

A stylized graphic of a ship's hull and wake, rendered in dark blue and white, set against a background of diagonal stripes in shades of blue and green.

[FLEXSHIP] Short Course - Electrification and Digital Twins for Green Shipping

Session 2

DATE

6/10/2025

FLEXSHIP

Season 2

Electrification technology in marine systems



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1. Introduction
2. Modular batteries for electrification
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What are the results of climate change ?

Rising Sea Levels:

Melting glaciers and ice sheets (Greenland, Antarctica) plus the thermal expansion of warming seawater are causing sea levels to rise.

Extreme Weather Events:

A warmer atmosphere holds more moisture and energy, intensifying weather patterns.

Ecosystem Collapse & Biodiversity Loss:

Species cannot adapt quickly enough to rapid temperature shifts and changing habitats (e.g., coral bleaching, shifting migration patterns, melting Arctic ecosystems).

Human Health Risks:

Heat stress becomes more deadly. Warmer temperatures expand the range of disease vectors like mosquitoes (spreading malaria, dengue, Zika). Air pollution worsens (linked to warming). Food and water insecurity increase.

Food and Water Security:

Changing precipitation patterns, more frequent droughts and floods, heat stress on crops, and ocean acidification harm agriculture and fisheries.

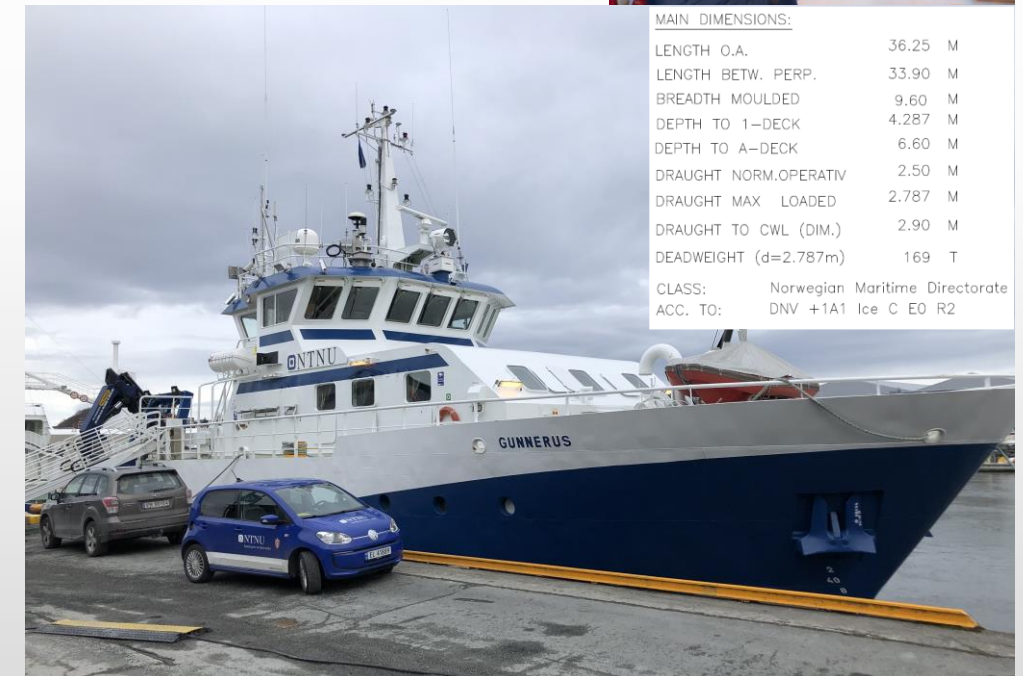
Economic Disruption:

Damage from extreme weather, loss of infrastructure (especially coastal), reduced agricultural productivity, health costs, and displacement of populations impose massive economic burdens.

Ocean Acidification:

The ocean absorbs about 30% of human-emitted CO₂, making it more acidic.

“Electrification aims to transform the energy conversion paradigm, promoting a clean and quiet sail with enhanced efficiency”, Mehdi Zadeh.



Source: <https://nyheter.ntnu.no/en/the-race-is-on-to-make-the-shipping-sector-fossil-free/>

1.3 Electrification technologies

A **hybrid ship** is a vessel that uses **two or more types of power sources** for propulsion and onboard energy needs—typically a combination of conventional engines (like diesel) and electric power. hybrid ship Enables operation in electric mode to reduce greenhouse gases and pollutants

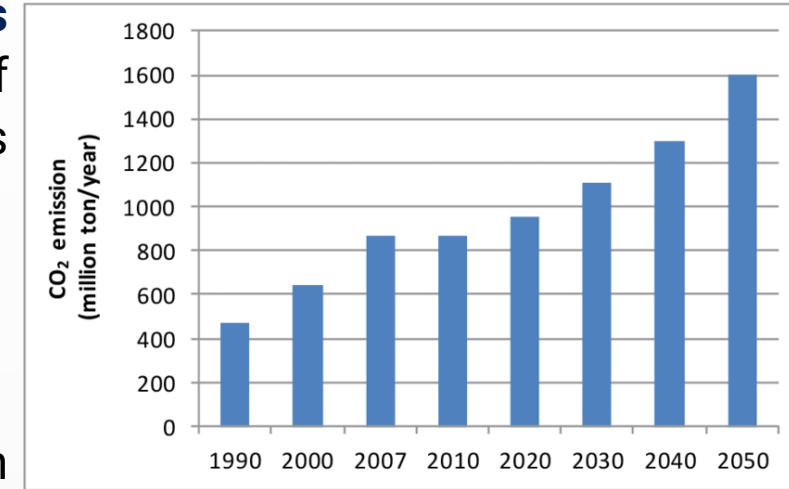
More than **80%** of global trade is from shipping.

More than **1038 million tons** of GHG were emitted between 2007 to 2012.

According to International Maritime Organization (IMO), total emission should be **reduce 50% by 2050**.

Advantage of marine hybrid systems

- Improve efficiency
- Reduce GHG emission
- Reduce fuel consumption
- Flexibility



Ref: <https://doi.org/10.1016/j.apenergy.2017.03.027>

Hybrid ships use **energy storage** to store energy from the diesel engine and convert it to chemical energy. Two primary energy storage for hybrid ships are **fuel cells** and **batteries**.

Feature

Energy Source

Reusability

By-products

Run Time

Efficiency

Environmental Impact

Batteries

Internal chemical storage

Rechargeable or single-use

Minimal (some heat, gases)

Limited to stored capacity

Moderate

Depends on battery chemistry

Fuel Cells

External fuel supply

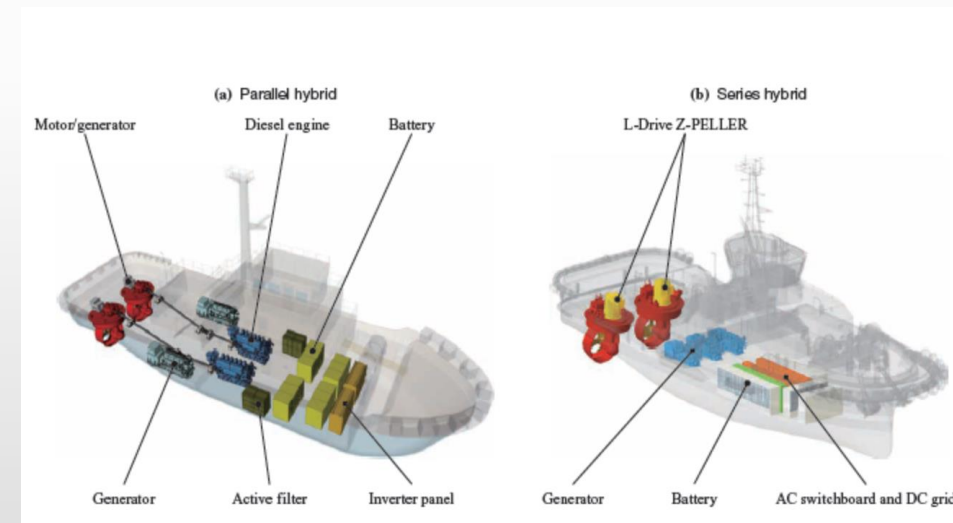
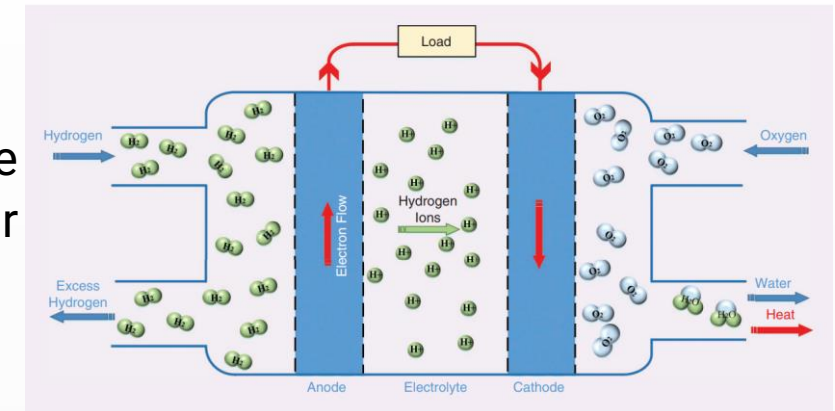
Continuous with fuel

Water + heat (in hydrogen cells)

Unlimited (as long as fuel flows)

High (especially for hydrogen)

Low (especially green hydrogen)



Ref:

https://www.ihl.co.jp/en/technology/techinfo/contents_no/1201051_13586.html



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2. Modular batteries for electrification

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2.1 Comparison of Electrification in vehicles and vessels

What are the challenges in electrification of vessels, in comparison to vehicles?

Aspect	Vessels	Vehicles (Cars, Trucks, Buses)
Energy Demand & Scale	Much larger power and energy requirements, especially for large ships and ferries; requires massive battery capacity or hybrid systems.	Lower energy needs relative to vessels; smaller batteries suffice for typical daily ranges.
Space & Weight Constraints	Space limited but often larger vessels have more room; weight distribution critical due to stability and seaworthiness.	Space and weight important but vehicles have more flexible design; weight affects efficiency but not stability as critically as in vessels.
Environmental Conditions	Harsh marine environment: saltwater corrosion, humidity, vibrations, temperature extremes.	Less harsh; mainly exposure to weather, dust, and vibration, but no saltwater corrosion.
Charging Infrastructure	Limited and emerging port infrastructure; slower charging cycles; ports must invest in high-power charging or battery swap solutions.	Widespread, growing fast charging network; standardization progressing; easier access to charging at home, work, and public places.
Range Requirements	Vessels often require longer operational ranges; some operate continuously for hours or days, challenging battery-only solutions.	Vehicles typically have shorter daily driving ranges; range anxiety decreasing with better batteries and charging.
Safety & Regulations	Stricter marine safety standards (IMO, classification societies) due to confined spaces and fire risks on vessels.	Road safety standards and battery safety regulations apply; generally easier emergency response.

2.1 Comparison of Electrification in vehicles and vessels

Thermal Management	More complex due to confined spaces and marine environment; needs robust cooling/heating systems.	Simpler cooling needs, generally easier airflow and heat dissipation.
Hybridization	Hybrid systems (battery + diesel/fuel cells) common due to range and power density limitations.	Hybrid vehicles are widespread, but many fully electric vehicles exist due to better energy density and infrastructure.
Cost and Economics	Higher upfront retrofit or build cost; fuel savings and emissions benefits significant but longer payback periods.	Lower upfront cost premium (decreasing), shorter payback periods; incentives and mass production reduce costs.
Maintenance & Monitoring	More challenging due to marine environment; requires specialized expertise and robust monitoring systems.	Easier maintenance with more service centers and less harsh environment.
Environmental Impact	High potential for reducing emissions in marine transport, which is a major source of pollution.	Significant emissions reduction for urban and suburban transport; major driver of passenger car electrification.

Some challenges are listed below

- **Space and Weight Constraints**
- **Marine Environment Harshness**
- **Thermal Management**
- **Safety Concerns**
- **Energy Density and Range Requirements**
- **Integration with Existing Propulsion Systems**

Space and Weight Constraints

- Limited Physical Space on Board

Trade-offs Between Capacity and Weight

- More battery capacity means heavier and larger battery packs but enables longer operating ranges or more power for propulsion and onboard systems.
- Conversely, restricting battery size to save weight or space can limit vessel range or require frequent recharging, which may not be practical.

2.3 Electrical propulsion and hybrid power architectures

•Marine Environment Harshness

Temperature Variations

- Batteries on vessels can be exposed to wide temperature ranges—from cold ocean air and water to hot engine rooms or direct sunlight on deck.
- Temperature extremes affect battery chemistry, capacity, and lifespan.
- Thermal management systems (cooling and sometimes heating) are critical to maintain batteries in the optimal temperature range.

Mechanical Vibrations and Shocks

- Vessels experience constant vibrations from engines, waves, and maneuvers, plus occasional shocks from rough seas or docking.
- Batteries and electronic systems must be ruggedized to withstand vibration without loosening connections or damaging cells.
- Shock-absorbing mounts and vibration isolators are often used.

Pressure and Altitude Effects

- Submersible or underwater vehicles face high water pressure that can compress battery enclosures, requiring specialized pressure-resistant designs.
- Surface vessels generally don't face extreme pressure but structural integrity is still important for safety.

2.3 Electrical propulsion and hybrid power architectures

Energy Density and Range Requirements

Why Energy Density Matters for Vessels

- Marine vessels often require large amounts of energy to power propulsion, onboard systems, and auxiliary loads over extended periods or distances.
- Batteries with **low energy density** need to be very large and heavy to provide sufficient range, which can be impractical due to space constraints and impact on vessel stability.
- Higher energy density batteries allow for longer operating ranges without excessive size or weight penalties.

Range Requirements

- **Range** is the distance or operational time a vessel can travel or operate on battery power alone before needing recharge.
- Commercial vessels, ferries, and cargo ships may require longer ranges (tens to hundreds of nautical miles), increasing battery capacity needs.
- Short-range vessels like harbor ferries or recreational boats can operate with smaller batteries and shorter charge cycles.

Challenges in Meeting Range Needs

- Current lithium-ion battery technologies, while improving, still have lower energy density compared to fossil fuels (diesel, heavy fuel oil), meaning batteries must be large and heavy to match the same range.
- The trade-off between battery size/weight and vessel payload or passenger capacity is a critical design consideration.
- For long-distance or heavy-duty vessels, battery-only propulsion might be impractical without frequent recharging or hybridization.



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3.1 Structure of control system

Distributed Architecture (Most Common):

Slave Modules / Cell Monitoring Units (CMUs):

- Small, ruggedized electronic boards attached directly to individual battery modules or groups of cells. These are typically flat, rectangular PCBs housed in protective plastic or metal casings, conforming to the shape of the battery module they monitor.

Master Controller / Central BMS Unit:

- A larger, ruggedized industrial enclosure (often a rectangular box or 19-inch rack-mountable unit) located in a protected electrical room or control panel. This houses the main processing power, communication interfaces, and safety logic.

Gateway/Communication Modules:

- Smaller boxes or modules facilitating communication between the BMS and other ship systems (propulsion control, energy management, monitoring).

Contactor/Relay Control Units:

- Enclosures (often smaller boxes) housing the high-voltage contactors/relays controlled by the BMS for connecting/disconnecting the battery pack. These are physically separate for safety and isolation.

Centralized Architecture (Less Common for Large Ships):

3.2 Key characteristics

Key Physical Characteristics & Influences:

Modularity: Shapes are designed for easy integration within battery racks/packs or standard marine electrical panels.

Cooling: Shapes often incorporate fins or mounting points for **passive cooling**. Larger central units may have provisions for **forced air cooling** (fans) or connections to **liquid cooling** systems, influencing vent shapes or fluid ports.

Safety & Isolation: High-voltage components (contactors, shunts) are physically separated from low-voltage control electronics within their enclosures. Clear labeling and safety barriers are common.

Scalability: For large ships, the "shape" is effectively the sum of many distributed units spread throughout the battery rooms/packs, connected via robust cabling in conduit.

Cabling: Extensive, robust, shielded cabling (often in conduit) connects all distributed components. This cabling "network" is a significant physical aspect of the overall system.



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Conclusions

- Electrification presents a promising solution to combat climate change.
- However, environmental concerns and space constraints pose significant challenges to the electrification of vessels.
- FLEXSHIP aims to prove the applicability of battery system as a way for electrification.
- Battery manage system structure need to be designed for real time operation.

Thanks for your attention!