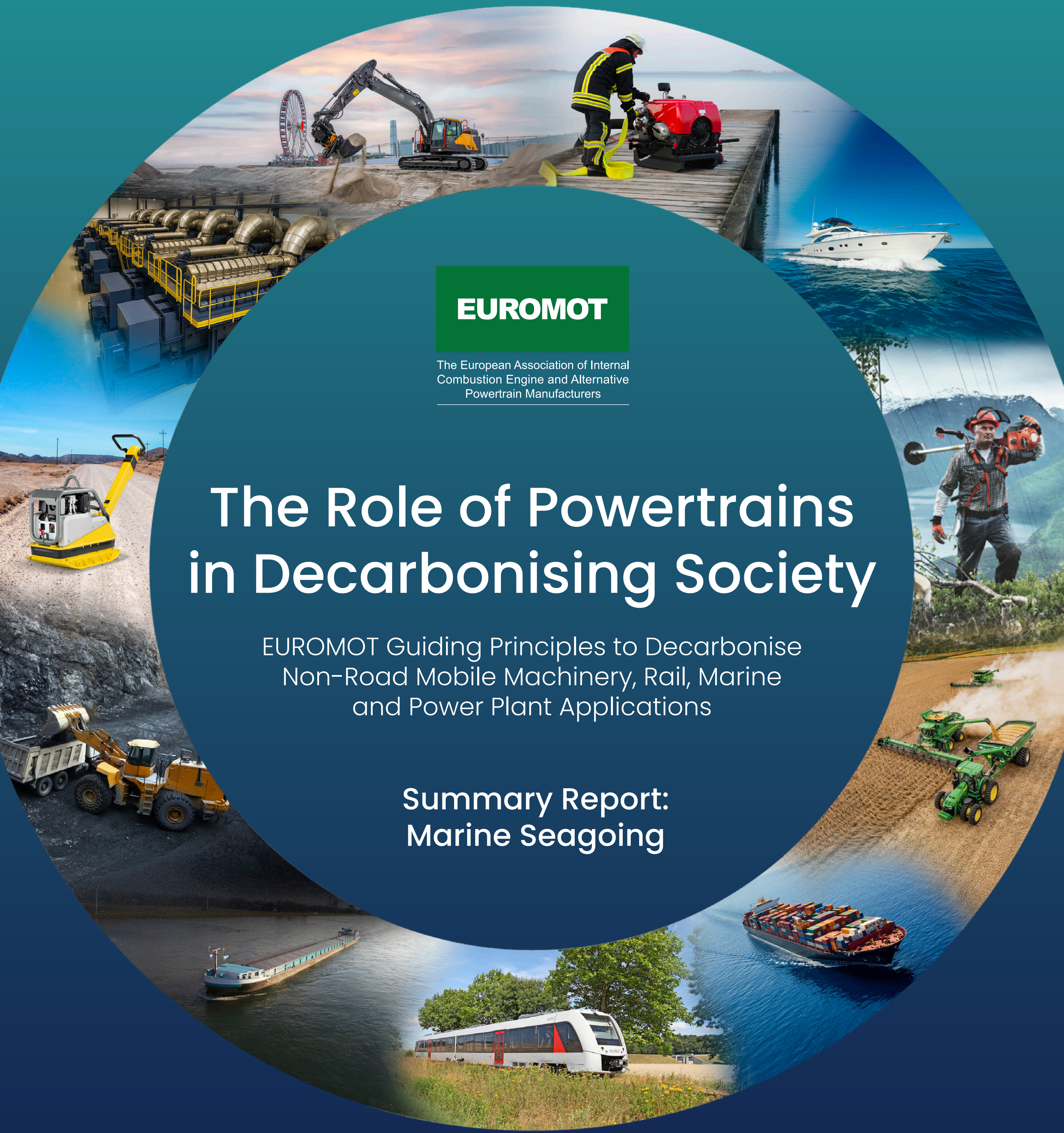

EUROMOT

The European Association of Internal Combustion Engine and Alternative Powertrain Manufacturers

The Role of Powertrains in Decarbonising Society

EUROMOT Guiding Principles to Decarbonise Non-Road Mobile Machinery, Rail, Marine and Power Plant Applications

Summary Report: Marine Seagoing

March 2026

The Role of Powertrains in Decarbonising Society

EUROMOT Guiding Principles to Decarbonise Marine Seagoing

This document is one of a portfolio of decarbonisation reports produced by EUROMOT, which are:

1. EUROMOT Guiding Principles
2. Executive Summary
3. Full Report
4. Sector-specific Summary Reports:
   - Non-road Mobile Machinery
   - Forestry, Lawn and Utility Machines
   - Marine Inland Waterways Transport
   - Marine Seagoing
   - Marine Recreational Craft
   - Rail Transport
   - Stationary Power Plants

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About EUROMOT

EUROMOT, the European Association of Internal Combustion Engine and Alternative Powertrain Manufacturers, represents the key manufacturers of internal combustion engines and alternative powertrains installed in Construction, Agriculture and Industrial; Forestry, Lawn and Utility; Marine; Rail; and Stationary power plant applications that are operating in Europe and globally.

Founded in 1991, we provide a recognised hub of expertise for businesses, authorities, regulators, and public stakeholders worldwide. In partnership with major sector associations and institutions, it is our mission to advocate better regulation, and to foster innovation that supports our sustainability and industry objectives.

Delivering reliable power for society at high energy conversion efficiency with low emissions remains a key objective of EUROMOT member companies. EUROMOT asserts internal combustion engines and alternative powertrains are a key enabler to address decarbonisation across multiple industry sectors. This can be achieved by continuing to advance the development of flexible highly efficient energy conversion systems capable of operating on various low and net zero greenhouse gas emissions energy carriers.

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EUROMOT Guiding Principles to Decarbonise Marine Seagoing

Marine seagoing is an international activity with vessels travelling across the world's oceans. World trade involves the shipment of large quantities of goods between continents using large ocean going vessels. The sector also includes smaller seagoing ships carrying goods shorter distances, ferries, auxiliary and work boats.

Core Principles:

Technology neutrality:

- Facilitate a diversified energy mix and do not be tempted to force a single technology.
- Base overall GHG reduction objectives in each industry sector on Life Cycle Analysis (LCA) considering different end uses and do not focus solely on emissions at point of use.

Predictable global approach:

- Align activities and levels of ambition at international level recognising internal combustion engines, alternative powertrains and the applications in which they are installed are developed for global markets.

Recognition of the needs of end users:

- Ensure the continued ability to deliver dependable power to perform the intended task wherever it is needed.
- Ensure the availability of new low or net zero greenhouse gas (GHG) energy carriers at competitive costs.
- Facilitate the availability and use of low and net zero GHG energy carriers suitable for existing in-use products.

Key Factors that Determine Decarbonisation Pathways

Decarbonisation solutions for large ocean going vessels have to accommodate the very high energy use and extended times at sea. Refuelling only occurs at the departing and destination ports.

Ferries, auxiliary craft and workboats may have more options depending on routes and work tasks.

Output of propulsion units ranges from **<1 MW to >50 MW**

Running times can vary from **short periods to long**, including **running continuously** for up to weeks at a time

The largest motor vessels can **consume** over **1 GWh** per day

Operating environments are oceans, seas and large harbours.

Fuel/energy is nearly always delivered to ships in harbours, or off-shore moorings.

As many vessels have long lifes it is important that their carbon emissions can be reduced; either by using drop-in low carbon and renewable fuels, or by upgrading the engines to run on other low carbon or renewable fuels.

Alternative propulsion systems must be of a **size and weight** that enables vessels to perform the tasks for which they are intended.

Evaluation of these low emissions technologies also needs to factor in other key criteria including:

Cost-competitiveness to drive maximum market penetration and ensure mechanised industry products remain **internationally competitive**

Availability of the required energy carrier **production, distribution, and storage** networks across all operating environments

Powertrain Technologies

The powertrain technologies, that are available to support decarbonisation and their attributes, are shown here.

Internal combustion engines

Efficiency

Highly operationally efficient as the most compact powertrain technology with readily available, energy-dense fuel sources and fast refuelling times.

Up to 55% energy conversion efficiency.

Emissions

Potential for decarbonisation when using reduced carbon, low carbon, and renewable fuels (including non carbon fuels such as hydrogen and ammonia). Lower embedded GHG emissions* than fuel cells or electric powertrain technologies.

Technological maturity

Proven technology across all industrial applications and use cases.

Security, cost, and availability

Secure, domestic supply chains and readily available material sources except some precious materials used in aftertreatment.

The technologies may be combined to improve system attributes - Hybrids

*"Embedded GHG emissions" refer to the greenhouse gas emissions associated with the production, transportation, and disposal of a product or material, but not necessarily emitted during its use.

Hydrogen fuel cells with batteries and electric motors

Efficiency

Similar refuelling times to ICEs but hydrogen tanks need 4-8x onboard storage space of diesel tanks. Can achieve up to 60% energy conversion efficiency for some applications (efficiencies may reduce with use).

Emissions

Zero air quality or GHG emissions at the point of use. Moderate embedded GHG emissions, usually higher than ICEs and lower than battery electric.

Technological maturity

Technology already in use in non-road applications including cars and forklift trucks, but unproven in heavy duty marine applications..

Security, cost, and availability

Supply chain costs and risks around some components. Fuel cell systems for dynamic applications require a hybrid configuration with batteries.

Electric Motors - Continuous electric supply or with battery storage

Efficiency

The highest energy conversion efficiency technology giving **75-90% efficiency.**

The overall operational efficiency can be reduced by downtime due to charging, and the extra storage space needed for large onboard batteries.

Emissions

Zero GHG emissions at the point of use. Usually higher embedded GHG emissions than ICEs or fuel cells.

Technological maturity

Proven technology across some industrial applications.

Security, cost, and availability

Supply chain security risks, high costs and projected shortages for raw materials and components in batteries and motors.

Energy Carriers

Energy carriers are predominantly fuels or electricity. Their carbon intensity depends on their provenance.

Fuels

Fossil fuels

Derived from ancient organic matter, fossil fuels like coal, oil, and natural gas are burned for energy. Their combustion releases greenhouse gases, contributing to global warming. Unlike renewable fuels, fossil fuels are finite and environmentally impactful.

Reduced carbon fuels

Fuels where the carbon footprint (CF) is lower than the fossil fuels they replace, for example natural gas replacing diesel/fuel oil; B20 biodiesel; E50 gasoline.

Low carbon fuels

Fuels where the CF is >70% lower than their fossil equivalent.

Non carbon fuels

Fuels that do not contain carbon such as hydrogen and ammonia (not necessarily renewable).

Renewable fuels

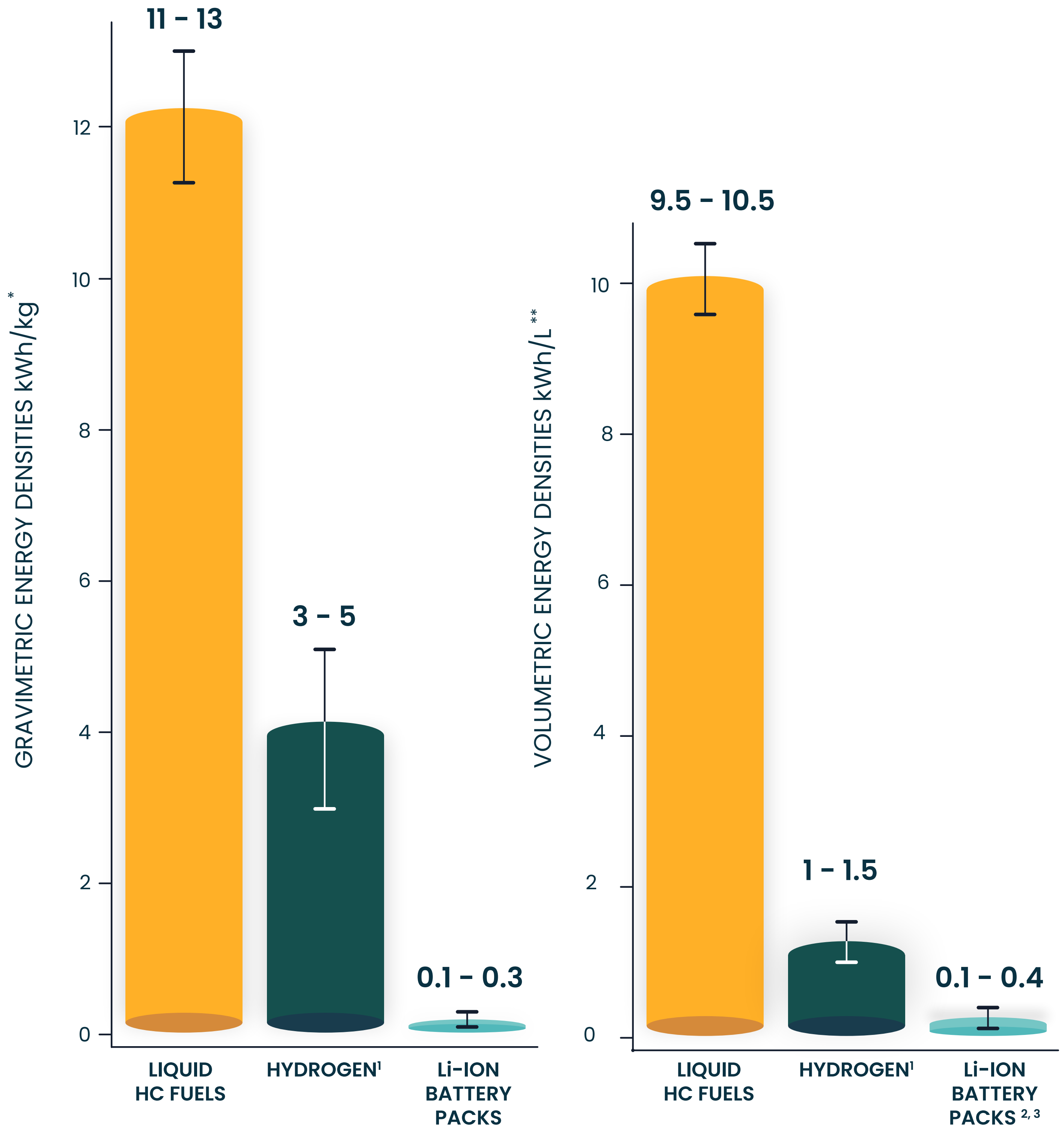
Fuels of biological or non-biological origin where the stored energy comes from renewable sources; either solar energy via photosynthesis or from renewable electricity. The EU Renewable Energy Directives (REDs) require the Carbon Footprint (CF) of renewable fuels to be >70% lower than their fossil equivalent.

Electricity

Generated from

- Fossil Fuels: coal, oil
- Natural Gas (RCF)
- Low cabon fuels
- Renewable fuels
- Non carbon fuels
- Renewable energy: solar, wind, hydro

Comparing energy densities for compressed hydrogen, liquid hydrocarbon (HC) fuels and lithium-ion (li-ion) batteries.



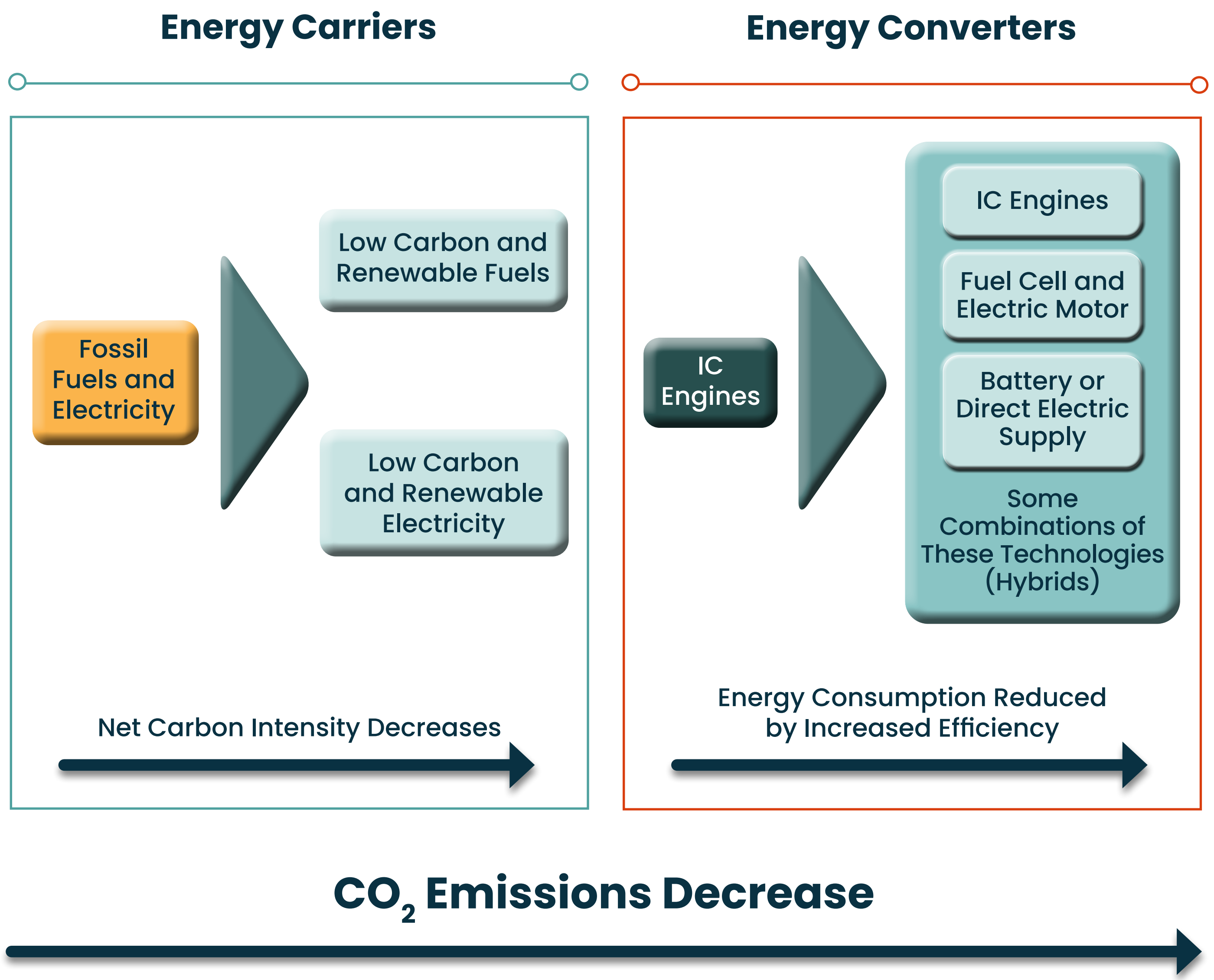
*Energy carriers with lower gravimetric energy density are heavier, which affects their feasibility for applications where weight is at a premium.

**Energy carriers with lower volumetric energy density need more onboard storage space, affecting their use in applications where space is at a premium.

[1]Compressed to 700 bar including the tank.
[2]STIHL. (2023). AP 300 S Battery.
[3]Husqvarna. (2025). Akku B330X.

Decarbonisation Journey

How sector decarbonisation will result by combining efficient energy converters with an increasing panel of low carbon and renewable energy.



Use Case Examples

The following section presents a selection of examples that demonstrate the fundamental principles of decarbonisation.

These examples are not exhaustive, and do not represent the only pathways to decarbonisation for each type of machine.

Each of these machines may require different powertrain technologies offering pathways to decarbonisation for different use cases.

The energy consumption numbers in the following examples include the efficiency of the ICE, i.e. they are comparable to the output of the electric motor of electric machines.

Important Criteria for Assessing Decarbonisation Pathways

Key Criteria*	Use Case Evaluation		
Energy use	Low	Is a large amount of energy used for the example task?	High
Work intensity	Low	Is the average power the machine is working at a high percentage of its maximum output power?	High
Type of use	Sporadic	Is the machine running for a high proportion of the task duration, or for a small portion?	Continuous
Availability of electricity on site	Available	Is electricity at a usable voltage and power available at the site of use of the machine?	Not available
Predictability of deployment	Pre-planned	Can the task be planned well in advance, or is it required to act urgently depending on circumstances?	Un-planned
Location of site	Adjacent to infrastructure	Is the machine being used in an area with infrastructure and service availability or any area without these?	Remote from infrastructure
Time on site	Extended	Is the time a machine is on site short i.e. days or weeks, or long i.e. months or years?	Short
Required machine mobility	Low	Does the machine used for the task move around the site (>100 m) or does it stay in one position?	High
Minimise refuelling/ recharging	Infrequent	Is it important to complete task without significant downtime for refuelling/recharging	Fast

*Terms used to explain the use case evaluations found in the following examples.

Marine Seagoing

Example 1: Transport of Large Quantities of Containers from East Asia to Europe

Use description:

The shipment of large quantities of containers from East Asia to Europe at lowest cost. Nonstop inter-continental travel (around 30 days). The largest vessels can carry 24,000 TEUs (20 ft container equivalents).

Vessel employed:

235,000 tonne container ship with a **58.6 MW** single-fuel Internal Combustion Engine (ICE), that consumes around **220 tonnes** of fuel oil daily and can store **10,000 tonnes** of fuel oil. This has an energy content of around **60 GWh** at the propeller shaft (**157 g/kWh**).[16]

Decarbonisation pathways:

High efficiency ICE using low carbon drop-in fuels such as biofuel or renewable fuels such as ammonia or methanol. Large bulk carriers and tankers have similar use cases and decarbonisation pathways.

[16]Maersk (2025) Vessel Particulars. ShipmentLink.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of voyage	Stop-start	Continuous
Predictability of voyage	Pre-planned	Un-planned
Remoteness	Lake or river	Open seas
Voyage duration	Low	High

Marine Seagoing

Example 2: Ammonia Tanker

Use description:

Ships carrying ammonia, e.g. as renewable energy carrier, for intercontinental transport.

Vessel employed:

The capacity of this ships can be over **90,000 m³** of liquid ammonia. These ships can use ICEs utilising their ammonia cargo as fuel. Image is of NoGAPS concept tanker.

Decarbonisation pathways:

Progressively decarbonise the ammonia fuel, moving to renewable ammonia. These ships could carry renewable energy with ammonia as an energy carrier and would use ICEs utilising their ammonia cargo as fuel.

Picture: 3D rendering

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of voyage	Stop-start	Continuous
Predictability of voyage	Pre-planned	Un-planned
Remoteness	Lake or river	Open seas
Voyage duration	Low	High

Marine Seagoing

Example 3: Transporting Timber from Sweden to UK

Use description:

Shipping bulk timber around 1,200 km from Sweden to UK. Non-stop journey of 2 days.

Vessel employed:

4,000 tonne general cargo vessel with a **1 MW** diesel engine. The vessel uses **20 MWh** of energy per day (4 tonnes of fuel oil).

Decarbonisation pathways:

Low carbon and renewable fuels used in ICEs. Other bulk carriers have similar use cases and decarbonisation pathways.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of voyage	Stop-start	Continuous
Predictability of voyage	Pre-planned	Un-planned
Remoteness	Lake or river	Open seas
Voyage duration	Low	High

Marine Seagoing

Example 4: Harbour Ferry Travelling a Fixed Route

Use description:

Harbour ferry travelling a fixed route of 2 km. Travels back and forth, unloading and loading at each quay. Consumes circa 20 kWh of energy per journey. Another similar use is crossing rivers and lakes.

Vessel employed:

Harbour ferry travelling a fixed route of 2 km. Travels back and forth, unloading and loading at each quay. Consumes circa 20 kWh of energy per journey. Another similar use is crossing rivers and lakes.

Decarbonisation pathways:

Battery and electric motor with charging whilst loading/unloading; retain ICE using drop-in low carbon fuels; ICE using renewable fuel.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of voyage	Stop-start	Continuous
Predictability of voyage	Pre-planned	Un-planned
Remoteness	Lake or river	Open seas
Voyage duration	Low	High

Marine Seagoing

Example 5: Tugboat

Use description:

Manoeuvring larger vessels in harbour and on open seas.

Vessel employed:

35 m, **300 tonne** hybrid diesel-electric tugboat. It uses electric-only propulsion in harbour, and diesel generators for open seas duties. The ship has two **1,000 kW** electric propulsion motors and a **2.5 MWh** battery, alongside two **1 MW** diesel engine generators. Energy consumption is typically around **10 MWh** a day for higher speed high load work at sea, or **2-4 MWh** per day in harbour.

Decarbonisation pathways:

The battery can be recharged whilst moored using renewable electricity. The diesel engine can use low carbon fuel moving to renewable fuel.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of voyage	Stop-start	Continuous
Predictability of voyage	Pre-planned	Un-planned
Remoteness	Lake or river	Open seas
Voyage duration	Low	High

Conclusion

Successful decarbonisation of the marine seagoing sector will require a broad, balanced technology-neutral approach to accommodate a diverse array of vessels, applications, and patterns of use.

Alternative solutions must be available at a large scale and future-proof to stay aligned with evolving international maritime frameworks such as the IMO, while ensuring continued cost-competitiveness and compatibility with the global maritime industry. Policy support will be key to accelerate development and distribution of sustainable marine fuels and establish domestic supply chains and bunkering facilities for renewable fuels.

The technology is ready, but deployment relies upon the availability of low carbon and renewable fuels at bunkering sites.

Recommendations

Manufacturers are developing powertrains that support decarbonisation of all the sectors in which they are used. For successful deployment of these technologies, policy and regulation need to be technology neutral, recognising the need for the full array of decarbonisation pathways, and assessing them on life cycle basis (LCA method).

Policy also needs to enable and support the supply of low carbon and renewable fuels; in particular ammonia, methanol and hydrogen. Policy also needs to support the production of drop-in fuels for use in existing ships.

Appendix: Definitions

Life Cycle Analysis (LCA) is a method of calculating the total CO_2e emissions from a product, including other emissions such as nitrous oxide (N_2O) and methane (CH_4), during its full lifecycle. That is throughout manufacture, use and disposal.

Well to Wheel, (or Well to Wake for marine) (WtW), or Well to X (WtX) emissions is the total (net) emissions generated when a fuel or energy carrier is created (such as when it is extracted from the ground or grown as a biological feedstock), when its energy has been converted in a machine and its end products emitted (e.g. CO_2 and water from burning a hydrocarbon fuel).

GHG Emissions CO_2 is the predominant Greenhouse Gas for this sector, but this also encompasses other GHGs such as nitrous oxide and methane, normally defined as CO_2 equivalent (CO_2e) when using the GWP100 definition (the global warming potential of a specific greenhouse gas over 100 years).

Energy Carriers are fuels and electricity (including batteries) containing stored energy that can be converted to other forms of energy which can then be used to power machines and power plants.

Energy Converters are the devices that convert energy from stored chemical energy (fuels) or electricity to mechanical energy – generally engines or motors (such as internal combustion engines, electric motors, hydrogen fuel cells combined with electric motors, hydraulic pneumatic motors, and hybrid systems).

Conversion Efficiency is the energy out of a converter divided by the energy input. For example, the mechanical energy at the flywheel, divided by the stored energy available in the fuel used.

Operational Efficiency is a measure of the work a powertrain application can do compared to a theoretical maximum or to the incumbent powertrain's performance. For example, operational efficiency is reduced if a proposed powertrain reduces the payload of a goods carrying vehicle, or if the use time available is reduced by increased refuelling times.

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