# Current Status of Maritime Batteries and Future Outlook

**Syb ten Cate Hoedemaker**, Maritime Battery Forum, Rotterdam/Netherlands,
director@maritimebatteryforum.com

**Abstract**

*The Maritime Battery Forum keeps track of the development of battery powered vessels in its Ship Register. This paper describes the development of maritime batteries over the past decades divided in 3 different periods. The number and type of vessels powered by batteries, as well as the size and type of the installed batteries are discussed. Current trends are evaluated and projected to create an outlook for the coming decades.*

## 1. Introduction

Battery powered boats have been around since the 19th century, but it is not until the last 15 years that batteries started to claim a more important role within the maritime industry. In 2014 the Maritime Battery Forum (MBF) was founded with the goal to promote batteries in the maritime industry by sharing knowledge and information. The MBF, in collaboration with DNV, maintains a Ship Register to keep track of the development of battery powered ships, https://www.maritimebatteryforum.com/ship-register. This study describes an analysis of the battery powered ships in the MBF Ship Register, divided in three main periods.

First the early years of battery powered ships between 1998 and 2013 are discussed. Then the industry saw a significant change with the delivery of the full electric ferry "Ampere", leading to the second generation of battery powered ships between 2014 and 2018. The current period between 2019 and 2022 is described as the current generation of battery powered ships, where a wider range of vessel types is being electrified and battery systems are increasing in size significantly. This is followed by a general overview of the development of the global fleet of battery powered ships up to 2022.

One specific country stands out when it comes to battery powered ships, Norway. The key factors for success in Norway are discussed, followed by a calculation of the future demand of maritime batteries up to 2050, based on the trends identified between 2008 and 2022. The current growth is projected to match the global marine decarbonization goals, and it is seen that a further increase in effort is required by the maritime industry to achieve the IMO goals of an overall reduction in emissions of 50% by 2050, compared to 2008.

This study is based on the data from the MBF Ship Register. This is considered as the most complete database of battery powered ships available, however, there can be specific ships missing in this database. Future updates of the Ship Register might change the conclusions in revisions of this paper.

## 2. The early years (1998-2013)

The oldest battery powered vessel in the MBF Ship Register is "Le passeur", a 10 m long ferry built in 1998 in La Rochelle, France, with an installed battery capacity of 20 kWh. In the period between 1998 and 2010 several other battery-powered ferries were built in France, with batteries ranging from 20 up to 130 kWh. These ferries used Lead-acid or Nickel-Cadmium batteries as energy source.

The first ship mentioned in the MBF Ship Register using a Lithium-ion battery system as energy storage system was the sailing yacht "Ethereal" built by Royal Huisman in the Netherlands in 2008. This 58 m long sailing yacht used a 500 kWh battery system in a hybrid propulsion system. From 2010 several car/passengers ferries and private submarines followed with battery systems between 40 kWh and 1446 kWh of installed capacity. In Canada a research vessel was retrofitted with a battery system in 2011. In 2013 the first hybrid tugs started sailing with a battery capacity ranging from 117 kWh up to 546 kWh.

74% of the battery installations on board of ships between 1998 and 2013 were on newbuild vessels, the other 26% were retrofits. The majority (48%) of the battery powered ships delivered in this period were pure electric, 37% of the vessels were hybrid and 15% of the battery powered vessels were plug-in hybrid, Fig.1.

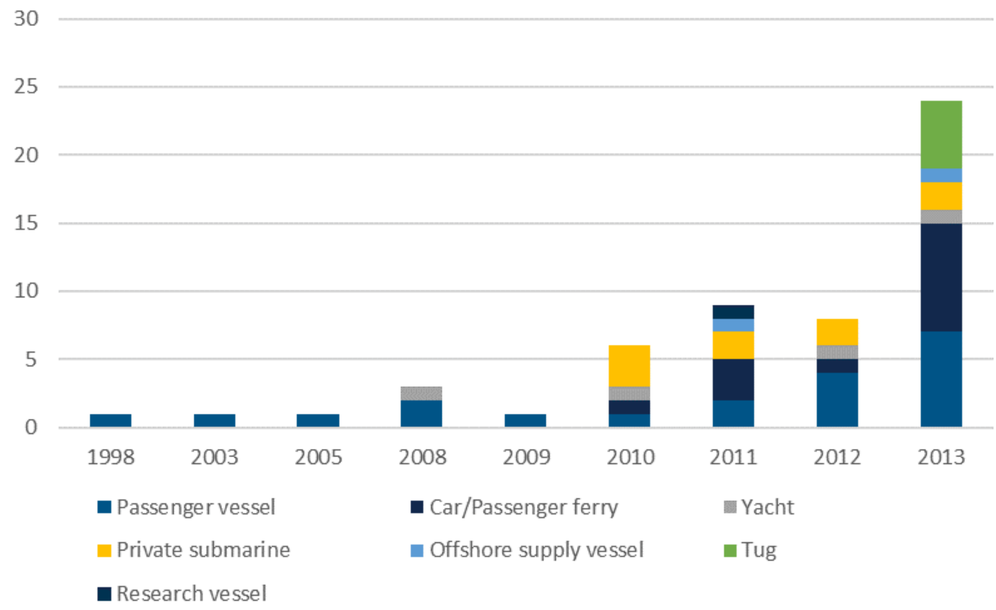


Fig.1: Types of ships with batteries installed between 1998 and 2013

The earliest battery powered ships used Nickel-Cadmium and Lead-acid types of batteries, Fig.2. In 2008 the first Lithium-ion battery system was installed on board a ship. For pure electric ships, only powered by batteries, Lead-acid and Nickel-Cadmium batteries were the preferred choice until 2011, and Lithium-ion batteries were predominantly used in hybrid propulsion systems.

From 2011 more ships started using Lithium-ion batteries, first mainly of the NCA type, but quickly LFP and specially NMC types of Lithium-ion batteries became more popular than NCA, mainly due to the higher fire risks related to NCA batteries.

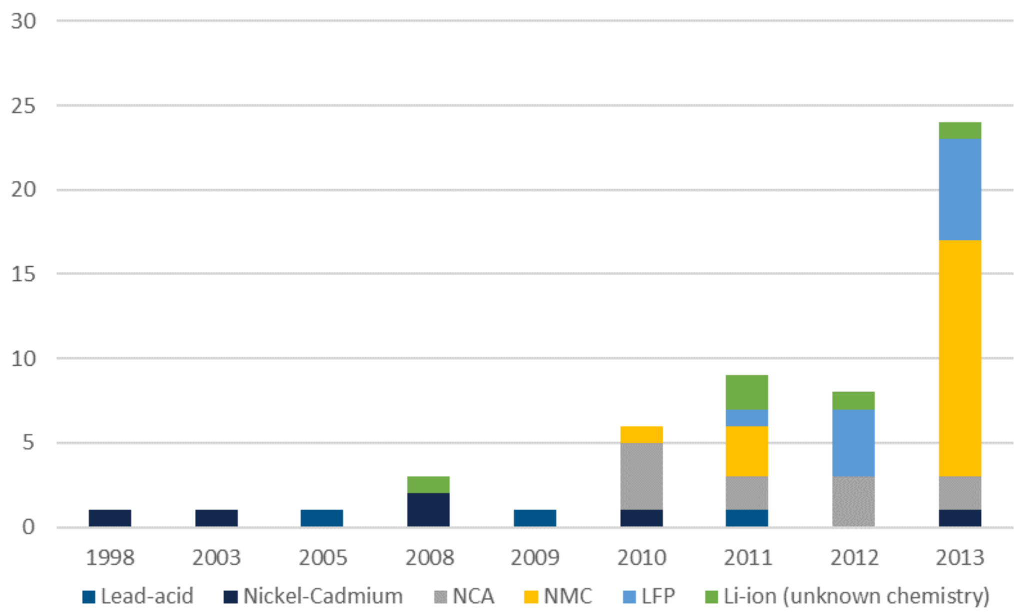


Fig.2: Types of battery chemistries installed between 1998 and 2013

The installed battery capacity for the oldest vessels in the Ship Register was only 20 kWh, but this soon started to increase with an average installed capacity of 253 kWh in 2008, 479 kWh in 2011 and 567 kWh in 2013. Due to the limited number of battery powered vessels in those years, the average installed battery capacity per year fluctuated significantly due to specific battery installations. The majority of the battery powered vessels between 1998 and 2013 were below 30 m in length. Pure electric vessels did not exceed 20 m in length.

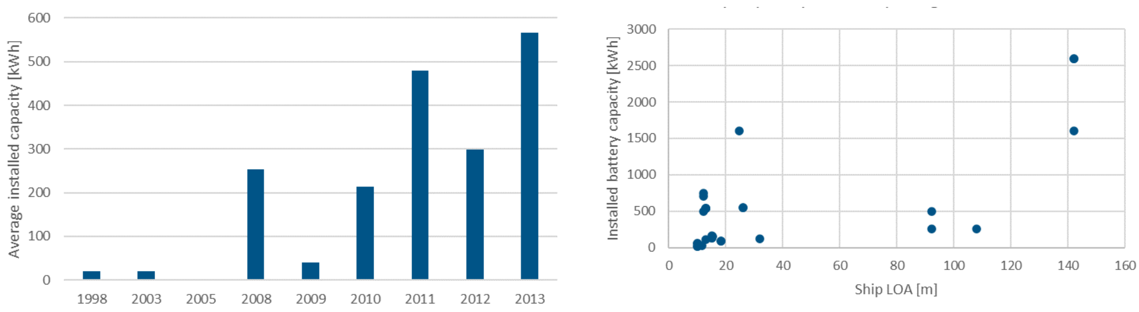


Fig.3: Average battery capacity installed per ship (left) and over ship length (right) in kWh between 1998 and 2013

## 3. The Ampere age (2014-2018)

In 2014 the first pure electric car/passenger ferry "Ampere" was delivered in Norway. With 1860 kWh of installed battery capacity, it was the start of a new age of full electric ships, and a good example of the possibilities for batteries in the maritime industry. Although in 2014 and 2015 the number of battery powered ships delivered was less compared to 2013 (Fig.4), and the average installed battery capacity was smaller as well (Fig.6), the different types of vessels using batteries for propulsion started expanding further. First, several workboats and different types of vessels for the fishing and fish farming industry were electrified. Followed by a variety of cargo vessels such as general cargo ships, RoRo cargo ships, bulk carriers, and Oil/chemical tankers, as well as a patrol vessel. The number of battery powered offshore supply vessels, yachts, tugs and research vessels continued to increase as well.

63% of the battery installations on board of ships between 2014 and 2018 were on newbuild vessels, the other 37% were retrofits. The majority (58%) of the battery powered ships delivered in this period had a battery integrated in a hybrid propulsion system, 17% of the vessels were plug-in hybrid and 25% of the battery powered vessels were pure electric. Compared to the period between 1998 and 2013 we see an increase in retrofits and an increase in popularity of both hybrid and plug-in hybrid propulsion systems.

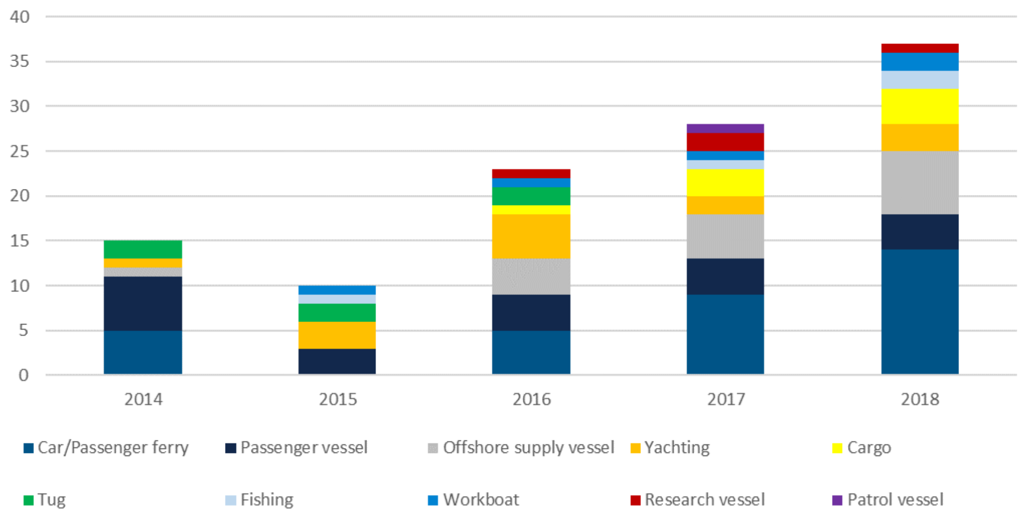


Fig.4: Types of ships with batteries installed between 2014 and 2018

Except for one ferry powered by a Lead-acid battery in 2014 and two Nickel-Cadmium powered ferries in 2016, Lithium-ion batteries showed their potential for electrification of ships. LFP and NCA were used in some cases, as well as LTO sporadically, but the majority of the vessels were powered by NMC batteries. Of the vessels delivered in 2018, 97% used NMC batteries.

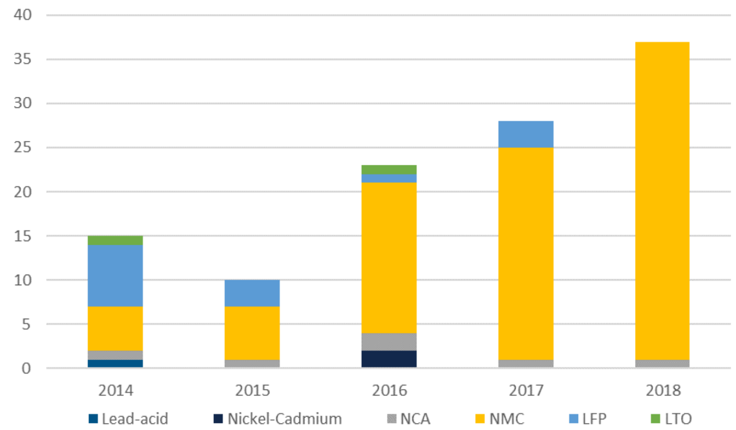

Fig.5: Types of battery chemistries installed between 2014 and 2018

Between 2010 and 2016 the average installed battery capacity per vessel varied between 200 kWh and 570 kWh, with no clear increase until 2017. The largest installed battery in 2013 was 2600 kWh, by 2018 this was 4160 kWh. On a year-by-year basis the average installed battery capacity fluctuates significantly, but an overall increase in battery size is shown to be the trend.

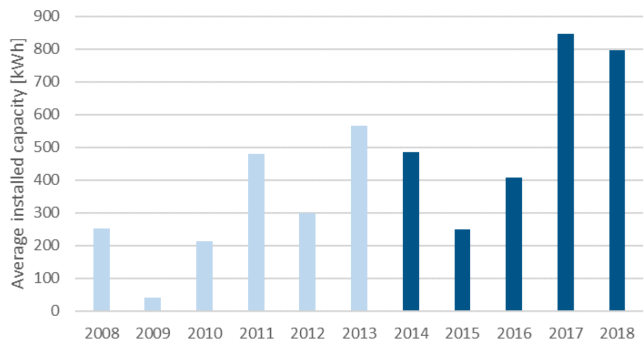

Fig.6: Average battery capacity installed per ship 2008-2018

There is no clear link between ship length and installed battery capacity, or between the installed propulsion power and the battery capacity, as can be seen in Fig.7. This can be explained by the large variety of applications for batteries on board of ships, as well as the varying operational profiles of ships. Batteries can be used for electric propulsion, but also for applications such as peak shaving, spinning reserve, or load leveling, which combined with the specific operational profile of the vessel, will have different requirements for the battery system size.

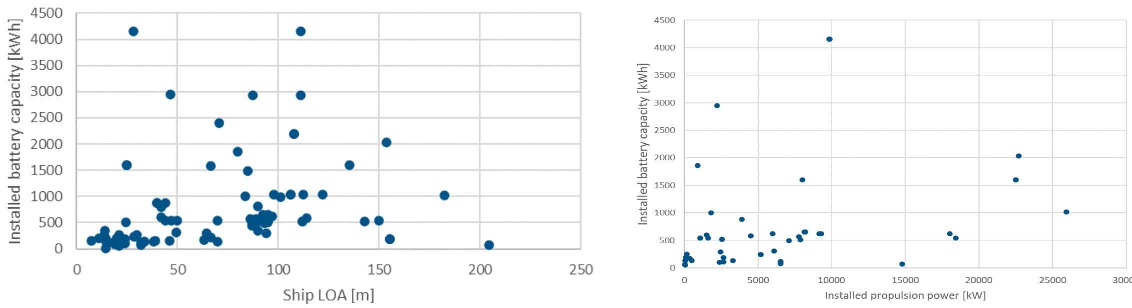

Fig.7: Battery capacity compared to ship length [m] and propulsion power [kW] (2014-2018)

## 4. Current generation of battery powered ships (2019-2022)

Over the last 4 years the diversification of types of ships with batteries has continued. Offshore supply vessels continued to gain a position as one of the most popular types of ships for battery installations, but an impressive growth is shown for cargo ships and ships in the fishing/fish farming industry. The category cargo vessels contains bulk carriers, container vessels, tankers, and general cargo vessels. The category fishing contains amongst fishing vessels also fish farm support vessels and fish carriers. Two categories that started to increase in size over the last two years are cruise vessels and vessels for the offshore wind industry. In 2021 there is a clear dip in the number of delivered battery powered vessels.

75% of the battery installations on board of ships between 2019 and 2022 were newbuild vessels, the other 25% were retrofits. The majority (53%) of the battery powered ships delivered in this period had a battery integrated in a hybrid propulsion system, 26% of the vessels were plug-in hybrid and 21% of the battery powered vessels were pure electric. Compared to the period before 2019 we see an increase in the percentage of newbuilds and an increase in popularity of plug-in hybrid propulsion systems.

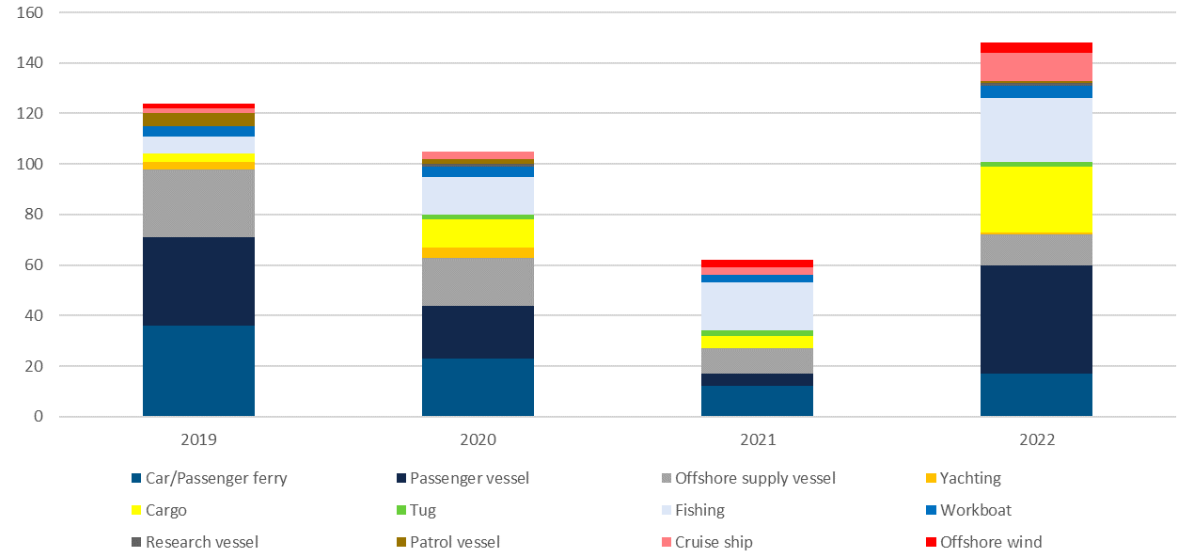


Fig.8: Types of ships with batteries installed between 2019 and 2022

As can be seen in Fig.9, NMC has taken the position as preferred Lithium-ion chemistry for maritime battery systems. Although LFP remains the choice for some of the vessels in France and China, there has not been a significant increase in the use of LFP battery systems, as is the case for the automotive industry. In the maritime industry it seems like LTO batteries are lining up to challenge NMC batteries.

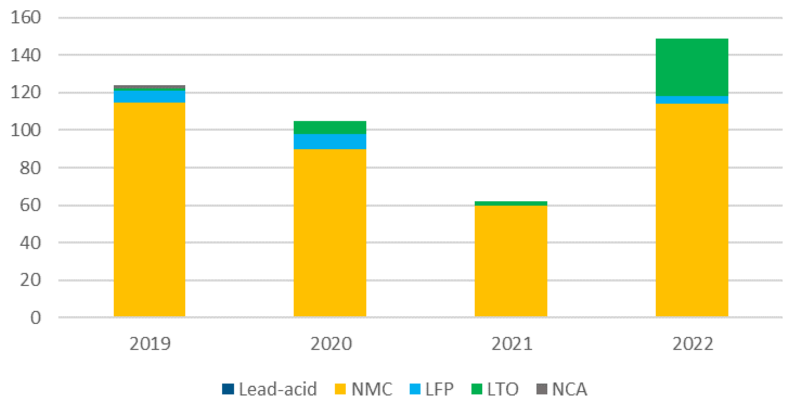


Fig.9: Types of battery chemistries installed between 2019 and 2022

The average installed capacity per ship continued to increase over the last four years to an average of approximately 1.2 MWh per ship. The largest installed battery in 2013 was 2.6 MWh, and in 2018 it was 4.2 MWh. By 2022 the largest installed battery system on board of a ship is 10 MWh.

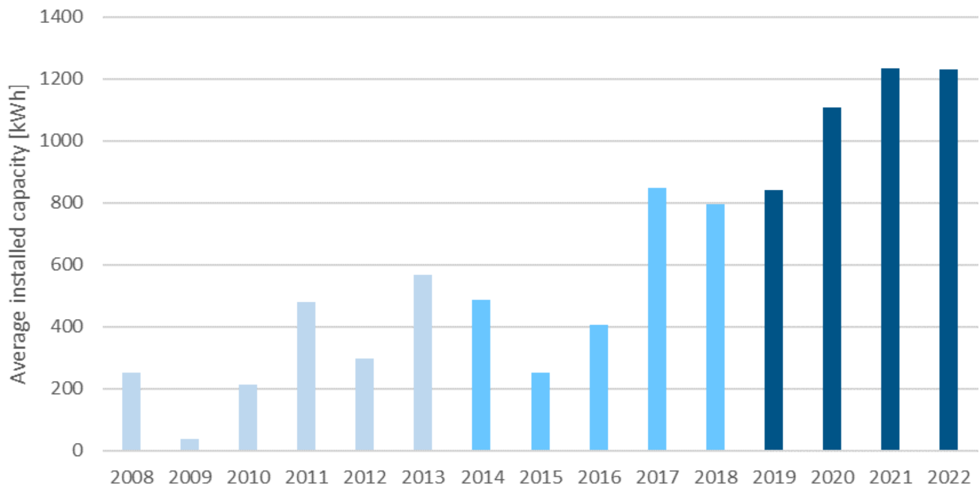


Fig.10: Average battery capacity installed per ship 2008-2022

**5. Summary of battery powered ships until 2022**

The average installed battery capacity per year is shown in Fig.11. Here it can be seen that a significant increase in installed battery capacity happened in 2019, and after a small decrease in 2021, the installed capacity in 2022 has increase significantly again to a total of approximately 180 MWh. Note that this paper is written in July 2022 and although many of the vessels under construction are taken into account in the ship register, the total installed battery capacity in 2022 is expected to increase.

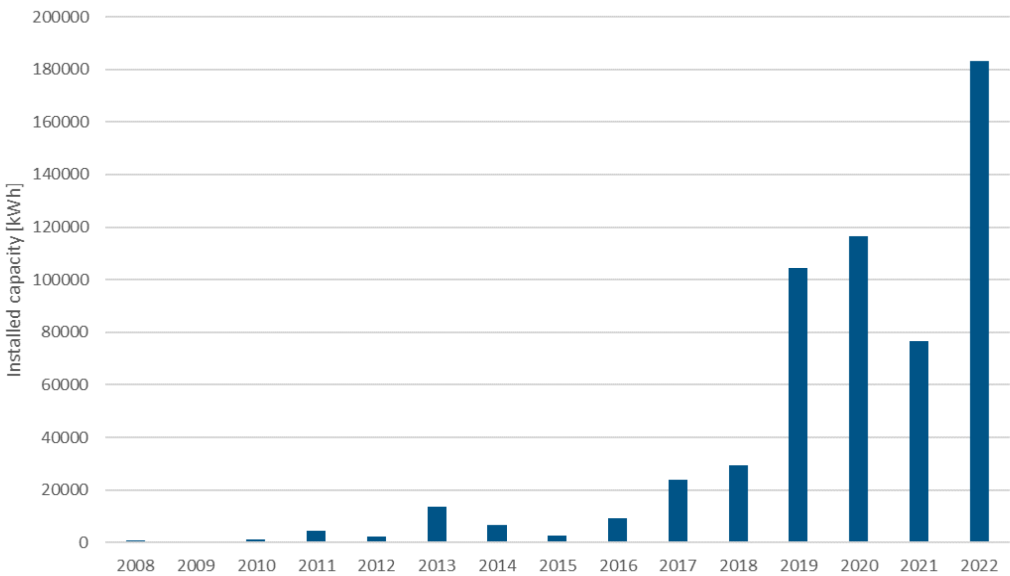


Fig.11: Total installed battery capacity per year in kWh (2008-2022)

Fig.12 shows the average installed capacity of the different ship types over the complete period between 1998 and 2022. The vessels with the largest battery systems installed are container vessels, Ro-Ro cargo ships, cruise ships and RoPax vessels.

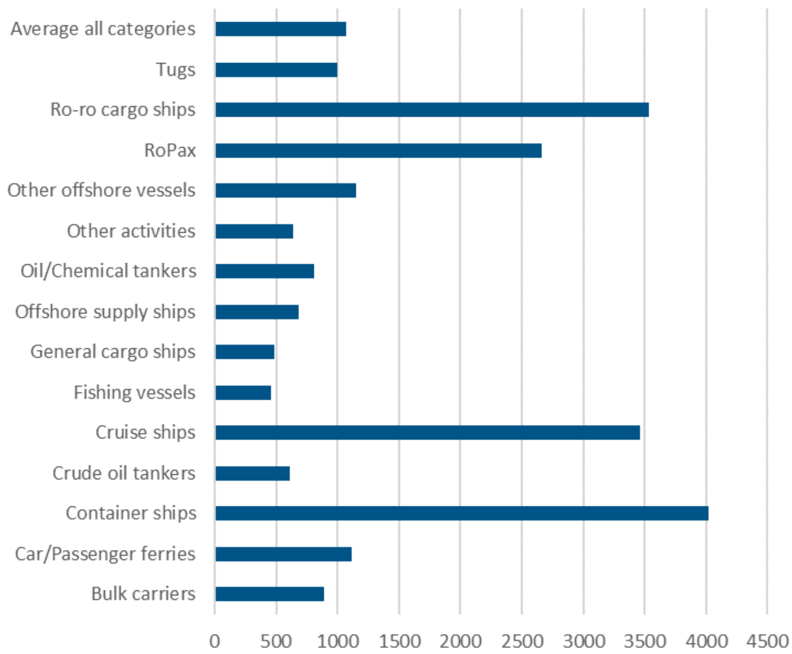

Fig.12: Average installed battery capacity per ship type

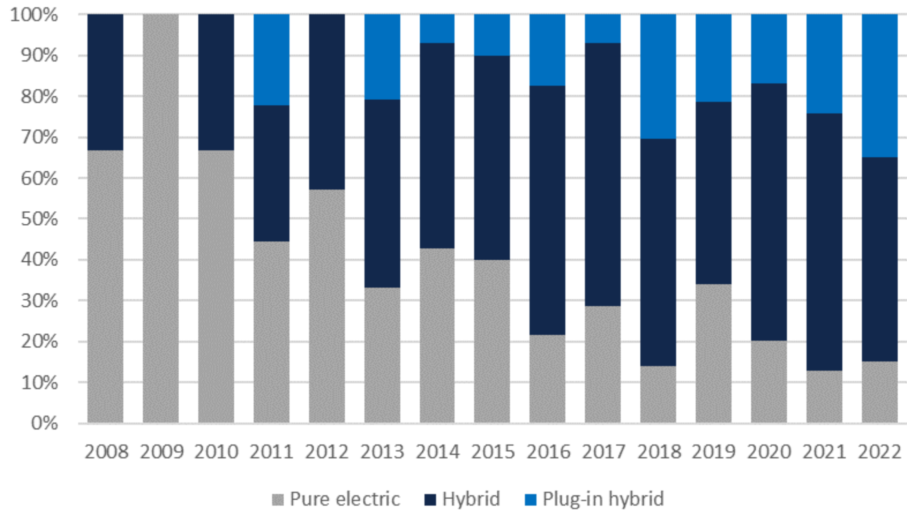

Fig.13: Types of electric propulsion configuration

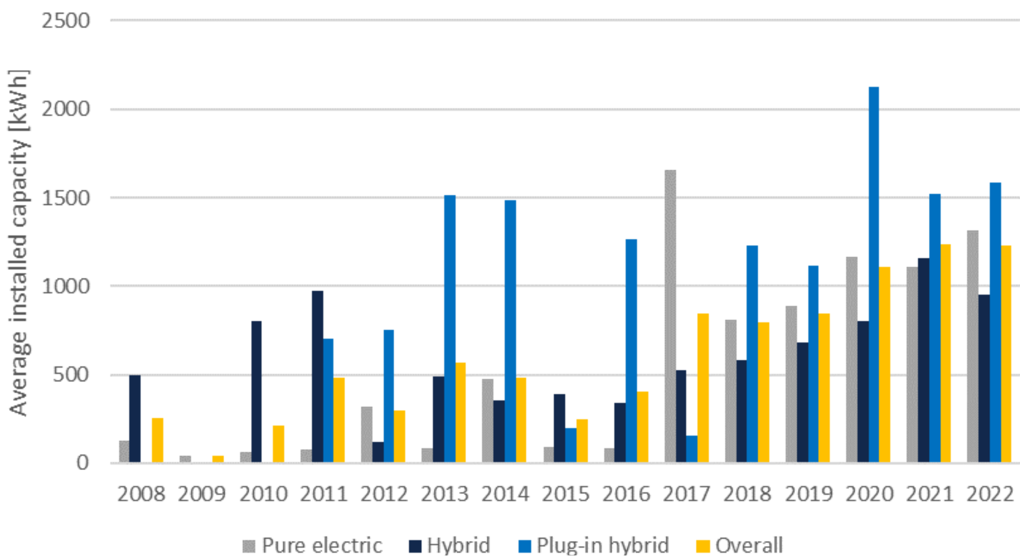

Fig.14: Average installed capacity for different configurations

The electric propulsion configuration of battery powered ships is divided in 3 types in the Ship Register: Pure electric, Hybrid, and Plug-in hybrid. Fig.13 shows the percentages of the types of configuration of the fleet of battery powered vessels per year. Pure electric ships was the largest group from 2008 until 2012. From 2012 the hybrid configurations took over as most popular configuration for battery powered ships, and it is still the most common configuration. However, there is an increase in plug-in hybrid vessels, which already outnumber the pure electric vessels and are approaching the same numbers as hybrid vessels. With a larger availability of shore power and standardization of charging systems, it is expected that plug-in hybrid vessels will gain more in number compared to hybrid vessels as well.

Since 2018 the average installed capacity on plug-in hybrid vessels has been the largest compared to pure electric and hybrid vessels. Except for 2021, the average installed capacity on board of pure electric vessels since 2018 has been larger compared to hybrid vessels, Fig.14.

**6. The accelerated adoption of batteries in Norway**

There is one specific area that stands out with the total number of battery powered ships, Norway. Almost half of all the battery powered ships are operating in Norway. 25% of the battery powered ships operate throughout the rest of Europe, 14% in Asia, 8% in the Americas (mainly North America), and 4% of the battery powered ships operate globally.

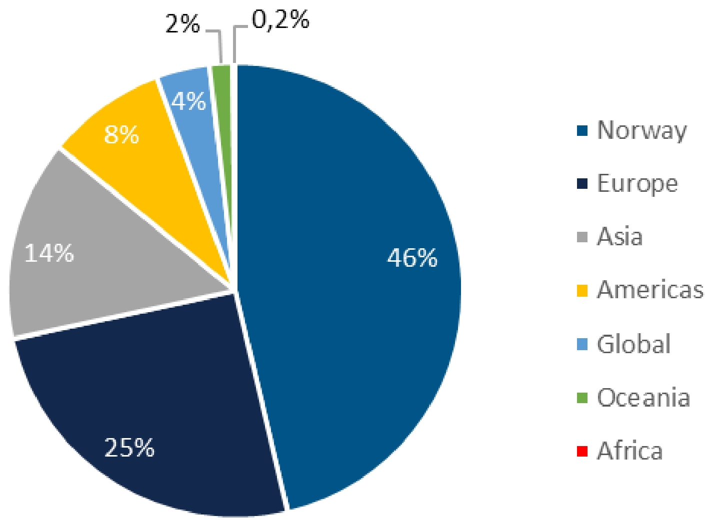


Fig.15: Area of operations of battery powered ships

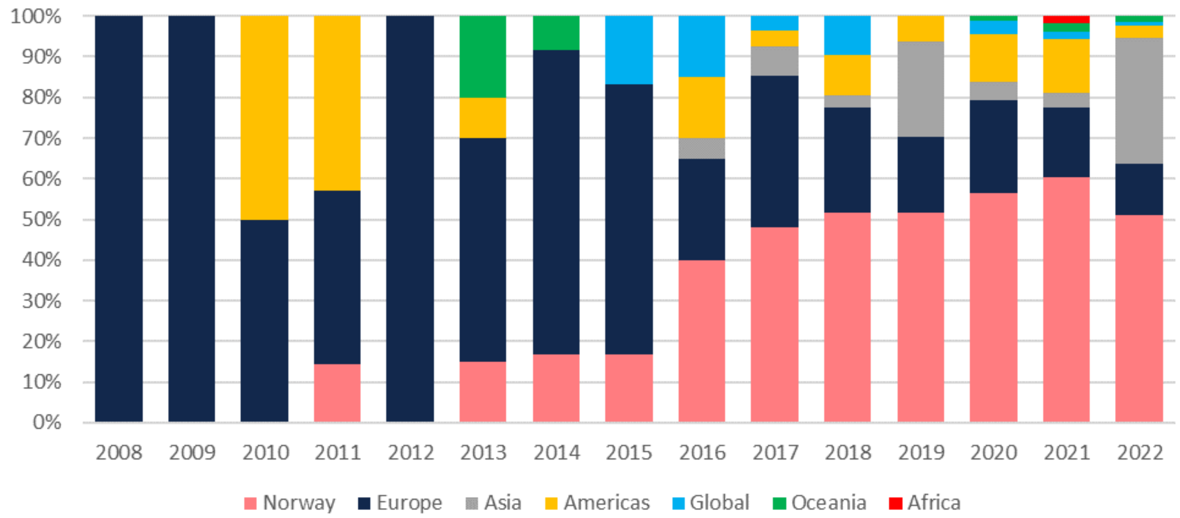


Fig.16: Area of operations of battery powered ships delivered per year

Fig.16 shows how the area of operation of battery powered ships delivered per year has changed between 2008 and 2022. Europe started first with the adoption of battery powered vessels, followed by North America. In 2011 the first Norwegian battery powered vessel went in operation. From 2013 until 2021 the market share of battery powered vessels for Norway increased every year. In 2022 for the first time the market share decreased slightly. The market share of (the rest of) Europe and North America decreased over the years. In 2019 and 2022 there has been a large increase in battery powered vessels in Asia.

*Rostad Sæther (2021)* identified four key factors for the success of electrification of Norwegian ferries:

1. Norway has a ferry innovation system characterized by a culture of close collaboration, mutual trust, and information-sharing. This made it possible to overcome potential initial resistance to electrification and for the maritime sector to pull in one direction.
2. The Norwegian state acted entrepreneurially, by moving beyond merely being a de-risker through playing an active role in market creation and transformation through public agencies and support schemes.
3. A lack of resistance from vested interests. The maritime sector constitutes a politically influential potential brake. It is important that there are no losers in the energy transition, as losers can make it go slower.
4. The transition was accelerated by a shock, namely the 2014 oil price crash, which inflicted empty order books on a maritime sector overly dependent on orders from the petroleum sector, providing an incentive to find new markets.

These key factors can also be transferred to match the local conditions in other parts of the world and can support the accelerated energy transition within the maritime industry on a global scale in a more general approach. Companies should focus more on collaboration, trusting partners, and sharing information, instead of competing for being the first to offer the best zero emission solution. Governments should play a more active role in market creation and transformation. Tender specifications should be made with technology development in mind, as battery technology is improving so fast that there is a fear of locking in solutions that might soon be obsolete. The parties relying on the traditional technology in ship propulsion should be motivated to become a part of the solution by transitioning to new technologies. The final part of the equation is a shock to accelerate the transition. This shock can also be considered as something created by governments, e.g. taxation of pollution, in combination with incentives on decarbonizing solutions.

Interesting to mention is that the incentives for battery powered ships in Norway, provided through Enova. Where applicants can apply for funding for infrastructure expenses for up to a maximum of 40% of the cost. Has been discontinued on 1 October 2021, as battery electrification has established itself as an economically feasible and suitable solution for zero- and low-emission ships, *Enova (2021)*.

**6. Effect of global decarbonization goals on maritime battery demand**

The initial GHG strategy by the IMO envisages a reduction of CO2 emissions compared to 2008 of at least 40% by 2030 and pursuing efforts towards 70% by 2050, and that total annual GHG emissions from international shipping should be reduced by at least 50% by 2050 compared to 2008, *IMO (2022).* This will not all be realized with installing batteries on board of ships only.

Alternative fuels like hydrogen, methanol and ammonia will play a crucial role in this as well. As the world is transitioning to different energy sources and fuels, the costs for these new technologies will be higher compared to the current situation. Therefore, there will be a stronger focus on energy efficiency and fuel reduction.

Batteries have proven over the last decade that they are very well capable of improving energy efficiency and reducing the fuel used on board of ships, *NN (2022)*. Hydrogen Fuel cells are for most applications dependent on a battery to handle the peak power demands and therefore it is expected that the future of ship propulsion will lay in hybrid propulsion systems, where batteries will play an important role to support the selected type of alternative fuel system.

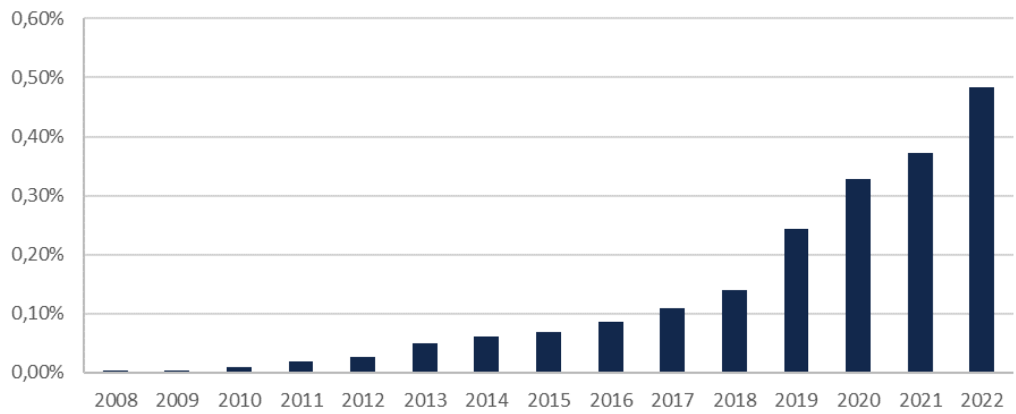


Fig.17: Percentage of global merchant fleet with batteries on board

Fig.17 shows the percentage of ships in the global merchant fleet that have batteries installed on board, based on the statistics of the global merchant fleet by *EMSA (2020)*. The increase in fleet percentage with batteries is fitted with a 3rd order polynomial trendline to estimate the increase in battery demand from now until 2050. These statistics show an average annual growth of 1,94% of the global merchant fleet between 2008 and 2020. This growth is assumed to applicable to the global merchant fleet up to 2050.

The increase of battery powered ships as percentage of the global merchant fleet is used to estimate the increase of battery powered ships up to 2050, based on the growth between 2008 and 2022, Fig.18. If the increase in adoption of maritime batteries continues to develop as it did between 2008 and 2022, it is calculated that by 2050 18.2% of the global merchant fleet, approximately 38.959 vessels will have batteries installed on board.

Assuming that by 2050 the goal is to reduce overall emissions by 50% compared to 2008, and the expectation that vessels with alternative fuels will need batteries as well, this is considered to be an underestimation of the growth in demand for maritime batteries. A significant growth in battery installations will be needed to reach the global decarbonization goals for the maritime industry by 2050.

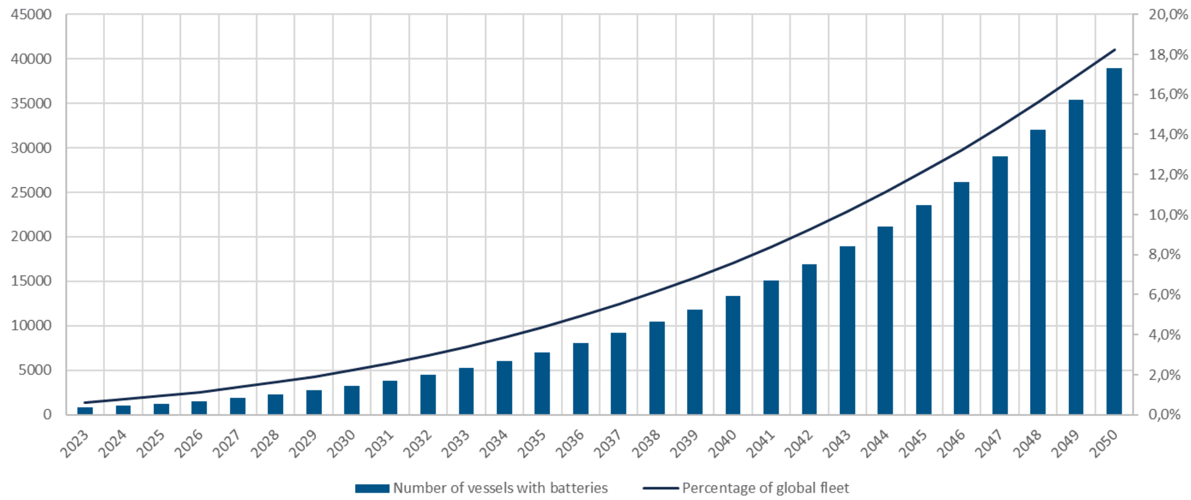


Fig.18: Increase in battery powered ships globally up to 2050 based on growth between 2008-2022 (conservative)

A calculation is made for the expected global demand of maritime battery systems based on the increase in number of battery powered ships, Fig.18, and assuming a linear growth of the average installed battery capacity per ship based on the batteries installed between 2008 and 2022 as shown in Fig.14.

This linear assumed growth in average installed battery capacity will result in an average installed battery capacity of 1778 kWh per ship in 2030 and 3343 kWh per ship in 2050. As shown in Fig.19, by 2030 the annual global demand for maritime batteries will be 916 MWh, by 2040 it will be 3950 MWh, and by 2050 it will be 11955 MWh. An average annual increase in battery demand 16% is calculated between 2023 and 2050 assuming the market will follow the same trends in growth of fleet size and battery size compared to the growth between 2008 and 2022.

As mentioned, this is not expected to be sufficient to reach the global marine decarbonization goals by 2050 and therefore the demand for batteries will be pushed even further up due to these goals.

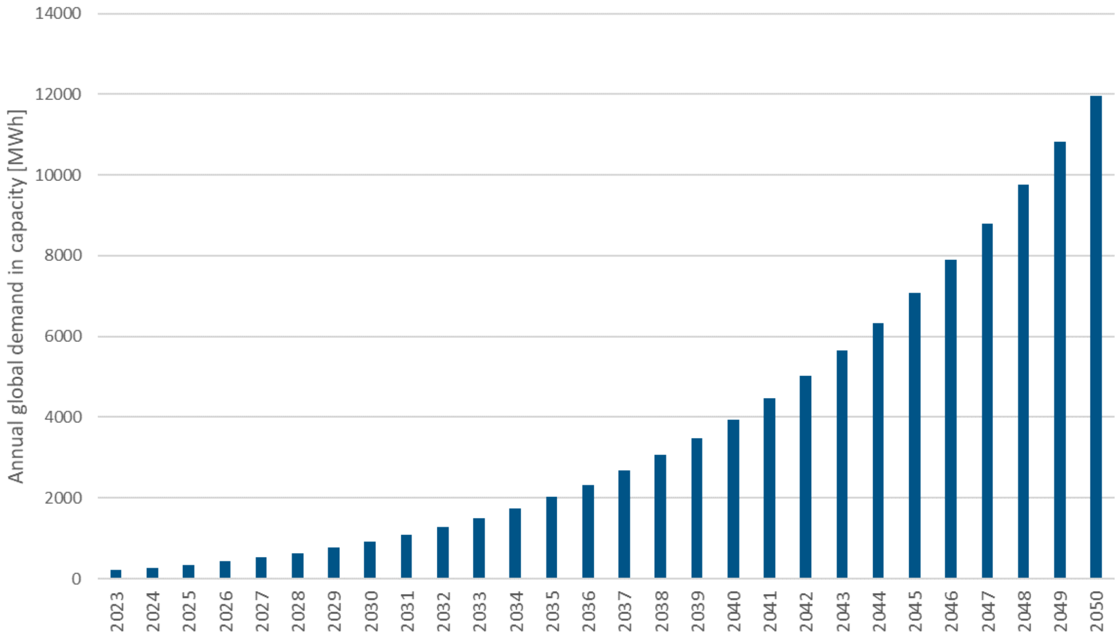


Fig.19: Global annual demand for maritime batteries based on growth trends between 2008-2022 (conservative)

## 7. Conclusions

Batteries have seen a promising uptake on a global level in the maritime industry. All types of vessels can potentially benefit from installing a battery system on board, when applied for the right reasons. Initially there was a strong focus on pure electric vessels. Soon the advantages of hybrid propulsion systems for other types of vessels were discovered. With the increase in availability of charging stations and standardization, the number of plug-in hybrid vessels will continue to grow, significantly reducing local emissions and pollution.

The projected estimations in this paper are based on the development of the maritime battery market between 2008 and 2022. Assuming the market will develop at a similar pace, it is expected that 18,2% of the global merchant fleet will have batteries installed by 2050. Assuming that batteries will be part of the solution for the adoption of future fuels like hydrogen, methanol and ammonia the current rate of installing batteries, with an annual growth in installed capacity of 16%, will not be sufficient to comply with the IMO goals of an overall emission reduction of 50% compared to 2008 by 2050.

The four key factors for the success of maritime batteries in electrifying the Norwegian fleet should be adapted to fit the local situation in other regions to increase the global uptake of maritime batteries.

These four key factors are:

- An innovation system characterized by a culture of close collaboration, mutual trust, and information sharing;
- An entrepreneurially acting state;
- A lack of resistance from vested interests;
- A market shock accelerating the transition.

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