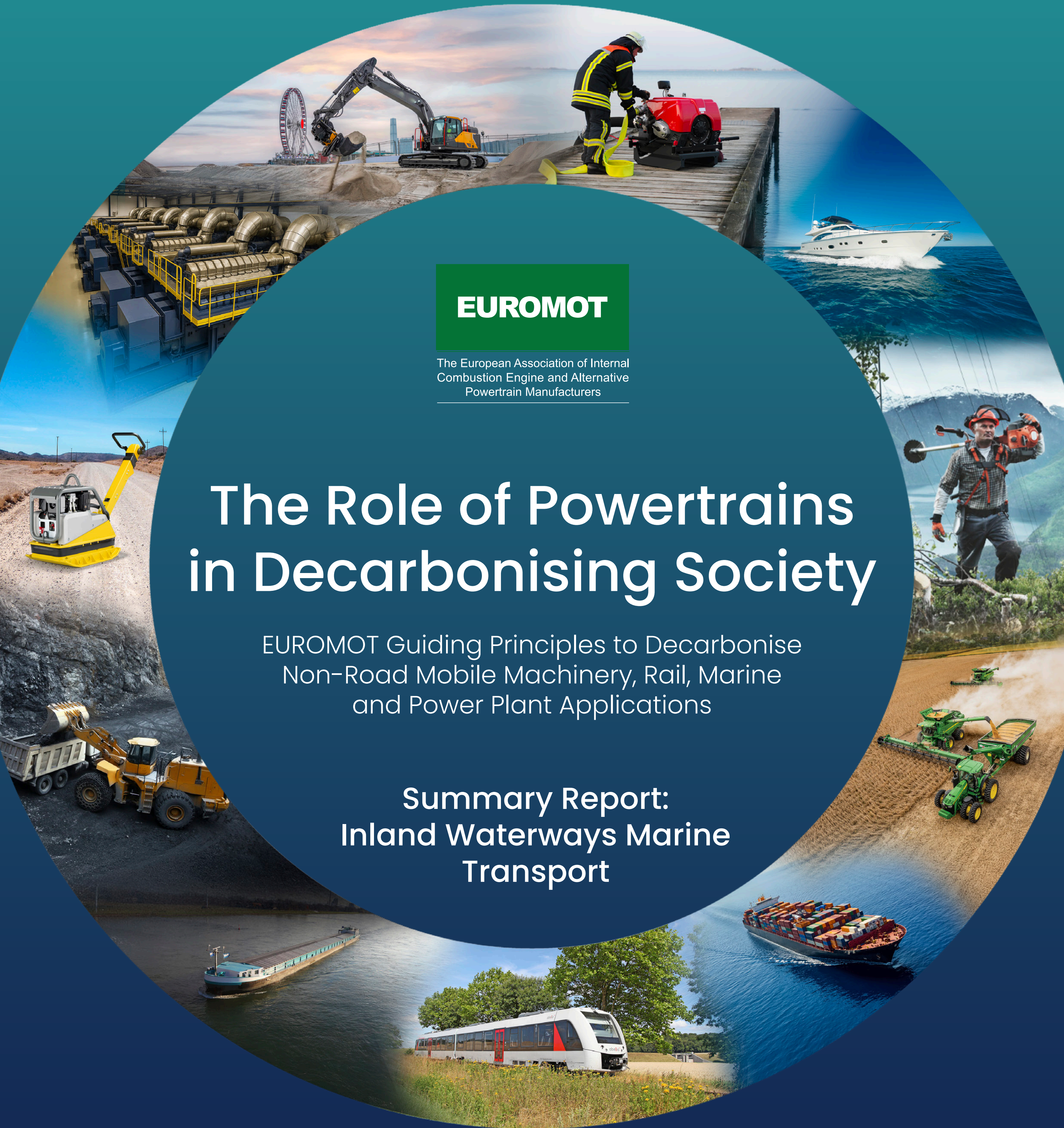

EUROMOT

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: Inland Waterways Marine Transport

March 2026

The Role of Powertrains in Decarbonising Society

EUROMOT Guiding Principles to Decarbonise Inland Waterways Transport

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 Inland Waterways Marine Transport

The Inland Waterways sector covers commercial transport on Europe's rivers, canals and lakes. Large ships carry general, bulk and container cargoes on the main rivers with smaller vessels using the tributaries and canals with specific cargoes.

Core Principles:

Technology neutrality:

- Facilitate a diversified energy mix with overall greenhouse gas (GHG) reduction objectives based on Life Cycle Analysis (LCA) rather than focusing 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 low carbon and renewable energy carriers at a competitive cost.
- 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 inland waterways vessels must accommodate a diverse range of sailing environments, energy needs, and journey types. These range from small passenger ferries to large cargo vessels.

They operate on waterways in urban and industrial areas to those in remote rural regions. Journeys can be short or lasting several days, with fuel or energy being taken to the vessels at bunkering sites.

Additionally, speed of deployment is an important consideration. Many vessels have a long life and hence the availability of drop-in low carbon and renewable fuels is needed.

Output of powertrain units ranges from **<100 kW to 10 MW**

Running times can vary from **short periods to long**, including **running continuously** several days

The largest powertrains can **consume** 50 MWh of energy **a day**

Waterways vary from large **arterial rivers** like the Rhine to **small tributaries and canals**

The availability of a **range of powertrain capabilities** using diverse energy carriers **ensures strategic independence** in times of fuel supply shortages

Vessels are refuelled at the waterway wharf at specific bunkering sites.

Alternative powertrains must be of a **size and weight** that enables industrial machines and power plants **to perform** the tasks for which they are intended.

Decarbonisation pathways must also consider the many cases where electrification is not viable such as remote, energy-intensive applications with round-the-clock operations.

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

Facilitate adoption to ensure widespread use.

Availability of **secure supply chains** and material sources such as precious and rare-earth metals, and the **technical feasibility and technological maturity** of the powertrains

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. Medium manufacturing phase GHG emissions.

Technological maturity

Technology already in use in non-road applications including cars and forklift trucks, but unproven in non-road industrial sectors such as construction.

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. Medium manufacturing phase GHG emissions.

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 intensitiy 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.

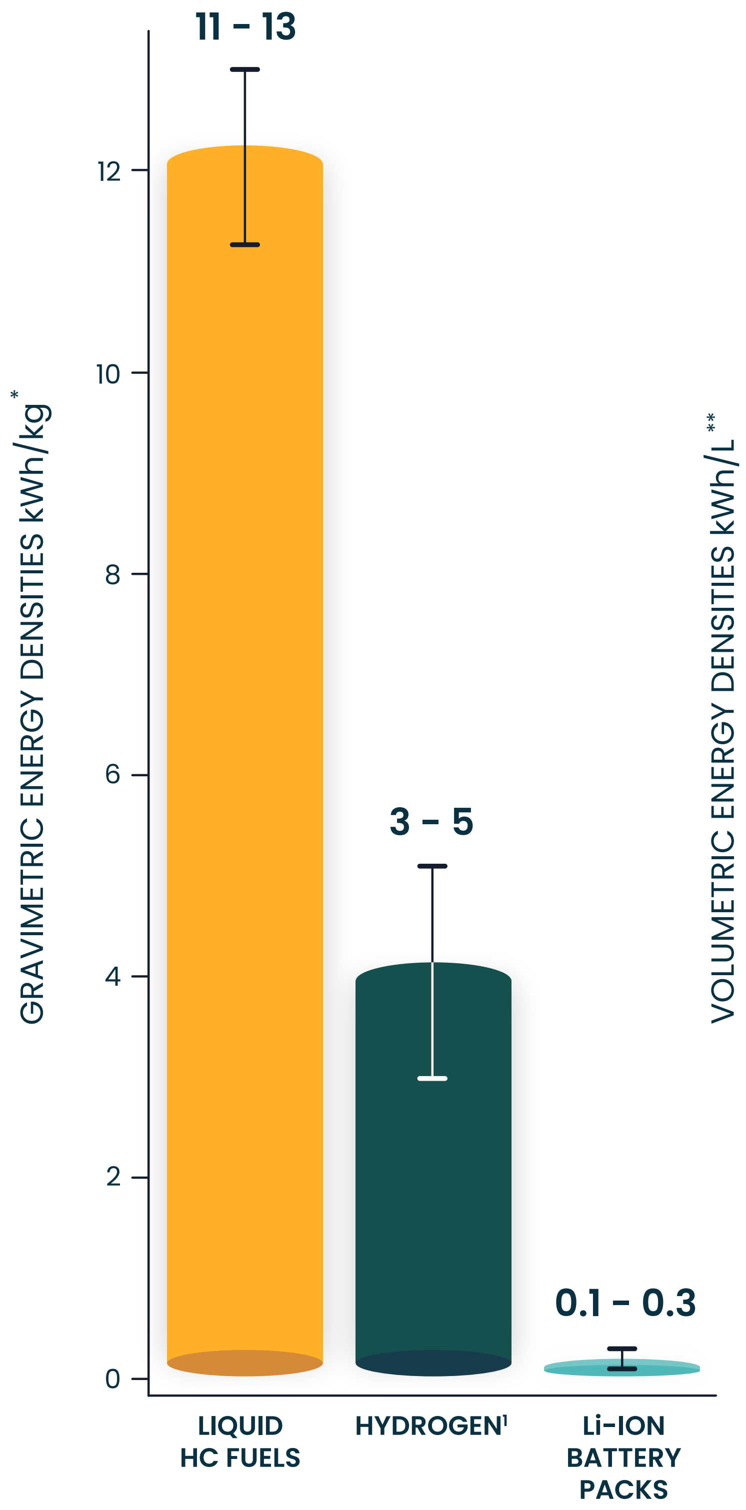
Electricity

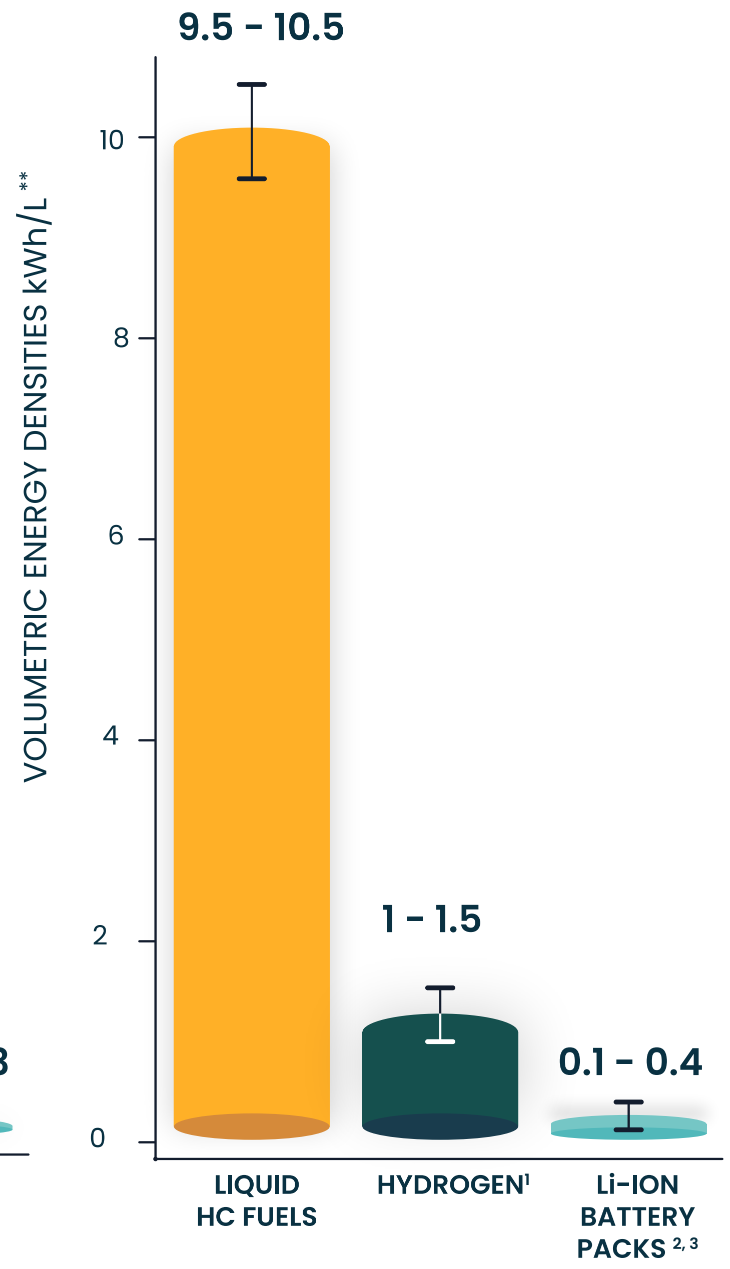
Generated from

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

Mobile machines and plant have to carry sufficient energy on board to complete their tasks. Energy is then brought to the machine at its place of use.

Energy density is therefore a critical factor in determining the feasibility of it's use for a particular application and use case.





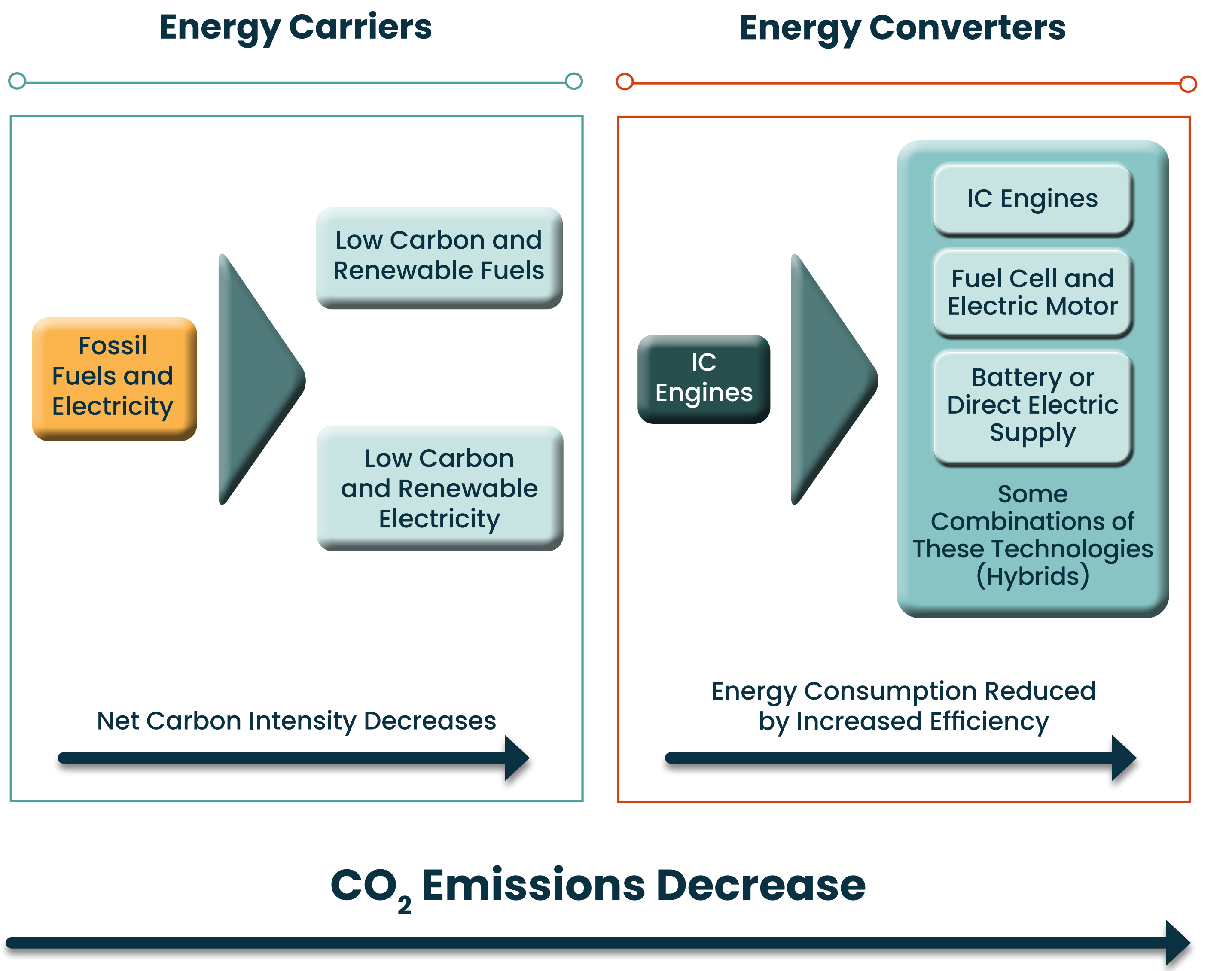
*Energy carriers with lower gravimetric energy density are heavier, which affects their feasibility for applications where weight is at a premium.

**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 Inlands Waterway Transport

Example 1: Transport of Miscellaneous Cargos on Varied Routes at Short Notice

Use description:

Operators of general cargo vessels travel major river routes to a variety of destinations on short notice contracts making miscellaneous on-demand cargo deliveries.

Vessel employed:

Shallow draft **5,000-20,000 tonne** general cargo vessel. Powered by diesel engines of **1-10 MW** and using between **1-10 tonnes** of fuel a day (equivalent to **5-50 MWh**.)

Decarbonisation pathways:

Drop-in low carbon fuels (such as HVO) moving to renewable liquid fuels.

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 Inlands Waterway Transport

Example 2: Shipment of 20 Containers Daily on Fixed Route

Use description:

Daily shipment of containerised materials on a fixed 60 km route

Vessel employed:

90 metre container ship with a capacity of **24 containers**. Powered by electric motors (**760 kW**) with **2 MWh** containerised and swappable battery packs.

Decarbonisation pathways:

Battery packs are recharged using renewable electricity.

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 Inlands Waterway Transport

Example 3: River Ferry Travelling a Fixed Route Back and Forth

Use description:

River ferry travelling a fixed route back and forth, unloading and loading at each quay. Using around 20 kWh of energy per journey. A similar use case is to cross lakes.

Vessel employed:

Small passenger and vehicle ferry using **100 kW** diesel engine for propulsion.

Decarbonisation pathways:

Battery and electric motor with charging taking place whilst loading or unloading. Retain Internal Combustion Engines (ICEs) using drop-in low carbon fuels and renewable fuels.

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

The technologies to decarbonise inland waterway transport are already available. However, successful adoption will require a transition period and sufficient lead time, for example, to facilitate development of the required enabling infrastructure of bunkering stations for low carbon and renewable fuels. Any decarbonisation pathways need to reflect the sector's specific ownership structure.

The benefits of different energy converters and energy carriers for decarbonisation need to be measured by assessing their respective carbon footprint using a Life Cycle Analysis (LCA) methodology, and this should be included in all policy

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 supply and distribution of renewable electricity and low carbon and renewable fuels. This includes production of drop-in low carbon and net zero fuels for use in existing equipment. This will be critical to balance decarbonisation with the continuing need for dependable power across society.

European Inland Waterway vessels represent a relatively small market for powertrains. Alignment with international direction, policy and standards is therefore important.

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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