The business case for hybrid and electric technology in Asia
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Q&A Summary

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What are the limitations of existing hybrid technology?

**LW |** Current hybrid technology is still evolving and developing fast today. Some challenges today are:

- capex costs
- limited energy density of energy storage systems compared to fossil fuels
- operational expertise.

As the technologies involve, develop and mature, it will help to bring down costs and increase operational expertise; and therefore help advance the adoption of hybrid technology in the industry.

For further discussions, we would refer you to our publication titled "Pathways to Sustainable Shipping" which can be downloaded free-of-charge at www.eagle.org.

The ‘ABS Advisory on Hybrid Electric Power Systems’ may also be referred to which enumerates challenges for various energy storage technologies and energy generation technologies - [https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_Hybrid_Advisory_17033.pdf](https://ww2.eagle.org/content/dam/eagle/advisories-and-debriefs/ABS_Hybrid_Advisory_17033.pdf)

**RC |** Although certain technology is still developing, some battery technology is now mature and widely adopted in large scale installation as well. Fuel cell technology, namely PEM Fuel Cell, has also been adopted in land based transportation, such as buses and trucks, however they are in the early stage of technological demonstration for marine applications as a whole industry, which covers the fuel cell technology itself, storage and bunkering technology, ship design, shipbuilding, operational, and Class rules / regulations.
What is the distance covered in short sea shipping?

LW | There is no defined distance. Some characteristics of short sea shipping are:
- access to frequent refuelling
- often travel on a fixed route
- relatively shorter distances as compared to the intercontinental cross-ocean deep sea shipping.

According to a US Department of Transportation statement, Short Sea Shipping is defined as commercial waterborne transportation that does not transit an ocean. It is an alternative form of commercial transportation that utilizes inland and coastal waterways to move commercial freight from major domestic ports to its destination.

Source: https://www.transportation.gov/testimony/development-short-sea-shipping

Short sea shipping is the maritime transport of goods over relatively short distances, as opposed to the intercontinental cross-ocean deep sea shipping. In the context of European Union transport statistics it is defined as maritime transport of goods between ports in the EU on one hand, and ports situated in geographical Europe, on the Mediterranean and Black Seas on the other hand.


When using battery power do you get an added advantage in terms of rapid changes, demands or surges in torque where electric can respond better to traditional engines types?

RC | Battery power will provide a faster response rate compared to the engine counterpart and therefore the vessel performance during fast load transients will be improved accordingly.
In Hybrid Vessels, what portion of total output comes from battery in general?

**LW** | This differs depending on the design and operating parameters of different vessels.

**RC** | It depends on the expected functionality of the battery as well as the installed capacity, which is typically a trade off between space/footprint availability, weight, cost, power.

**What is the impact of fast charging on battery life?**

**LW** | Generally, there will be a trade-off between fast charging and battery life. Thermal management and electrochemistry are affected during fast charging.

**RC** | Battery should be charged (and discharged) according to the C-rate as recommended by the battery makers. Exceeding the C-rate for a prolonged period or more frequently will lead to faster aging of the battery. In addition, one should also select the right battery chemistry or technology that is suitable for the intended application.
Any special skills required for the crew to operate such vessels?

**LW** | Yes, for example: putting out large scale battery installation fires.


**RC** | Knowledge on electrical power distribution, converters, different operational mindset and approach compared to operating vessels with diesel mechanical systems. Proper training and certification should be provided to the crew members so that they are equipped how to operate, trouble shoot, and maintain the systems.

I would like to have some metrics about electric and hybrid system. Let us consider a standard Diesel Mechanical vessel: what are the added cost, mass volume for a Diesel Hybrid vessel? What is the size of the battery needed? (power as % of installed power and endurance in hours)

**LW** | For comparison; Marine Diesel Oil (MDO): energy density of 42,190 kJ/kg, volumetric density of 39,970 kJ/l.

Best available commercial battery: energy density of 1,224 kJ/kg, volumetric density of 2,434 kJ/l

**RC** | The dimensioning of the battery and engines in hybrid configuration will be impacted by how the system is intended to be operated, e.g. duration and power requirement from battery, availability of shore charging.
What is the expected international standard for voltage / current connections?

**LW** | At the current moment, there is no one internationally accepted standard for voltage / current connections for vessel chargers. Adoption will depend on the market. Similar to current vessel voltage / frequency standards, we may well see different standards for different regions.

**RC** | In the current application, it is believed LV system is applicable and this means voltage up to 690 VAC 3 phase or 1000 VDC.

What are the benefits of Hydrogen vs LNG as a marine fuel in terms of Capex investment, Opex, bunkering, efficiency (calorific value), etc?

**LW** | LNG is a relatively mature fuel as compared to Hydrogen, thereby CAPEX and OPEX are expected to be less. For further discussions, we would refer you to our publication titled "Pathways to Sustainable Shipping" which can be downloaded free-of-charge at www.eagle.org.

**RC** | Hydrogen fueled vessel would achieve fully zero emission operations, including CO2. In addition, when the hydrogen is produced by electrolysis powered by renewable energy sources then the entire value chain is zero emission.
What will be the life of batteries? Considering their replacement costs how do they compare with conventional vessels for similar power?

LW | Currently, the typical lifetime for li-Ion batteries are around 5 - 10 years.

RC | The life of the batteries are impacted by the dimensioning and the operational cycle. The typical dimensioning usually targets between 5 - 10 years.
I understand that storing non small quantities of hydrogen onboard would not be easy (either very high pressure or very low temperature). What is the solution? Frequent refuelling? What about using ammonia or methanol as a way of storing hydrogen?

**LW** | Both hydrogen and ammonia could be the long-term fuel option towards decarbonisation.

Hydrogen offers the high energy content per mass, high diffusivity, and high flame speed. Hydrogen as a fuel has been demonstrated in internal combustion engines, gas turbines, and fuel cells. However, it requires cryogenic storage (-253 degree C or lower) and dedicated fuel supply systems for containment. Significant technical advances are needed before hydrogen can be considered a viable, large scale, commercial fuel option; particularly for marine applications where energy content on a volumetric basis is low for hydrogen (9.2 GJ/m³) and application would therefore significantly impact deep sea ship design. Energy loss during storage, and BOG generation are also the challenges for the application.

Compared to hydrogen, storing ammonia will be relatively more practical due to its energy density (15.7 GJ/m³) and liquefaction temperature (-33.6 Degree C). The weakness of ammonia is its toxicity. It has been handled as cargo and reductant in SCR for many years. Therefore, handling of ammonia in ships will be sufficiently feasible. Ammonia as fuel for internal combustion engine is under development. The challenges inherent in its combustion is that it usually requires a large percentage of pilot fuel to achieve ignition. Ammonia can also be used as feeder to hydrogen-fed fuel cell.

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**RC** | The technology for hydrogen storage in gaseous form is maturing and bunkering technology is being developed with several alternatives that have been adopted, such as swappable tank modules.

The tradeoff of using ammonia, methanol, or other storage is the additional footprint required for the onboard reforming process to extract the hydrogen. Onboard reforming plant technology is also one area being researched and developed.
In a short sea voyage what is the criteria for selection of a li-ion battery configuration vs. NMC, LTO, LiFePO4 etc?

RC | The criteria in selecting the battery technology is the charge/discharge power requirements as well as the duration, as well as energy requirements.

Is the lubricant requirement for a hydrogen fuel powered engine the same as LNG-powered engines?

LW | At present, hydrogen fueled engines applicable to ships of larger size have not been developed. IMO expects hydrogen fueled engines not to be the spark ignition type, i.e. Otto type but to be the direct injection type, i.e. Diesel type, because the latter could be easily enlarged.

Source: Fourth IMO GHG Study 2020, MEPC 75/7/15; Q.2.7 - https://docs.imo.org/Search.aspx?keywords=GHG

As research progresses in building hydrogen fueled engines, its lubricants will be developed accordingly.

Also, see SAE publication on lubricants for hydrogen fueled spark ignition engines - https://www.sae.org/publications/technical-papers/content/2019-28-2511/

RC | In this context, our approach is to utilize hydrogen fuel with PEM (Proton Exchange Membrane) fuel cells. The energy conversions and distribution are done using power electronics based power converters, therefore no (or very minimal) lubrications are needed. The only lubrication needed is at the propulsion motors.
How much time required for charging and how often?

**LW** | This depends on various factors such as the operational profile, battery size and capacity of battery chargers.

**RC** | The charging requirement is a function of the operational cycle of the vessel and the energy consumed from the battery, the installed battery capacity, as well as the national grid strength.

What is the charging infrastructure required, and additional Capex needed to install the charging stations?

**LW** | The CAPEX and investment required for the charging infrastructure has to be factored in when embarking on the use of hybrid and electric vessels.

**RC** | The charging infrastructure required is closely coupled with the charging power required for the vessel of the fleet of the vessels. If the national grid is strong and capable of handling the additional power (current) requirements, no special arrangement is needed. However, in the case it is not, one may need to consider additional battery banks on the shore side to cater to the peak and intermittent demand.

The other aspect is the charging unit itself. For this selection, we need to consider how the vessel is berthed (bow vs. side), availability of real estate on the pier, degree of tolerance against movement of the vessel due to wave, wind, and current, automatic vs. manual connection, to name a few.
How do rough sea states impact performance?

**LW** | This may have an impact on the sizing of the propulsion power and energy storage system capacity and endurance.

**RC** | With the installation of energy storage onboard, performance during rough sea state will be further enhanced. The first one related to the propulsion power, energy storage is able to response at a much faster rate compared to diesel engine, therefore any load transient can be met quickly.

The second is towards the engines. With the battery absorbing and providing the transient load power, the power delivered to the ship network seen by the engine will be essentially constant, therefore we would be able to maintain the operation at the most optimal point and we don't need to start an additional engine to cater the transient power.
The electrical distribution system for the tug is it a DC network with zonal AC? Also, what fire detection/suppression systems are used?

**RC |** In ABB, we believe that DC distribution system is the leading alternative for integration of renewable energy sources, such as battery and fuel cell, which are attractive solutions in the short distance shipping sector. AC power can be generated to power smaller conventional loads and other hotel loads.

If the charging source is not carbon free, then how does that contribute for green technologies?

**LW |** As the question rightly points out, the analysis has to consider the entire life-cycle analysis of alternative fuels / source of power from well-to-propeller / well-to-wake.

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**RC |** We believe that in order to holistically achieve the vision of zero emission shipping, we need to consider the whole ecosystem or value chain from the energy production, distribution, to consumption in the vessel.
What kind of charging station is required? Is it a normal wall plug or like something for an electric car?

LW | This is dependent on the technology used and the size of vessel and battery capacity. In all likelihood, dedicated charging stations for vessels will be required.

RC | The other aspect is the charging unit itself. For this selection, we need to consider how the vessel is berthed (bow vs. side), availability of real estate on the pier, degree of tolerance against movement of the vessel due to wave, wind, and current, automatic vs. manual connection, to name a few.

At the moment, there is no international standard of vessel charging system. ABB is working closely with other major players in the market, regulation bodies, and other partners in this topic.
Is the technology mature enough for sea water electrolysis for hydrogen production?

The technology of seawater electrolysis for hydrogen production has been around for a while. A desalinator and electrolyzer can be used in tandem. However, this has not yet entered mainstream maritime use. Electrolysis is an energy intensive process.

One project titled ‘Energy Observer’ vessel has tried to do this. However, on this particular project it doesn't work while the vessel is at sea, only when it's docked, when it could theoretically secure new fuel anyway. That's because the electrolyzer uses 25kW of energy, almost all of the boat's total output of 28kW. Do this at sea and there wouldn't be any power left over to propel the boat and keep the crew alive and warm.

Source: https://www.engadget.com/2019-10-08-energy-observer-solar-hydrogen-power-boat.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAANDXts4E5Z8O0k74r9bnetG8gYlcwP2QZuPmhM1fKtIN6Bart7VD4O90IPp4Puj43D3Lz_rBT_j-Ld8fL60SCsjg9TDRTmBKrVH-GsNakYmVWpc_ulfjrs-pd3W0dJX9twAu_iwJeSxOtZ6nEEzdCx-YTjjGY5dHO7flH__7ORE
How does the use of a hybrid system affect the structure of a ship? Can we change the ship design rules to create a better system?

**LW** | In the case of full electric vessels, this provides opportunities to re-think the design of the vessel in terms of arrangement of equipment and offers up more possibilities to optimize the use of space.

**RC** | We believe that with electric and hybrid power system, the equipment arrangement onboard is more flexible and still according to certain requirements, such as battery room. With such flexibility, ship designers can further optimize the vessel design according to its goal.

Are same number of crew needed for diesel vs electric?

**RC** | We believe the number of crew required for an electric ship will be reduced due to simplicity of the solution and reduced need of maintenance compared to the diesel counterpart.