We Have the Technology

This presentation summarises the results of a thought-provoking study by Lateral Naval Architects and PA Consulting into the feasibility of developing a net zero fuel manufacturing and bunkering infrastructure to support a superyacht powered completely by hydrogen technology.

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We are frequently asked what the best fuel choice will be in the future. The only reponse is, "There is no single answer." The net zero future will be an eco-system, and as such no one solution will prevail. No one can operate in isolation, because as an eco-system there has to be interdependence. Many fuel types, technologies and solutions will be leveraged to serve various industries. Collaboration is therefore key at regional, national and international level.

The decarbonisation of the wider marine industry has already begun with numerous alternative fuel projects underway. Many are technology demonstrators on a modest scale, but the challenge lies in the scalability and speed of bringing solutions to market in a practical, operational manner. This is a slow process and the transition away from a fossil fuel-based infrastructure will take a significant amount of time.

THE PROPOSITION

In the context of superyachts, and the wider marine industry, the issue is not one of technology. We have the technology available today to deliver net zero solutions, whichever chemistry of alternative fuel is pursued. The laissez-faire approach will be to wait for the commercial marine industry to coalesce and then leverage the solutions adopted. However, it is unrealistic to expect that the specific needs of the superyacht industry will be considered with the result that we are left on the back foot and forced to use ship-side solutions that are ultimately a compromise.

Could we, for example, build our own fuel production and distribution network specific to our needs? If we had decentralised alternative fuel production facilities, say one in the Mediterranean and one in the Caribbean, could we create a green corridor with sufficient footprint to cover the majority of the superyacht milk-run? It is not difficult to imagine how with time and investment that network might expand to cover a greater geographical area. This is not a silver bullet solution. It would require us to start small and think big, take a long-term view and lead by example.

Consider this: of our industry's existing client base, six out of 10 of the wealthiest people in the world already own a superyacht. We have already sold them our products; how can we make it compelling for them to invest in the future of alternative fuelled superyachts?

To answer this, we first set about investigating smaller questions. What would be involved, and what is the scale of investment needed? As a starting point, we have used the *Aqua* project, a 110-metre liquified hydrogen concept design from 2019. As noted in our opening narrative, liquefied hydrogen will not be the only answer to the net zero future, so the metrics and outcomes may differ for other fuel types, but the feasibility of the proposition still holds.

To determine the building blocks of the required production and bunkering demand, an operational profile was assumed. This profile is typical of the majority of superyachts in seasonal use in the Mediterranean and Caribbean. Using the *Aqua* design and operational profile, we defined the month-by-month bunkering demand, assuming two facilities as previously described. »

THE CONTEXT

It should be clarified that the study of infrastructure is based on the production of green hydrogen, which refers to hydrogen produced by electrolysis. Electrolysers are relatively embryonic in technology, but are undergoing rapid improvements in capability. Energy used to produce the hydrogen is from low carbon and renewable sources such as wind, hydro and photovoltaics.

The production of green hydrogen via electrolysis demands a significant supply of water, generally between 40-45 litres for every kilogram of hydrogen produced. This water demand would typically be met by desalination. Lastly, the gaseous hydrogen output from the electrolyser, undergoes cryogenic liquefaction to improve the volumetric energy density of the final product.

Liquefaction, whilst essential from an energy density perspective, is in itself a very energy intensive process. The gaseous hydrogen must be converted at approximately 30 bar and stored at -253°C. This requires approximately 10kWh for every kilogram of hydrogen, which is about one-third of the energy contained within the hydrogen itself.

Approximately 90 million tonnes of hydrogen is used across three principle industry sectors: refining, fertiliser and chemical production. This is mainly black or grey hydrogen derived using energy from fossil fuels. Decarbonisation of this hydrogen footprint is a huge challenge for industry. To put it into context, if all of the available renewable electricity derived from hydro, nuclear, wind and photovoltaics was employed in this task, around 50 percent of that energy would be required to decarbonise the current demand from these three primary markets. This highlights how far there is to go before the availability of green hydrogen would reach wider scale availability.

Globally, however, there is significant investment in hydrogen infrastructure. Around 17 governments have announced hydrogen policies and strategies with approximately 500 green hydrogen infrastructure projects underway around the world. These are mainly clustered around coastal locations to support local industry and maritime infrastructure.

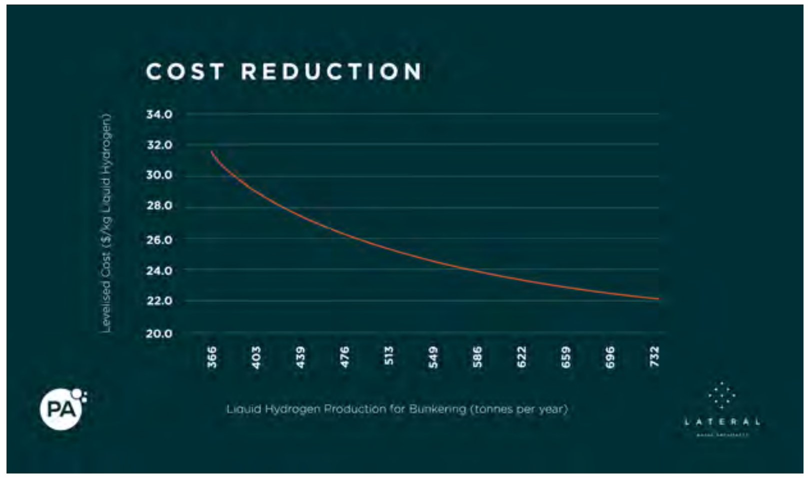
THE SPECIFICS

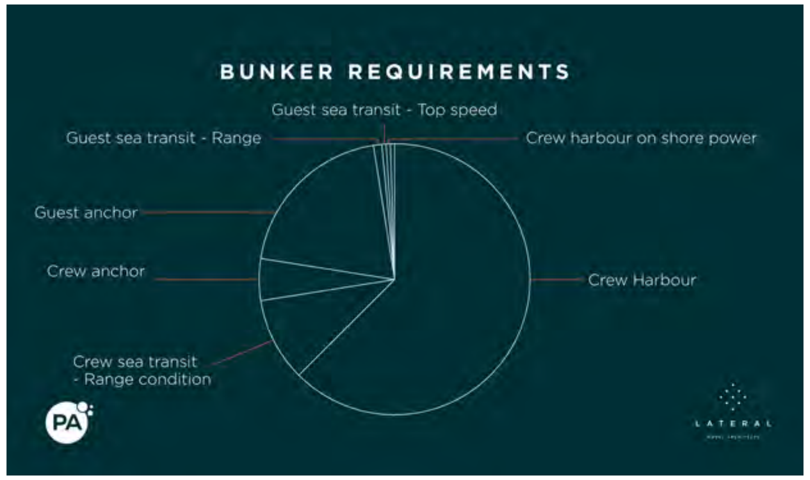
Our study examines two scenarios to determine, firstly, the overall technical feasibility and, secondly, the economics of the proposition. The first scenario draws directly on the worldwide development of green hydrogen infrastructure and examines how a hydrogen bunkering facility might be strategically located, but with the fuel procured from a hydrogen production hub.

The second scenario examines the creation of a truly independent network incorporating onsite production and bunkering at a local decentralised facility. Within this presentation, only results relating to scenario two are presented (the outcome of scenario 1 can be found in the full text of the public domain technical paper supporting this work).

The study of bunkering requirements established an average output of approximately 30 tonnes per month would be required. To supply this demand, the various components of the decentralised facility have been determined and the level of renewable energy needed to power the process calculated at approximately 4MW.

Considering equipment sizing for the capacity demand, access and safety distances, the total footprint of the facility would be approximately 20,000 square-metres. To give a sense of scale, if the same energy was to be provided by a solar array then approximately 50-80,000 square-metres would be needed. This is a utility scale facility and highlights any notion of onboard solar energy production as wholly unfeasible.





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THE COST

The headline CapEx (capital expenditure) to establish two bunker facilities, would be US$84 million with an annual OpEx (operational expenditure) of US$5.7 million dollars. With the CapEx amortised over 15 years, there is an average annualised cost of US$11-12 million. Based on comparison with the operational fuel costs of an equivalent diesel-powered yacht, the cost of achieving net zero via this approach would be approximately US$7-10 million per annum.

How could the economics be improved? This study is based on an idealised scenario of building two bespoke production and bunkering facilities, serving a single yacht with seasonal operation. Not surprisingly, the levelised cost per kilogram of hydrogen derived by this approach is extremely high. If the CapEx could be leveraged across a greater number of yachts, then costs rapidly begin to fall. Additionally, non-seasonal production would in practice be sold to other industries, thereby further increasing plant utilisation and reducing the cost per kilogram further.

By way of comparison, there are large hydrogen projects currently under development that will produce gaseous hydrogen for under $10 per kilogram. Whilst that cost excludes liquefaction, it gives an indication of just how far costs could be reduced to make the proposition more economically compelling. »

SOME CONCLUSIONS

Is it a plausible and feasible proposition for the superyacht industry to invest in their own net zero fuel production and distribution infrastructure? We believe our study illustrates that it is both technically possible and that the economics could be made compelling.

The size of the production and bunkering plant required is relatively small, but the geographical footprint of the renewable energy to power it is large. This is an interesting reflection point for our industry to understand the scale of renewable energy required to achieve net zero. A 4MW power plant in fossil fuel terms is relatively easy to understand, but a solar farm of 50-80,000 square-metres puts our energy use into stark context.

The cost on a single yacht basis is clearly very high, possibly as high as a quarter of the procurement cost of the yacht itself. And as a first-in-class example a fully liquified hydrogen design represents a significant investment and technology risk.

However, the potential to reduce costs on a multi-yacht investment basis is plausible, and the technology to implement both the land-based and ship-side technical solutions are commercially available. In our view, a purely hydrogen powered superyacht is also feasible within the next generation cycle of superyacht development, at acceptable technology readiness levels and within a properly strategized project. Other alternative fuels, such as methanol, can further leverage the proposition of an industry-led approach to net zero production and bunkering.

The technical solutions to our net zero future already exist. We need to inspire those who have the means to enact them to take action. If you are reading this as a stakeholder in our industry, then you can help make it happen.

Above: Could the yachting industry develop its own net zero fuel bunkering infrastructure like Tesla's global, fast charging network?