Pushing the boundaries

A mix of battery and hydrogen boat power is an environmentalist's dream come true – but will it be able to perform alongside diesel-powered tugs instead of constituting a well-intended vanity project? Stevie Knight meets the developers making it happen

A zero-emission, hybrid H_2 and battery tug would be difficult enough to achieve. But one that is capable of pushing a 1,400tonne loaded barge nearly 400km?

That's the solution proposed by BEHALA, Berlin harbour's warehousing and logistics firm. It's aiming to pick up heavy-duty gas turbines from Siemens' production plant and deliver them to Hamburg Port.

The design of the c.130tonne-displacement *Elektra*, which will be built at the Hermann Barthel yard commencing in October, inevitably raises challenges. The 20m-long pusher design has a beam of 8.2m and draught of 1.25m, but it has taken – quite literally – in-depth research to get right.

"There's no problem with a shape like a box when fuel is cheap and the power's as big as you'd like," says Professor Gerd Holbach of project leader and partner Technische Universität Berlin. "But if you can't just turn up to a bunker station and ask for a refill, energy conservation becomes the most significant element."

Single thruster channel

Therefore, rather than work with a conventional push-tug hull, the team turned to CFD calculations followed by intensive tank tests. This development couldn't just focus on the tug alone; for realistic evaluation, it had to account for the pusher and barge pairing.

This resulted in a long, shallow entry at the bow which, while it shaved just a little from hydrostatic parameters, led to much improved hydrodynamic efficiency. However, further challenges were waiting at the other end of the tug.

When it came to seating the pair of 200kW, fully rotating Schottel units, the hullform deviated sharply from expectations. The two thrusters have not been positioned in separate ducts but are instead in a single channel that nearly spans the entire rear of the vessel. Holbach explains: "There's a very wide range of depths along the route, and sometimes we'll only have a couple of metres of water... separate tunnels wouldn't have resulted in enough flow to the thrusters to make it efficient."

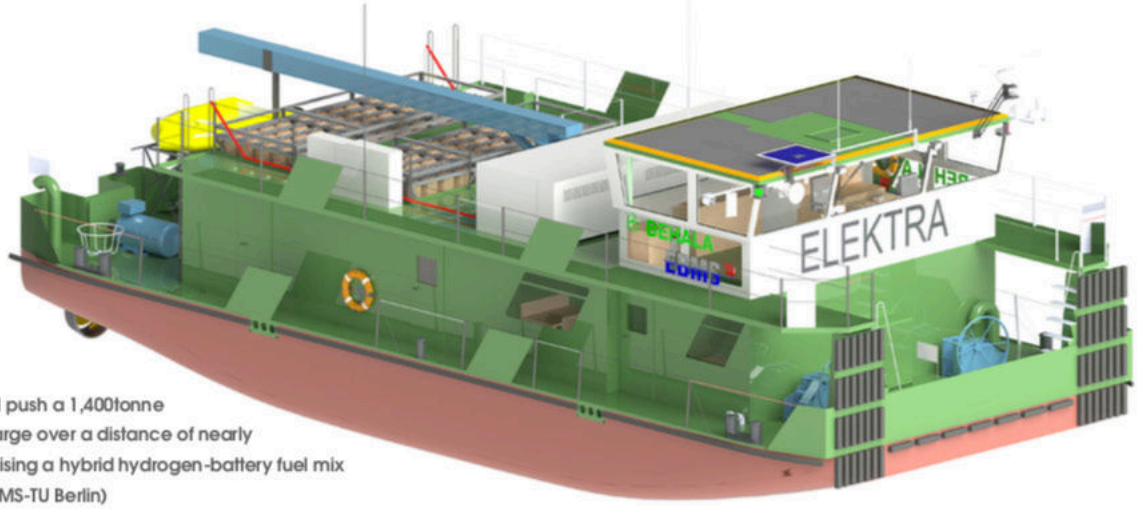
Vessel weight was also an issue. However, although the project decided on steel instead of more expensive, specialist materials for the hull, Holbach says: "We looked into the details and changed a lot of small things like the railing stanchions. In fact, we were astonished at how much weight we could save – it worked out to be around 20tonnes."

H_2 storage modules

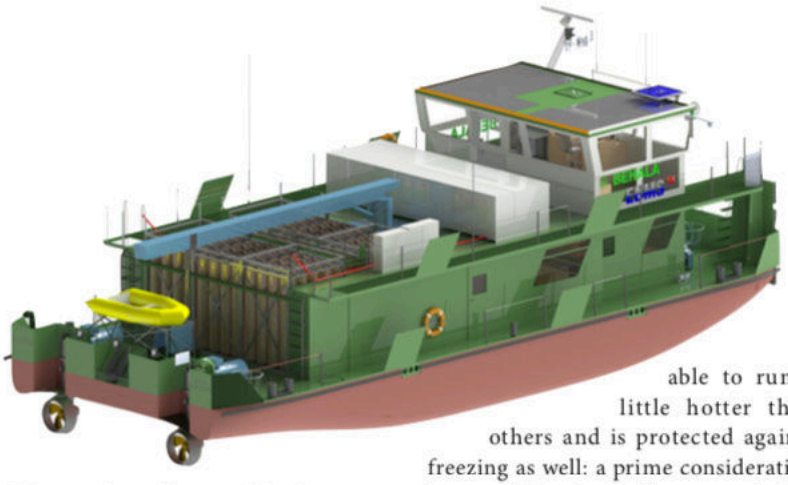
Energy saving is one element of the challenge. However, as the operation will demand around 21,200kWh for the Berlin-Hamburg round-trip, which is far too much to store on board, there are further issues concerning recharging and refuelling, points out Kilian Hoffmann, who handles business development for battery manufacturer EST-Floattech. Despite the vessel's novel power arrangement, "*Elektra* has to provide a service as reliable as a diesel equivalent", he stresses. Holbach adds that the vessel must be completely commercially viable, "and not just a prototype that gets left in the corner of a port, too expensive to use".

With scant chance of finding a handy compressed hydrogen fuelling stop along the route, tank manufacturer Anleg GmbH has developed novel storage modules that can be delivered by truck or train to a couple of pick-up points, where 'empties' can be swapped using the vessel's onboard crane.

These modules consist of bundles of 125kg-capacity Type IV composite tanks: six bundles together holding 750kg of fuel in a containment area on *Elektra*'s back deck. However,



Elektra will push a 1,400tonne loaded barge over a distance of nearly 400km, utlising a hybrid hydrogen-battery fuel mix (credit: EBMS-TU Berlin)



"We are not creating a pushboat; we are creating an energy system," says Professor Holbach, commenting on *Elektra*'s potential influence on future eco-friendly vessel designs (credit: EBMS-TU Berlin)

while the H_2 itself is light enough, the bundles can be hefty, especially if deemed safe for road transport, forcing an innovative approach. "Without Anleg reducing the weight of the individual tanks by 30%, this operation wouldn't be possible at all," says Hoffmann. As it is, the full hydrogen storage system comes in at roughly 20tonnes.

Safety concerns

Another challenge arose from safety concerns: the hydrogen tanks had to be installed toward the aft of the ship. "Normally something like this would be positioned in the middle to help balance the reduction in fuel along the trip," Holbach explains. Again, the low onboard energy requirement means no additional demand "and no ballast system". Instead, the change has been managed by playing with the fixed weight distribution: the result is a slight trim aft at the beginning of the journey, and a minimal forward trim at the end.

The compressed hydrogen feeds three 100kW Ballard fuel cell units, sitting just forward of the tanks and behind the superstructure. These are of a modular, high-pressure design with separate compression, air and cooling subsystems which allow individual operation. Usefully, this proton exchange membrane (PEM) variety is able to run a little hotter than others and is protected against freezing as well: a prime consideration in rural Northern Germany. Safety features, such as ventilation fans, smoke and gas detectors, are also integrated into the design.

Separate systems

However, while the battery and fuel cells will come together at the electric drive motors, for complete redundancy, the two different powertrains are not further intertwined. Instead, they remain entirely independent. Hoffmann describes the energy storage system (ESS) requirements: firstly, it has to be a high- energy density unit, despite being as light as possible; and secondly, "it needs a very precisely calculated lifetime".

Therefore, the system developed by EST-Floattech centres on a 2.5MW battery supplying 2.32MWh for the propulsion: it's expected to cycle once a day to roughly an 80% depth of discharge before being plugged in overnight at three shoreside connection points. The most likely en-route locations include Berlin and Lüneburg, the stop allowing for the simultaneous swapping of the hydrogen tanks.

Although the power from the batteries can be drawn more deeply, it's a moderately kind treatment that should lead to around 5,000 cycles and a 10-year life before capacity drops to below 80%. "We have arranged for onboard and remote monitoring of the installation so that everyone can check the performance," says Hoffmann.

It's not too much affected by the other bugbear for ESS: thermal energy built up from charge and discharge cycles. "The EST GO 1050 module's key feature is low internal impedance, on both cell and pack level," Hoffmann explains. As a result, the heat can be dissipated with a simple, off-the-shelf aircon unit.

However, the ESS has another trick up its sleeve. Hoffmann explains that typical battery management systems can deliver an uneven top-up. As a result, if the state of charge across a battery's cells becomes unbalanced, the whole system can take hours or even days to find its feet again, "during which time it's offline", says Hoffmann.

EST-Floattech's design avoids this by using a buffer. When it detects a cell-level input voltage drop of 10millivolts, it diverts the charge to the other cells in the pack. Further, the same 'active balancing' system is applied on module and string level, helping to keep everything running smoothly and extending the batteries' life.

Next stages

So, what about its weight? While the ESS comes in at around 22tonnes, or 15% of the vessel's total, it's positioned below deck in a way which helps mitigate the fluctuating fuel levels of the hydrogen tanks.

Finally, running in battery/electric mode, the pusher tug should be able to cover 65km over an eight-hour day before recharging. On the hydrogen-hybrid drive, it will be able to travel a minimum 100km, taken over a 16-hour day or longer.

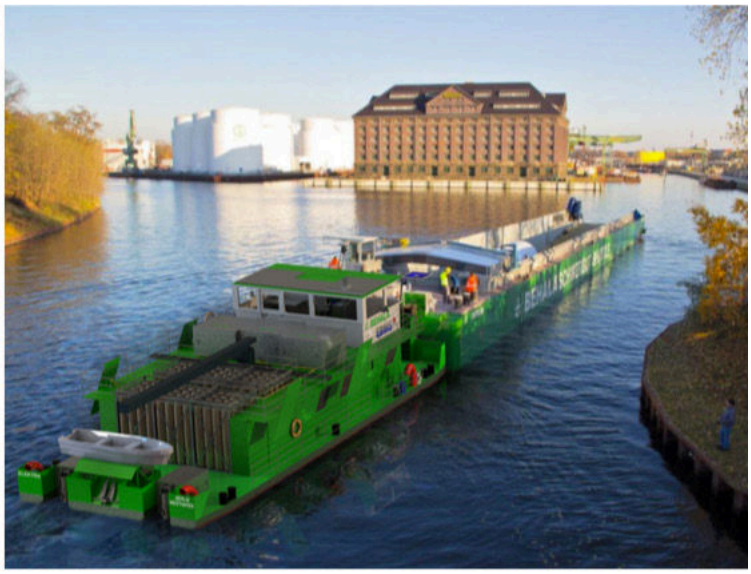
So, how are these different power sources best utilised? The initial concept is that load collections directly around Berlin's Westhafen area may be accomplished by battery power, with the more extended operation achieved mostly under H_2. However, all this will be investigated as the tug is put through its paces and both forms of energy are trialled under different conditions.

Those watching Berlin's harbour will see the vessel being tested and unloaded, "before we begin to widen its range", says Hoffmann. During the next stages, the tug will start pushing cargo, each step taking it a little further. Finally, it will begin complete, fully loaded runs all the way to Hamburg. The vessel and supporting logistics will be handed over to BEHALA as a fully working, commercial enterprise.

Setting the rules

The rulebook, or rather lack of it, created a 'Catch-22' problem during this project. "Everyone we spoke to said 'Great idea!', but then told us they wouldn't allow us to sail without meeting regulations – but there weren't any to meet," says Holbach. Too new for an answer based on class rules, the developers were left just one option.

"We took the case to the authorities ourselves – CESNI-PT in Strasbourg – and spent two years helping develop the permissions," Holbach explains. "We're a little bit proud of what we've achieved for the future. We are not creating a pushboat; we are creating an energy system." He underlines that this kind of solution could alleviate pollution pressures in regions around Berlin, Brandenburg, Hamburg and the Rhine-Ruhr area as well as helping meet the needs of ecologically sensitive regions further afield, outside Germany.



Elektra must provide a service as reliable as a diesel equivalent, so she doesn't end up abandoned "in the corner of a port, too expensive to use" (credit: EBMS-TU Berlin)

Most importantly, Hoffmann concludes, this project could "help secure the supply chain and acceptance of hydrogen as a marine fuel", allowing other inland waterway or leisure sectors to pursue their own zero-emission strategies. ***SBI***