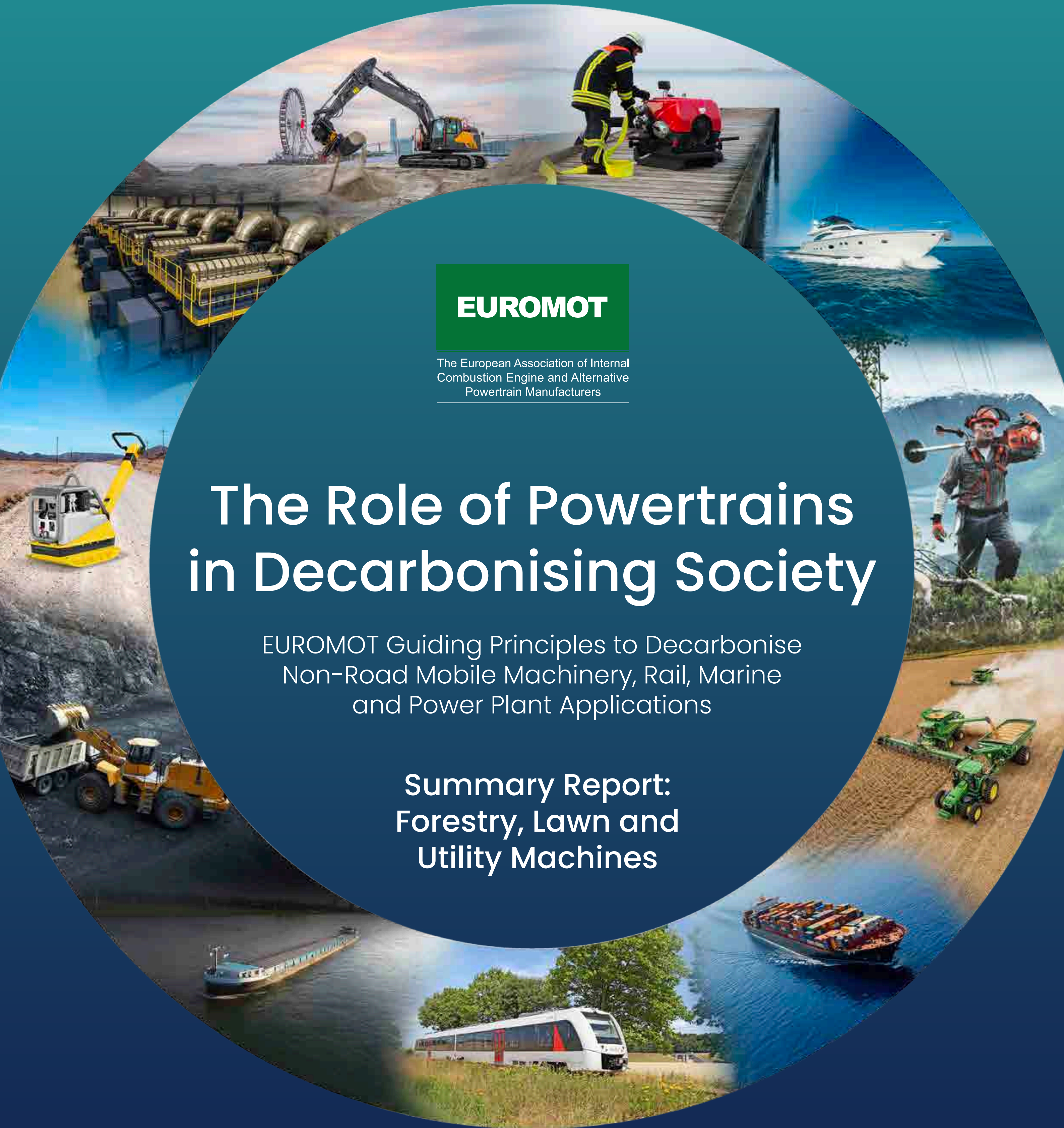

EUROMOT

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: Forestry, Lawn and Utility Machines

March 2026

The Role of Powertrains in Decarbonising Society

EUROMOT Guiding Principles to Decarbonise Forestry, Lawn and Utility Machines

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

Contents

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 Forestry, Lawn and Utility Machines

Forestry, Lawn and Utility machines comprise smaller machines, usually handheld or manually transportable, used in forestry maintenance, lawn and garden care and in a variety of utility roles.

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

This sector spans a diverse mix of machines, applications and uses for maintaining our green spaces and forests, and a multitude of smaller tasks in industry, construction and agriculture. The machines covered in this sector are largely handheld or hand moved.

Forestry includes equipment such as pole pruners, brush cutters and chainsaws for applications such as reforestation and stock maintenance. This includes machines for professional use in remote off-grid forests accessible only by foot where a day's worth of fuel must be carried by hand. The sector also covers machines for personal use running intermittently and used sporadically.

Lawn and Garden machines maintain our natural and green areas; such as lawn mowers, chainsaws, hedge trimmers, and brush cutters. Machines for personal use operate intermittently with lower daily runtimes mostly in urban environments. Professional equipment is operated continuously with moderate runtimes, often in remote locations.

Utility covers a broad mix of small industrial, construction and agricultural machinery predominantly for professional use, from concrete drills, saws and cut off saws to pumps, generators, handheld harvesters and earth augers. These machines need to run continuously, often in harsh conditions, across both populated and remote areas where fuel must be brought to the site.

Output of powertrain units ranges from **<1 kW to 35 kW**

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

Depending on the application up to **250 kWh** per day are needed

For hand-held equipment a low machine weight and ergonomic design, including the energy storage unit, is crucial for safe and efficacious operation

Operating environments range from urban to remote locations such as islands, oceans and forests

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.

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

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

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.

Emissions

Potential for decarbonisation when using reduced carbon, low carbon, and renewable fuels.

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.

Electric Motors - Continuous electric supply or with battery storage

Efficiency

The highest energy conversion efficiency technology.

The overall operational efficiency can be reduced by downtime due to charging, battery handling, and storage.

Emissions

Zero GHG emissions in use.

Technological maturity

Proven technology across some industrial applications. Above all, the energy density of the battery cells is a limiting factor for the application of electric drives in this segment.

Security, cost, and availability

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

The technologies may be combined to improve system attributes - Hybrids

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.

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.

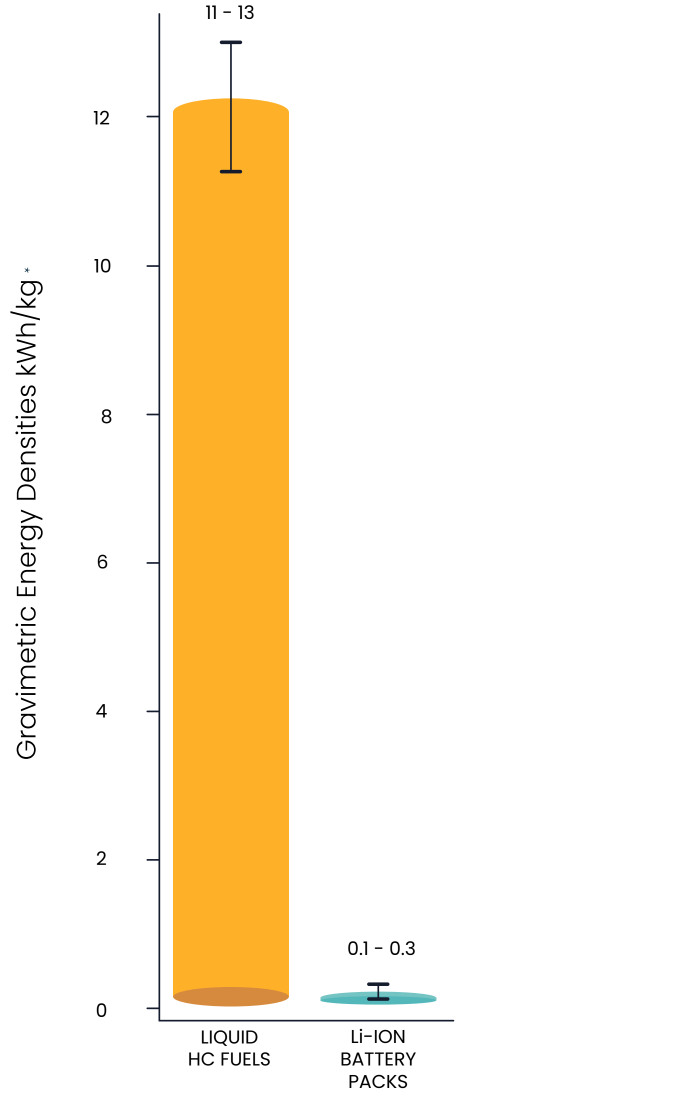
Electricity

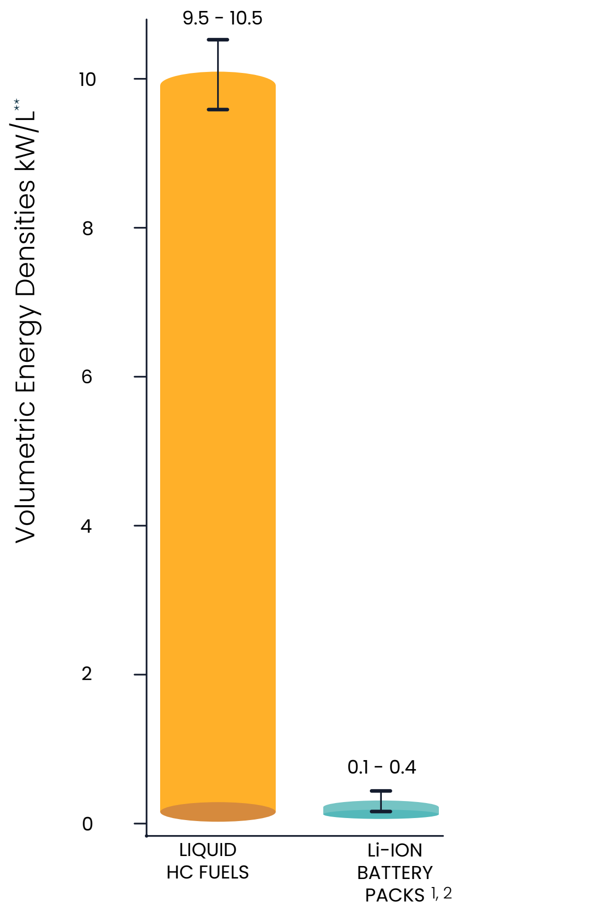
Generated from

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

Sufficient energy must be transported to the construction site for mobile machines. Depending on the work schedule, a construction crew has to work on construction sites at different locations in one day. The energy is always supplied to the machine at its place of use. Energy density is therefore a critical factor in determining the feasibility of use for a particular application and use case.

Comparing energy densities for compressed hydrogen and lithium-ion (li-ion) batteries.





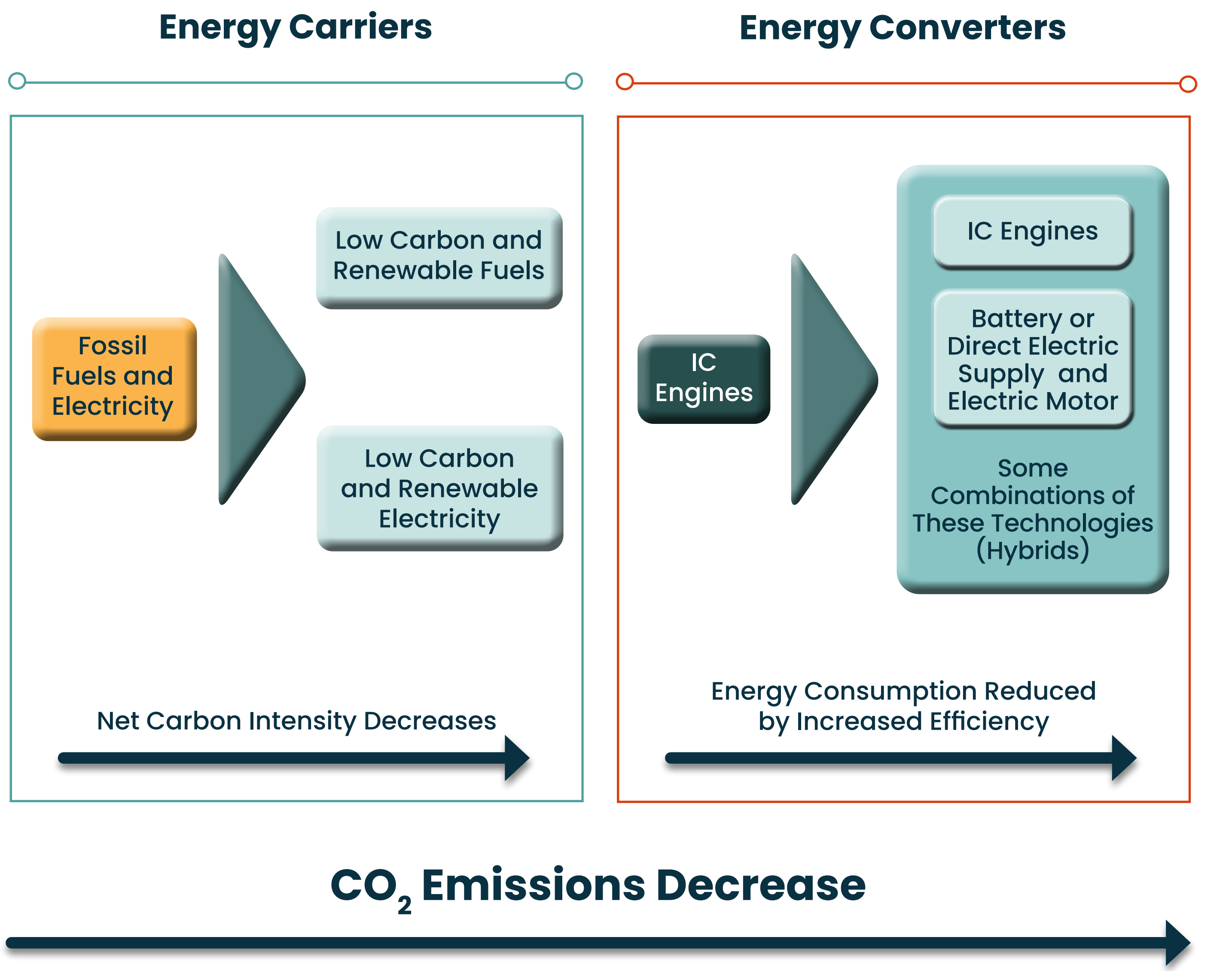
*Energy carriers with lower gravimetric energy density are heavier, which affects their feasibility for applications where weight is at a premium.

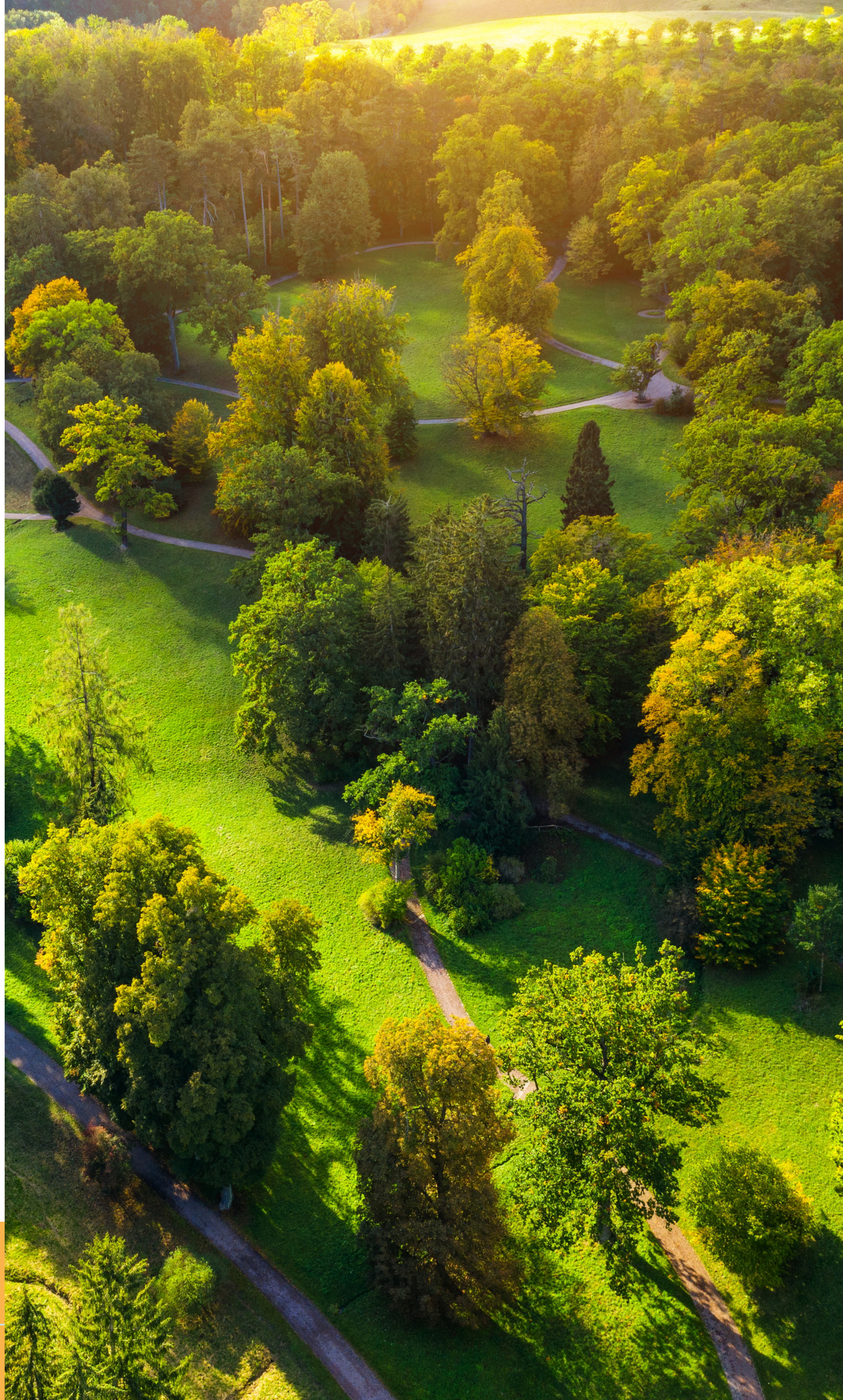
**Energy carriers with lower volumetric energy density need more onboard storage space, affecting their use in applications where space is at a premium.

[1]STIHL. (2023). AP 300 S Battery.
[2]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.

Forestry

Example 1: Silvicultural measures to prevent forest fires

Use description:

Creating fire breaks and protective strips in the forest to prevent forest fires from spreading. Predominantly used in remote woodland locations far from electric grid infrastructure. These machines are operated intermittently at medium-and high-intensity throughout the working day. Fuel must be carried to the worksite.

Machines employed:

Clearing saws and brush cutters with petrol engines of **2-3 kW**. Typical fuel consumption of **5-10 L** per day (equivalent to a battery capacity of **10-20 kWh**.)

Decarbonisation pathways:

ICEs running on low carbon fuels, moving to renewable liquid fuels.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Forestry

Example 2: Sequential timber harvesting

Use description:

Medium-and heavy-duty timber harvesting usually in remote forests where fuel must be carried to the site by hand. Machines are used continuously for the full working day.

Machine employed:

Larger handheld chainsaws with petrol engines of **3 kW to 6 kW**. Typical fuel consumption of **10-20 L** per day (equivalent to a battery capacity of **20-40 kWh**).

Decarbonisation pathways:

ICEs running on low carbon, moving to renewable, liquid fuels.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Forestry

Example 3: Professional tree and young stock maintenance in forestry

Use description:

Newly planted and younger trees are pruned in managed forests. Machines are used at light-to mid-range intensities, in short durations throughout the working day. This is usually in remote forests and fuel is carried to the forest with the tools.

Machine employed:

Pole pruner with **1-2 kW** petrol engine. Fuel consumption is typically **1-2.5 L** per day (equivalent to a battery capacity of **2-5 kWh**).

Decarbonisation pathways:

Battery electric is viable if charging infrastructure is next to working place. ICEs running on liquid low carbon fuels, moving to renewable fuels are needed for higher intensity use over longer durations or in locations without charging infrastructure.

Evaluation Criteria	Use Case Evaluation		
Energy use	Low		High
Work intensity	Low		High
Type of use	Sporadic		Continuous
Availability of electricity on site	Available		Not available
Predictability of deployment	Pre-planned		Un-planned
Location of site	Adjacent to infrastructure		Remote from infrastructure
Time on site	Extended		Short
Required refuelling /recharging	Low		High

Forestry

Example 4: Power lines clearing, maintenance of roads and railways in forestry

Use description:

For clearing young trees beneath power lines and clearing vegetation around roads and railways for maintenance. Machines are used for short periods or continuously in medium-and heavy-duty operations, often in remote locations. Fuel is taken to the work site to last for a whole day's work.

Machines employed:

Brush cutters, clearing saws and strimmers with **2-3 kW** petrol engines. Typical fuel consumption is **4-10 L** (equivalent to a battery capacity of **8-20 kWh**) per day.

Decarbonisation pathways:

ICEs running on low carbon fuels, moving to renewable liquid fuels is the most practical pathway.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Lawn

Example 1: Lawncare in private gardens

Use description:

Grass cutting and other lawncare work in private gardens, in developed or urban locations. They are used in both short and longer spells and for light-and medium-intensity operations.

Machine employed:

Mowers, edge trimmers, trimmers, aerators, scarifiers with **1-2.5 kW** petrol engines. Fuel consumption is typically of **0.2-2 L** per day (equivalent to a battery capacity of **0.4-4 kWh**).

Decarbonisation pathways:

Battery electric solutions can be deployed for shorter low-and medium-duty use in locations where recharging is practical. The speed of the transition to battery electric is mainly affected by economic considerations.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Lawn

Example 2: Lawncare in municipal spaces, sports grounds, parks

Use description:

A variety of lawncare tasks using varying degrees of intensity including heavy-duty tasks, typically for 8 hours a day and often in remote locations.

Machine employed:

Mowers, aerators, scarifiers, rollers with **10-45 kW** engines using petrol or diesel. Fuel consumption is typically **6L-38 L** per day (equivalent to a battery capacity of **12-76 kWh**).

Decarbonisation pathways:

ICEs running on low carbon fuels, moving to renewable fuels for heavier duty and longer duration uses and for uses on remote sites. Battery electric can be used in light-intensity applications where the weight of batteries can be accommodated within machine designs and electricity is available for recharging.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Lawn

Example 3: Professional tree services for private gardens, parks and public places

Use description:

Pruning, reducing and felling of trees in gardens, municipal parks and other public places. Intensity varies from low to high and machines are used from 1-8 hours per day. Locations are often urban and developed but may be remote.

Machines employed:

Chainsaws and trimmers with **1 -2 kW** petrol engines. Fuel consumption is typically **1 L-4 L** per day (equivalent to a battery capacity of **2-8 kWh**).

Decarbonisation pathways:

Battery electric is viable in operating environments with electric infrastructure. ICEs using low carbon fuels, moving to renewable fuels are required in other worksites.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Utility

Example 1: Rail cutting

Use description:

For railway maintenance, sections of rail are replaced when worn or distorted. A rail saw is used. This involves medium- to heavy-duty use for short to intermediate periods, often in remote locations without electric grid or charging infrastructure.

Machine employed:

Cutting saw with **3 kW to 6 kW** petrol engine consuming around **4-10 L** of fuel a day (equivalent to a battery capacity of **8-20 kWh**).

Decarbonisation pathways:

ICEs running on low carbon, moving to renewable liquid fuel is the most practical pathway. Battery electric may be feasible for light-medium duty use for short times (battery capacity being limited by the size and weight of the saw) and where charging infrastructure is available next to the jobsite.

Evaluation Criteria	Use Case Evaluation		
Energy use	Low		High
Work intensity	Low		High
Type of use	Sporadic		Continuous
Availability of electricity on site	Available		Not available
Predictability of deployment	Pre-planned		Un-planned
Location of site	Adjacent to infrastructure		Remote from infrastructure
Time on site	Extended		Short
Required refuelling /recharging	Low		High

Utility

Example 2: Cutting concrete and asphalt

Use description:

Cutting concrete and asphalt paving to separate areas for replacement or repair. Thicker sections require large cutting discs and higher drive power. Medium- and heavy-duty operations over short to moderate durations. They are often used in remote locations with little to no electric grid or charging infrastructure.

Machine employed:

Circular saw/cut-off machines powered by petrol or diesel engine of **3-30 kW**. Fuel consumption is typically **2-30 L** per day (equivalent battery capacity of **4-60 kWh**).

Decarbonisation pathways:

ICEs running on low carbon fuels and then renewable fuels is the most practical decarbonisation pathway. Medium-duty, short term operations may be able to use battery electric systems depending on the availability of nearby charging infrastructure.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Utility

Example 3: Special saws for rescue operations

Use description:

Rapid cutting through metal and other materials to rescue people trapped after accidents such as vehicle crashes. 4-5 kW rescue saws for medium-to heavy-duty use over short periods in emergency scenarios such as train accidents. They are used for emergencies often in off-grid locations.

Machine employed:

Rescue saws with **4-5 kW** engines running on petrol. Fuel consumption is typically **2-3 L** per day (or an equivalent battery capacity of **4-6 kWh**).

Decarbonisation pathways:

Battery electric is viable for short, medium intensity use, but heavy-duty operations over longer timespans may require ICEs running on low carbon fuels, moving to renewable fuels.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Utility

Example 4: Small machines for house construction

Use description:

Various tasks involved in house building such as sawing and forming wood, cutting bricks and blocks. Handheld or hand moved machines, usually operating for short times with medium power requirements in urban areas that typically have infrastructure for electrification.

Machine employed:

Chainsaws, circular saws, masonry cutters. Using **1–2 kW** petrol engines. Fuel consumption is typically **0.1–2 L** per day (equivalent to battery capacity of **0.2–4 kWh**).

Decarbonisation pathways:

Battery electric is viable for short, medium intensity use, but heavy-duty operations over longer timespans may require ICEs running on low carbon and then renewable fuels.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Utility

Example 5: Olive harvesting

Use description:

Harvesting olive groves usually in remote areas with fuel carried to the jobsite by hand. The machine is used for round-the-clock operations at medium intensity.

Machine employed:

Special purpose olive harvester with **1.5-2.5 kW** petrol engine. Fuel consumption typically **1-2.5 L** per day (equivalent to a battery capacity of **2-5 kWh**).

Decarbonisation pathways:

Battery electric is viable if charging infrastructure is next to the jobsite. Liquid low carbon fuels, moving to renewable fuels are needed for higher intensity use over longer durations or in locations without charging infrastructure.

Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Utility

Example 6: Mobile water pump

Use description:

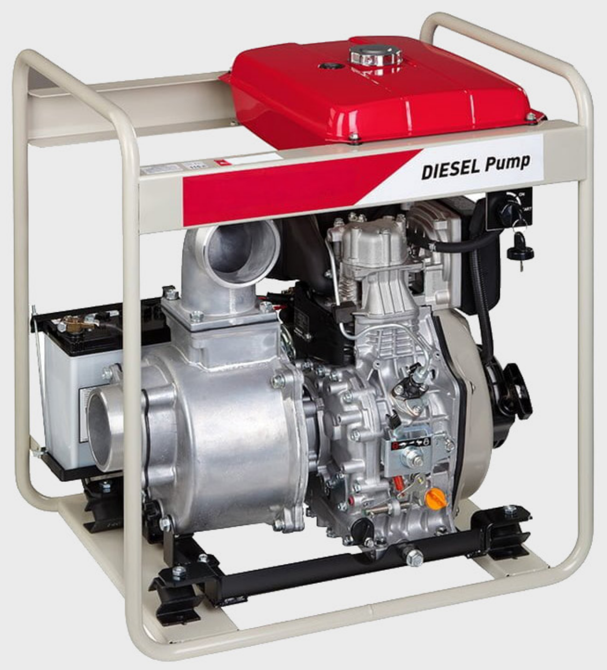
Water pump for use on construction sites, farms and for flood alleviation.

Machine employed:

100–150 mm bore pump with **10–15 kW** diesel engine. Petrol engines and small generators can also be used. Electric version can be used if power is available on site.

Decarbonisation pathways:

ICEs running on low carbon fuels, moving to renewable fuels. Renewable electricity for electric version.



Evaluation Criteria	Use Case Evaluation	
Energy use	Low	High
Work intensity	Low	High
Type of use	Sporadic	Continuous
Availability of electricity on site	Available	Not available
Predictability of deployment	Pre-planned	Un-planned
Location of site	Adjacent to infrastructure	Remote from infrastructure
Time on site	Extended	Short
Required refuelling /recharging	Low	High

Conclusion

The machines used in this sector are lower powered and often handheld or moved by hand. Use cases vary widely from occasional domestic use to high-intensity long-duration use in remote locations, when fuel must be carried to the site with the machine.

Battery electric powertrains are potentially viable for lighter use, short-duration work where recharging is feasible, but internal combustion engines using energy-dense liquid fuels will be required for higher intensity, longer duration work in remote locations.

A tenfold increase in the gravimetric energy density of the battery pack would be needed to maintain usage patterns for machines that are mainly used in remote locations with high operating times for extended periods.

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 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.

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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