BATTERY

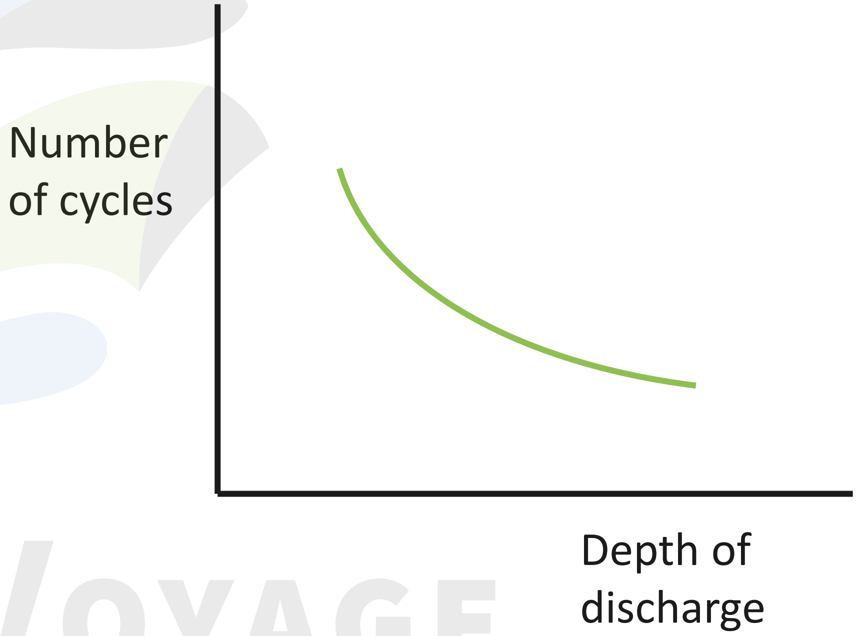
GREENVOYAGE 2050

Overview

- Background and key characteristics
- Battery technologies
- Onshore requirements
- Onboard requirements
- Regulations, standards and guidance
- Environmental impact
- Cost overview
- Barriers and risks
- Summary

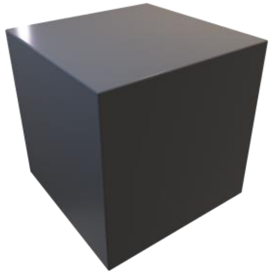
Batteries – key concepts

- When a battery is charged and then discharged during use, this is referred to as a use cycle.
- As the overall number of cycles that a battery is subjected to increases, the overall useful energy storage capacity of the battery decreases
- The number of cycles that a battery can withstand before reaching a certain proportion of its initial capacity is known as its **cycle life**.
- Commonly a level of **80% of initial capacity** is used in a cycle life definition.



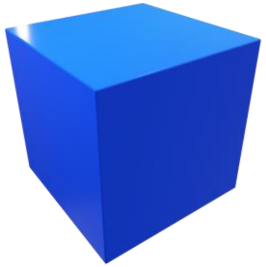
Applications for shipping

- While batteries have seen dramatic technological improvements in recent years, their applications in shipping for propulsion purposes are primarily still **constrained by energy density**.
- Currently ships using batteries and electric motors for propulsion are unable to travel more than **approximately 95km[1] (dependent on voyage conditions)**, and are therefore most suited to vessels with short inland or coastal voyages such as ferries.
- We will examine some current examples of battery powered vessels later in this session.



HFO volumetric energy density = **35 MJ/l**

HFO gravimetric energy density = **42 MJ/kg**



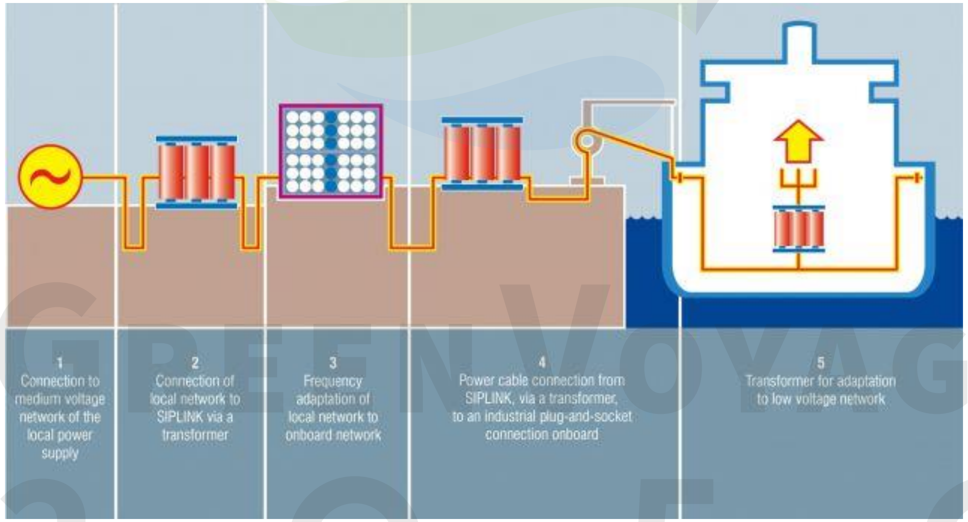
Li-ion battery volumetric energy density = **Approx. 1.4 MJ/l**

Li-ion battery gravimetric energy density = **Approx. 0.6 MJ/kg**

[1] IRENA (2019), Navigating to a renewable future: Solutions for decarbonising shipping, Preliminary findings, International Renewable Energy Agency, Abu Dhabi'

Onshore requirements

- The primary onshore requirement to support battery-powered vessels is the provision of a shore-to-ship electrical connection. Such a supply system is known as **shore power**.
- Shore-to-ship electrical connections are well understood, and while not widely used for charging batteries used for propulsion, they are used to power auxiliary electrical systems when berthed. This is referred to as **cold ironing**.



Onshore requirements

- Depending on its size and onboard power requirements, the onboard power systems for vessels will operate at different voltage and frequency levels (e.g. some may operate with low voltage supply at 400V, others may operate with high-voltage supply at 1,100 V).
- Depending on location, shore-based electricity supplies will **also operate** at different voltage or frequency levels. For example, frequencies will be at either 50 or 60Hz, in line with the power infrastructure characteristics of that country (e.g. Europe operates on 50Hz, and America operates on 60Hz).
- The power demand required from the shore power unit will also vary for different ship types (e.g. small ships may require 300 kVA, but cruise ships could require 20 MVA, which is 20,000 kVA).
- Ships will often carry onboard voltage and frequency converters, providing them with universal compatibility no matter where they berth.

Onshore requirements – battery charging for propulsion

- While ships using shore power for cold ironing is well understood, using shore power to charge large onboard battery systems for propulsion power does present different challenges.
- Generally power requirements for recharging batteries used for propulsion will be larger than those used for cold ironing (supplying the auxiliary power to the vessel only when in port).
- Whereas some liquid fuels can be bunkered 'ship-to-ship', current charging systems all require the ship to be berthed in order to provide a direct connection.
- If charging infrastructure is to be widely installed, this will likely require **significant upgrades to electricity distribution and transmission infrastructure** local to port areas.

Onshore requirements – example power connections

Example charging and power supply solutions Stemann-Technik

Onshore requirements – example power connections

Induction charging system Wärtsilä and SINTEF

Induction charging uses a magnetic field generated by the onshore charging station to induce a charging current onboard the vessel.
It means no physical cable connection is required between the shore and the ship, which is well suited for ships with fast charging time requirements such as ferries.

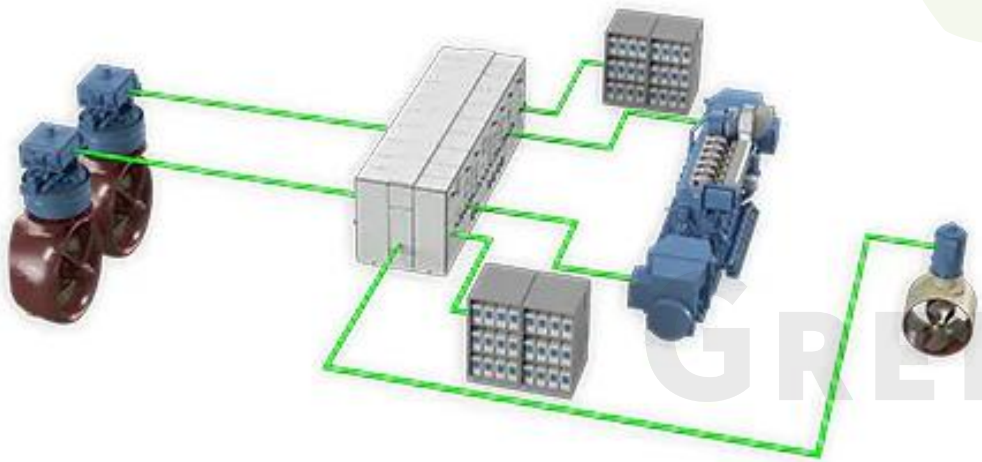
MF Folgefonn Norled

This system is in use in Norway on MF Folgefonn, a ferry operated by Norled.

Onboard requirements - battery propulsion systems

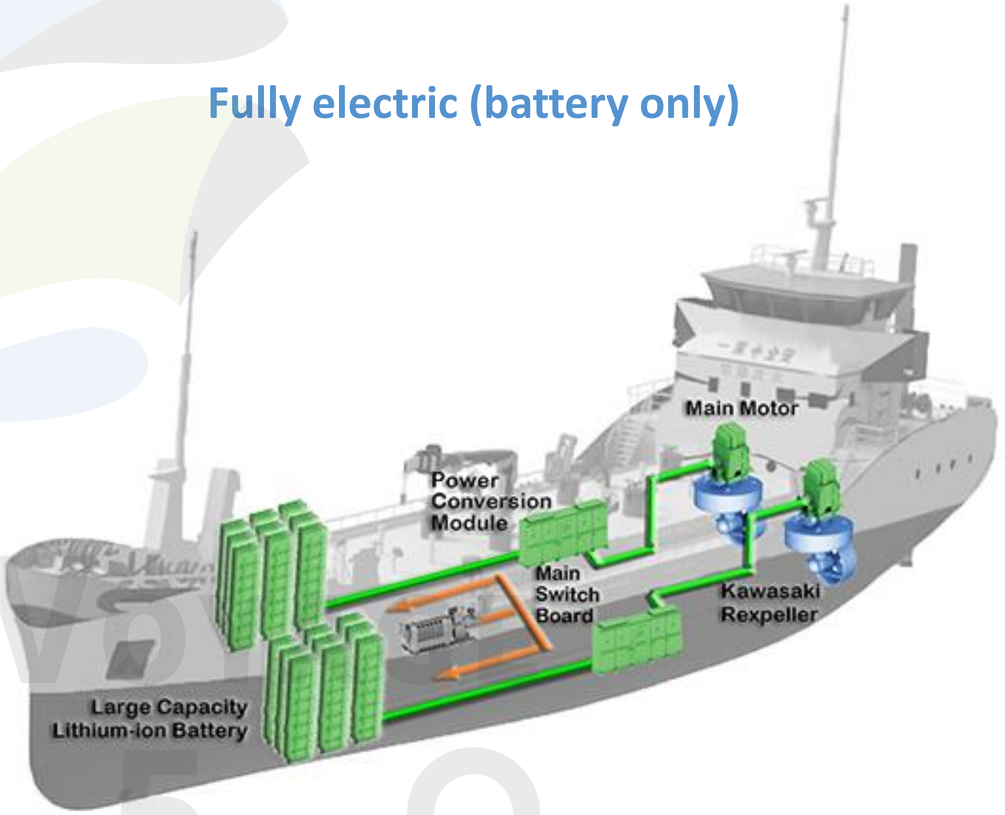
Batteries can be used as part of vessel propulsion systems in two main configuration types:

Hybrid (battery with conventional combustion engine)



Hybrid propulsion system for tugboat Rolls Royce

Fully electric (battery only)



Proposed large battery propulsion system Kawasaki

Other onboard requirements

- Safety onboard is an important consideration for vessels with large amounts of onboard battery storage.
- Additional precautions are therefore recommended in the following areas:
  - Temperature control – battery systems must be housed in a space that is adequately ventilated and temperature controlled.
  - Fire prevention and detection – additional requirements for monitoring of battery spaces

Regulations, standards and guidance

Body/Organisation	Documentation	Status/Comment
UL LLC	UL1642 Standard for Lithium Batteries	Published. Globally recognised safety standard.
DNV GL	Rules for classification and class programmes	Adopted. Example of classification standards related to onboard battery storage and associated electrical systems.
DNV GL and others	Maritime Battery Safety Joint Development Project - Report	New joint industry report with recommendations on improved safety of battery use on vessels

Examples of battery powered vessels (1)

Ellen, fully-electric ferry EU Horizon 2020 Project

- 60m vessel, 200 passengers and 30 cars
- 4.3MWh battery system
- 4MW charging rate (less than 25 minutes for full charge)
- 22nm voyage length

Aurora, fully-electric ferry ForSea

- Converted diesel-electric ferry (diesel generators retained for back-up or occasional hybrid use)
- 4.1MWh lithium ion battery system installed in containers on deck
- 46 crossings per 24 hours
- 4km route, with short (<10 minute) charging times at each port
- 28,000 tonnes CO_2 saved per year

Examples of battery powered vessels (2)

2000dwt fully-electric tanker Guangzhou Shipyard Int.

- 70m long, 14m wide
- 2.4 MWh battery storage capacity (>1000 Li-ion batteries)
- 2hrs charging time for inland voyage of 43nm
- Operational in southern province of Guangdong

Stena Jutlandica, hybrid Stena Line

- Project began in 2018, and has three phases:
  - Phase 1: Initial integration of electrical operation (manoeuvring, reduced use of generators)
  - Phase 2: increase battery storage to provide 10nm of fully-electric range
  - Phase 3: increase battery storage to provide 50nm of fully-electric range

Examples of battery powered vessels (3)

- 120 TEU battery-powered container ship, completed in 2020
- 80m long, 15m wide
- Designed to be fully autonomous
- 7MWh battery
- ‘Eco’ speed: 6-7 kts, max. speed: 13 kts
- Due to undergo full testing

Yara Birkeland, Fully-electric container ship

Kongsberg/Yara Intl.

Environmental impacts

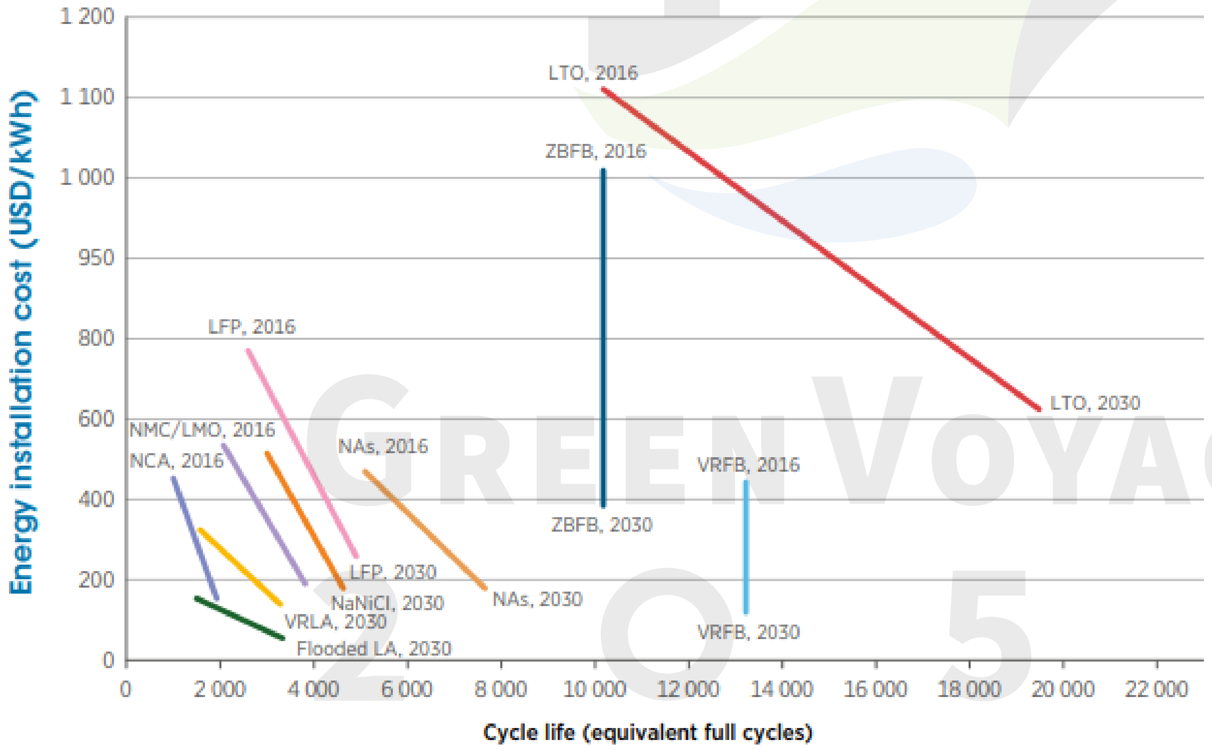
- When using a propulsion system fully powered by batteries, there are **no emissions at the point of use**, as no combustion takes place.
- **However**, the overall environmental impact of fully electric vessels is dependent on:
  - The **carbon intensity of the electricity used to charge the batteries** (this will depend on the electricity generation mix for the power supply at the charging location).
  - Lifecycle emissions of battery manufacturing (**however**, because batteries can be recharged, these account for the total propulsion energy provided over the lifetime of the battery).*
  - Battery recycling or re-deployment when their end of useful life is reached.*

	GHGs	NOx	SOx	PM
Reduction at point of use	-100%	-100%	-100%	-100%

*Note that for other fuels, we have not considered associated lifecycle emissions beyond those of the production process and end-use, such as those associated with engine manufacture for that option.

Cost of batteries in shipping (1)

- The capital cost of batteries depends on the battery technology, with Li-ion batteries (increasingly adopted for shipping electric propulsion purposes) have seen dramatic cost reductions over recent years.
- The chart below provides an overview of how battery technologies are expected to improve in the future, in terms of **capital cost** and **cycle life**.



LA: Lead-acid
LFP: Lithium iron phosphate
LMO: Lithium manganese oxide
LTO: Lithium titanate.
VRFB: Vanadium redox flow battery
NaNiCl: Sodium nickel chloride flow battery
NaS: Sodium sulphur
NCA: nickel cobalt aluminium
NMC: nickel manganese cobalt
VRLA: Valve-regulated lead-acid
ZBFB: Zinc bromine flow battery

Image source: IRENA (2019), Navigating to a renewable future: Solutions for decarbonising shipping, Preliminary findings, International Renewable Energy Agency, Abu Dhabi

Cost of batteries in shipping (2)

- The operational cost of using batteries is dependent on the price paid for the electricity used for charging.
- This could vary significantly depending on:
  - Commercial supply arrangements (e.g. type of consumer, offtake relationship)
  - Other current demand levels on the relevant system
  - Generation mix at the current time (e.g. amount of power supplied by renewables)

- For 2018, the average electricity prices paid by industrial consumers globally was:

Average cost of electricity	6 – 67 USD/GJ[1]	**(Global average = 27 USD/GJ)**
Cost compared to HFO market price	Additional -6 to 61 USD/GJ[2]	

[1] IEA (2020), Energy Prices 2020, IEA, Paris. Prices for industrial consumers for 2018.
[2] based on HFO market price of 250 – 500 USD/tonne.

Barriers and risks

Category	Barrier / Risk	Rating
Technical	Energy density may put limitations on voyages that could use battery	High – either shorter distance vessels or frequent recharge requirements are needed
	Lack of standardised shore power connections	Medium – further development of international standards needed.
Commercial/ economic	Lack of available charging infrastructure	Med/high – this presents a strong barrier to initial uptake as it would lead to severe operational constraints.
	Infrastructure upgrade costs	Med/high – while the development of charging infrastructure at ports would follow known engineering practices and understood technologies, the costs associated with upstream power infrastructure upgrades are likely to be high. Potential for split incentives.
Sustainability	Sustainability depends on source of electricity	Low – in general most power sectors globally have separate plans to decarbonise (albeit at different rates).

Batteries summary

Key points

- The use of batteries for propulsion in shipping is primarily limited by energy density.
- Battery energy density and technology has improved dramatically over recent years (and is expected to improve further), although the overall motive energy requirements of long-distance voyages mean that widespread use of batteries for international shipping is **highly unlikely**.
- However, they provide a good solution for some short-distance coastal and inland applications, or where there is a fixed route where the vessel and infrastructure can be designed to the voyage distance and charging frequency.