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CIMAC and Maritime Battery Forum Joint Whitepaper

Environment for the use of batteries in deep-sea shipping

Use cases and application areas

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Content

1 Introduction and motivation

By means of the 2023 GHG strategy, the International Maritime Organization (IMO) set the course for the decarbonization of the shipping industry. The goal is “to reach net-zero [Greenhouse gas (GHG)] emissions by or around, i.e. close to, 2050” (IMO 2023a: 1), with additional sub-targets set for 2030 (by at least 20%, striving for 30%) and 2040 (by at least 70%, striving for 80%). While further policy measures will follow, the industry is already working on different solutions to decarbonize. According to DNVs Maritime Forecast to 2050 (DNV 2023a: 33), hydrodynamics and machinery are expected to lower GHG emissions by 5% to 15% or even 20% respectively. Logistics and digitalization may also contribute to 20% GHG emission reduction from ships. Even more emission reductions can be expected from the usage of alternative energy sources and carbon capture and storage: 0% to 100% and 0% to 90% reduction potential respectively.

Especially deep-sea shipping needs to reduce emissions, since it causes most of today’s shipping sector emissions (Transport & Environment 2024: 1). Accordingly, the question arises: how to achieve the needed reduction, especially in deep-sea shipping? Although alternative fuels are key to achieve decarbonization, further steps need to be taken.

In multiple studies (e.g., DNV 2023b, IMO 2023b, IEA 2023) there have been discussions on the upcoming challenges in terms of technologies (e.g. alternative fuels, carbon capture/storage) and the required changes with respect to infrastructure, demand signals, the rate of change itself, and last but not least the political measures to be implemented by the international community. These developments emphasize the need to implement reduction measures to enable the industry sub targets already on the horizon in 2030.

Electrification and battery usage are important for the global energy transition and are also mentioned in the context of deep-sea shipping. However, are battery-electric propulsion and spinning reserve realistic options and, if so, to which extent?

Since the answer is way more detailed than a simple yes or no CIMAC and the Maritime Battery Forum decided to jointly work on and publish a series of papers helping to clear the fog around the topic battery usage in deep-sea shipping. In fact, we see a certain lack of transparency on the battery usage in deep-sea shipping as today’s public discourse tends to include positions that either try to give an easy answer e.g., only including specific use-cases, or are highly complex hypothetical scenarios with very specific assumptions.

Thus, as the interconnecting piece between technology supplier and buyer, we strive to provide an unbiased overview of the industry through various angles addressing technological, environmental, economic, operational, or legal aspects. Furthermore, we aim to give a better overview on the status quo enabling CIMAC, Maritime Battery Forum members and other stakeholders to better assess hypotheses and scenarios on future developments in the merchant ship industry.

This is the first paper in the series – here we focus on the use-cases, application areas and limits. To this end, we want to answer two questions concerning the battery use in deep-sea shipping:

1. What use-cases for batteries are and will (likely) be existent in the industry?
2. Which are the application areas and their corresponding limitations?

2 Use cases

2.1 Battery-powered cargo ships

The statistics in this section are coming from the Maritime Battery Forum (MBF) Ship Register. This database contains information from battery manufacturers, integrators, shipyards, shipowners, and class societies on the global fleet of battery-powered ships. In January 2024, the database contained 1228 ships in total, of which 879 were in operation and 349 were on order or under construction. Figure 1 shows the numbers of cargo ships with batteries installed per year (left), and in total (right) between 2016 and 2023. The total number of cargo ships with batteries installed in a hybrid, plug-in hybrid, or fully electric propulsion system is 94.

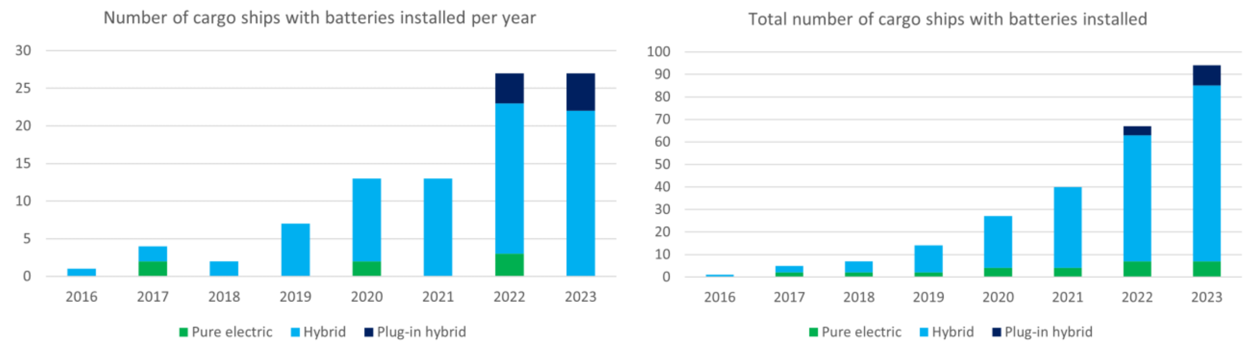

Figure 1. Overall number of cargo ships with batteries installed[1]

Amongst these 94 battery-powered cargo ships are inland ships, coastal ships and deep-sea ships. Figure 2 shows the total share of inland, coastal, and deep-sea ships. The majority (64%) of the battery-powered cargo ships are operating in coastal waters. The inland cargo ships account for 17%, and 19% (18 ships) are deep-sea cargo ships.

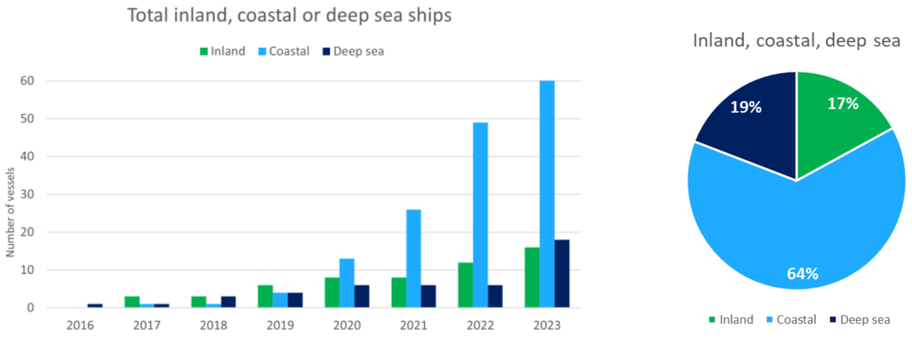

Figure 2. Types of cargo ships with batteries

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[1] The pure EV tankers "Asahi" and "Akari" have been delivered in 2022 and 2023, but were both integrated in 2022.

2.2 Deep-sea cargo ships with batteries

Figure 3 shows the different types of deep-sea cargo ships with batteries installed per year. Over the years batteries have been installed on board different types of cargo ships: General cargo ships, Oil/chemical tankers, Container ships, Bulk carriers, and more recently Ro-Ro cargo ships.

The Ro-Ro cargo ships show a significant increase in 2023 with 11 delivered ships. More specifically these are vehicle carriers. As these ships are transporting increasingly more electric vehicles, this hybridization trend could partially be explained to benefit the overall image of electrification in the transport sector. Besides image, for this type of ships it is already more common to have a higher level of electrification within the propulsion system and therefore make it easier to integrate batteries into the system.

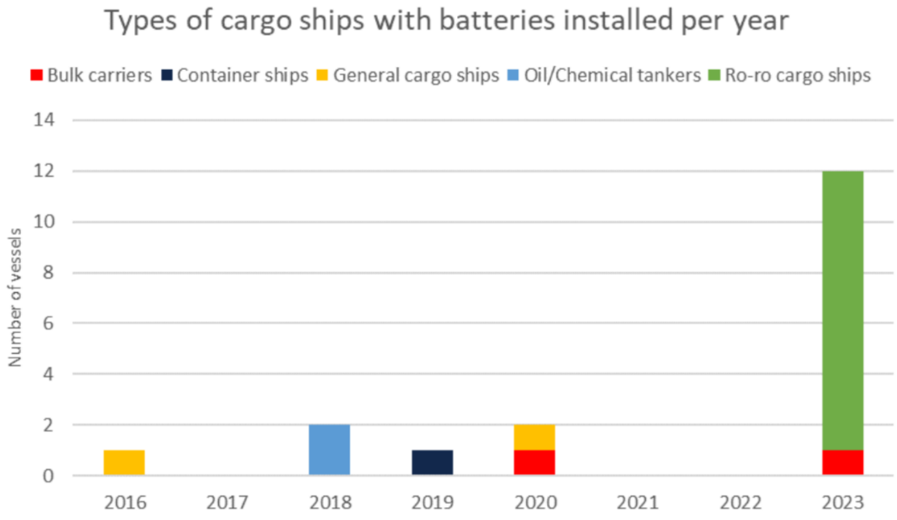

Figure 3. Types of deep-sea cargo ships with batteries installed per year

Figure 4 shows the types of propulsion configurations for deep-sea cargo ships with batteries. The majority (78%) have hybrid systems, but a significant increase in plug-in hybrid systems (22%) can be seen in 2023. A ship is considered as plug-in hybrid when the battery can be charged by an external charging station, in comparison to hybrid ships where the battery can only be charged by sources on board such as the generators. The plug-in hybrids are all vehicle carriers.

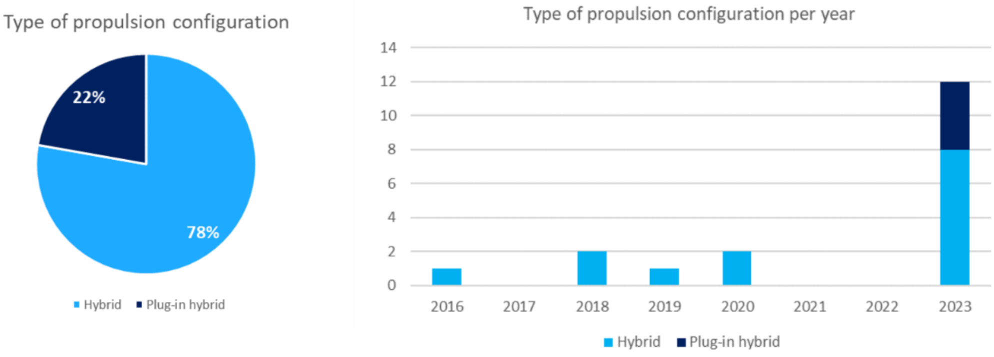

Figure 4. Types of propulsion configuration

Figure 5 shows newbuild and retrofitted deep-sea cargo ships with batteries per year. A significant increase in newbuild ships can be seen in 2023.

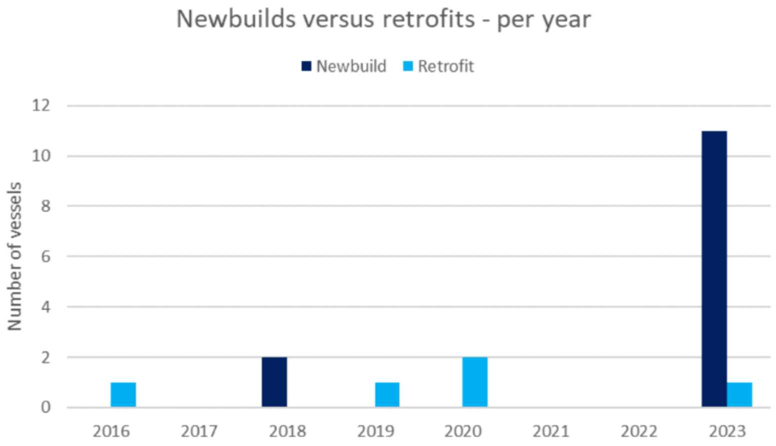

Figure 5. Newbuilds and retrofitted ships per year

Figure 6 shows the installed battery capacity on deep-sea cargo ships. The total installed capacity on deep-sea cargo ships increased significantly in 2023, to a total of 8388 kWh. This is due to an increase in both the number of ships with batteries and the average installed capacity per ship.

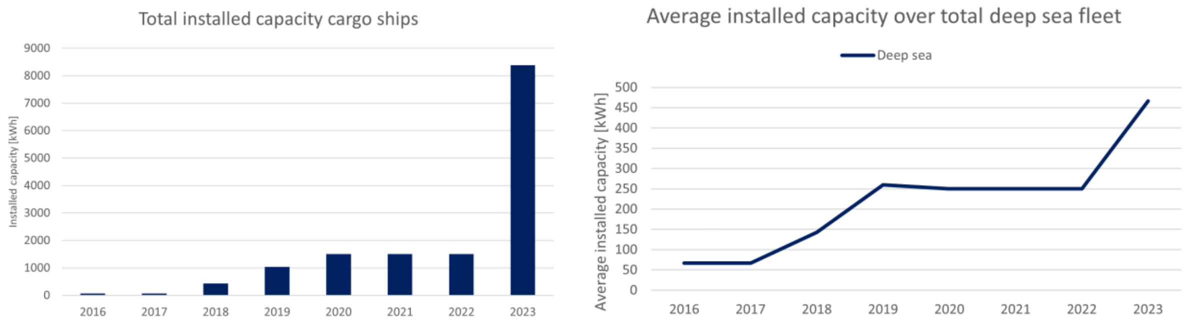

Figure 6. Installed capacity on board deep-sea cargo ships with batteries

The average installed battery capacity per deep-sea cargo ship was 466 kWh overall, 531 kWh for newbuilds and 296 kWh for retrofits (Figure 7). The plug-in hybrid ships use slightly larger batteries with an average capacity of 565 kWh compared to 438 kWh for the hybrids. There is one container ship, which has a battery capacity of 610 kWh. The 11 Ro-Ro cargo ships have an average installed capacity of 595 kWh. The other ship types have relatively smaller batteries installed. To put the installed battery capacity into context the maximum tank capacity onboard the example Paolo Topic (see chapter 3.2.5) is 1703,5 t of intermediate fuel oil (IFO) plus 172 t of marine diesel oil (MDO) and 72.8 t of low sulfur marine gas oil (LS MGO), which together equals around 22 GWh[2], while the installed battery size is 500 kWh (Marfin Management S.A.M 2022: 1).

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[2] Based on RMG as IFO with lower calorific value (lcv) of 42000 kj/kg, MDO with a lcv of 42700 kj/kg (MEPC 70 2016) and LS MGO with a lcv of 42500 kj/kg (Integrat8e fuels 2019).

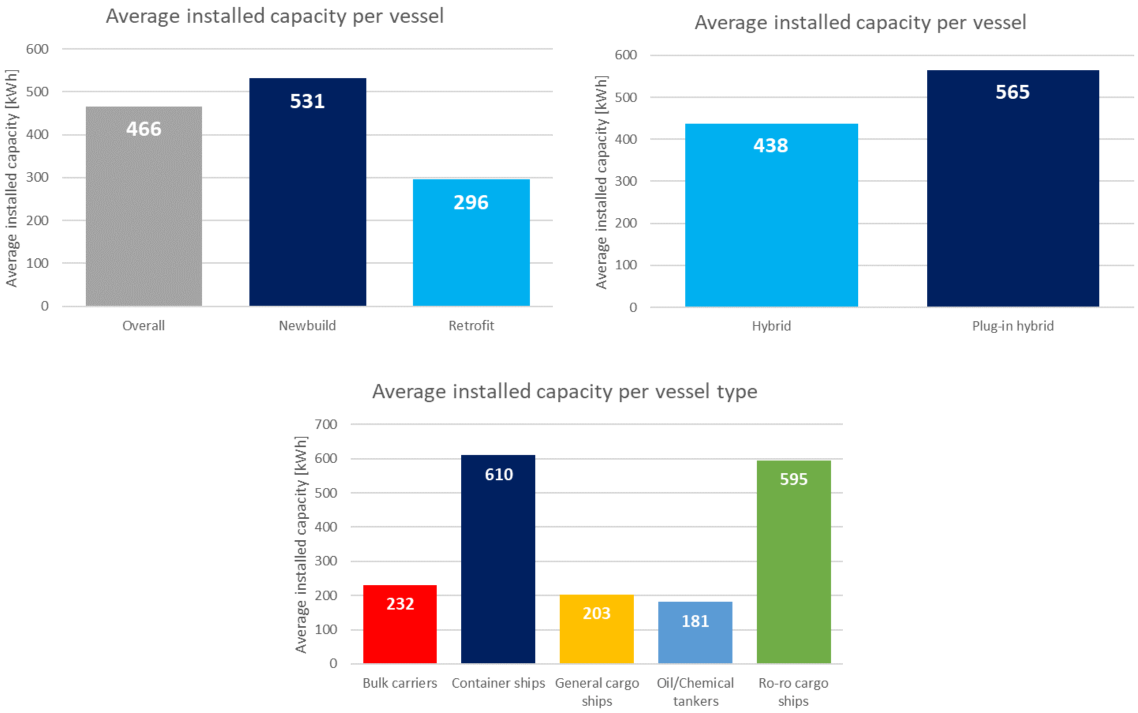

Figure 7. Average installed battery capacity per deep-sea cargo ship

2.3 Applications of batteries on deep-sea cargo ships

Figure 8 shows the installed battery capacity, if it is a newbuild or retrofit, and if the batteries are used for auxiliary loads only, or also for increasing the efficiency of propulsion. For one of the ships, it is not confirmed if the batteries are being used for propulsion or not, therefore this ship is located on the 0 line for the horizontal axis. If this ship is left out of the overview, it shows that on all the newbuild ships, the batteries are also used for propulsion. Whilst on all the retrofitted ships the batteries are only used for auxiliary loads. This could indicate the difficulty of retrofitting a diesel-mechanic propulsion system to a hybrid propulsion system. However, it will be interesting to see the development of this figure in the coming years.

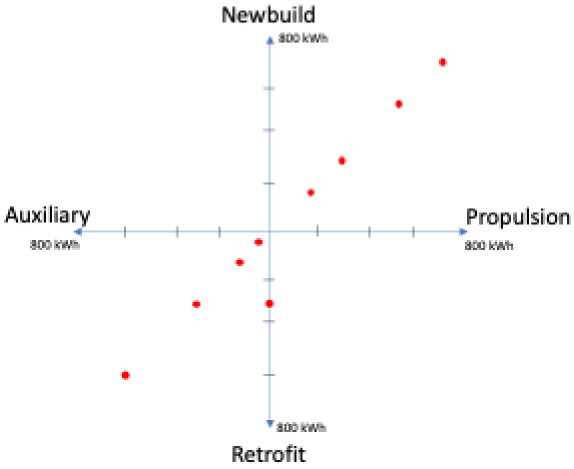

Figure 8. Use of batteries on newbuild and retrofitted ships

2.4 Batteries on deep-sea cargo ships in the order book

The MBF Ship Register also contains statistics of ships on order or under construction. There are currently 15 deep-sea cargo ships with batteries listed to be delivered with the next 2 years. Most of these ships are vehicle carriers (12), but there are also 2 oil/chemical tankers and 1 general cargo ship. All these ships are newbuilds and will have a hybrid propulsion system.

The size of the battery installations on these ships will be increasing. Ranging from 350 kWh for the smallest installation to 2847 kWh for the largest installation. If all these battery installations are included, the average installed battery capacity per ship, calculated over the total fleet of deep-sea cargo ships with batteries, will be approximately 659 kWh. This will be a 41% increase compared to the current average installed capacity per ship (Figure 6).

Figure 9 shows the total installed battery capacity on deep-sea cargo ships including the ships under construction that are currently included in the MBF Ship Register. This is likely to increase, since not all ships under construction are included in the ship register.

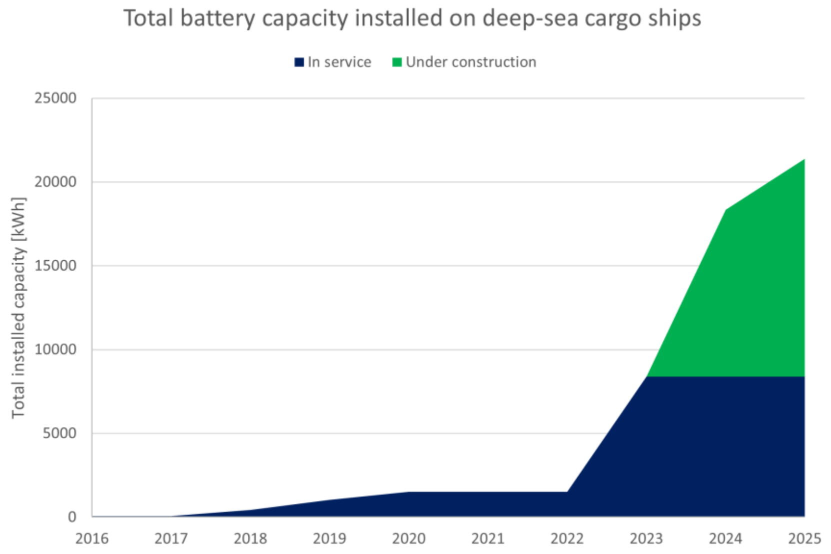

Figure 9. Installed capacity including ships under construction known currently.

3 Application areas

The previous chapter summarizes the status quo of battery usage in deep-sea shipping and provides insights of the current situation on the market. Building on that, this chapter will go further into detail elaborating on the various possibilities for battery application.

3.1 Clustering of application cases

Battery application onboard ships can have multiple functional roles. Relevant roles are presented and structured in Figure 10. For that purpose, several sources (Alnes et al., 2017; EMSA, 2020; Kern, 2019; Kolodziejski & Michalska-Pozoga, 2023; Lasselle et al., 2016; MAN ES, 2019; MAN ES, 2021; Mo, 2019; Pitkänen, 2022; Willstrand et al., 2022) have been screened in order to determine common patterns or examples of battery application on maritime ships. Considering the potential customer's perspective, Figure 10 focuses on the underlying motivation for the battery use ('Why?') which is here divided into three categories, namely:

1. ‘Redundancy/Safety‘
2. ‘Operational Efficiency’
3. ‘Environmental‘

Subsequently, after choosing ‘how’ to apply the battery energy storage system (BESS) – for instance, in one of the four following application schemes the desired actual battery application (‘What?’) may be selected:

1. ‘Zero-emission’ application
2. ‘Hybrid’ application
3. ‘Dynamic’ application
4. ‘Harvest Energy’ application

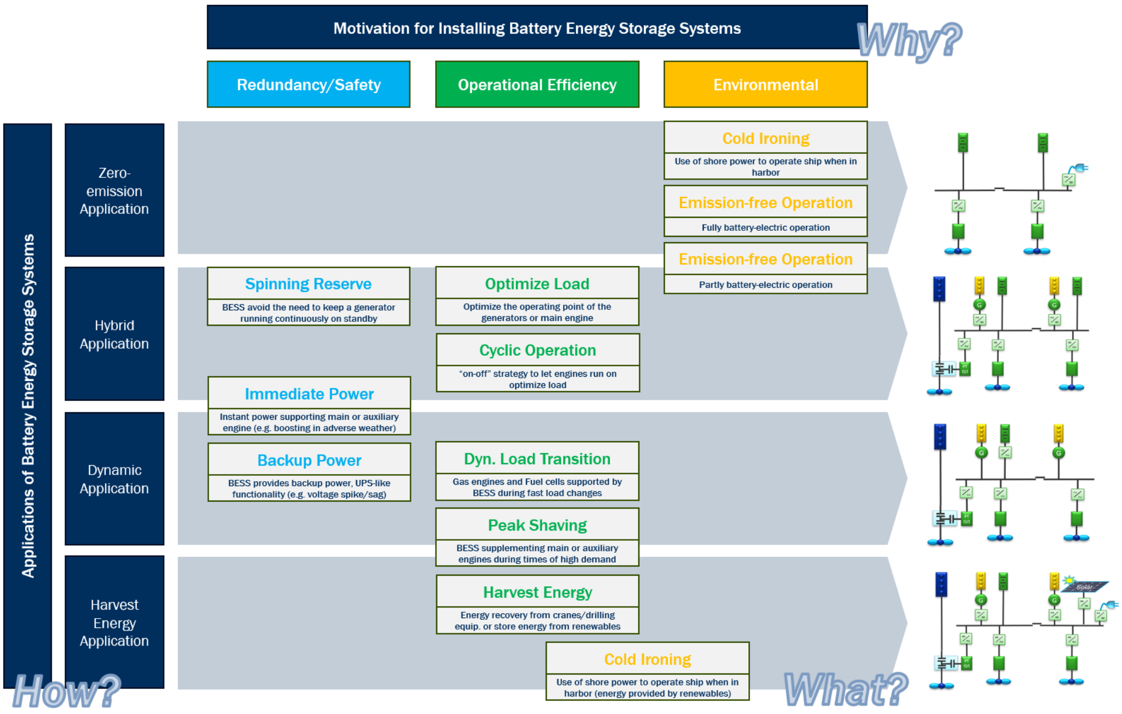

Figure 10 – Clustering of Battery Application Cases

Eventually, depending on the selection made above and in combination with the intended use case (i.e. ship type, battery capacity, etc.) the propulsion system topology and the battery characteristics may be determined.

Apart from the potential application areas, Figure 10 contains a number of line diagrams proposing for each application scheme an exemplary system topology. In the subsequent chapters, these topologies will be further discussed, alongside a more detailed description of the individual application areas.

3.2 Description of application areas

While batteries can fully power a ship for a short distance or duration, improving performance and operational efficiency of the overall ship is often the key purpose. Different ships have different operating profiles and batteries must respond to specific energy and power demand, while also considering the desired/expected service life cycle for the battery.

There are several different ways to integrate a battery into a ship's electric power system, and the method used will determine which potential benefits can be realized. The traditional cargo ship configuration, where the propulsion power is provided by a main combustion engine directly connected to the ship’s propeller through a shaft, will have more limited possibilities than for diesel-electric configurations. Recently, diesel-electric DC-grid designs allowing for easy integration of battery systems have received much attention, with promises of improved overall efficiency due to generator sets running on variable speeds and fewer energy conversions.

The most common applications of maritime battery energy storage systems are presented in the following sections. The applications are often combined such that the overall fuel saving, and emission reduction are optimized.

3.2.1 Zero-emission application

Battery energy storage systems can enable zero-emission operation of ships all of or part of the time. Figure 11 shows a line diagram of zero-emission application of batteries.

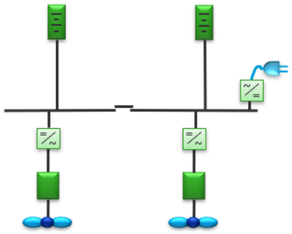

Figure 11: Line diagram – zero-emission application

3.2.1.1 Fully battery-electric operation

Fully electrical operation will be limited by the size of the batteries, sailing distances, and power demand. Hence this mode could typically be used on ships operating at short distances – ideally at slow speed. Running large ocean-going ships on batteries all alone would be a challenge since it would require too large battery systems. The advantages and disadvantages as well as the limitation of fully battery-electric operation are shown in Table 1.

Table 1: Fully battery-electric operation

Pro	**Con**	**Limitations** (preventing deployment)
Reduction/avoidance of local GHG or pollutant emissions (incl. effects on fleet emission, regulatory compliance, etc.)	Large battery installation is needed (lower energy density)	Operability limitations – such as short range and long charging times
Technology simpler (fewer moving parts)	Weight and space limitations on cargo ships	Uncertainties (standardization of classification requirements, perceived risk, financing and insurance)
Operational cost savings (energy, maintenance)	(Missing) charging infrastructure and long charging times (operational downtime)	high cost of energy supply in ports compared to energy generation on board
Comfort, noise reduction	Substantial upfront capital investment	
"Green image"/reputation		

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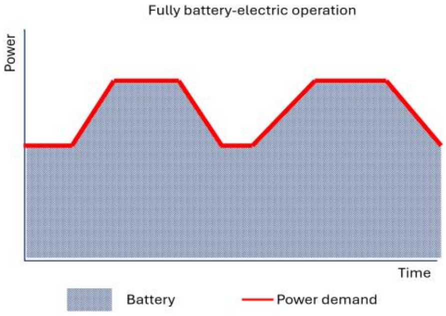

3.2.1.2 Partly battery-electric operation

Part of the operation, e.g. operation to/from and in port could be done by having the batteries as the main energy source. The batteries can then either be charged during the port stay and/or during transit.

For ship having direct shaft-driven propellers the installation of power take in (PTI) / power take-off (PTO) electrical machines is required on the shaft in order to utilize hybrid operation for main propulsion.

Ships having direct shaft-driven propellers can have electrical driven thrusters that are used when manoeuvring. Those thrusters could be powered directly from the batteries. Pros, cons, and limitations for this application area are shown in Table 2.

Table 2: Partly battery-electric operation

Pro	**Con**	**Limitations** (preventing deployment)
Zero-emission periods during sailing and in port	Maintenance cost (for two systems)	Expertise in energy management – optimization requires sophisticated solutions and expertise of electrical and mechanical domain (availability)
Reducing harmful emissions in environmental restricted and densely populated areas (partly electric operation).	Higher investment costs compared to pure diesel-mechanic propulsion (components, system integration)	Customer value compared to diesel-mechanic propulsion exists but yet needs to be proven (to justify higher system complexity)
Possible higher responsiveness during manoeuvring.	Complexity (operational and maintenance)	
Operational cost savings (energy, maintenance)	Limited energy storage capacity (potentially affecting utilization factor of the batteries)	
Comfort, noise reduction		

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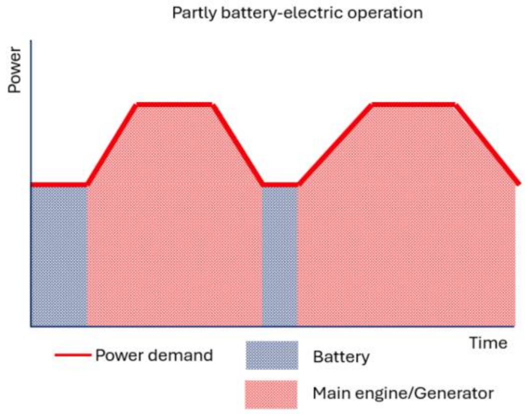

3.2.1.3 Cold ironing / onshore power supply

Cold ironing refers to the use of shore power connection while the ship is in port in order to allow for zero-emission operation in port. Typically, there are many electrical consumers on board (air conditioning, pumps, cranes, refrigeration, etc.) which require energy during berthing. By means of cold ironing, auxiliary engines can be switched off, hence reducing noise and emissions at berth, while increasing energy efficiency (Table 3). In this context, batteries can foster the application of cold ironing via blackout prevention, peak shaving or support during transitioning.

Table 3: Cold ironing / onshore power supply

Pro	**Con**	**Limitations** (preventing deployment)
Emission reduction in port (protecting public health and environment in the densely populated areas around ports)	Costs for infrastructure (distribution systems, shore power connections, etc.)	Ship compatibility: Currently, only a few ships are equipped with systems that are able to connect to shore power
Operational cost savings (energy, maintenance)	Availability of (renewable) energy supply may be limited in ports	Uncertainty (standardization of classification requirements)
Comfort, noise reduction		

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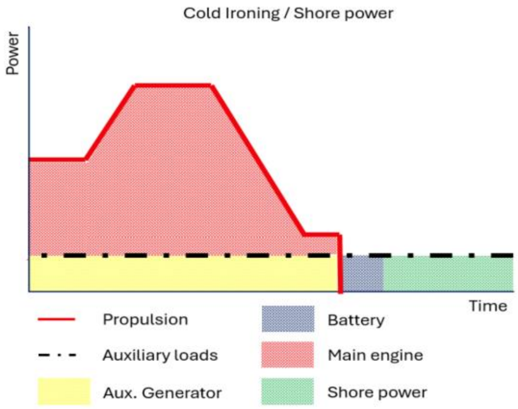

3.2.2 Hybrid application

The specific fuel oil consumption and the emissions from an internal combustion engine are dependent on the engine load. Typically, engines are tuned for optimal performance at 60-85% of the engine load. For ship types that experience large load variations during operation, the introduction of batteries may allow the engines to operate at an optimized set point with respect to fuel oil consumption and/or emissions.

Figure 12 shows the possible max efficiency benefit, which could be achieved by shifting the load from different current load points to the optimum load point with highest efficiency. Two different curves are plotted. One for a two-stroke main engine and one for a four-stroke marine genset, which are typically used for a container vessel with a deadweight of round about 44 000 metric tons. Due to the different fuel consumption characteristics of the engines, load shifting by battery makes much more sense for the gensets than for the main engine. Moreover, a significant shift to higher loads is needed to overcome the electrical losses of the battery and power conversion system.

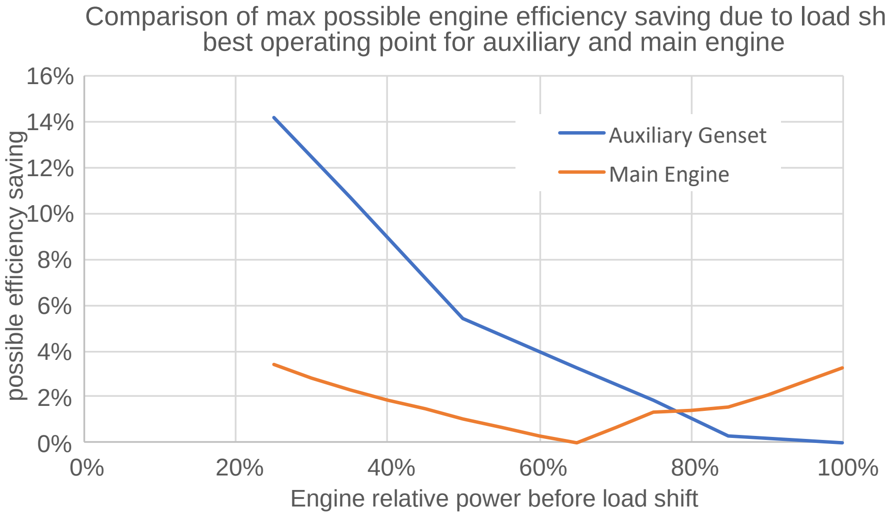

Figure 12: Comparison of efficiency saving for a two- and four-stroke engines

For ship having direct shaft driven propellers, power take in (PTI) / power take out (PTO) electrical machines must be installed on the shaft to utilize hybrid operation for main propulsion (Figure 13).

In the scope of hybrid application, batteries can help in cases of blackout prevention, load optimization, and power system availability.

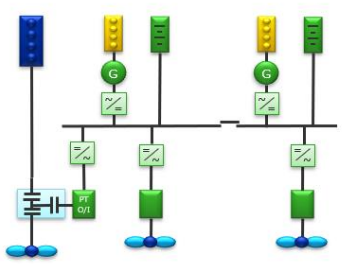

Figure 13: Line diagram – hybrid application

3.2.2.1 Optimise load (load levelling)

Load optimisation can be achieved by selecting the size of the engines such that they operate at optimal set points for most of the time, with additional power obtained from the battery when required. Furthermore, when the power requirements are low, the battery can be charged because of the excess energy production resulting from running the engine at the optimal load. Additionally, under operating conditions requiring very low loads, the ship may be able to operate on battery power alone for a certain period. Pros, cons, and limitations for this application area are shown in Table 4.

Table 4: Optimise load/load levelling

Pro	**Con**	**Limitations** (preventing deployment)
Fuel saving and emission reduction by running the engine(s) with optimum performance	As in all hybrid systems, higher CAPEX compared to pure diesel-mechanic propulsion (components, system integration) – however, in this case particularly the battery investment cost	Expertise in dealing with system complexity/energy management – for example: load levelling may introduce additional points of failure or vulnerability into the propulsion system
Reduced maintenance costs (by preventing excessive loads)	Complexity (operational and maintenance)	Operability limitations: optimal load levelling strategies may depend on the chosen routes, weather/sea conditions, etc. The benefit in fuel consumption of the engine must overcome the electrical losses by power electronics and the battery. Depending on the specific fuel consumption of the engine this is only the case for specific applications where the engines are operated a significant time at part load.
	Increased weight and size of the system compared to engines only, if engines downsizing with batteries cannot necessarily be fully achieved	Limited number of battery charge and discharge cycles in battery life reduces feasibility of this solution. The batteries are typically limited to 5000-10000 cycles

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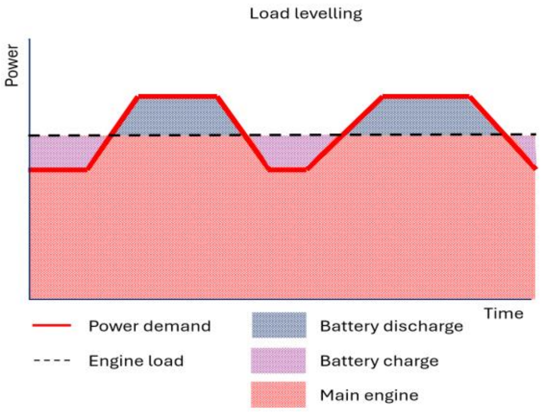

3.2.2.2 Cyclic operation

Cyclic operation is another way of utilizing load levelling. This is done by using an “on-off” strategy: The engine(s) run on optimize load when the batteries are being charged. When the batteries are fully charged, the engine(s) can be stopped, and the ship runs on batteries. When the batteries, in turn, are discharged, the engine(s) start again and can operate at optimal load while charging the batteries. This “on-off” strategy is repeated during the voyage and/or harbour stay. Pros, cons, and limitations for this application area are shown in Table 5.

Table 5: Cyclic operation

Pro (as load levelling, plus …)	**Con** (as load levelling, plus …)	**Limitations** (preventing deployment)
Less running hours on engines	Impaired usability and durability: Many start and stop cycles of the engines	Operability limitations: cyclic operation may be constrained by factors such as voyage duration, weather/sea conditions, etc.
	Potentially detrimental operation behaviour for batteries. Many cycles (depleting the batteries) may cause reduced lifetime.	The benefit in fuel consumption of the engine must overcome the electrical losses by power electronics and the battery. Depending on the specific fuel consumption of the engine this is only the case for specific applications where the engines are operated a significant time at part load.
		To keep number of battery cycles on reasonable level during battery lifetime the battery system requires significant size.

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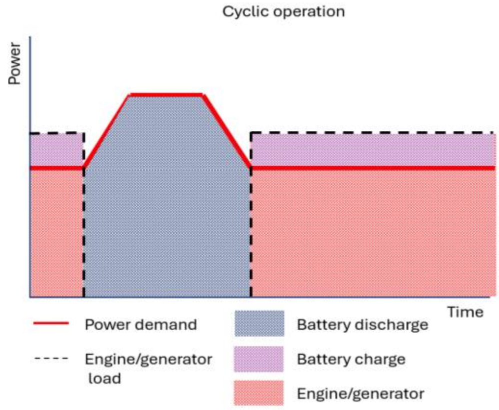

3.2.2.3 Spinning reserve

Several ship types have requirements for power redundancy for certain types of operations. This is particularly relevant for ships with dynamic positioning (DP) systems. The requirements for DP do not allow for the start of generators, and the redundancy requirements must therefore be ensured by the machinery in operation at any time (the spinning reserve). Running engines at low loads generally leads to higher specific fuel oil consumption, higher specific emissions, and increased maintenance costs. The current DNV DP rules allow for Li-ion batteries to fulfil the requirement for redundant power. This enables fewer running engines, leading to reduced fuel consumption, emissions, engine running hours, and maintenance costs (Table 6).

Table 6: Spinning reserve

Pro	**Con**	**Limitations** (preventing deployment)
Redundancy: Spinning reserve ensure a redundant power supply (e.g. in critical situations)	As in all hybrid systems, higher CAPEX compared to pure diesel-mechanic propulsion (components, system integration)	Expertise in dealing with system complexity/energy management
Lower cost (fuel consumption, maintenance/less running hours) compared to spinning reserve provided by ICEs	Complexity (operational and maintenance)	
Providing additional flexibility in the energy management and system layout		

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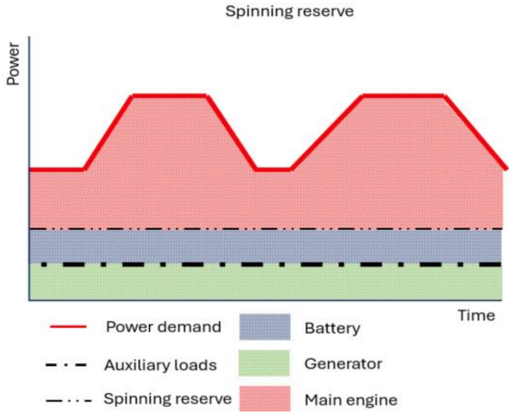

3.2.3 Dynamic application

The batteries can be used for assisting the internal combustion engines in various operation modes to improve their dynamic response behaviour, for example, during load fluctuations. Figure 14 shows a line diagram of dynamic application of batteries.

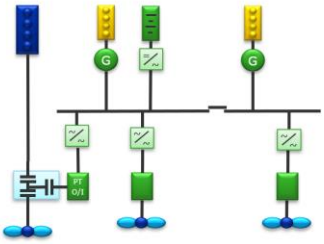

Figure 14: Line diagram – dynamic application

3.2.3.1 Dynamic load transition

Certain technologies such as (Otto-cycle) gas engines or fuel cells may improve their dynamic response behaviour when supported by BESS. Gas engines, for example, when operated according to the Otto-cycle principle are controlled via the air path. Consequently, changes in load demand can only be served as fast as the air path can react. In case a load demand is imposed too fast, the engine may face abnormal combustion impairing engine health and operability. A BESS can help to soften the rate of load requests to the engine and thus improve its dynamic operability (Table 7).

Table 7: Dynamic load transition

Pro	**Con**	**Limitations** (preventing deployment)
Improved ICE operability (e.g. more reliable operation in heavy sea) Less operating engines at higher load during phases of fast load changes (e.g. on-board crane operation in harbou**r**) lead to lower operational cost	As in all hybrid systems higher CAPEX compared to pure diesel-mechanic propulsion (components, system integration)	Expertise in dealing with system complexity/energy management – especially important in this case, as detailed knowhow and even access to the controls system of the ICE or fuel cell are required
Avoidance of abnormal (detrimental) operation may improve durability	Complexity (operational and maintenance)	

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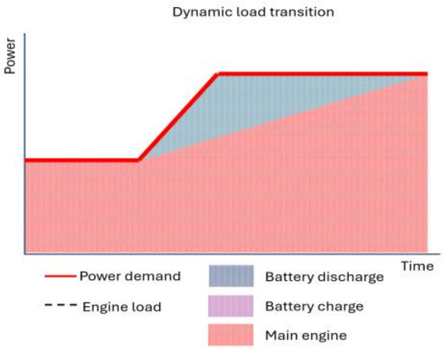


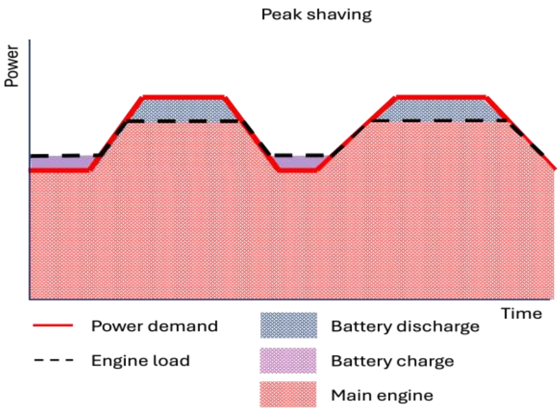
3.2.3.2 Peak shaving

The fuel oil consumption and emissions are affected by engine transients in the form of rapid increases or decreases in engine speed and/or load. The effects of the transients depend on the type of engine, the magnitude of the load variations, and the rate of change of the engine load. Introducing a BESS may eliminate the engine load transients by ensuring a steady engine base load and covering additional transient loads through the energy storage device. The fuel savings achieved will depend on the engine used. Peak shaving is also expected to result in reduced engine wear and consequently lower maintenance costs (Table 8).

Table 8: Peak shaving

Pro	**Con**	**Limitations** (preventing deployment)
More stable engine operation (e.g. in heavy sea conditions)	Not beneficial in all situations. In certain cases, peak shaving can be also detrimental with respect to fuel consumption.	Expertise in dealing with system complexity/energy management – especially important in this case, as detailed knowhow and even access to the controls system of the ICE are required.
Lower cost (fuel consumption, maintenance)		Uncertainty: customer value is challenged.
May enable lower rated engine or fewer engines		

Usage display:



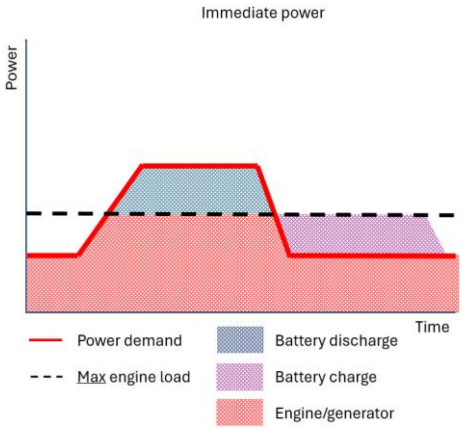
3.2.3.3 Immediate power

Instant power supplied by BESS to support, for instance, the main and/or auxiliary engines in situations when high power output is required. The idea behind is to provide a temporary boost which can serve the specific purpose of the vessel, e.g. hybrid tugboats. Pros, cons, and limitations for this application area are shown in Table 9.

Table 9: Immediate power

Pro	**Con**	**Limitations** (preventing deployment)
Providing additional flexibility in the system layout	Depending on the operational profile, high investment cost for large batteries	Operability limitations: system layout is designed to a certain operational profile.
		Customer value yet to be proven (to justify higher system complexity).

Usage display:



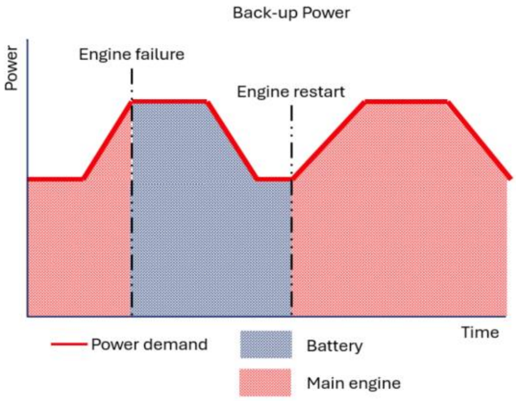
3.2.3.4 Back-up power

BESS can be used for black-out prevention. This means, batteries that supply to the electrical grid can be arranged such that there is always power available on the main power system. If a genset is failing, then the batteries can supply the needed power until a standby genset is up and running. Pros, cons, and limitations for this application area are shown in Table 10.

Table 10: Backup power

Pro	**Con**	**Limitations** (preventing deployment)
Increased reliability through blackout prevention.	Lifecycle consideration: utilization factor of the batteries	Higher system complexity compared to standard UPS systems.
Increase safety due to another source of redundancy	Additional complexity and maintenance cost	

Usage display:



3.2.4 Harvest energy application

Battery energy storage systems can enable harvesting of energy from the surroundings. Figure 15 shows a line diagram of harvest energy application of batteries.

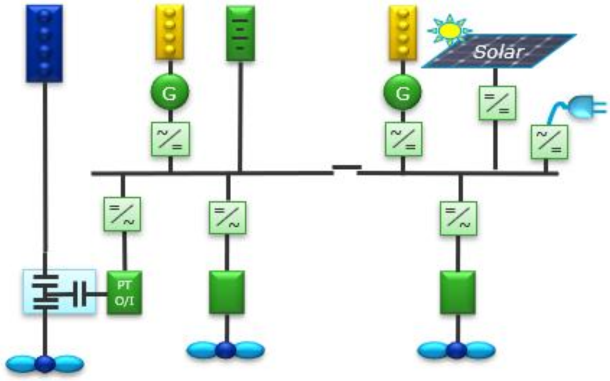


Figure 15: Line diagram - harvest energy application

3.2.4.1 Harvest energy onboard

To enable the harvesting of energy from alternative sources onboard a ship, it is necessary to provide facilities for energy storage. There are potentially several sources of energy on a ship that can be converted to propulsion or auxiliary power if stored in a battery, e.g., solar, wind, and wave energy. Utilizing energy from onboard equipment such as cranes and winches through regenerative breaking is also feasible. Pros, cons, and limitations for this application area are shown in Table 11.

Table 11: Harvest energy onboard

Pro	**Con**	**Limitations** (preventing deployment)
Enables continuous harvesting of energy from alternative sources onboard the ship.	Alternative sources do not generate much energy.	Current ship designs may not be suitable/ideal for use of alternative energy sources

3.2.4.2 Harvest energy from shore

When the ship is in port, it can have its power supply from shore, i.e. shore power. In addition, the power from shore can also be used to charge batteries onboard. Pros, cons, and limitations for this application area are shown in Table 12.

Table 12: Harvest energy from shore

Pro	**Con**	**Limitations** (preventing deployment)
Environmentally friendly charging.	Power demand for shore power supply.	
Energy charged from shore enable zero emission operation	The need to improve infrastructure, depending on location.	

3.2.5 Selected examples

Ship name:	Star Laguna	
Year build:	2012	
Battery installation year:	2019	
Battery size:	67 kWh	
Hybrid or plug-in?	Hybrid	
Source: https://corvusenergy.com/projects/star-laguna/		

Battery application type

Zero-emission	**Hybrid**	**Dynamic**	**Harvest energy**
Fully battery electric	🟩 Load levelling	Dynamic load transition	Onboard harvesting
Partly battery electric	Cyclic operation	🟩 Peak shaving	From shore harvesting
Cold ironing	Spinning reserve	Immediate power	
		Back-up power	

Ship name:	Maersk Cape Town	
Year build:	2011	
Battery installation year:	2019	
Battery size:	610 kWh	
Hybrid or plug-in?	Hybrid	
Source: https://corvusenergy.com/projects/maersk-cape-town/		

Battery application type

Zero-emission	**Hybrid**	**Dynamic**	**Harvest energy**
Fully battery electric	🟩 Load levelling	Dynamic load transition	Onboard harvesting
Partly battery electric	Cyclic operation	🟩 Peak shaving	From shore harvesting
Cold ironing	🟩 Spinning reserve	Immediate power	
		🟩 Back-up power	

Ship name:	Paolo Topic
Year build:	2016
Battery installation year:	2020 (2024 upgrade)
Battery size:	124 kWh -> upgraded to 500 kWh
Hybrid or plug-in?	Hybrid
Source: Marfin Management S.A.M.	

Battery application type			
Zero-emission	**Hybrid**	**Dynamic**	**Harvest energy**
Fully battery electric	Load levelling	[✓ Dynamic load transition]	Onboard harvesting
Partly battery electric	[✓ Cyclic operation]	[✓ Peak shaving]	From shore harvesting
Cold ironing	Spinning reserve	[✓ Immediate power]	
		[✓ Back-up power]	

4 Conclusion

The discussed examples of battery use cases proof that there is a potential for batteries on board ocean-going cargo ships to reduce their emissions. With only 18 ocean-going cargo ships with batteries installed on board, the industry is only at the beginning of adopting this technology. These first pioneers are paving the way, but much has yet to be learned on how to make the most optimal use of battery systems on board. Different types of applications will have different results on the performance of the large variety of ship types, operational profiles, and propulsion configurations.

The limited number of plug-in hybrid ocean-going cargo ships is expected to be related to the limited availability of shore power installations and standardized charging systems. Charging batteries from the grid is, depending on the local electricity mix, the most beneficial for bunkering energy with the lowest environmental impact. The development of shore power installations and charging systems can increase the benefits from installing batteries on board ships, and therefore accelerate the adoption of maritime batteries further. A further deep dive on the topic of onshore power as well as standards of charging systems will be delivered within our upcoming papers.

There is an increase in both number of ships and in size of the installed battery systems that are being installed on newbuild ships. But there is not yet a clear guideline or recipe for each specific ship owner on how to integrate batteries in for them the most optimal way. Based on the numbers it shows that retrofitting existing ships with batteries is more difficult compared to integrating batteries into the design of a newbuild ship. But to reach the emission reduction goals set by the IMO a smart, easy, and affordable retrofitting solution can be critical.

Apart from “Zero Emission” by going fully battery powered, all application schemes/areas are already possible today, both technically and economically. The further improvement of battery technologies and development of smart integration methods will increase the number of ships with batteries. The adoption of alternative fuels can also boost the number of ships with battery systems installed, although this might also have an impact on the design choices and sizing of the batteries to fit the requirements for systems with different types of fuels.

5 Outlook

This is the first of a series of papers attempting to describe the environment for battery use in deep-sea shipping. In total, the topic of battery use in deep-sea shipping shall be examined from seven different angles that are:

1. Use cases
2. Application areas and limits
3. Regulation
4. Safety
5. Human factor
6. Energy storage (operating range and capacity)
7. Integration into propulsion systems

As we continue to explore the application of batteries in deep-sea shipping, several important dimensions warrant further discussion. These include regulatory and safety aspects, as well as the human factors associated with integrating these technologies into maritime operations. In particular, legislative challenges and training needs for the crew are critical to ensuring the successful deployment and operation of battery systems on board. These three dimensions will form the scope of the next paper leaving the topics of energy storage and integration for the last paper of the series that is expected to be published by end of 2026.

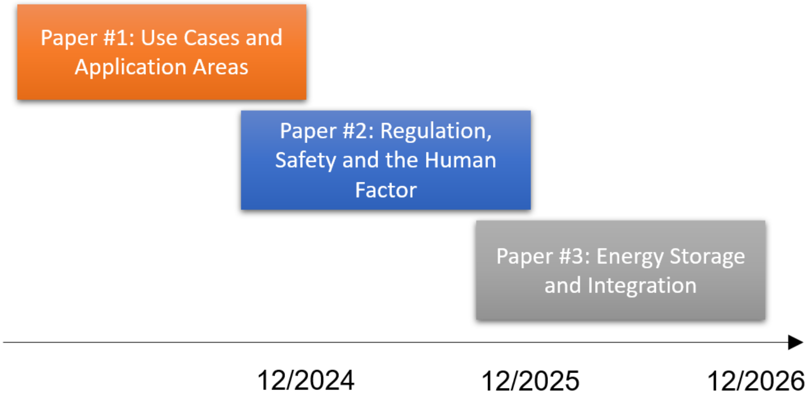


Figure 16: Timeline for Publishing CIMAC and Maritime Battery Forum Papers

In the current paper, we presented various applications of batteries on deep-sea vessels. It is important to note that the size of batteries currently in use is relatively small compared to the total propulsion power required for deep-sea vessels. Therefore, batteries are not yet a viable primary energy source for complete propulsion. Instead, they are primarily used to support auxiliary systems in several scenarios, including thruster operation, blackout prevention, peak shaving for shore connection, load shifting and load levelling, spinning reserve for dynamic load transitions, blackout prevention, and energy harvesting applications, such as those involving solar panels. Due to their limited capacity, zero-emission applications of batteries are currently feasible only for short segments of a ship's journey, particularly when approaching ports.

Marine regulations are increasingly mandating the integration of novel technologies to reduce greenhouse gas (GHG) emissions. This necessitates the development of more integrated systems.

At present, fully electric propulsion is not feasible for deep-sea vessels due to the limited capacity of batteries. However, batteries play a crucial role in supporting various auxiliary functions and enhancing the efficiency of other energy sources. For example, wind-assisted propulsion systems require batteries to buffer transient conditions effectively. Similarly, there is a growing demand for fuel cells to enable zero-emission operations, and batteries are necessary as vital support to fuel cells during periods of transient loads especially given that fuel cells often underperform during transient load operations. Potential future technologies where batteries might play a crucial role include air lubrication systems, which reduce friction between the hull and water and may require batteries to support transient loads, and carbon capture technologies, which capture and store carbon emissions and could need batteries to provide the necessary power during load fluctuations.

In our upcoming paper on regulation, safety and the human factor, we will explore the existing boundaries and opportunities given by international policies to use batteries for deep-sea operation. Furthermore, as standards for training as well as safety parameters are part of the political process they need to be discussed jointly. The combination also allows to check regulatory circumstances against the reality of the technical progress within the sector.

Eventually, in our last paper of the series, we will dive deeper into the limitations and potential of combining batteries with other technologies. Key areas of focus will include investigating how batteries can complement such a technology as fuel cells and exploring how batteries can support wind-assisted propulsion systems by providing the necessary energy during transient conditions to optimize thrust from sails.

In conclusion, while the current use of batteries in deep-sea shipping is primarily auxiliary, their role is expected to grow as we integrate them with other emerging technologies.

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