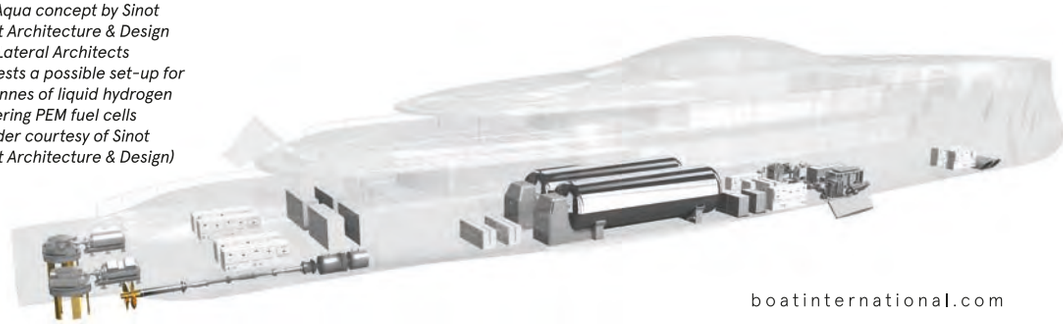
Whether going hybrid is currently a "green" solution is hotly debated and it's nearly impossible to quantify fuel (and emissions) savings because yachts have such different operating profiles. "We do not have any numbers to show that diesel-electric hybrid systems are better or worse in terms of their fuel efficiency," Richter says, "but they have a number of advantages over conventional engines" – reduced noise and increased comfort.

The best way to do that would be to equip two identical yachts with hybrid and conventional propulsion systems, access their data, and compare their fuel consumption over time. Tankoa comes close to this scenario, having equipped its 50-metre aluminium platform with





The Aqua concept by Sinot Yacht Architecture & Design and Lateral Architects suggests a possible set-up for 28 tonnes of liquid hydrogen powering PEM fuel cells (Render courtesy of Sinot Yacht Architecture & Design)



PHOTOGRAPHY: COURTESY OF PHILLIPE BRIAND; ENERGY OBSERVER PRODUCTIONS – GEORGE CONTY; ENERGY OBSERVER PRODUCTIONS – FITZGERALD JEGO; COPYRIGHT VOLVO PENTA; COURTESY OF MERVEILLE YACHTING; LATERAL NAVAL ARCHITECTS. SOURCES: ROLLS-ROYCE; EGIL MOLLESTAD; ZEM

both conventional and hybrid systems.

The shipyard worked with E-Motion on the parallel hybrid system installed on the World Superyacht Award-winning 50-metre *Bintador*. The set-up combines two diesel engines (with maximum rated power of 895kW), generators and electric engines. Good management is key of course, but the shipyard's technical director, Andrea Parodi, says that in the range of 15 to 17 knots and using the shaft alternator option (diesel engines on, generators off and electric motors producing electricity) it's realistic to expect to save 15 to 20 per cent in fuel consumption and extend the range from 4,000 to 4,400 nautical miles. This platform, he says, is well suited to hybrid because "the hull is very efficient in low-speed conditions, seven to 11 knots, and does not need a lot of power to start moving." It takes two small generators (500kW) and electric motors to run the yacht up to 11 knots and keep all the lights on. An in-build hybrid yacht at Tankoa will also have a zero-emission mode.

With the introduction of improvements such as variable-speed generators and energy-dense batteries, the range of potential applications has grown significantly since 2006 when the founder of E-Motion, Michele Maggi, worked with Ferretti on the first hybrid system to be fitted on a motor yacht (a 23-metre Mochi Craft). Maggi sees perfect applications on everything from 30-metre planing yachts to sportfishers, which can charge batteries while heading to their fishing grounds, then trawl for hours on electric power, with savings of up to 30 per cent in fuel and emissions, he says. And thanks to the fast progress in batteries, it's only going to improve. E-Motion currently works with shipyards in the US and Italy, including Azimut-Benetti, for whom it is developing hybrid solutions for several models in the builder's semi-custom lines.

In the superyacht segment, Benetti has already implemented hybrid solutions from relatively simple systems (an additional electrical input on a shaft line, for example) to diesel-electric systems with Azipod propulsion – the 107.6-metre *Luminosity*, for instance. The giant yacht's 3,000kW battery bank can power the hotel load for 12 hours.

Most, if not all, superyacht builders have delivered or are working on hybrid projects. At the same time, more companies are developing hybrid systems, including Rolls-Royce, which already offers custom solutions and is working on the 2022 release of a turnkey system suitable for yachts 30 metres and up. MTU's neighbour, ZF, which is known to the yachting world for its transmissions, is working on a power-take-in (PTI) solution that allows plugging in an auxiliary electric motor.

2: DIESEL-ELECTRIC

ABB Marine & Ports, which has already fitted several Azipod-driven superyachts, including *Luminosity* and the 80-metre Nobiskrug *Artefact*, has recently struck an agreement with Ballard Power Systems to speed the development of fuel cell-based solutions for the maritime industry.

Right now, the company posits that electrically driven propulsion (Azipods) is the best way to go. Why? Diesel engines on yachts seldom operate at their peak performance, particularly in slow manoeuvres. "A superyacht's engines are typically rated for a maximum vessel speed of, say, 18 knots, but the yacht may for a significant part of its life idle around at speeds between nine and 12 knots," says Riccardo Repetto, global segment manager, yachts at ABB Marine & Ports. "Apart from reducing fuel efficiency, operating at lower loads increases exhaust emissions, generates particles and soot and shortens the service intervals of the engine." He adds that electrical propulsion is much more efficient and a solution such as electric Azipods "further increases fuel efficiency through electric and gearless thrust, as well as through the reduced vessel hull resistance".

Other benefits include comfort at anchor and underway and flexibility in design on large yachts. "The electrical power and propulsion plant in its many shapes forms the platform in the development towards zero emissions," says Thomas Hackman, market development manager for yachts at ABB.

Again, numbers are not readily available due to the individual

WHY FUEL CELLS?

A fuel cell is an engine that works without ignition and converts fuel to electricity via an inherently more efficient electrical-chemical process than combustion. There are essentially two different types of fuel cells: low-temperature cells that operate primarily with hydrogen (the most commonly used in cars and most likely for early applications on yachts are PEM fuel cells) and high-temperature fuel cells that can convert other fuels, including gas and diesel, to electricity.

Kristian Holmefjord of Corvus Energy anticipates that fuel cells will become the go-to solution on yachts and ships within 10 to 40 years from now, depending on vessel type.

The biggest challenges with hydrogen are storage and handling. Cost and availability are also current hurdles, which is why vessels that don't need a lot of range or that operate on predictable routes in regions where hydrogen is already available will be the first to benefit from the technology, he says. Corvus Energy is working with Toyota, one of the world's largest producers of fuel cells, to adapt the Japanese carmaker's technology to the marine environment. Corvus is also assisting with a pilot project that is converting a Sunseeker Predator 95 into the first "green" fast-hydrogen power yacht. "Hydrogen Viking should sail long before 10 years, but there is a big difference between a pilot and a commercially viable technology," says Holmefjord, who foresees a long transition from combustion engines. By 2060, however, he expects no one will be building engines as we know them today.

Left centre and top: SY200, a 63m emissions-free concept by Philippe Briand; right top and centre: a concept by Merveille Yachting that uses wingsails for propulsion in addition to small diesel engines; lower right: Energy Observer, *which carries 63kg of hydrogen on board providing 1MWh of electricity*

Above: 80m Artefact *and its bank of batteries. Her captain enjoys the flexibility the system offers, from zero-emissions, to an Atlantic crossing using just one engine. Below: tank testing and underbelly Hull Vane of 42m* Alive, *which her builder says saves 20 per cent fuel*

operational profile of each yacht, but a diesel-electric system, such as the one fitted on *Artefact*, offers great flexibility and the ability to fine-tune power needs. *Artefact* can cross the Atlantic with just one diesel engine; one generator suffices to power the house and propulsion pods at cruising speed, plus she can cover short distances on batteries alone, which all add up to less fuel consumption and reduced emissions. After a few months of running the yacht in various conditions, including a transatlantic crossing, *Artefact*'s captain, Aaron Clark, estimated diesel fuel savings to be 20 to 30 per cent, depending on the operational mode. In the future, elements of *Artefact*'s hybrid propulsion system can be changed to newer solutions, including fuel cells.

Ivo Veldhuis, co-founder of superyacht consultancy Mayfair Marine, also says diesel-electric is a giant step forward. "You have the opportunity to change the way you generate power – part batteries, part engines – and you can decide to run those engines either on diesel, liquid natural gas [LNG] or even ammonia to reduce environmental impact and emissions."

This does not take care of all CO_2 emissions, and LNG is only considered an intermediate solution since it is a fossil fuel, but such systems can be built (as it was on *Artefact*) for eventual upgrades to fuel cells that use methanol or liquid hydrogen when that becomes more feasible. "The key element is the electric propulsion plant," says Veldhuis.

A FOSSIL-FREE FUTURE?

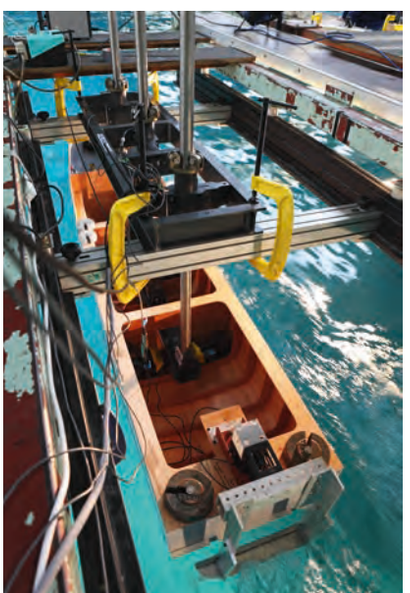
This unavoidable goal is driving many to explore all solutions, including hydrogen. In 2019, Sinot Yacht Architecture & Design and Lateral Naval Architects made a big splash with a concept presented at the Monaco Yacht Show for a 112 metre called Aqua that integrated a 28-tonne capacity liquid-hydrogen system powering PEM (polymer electrolyte membrane) fuel cells. This concept, as well as pilot projects such as *Energy Observer*, a zero-emissions energy self-sufficient catamaran that uses hydrogen, wind and solar as its only power sources to go around the world, have helped revive the hydrogen discussion.

Hydrogen has many virtues: it is the most widely available molecule in the world; it is carbon free, energy dense and its only byproduct is water. Seems like a dream? Maybe.

"Hydrogen has got this habit of making false starts. Everybody thinks, it's going to happen. And then it doesn't," says Veldhuis, who wrote his doctoral thesis on the application of hydrogen to marine systems and helped set up Hydrogen Europe's maritime working group.

One issue with hydrogen is storage. In gas form it's very voluminous and tends to spook people based on safety, and in liquid form it needs to be kept at very low temperatures and requires roughly four times the space of diesel. That does not stop superyacht builders (and classification societies) from investigating options.

Hydrogen use requires extensive modifications of the yacht, says Bram



ELECTRIC PROPULSION FOR SMALLER YACHTS

While diesel-electric systems and Azipods are suitable on superyachts, pod solutions are in the works for smaller yachts. Volvo Penta brought IPS and pod drives to yachting and we should soon see the company's first hybrid IPS application on a yacht. Italian startup Sealence, meanwhile, has developed an electrically powered waterjet called DeepSpeed, which can be fitted to boats of all sizes and draws power from a hybrid system that includes fuel cells. The company is planning its first commercial installations for 2022.

PHOTOGRAPHY: FRANCISCO MARTINEZ; DICK HOLTUIS | COURTESY OF HEESEN

>>

Jongepier, a senior specialist with Feadship's De Voogt Naval Architects, adding, "We know – we are building one." However, he describes this zero-emission solution as best for "the purist" and says that "a partial range on hydrogen is a smart solution". An early adopter of synthetic fuels, Feadship deems them (specifically HVO) "most suitable for retrofitting" with few modifications and a substantial reduction in emissions. Jongepier says methanol's availability and pricing gives it the edge and may push it into "a dominant position". Despite the shortcomings of existing solutions, it is possible to build a fossil-free yacht now, he says, "if the owner really wants it".

And owners do want it. Just before this issue of *BOAT International* went to press, Lürssen announced it had received its first order for a yacht with fuel-cell technology. The company was working on this development as part of a consortium of German builders. "We feel comfortable putting this technology on board," says Björn Berndt, who is part of the project development team. However, Lürssen is looking at more widely available energy carriers, such as green methanol or ammonia.

"With hydrogen, you really have a range issue," Pundt says. "The handling is complicated, and the space requirement is in areas of the vessel where you usually have dry storage, freezers, laundry and is quite valuable space." And then "you lose the greatest benefit that you have for a yacht, that you are independent, that you can travel wherever you want, to the most remote and beautiful places where there is no hydrogen supply chain".

While it has its limitations, methanol is easier to handle and has higher energy density than hydrogen, so Lürssen has built a testbench to prove its methanol fuel cell and auxiliary systems under realistic conditions. The recent sales announcement will shorten the timeline for the first application, which Pundt had said would be within five to 10 years.

Methanol is sulphur-free and has low overall emissions, although in that respect, it is not the dream scenario that green hydrogen represents – no emissions other than water.

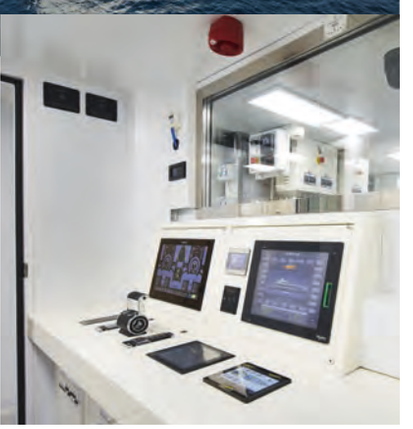
DON'T FORGET ABOUT SAILS

"The first fossil-free yacht should be a sailing yacht," says naval architect Philippe Briand, just as the first hybrid superyacht was a sailing yacht – Royal Huisman's 58-metre *Ethereal*, delivered in 2008. Briand's studio recently released a concept for a 63-metre, 490-gross-tonne fossil-free sloop with an efficient hull form, 20 tonnes of batteries and underwater turbines to generate 500kW at 20 knots. Whether sail or power, Briand believes hydrogen can play a supporting role in yachting and he has a solution ready for the 50-metre Vitruvius *Exuma* to generate hydrogen on board. "We made a whole study, and it is completely doable, particularly for this yacht that has a generously sized garage," he says. "It is a wonderful solution. While we don't promise to generate enough power for the propulsion, it would be sufficient for the hotel load."

The self-sufficient, floating laboratory *Energy Observer* combines the hydrogen it generates on board with solar and wind power to provide for all its energy needs. To harness wind power, it switches from wind turbines to wind propellers, known as wings. These have also caught the attention of the developers of the Merveille concept, a superyacht that combines renewable energies (like the sun and wind) with small combustion engines. The solutions, says Merveille Yachting CEO Nicolas Cantenot, are "simple, reliable and doable". Wings can be seen as motors that work with the wind, twice as efficient as regular sails, which allows reducing the size of the combustion engines on board.

"Even on a sailing yacht you need a diesel engine," says EODev's Perignon. "The best option now is the combination of solutions, and engineering [the yacht] so that you can adapt to the accelerating technologies that are emerging."

There may not be a consensus on how to reach the goal of fossil-free yachting in the future, but electrification holds the keys to a better lifestyle on board and opens the door to technology such as fuel cells. Kilowatts, it seems, will be the new knots. B



Above and top: 108m diesel-electric Luminosity *and her 3,000kW battery bank; right and bottom: 50m* Bintador, *which has a parallel hybrid system developed with E-Motion*

250%
The amount emissions from shipping could increase by 2050 due to growth in maritime trade

60-70%
The amount battery costs have dropped in the last four years

<$200
The cost per kWh at the cell level in the not-too-distant future, as predicted by Elon Musk

PHOTOGRAPHY: RICCARDO BORGENNI; JOBDV NICO FULCINITI; COURTESY OF BENETTI. SOURCE: ROLLS-ROYCE