



**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:  
Non-Road Mobile Machinery  
(NRMM)**

March 2026

# The Role of Powertrains in Decarbonising Society

EUROMOT Guiding Principles to Decarbonise  
Non-Road Mobile Machinery (NRMM)

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

|   |           |
|---|-----------|
| <b>About EUROMOT</b>  | <b>04</b> |
| <b>EUROMOT Guiding Principles to Decarbonise Non-Road Mobile Machinery (NRMM)</b> | <b>07</b> |
| <b>Key Factors that Determine Decarbonisation Pathways</b>                        | <b>08</b> |
| <b>Powertrain Technologies and Energy Carriers</b>                                | <b>10</b> |
| <b>Use Case Examples</b>  | <b>16</b> |
| <b>Conclusion and Recommendations</b>   | <b>48</b> |
| <b>Appendix</b>   | <b>50</b> |

# 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.

# Our Members





# EUROMOT Guiding Principles to Decarbonise Non-Road Mobile Machinery

The sector encompasses a wide array of industrial machines that either move under their own power or can be moved between sites with vital economic applications including agricultural, construction and material handling machines, mobile generator sets and transportable industrial plants.

## 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.

### 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.

### 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.

# Key Factors that Determine Decarbonisation Pathways

Decarbonisation solutions for this industry must accommodate a diverse array of applications, operating environments, energy needs, and patterns of use. These range from mini excavators and yard tractors to massive harvesters and mining machines.

They operate in environments ranging from cities to remote regions, running both intermittently and continuously, on short term sites or longer term works, with fuel or energy being taken to the machines.

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

Output of powertrain units ranges from <20kW to >1MW

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



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.

The largest powertrains can consume up to several GWh of energy a day

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



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

The availability of a range of powertrain capabilities using diverse energy carriers ensures strategic independence in times of fuel supply shortages or the need for disaster relief

Fuel/energy is nearly always delivered to the machines or power plants, especially those used in remote areas.

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

|   |   |  |
|---|---|--|
| <p><b>Efficiency</b></p> <p>Highly operationally efficient as the most compact powertrain technology with readily available, energy-dense fuel sources and fast refuelling times.</p> <p><b>Up to 55% energy conversion efficiency.</b></p> | <p><b>Emissions</b></p> <p>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.</p> | <p><b>Technological maturity</b></p> <p>Proven technology across all industrial applications and use cases.</p> <p><b>Security, cost, and availability</b></p> <p>Secure, domestic supply chains and readily available material sources except some precious materials used in aftertreatment.</p> |
|---|---|--|

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

|   |  |   |
|---|--|---|
| <p><b>Efficiency</b></p> <p>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).</p> | <p><b>Emissions</b></p> <p>Zero air quality or GHG emissions at the point of use. Moderate embedded GHG emissions, usually higher than ICEs and lower than battery electric.</p> | <p><b>Technological maturity</b></p> <p>Technology already in use in non-road applications including cars and forklift trucks, but unproven in non-road industrial sectors such as construction.</p> <p><b>Security, cost, and availability</b></p> <p>Supply chain costs and risks around some components. Fuel cell systems for dynamic applications require a hybrid configuration with batteries.</p> |
|---|--|---|

## Electric Motors - Continuous electric supply or with battery storage

|  |   |  |
|--|---|--|
| <p><b>Efficiency</b></p> <p>The highest energy conversion efficiency technology giving <b>75-90% efficiency.</b></p> <p>The overall operational efficiency can be reduced by downtime due to charging, and the extra storage space needed for large onboard batteries.</p> | <p><b>Emissions</b></p> <p>Zero GHG emissions at the point of use. Usually higher embedded GHG emissions than ICEs or fuel cells.</p> | <p><b>Technological maturity</b></p> <p>Proven technology across some industrial applications.</p> <p><b>Security, cost, and availability</b></p> <p>Supply chain security risks, high costs and projected shortages for raw materials and components in batteries and motors.</p> |
|--|---|--|

# 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

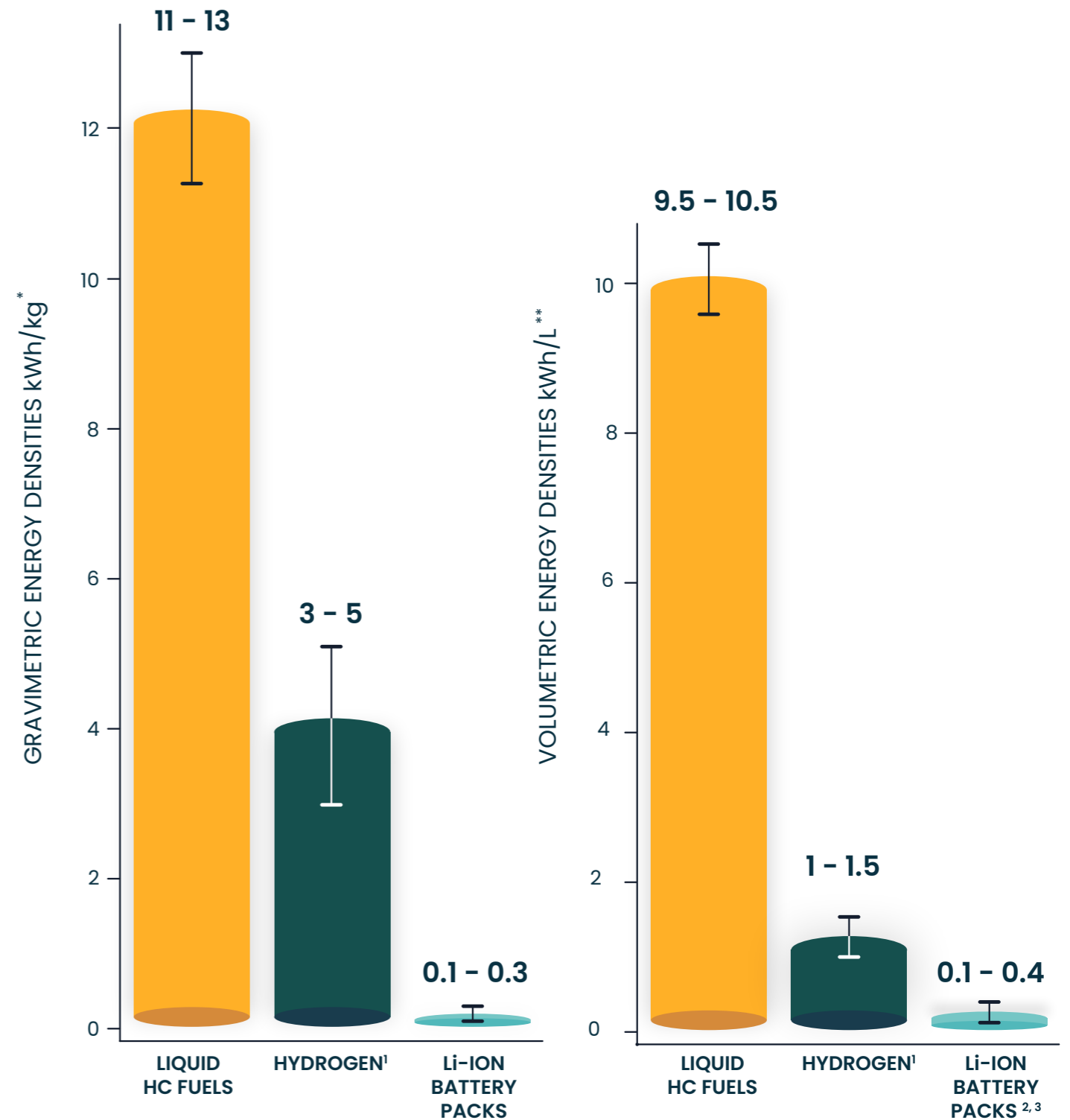
Fuels of biological or non-biological origin where the stored energy comes from renewable sources; either solar energy via photosynthesis or from renewable electricity. The EU Renewable Energy Directives (REDs) require the Carbon Footprint (CF) of renewable fuels to be >70% lower than their fossil equivalent.

## Electricity

### Generated from

- Fossil Fuels: coal, oil
- Natural Gas (RCF)
- Low carbon 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.

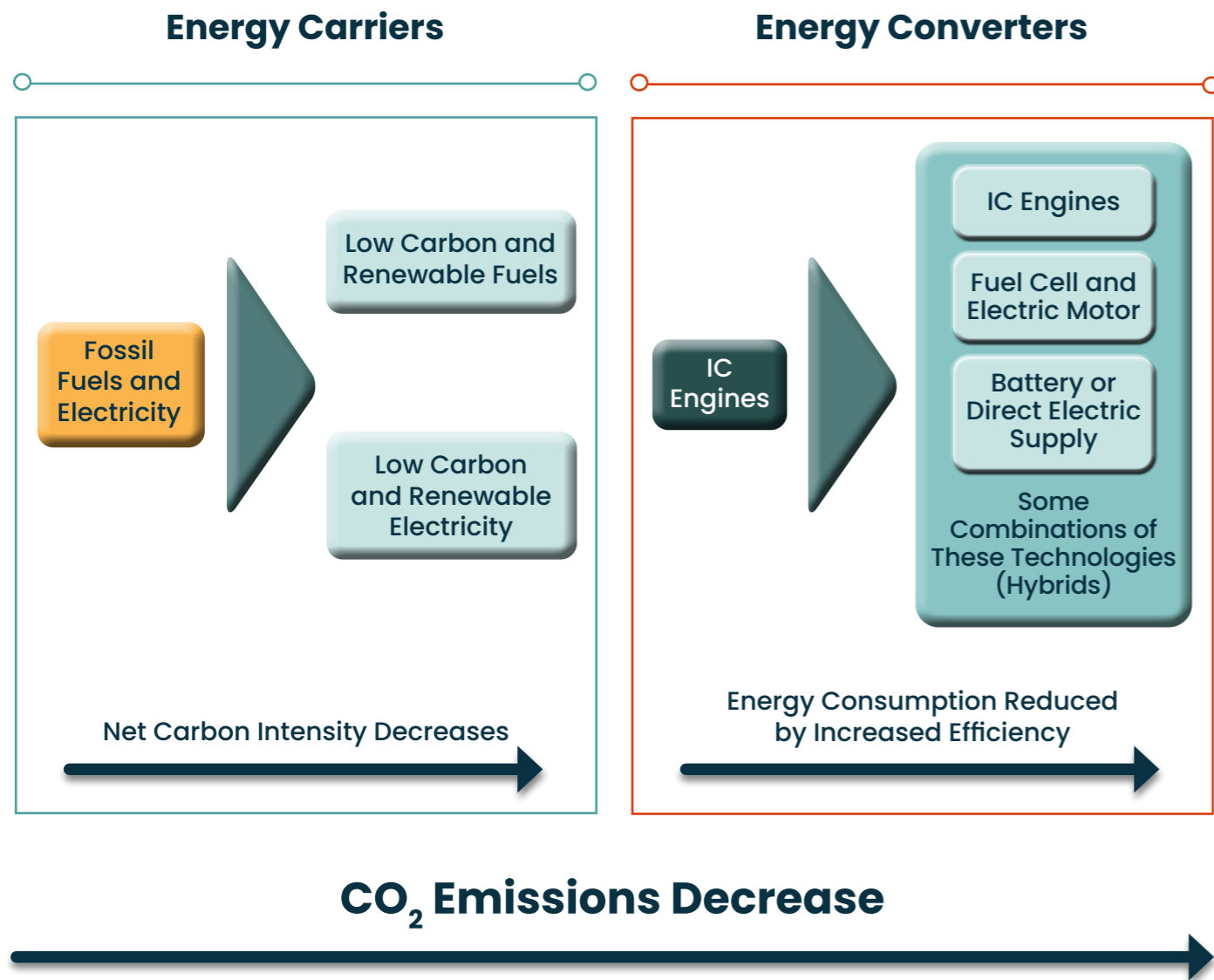
<sup>1</sup>Compressed to 700 bar including the tank.

<sup>2</sup>STIHL. (2023). AP 300 S Battery.

<sup>3</sup>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.

# Agriculture

## Example 1: Front-Line Field Tractor

### Use description:

Used for ploughing, harrowing and planting on large arable farmland of over 100 hectares. The machine operates in remote rural environments at high intensities for periods exceeding 20 hours with usage dictated by the weather and crop cycles.

### Machine employed:

Agricultural tractor with **200 kW** engine running on diesel. Fuel consumption is typically up to **500 L** diesel per day (equivalent to a battery capacity of **2 MWh**).

### Decarbonisation pathways:

High density energy carriers are required that offer rapid refuelling and can be taken to the machine in the field. ICEs running on low carbon fuels, moving to renewable, gaseous and liquid fuels such as biomethane, synthetic diesel or renewable hydrogen. Fuels of biological origin may be favoured in the agricultural industry.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="85"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="85"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="85"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="85"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="15"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="85"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="85"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="85"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="85"/> | Fast                       |

# Agriculture

## Example 2: Combine Harvester

### Use description:

Harvesting crops continuously for up to 24 hours/day at high (75%) intensity in suitable weather when crops are ready for harvest. It is used for a few days at each farm in turn, across remote rural locations. Fuel is taken to the machine, and fast refuelling occurs in the field. Outside of harvest season, the machine is parked out of use until the next year.

### Machine employed:

Combine harvester with **400 kW** diesel engine. Fuel consumption is typically **1,800 L** of diesel a day (equivalent to a battery capacity of **7 MWh**).

### Decarbonisation pathways:

High density energy carriers are required that offer rapid refuelling and can be taken to the machine in the field. ICEs running on low carbon fuels, moving to renewable, liquid fuels. Fuels of biological origin may be favoured in the agricultural industry.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="85"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="85"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="85"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="85"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="15"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="85"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="85"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="85"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="85"/> | Fast                       |

# Agriculture

## Example 3: General Purpose Tractor

### Use description:

Used for towing, silage and support field work in a mix of medium sized farms of around 30-100 hectares including centralised livestock, dairy and dispersed arable farms. It has a load factor of 20-70% and is used at varying intensities including high intensity.

### Machine employed:

130 kW tractor. Fuel consumption is typically 100 L diesel a day (equivalent to battery capacity of 400 kWh).

### Decarbonisation pathways:

ICEs running on low carbon liquid and gaseous fuels, moving to renewable fuels. Fuels of biological origin that could be produced on the farm may be favoured, such as biomethane (produced from manure). Other gaseous fuels such as hydrogen, may be feasible when available onsite, while battery electric is potentially viable for low intensity uses if onsite recharging infrastructure is available.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="75"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="75"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="75"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="75"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="50"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="75"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="75"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="75"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="75"/> | Fast                       |

# Agriculture

## Example 4: Yard Tractor

### Use description:

Small tractor used on various types of farms primarily for moving materials in barns, cleaning animal pens and other miscellaneous tasks. A range of intensities and load factors are experienced.

### Machine employed:

35–50 kW tractor. It runs on diesel. Fuel consumption is typically 25 L diesel per day (or equivalent to battery capacity of 100 kWh).

### Decarbonisation pathways:

ICEs running on low carbon liquid and gaseous fuels, moving to renewable fuels. Fuels of biological origin, that could be produced on the farm, may be favoured. Battery electric is feasible. The choice of powertrain will depend on the use case and which alternative energy carriers are available on farms.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="25"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="25"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="25"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="25"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="75"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="25"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="50"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="75"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="25"/> | Fast                       |

# Construction

## Example 1: Excavator for Emergency Reconstruction

### Use description:

Emergency rebuilding of remote breakwater after storm damage, operating continuously at high intensity for 20 hours a day for 10 days to finish its job before the arrival of spring tides. It is refuelled once per day from a fuel tanker.

### Machine employed:

**20 tonne** excavator with a **125 kW** diesel engine. Fuel consumption is typically **300 L** per day (or equivalent to battery capacity of **1,250 kWh**).

### Decarbonisation pathways:

Diesel could be replaced with low carbon liquid fuels moving to liquid renewable fuels. Whilst battery electric 20 tonne excavators are viable, they have limited battery capacity and are not suited to extended or continuous operation or for emergency use in areas where a suitable electricity supply is not available. It could run on hydrogen, but this would require refuelling 3-5 times a day.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="80"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="80"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="80"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="20"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="50"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="20"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="50"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="80"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="20"/> | Fast                       |

# Construction

## Example 2: Excavator for Housing Construction

### Use description:

Part of a fleet of 10 similar sized excavators, dump trucks and loading shovels, used for groundworks in new housing developments. It operates continuously for 16-hour shifts at moderate intensity.

### Machine employed:

**20 tonne** excavator with **125 kW** diesel engine. Fuel consumption is typically **200 L** per day (or equivalent to battery capacity of **800 kWh**).

### Decarbonisation pathways:

Low carbon liquid or gaseous fuels moving to renewable fuels such as biofuels, synthetic diesel or renewable hydrogen. It is currently refuelled once a day but would need to be refuelled 2-3 times a day with hydrogen. Electrification is unlikely to be practical as the necessary infrastructure is not currently available onsite, and electric power would require the installation of a high power supply and chargers, or battery packs brought to the site.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="75"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="75"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="75"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="75"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="50"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="75"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="75"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="75"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="75"/> | Fast                       |

# Construction

## Example 3: Excavator for City Centre Basement Redevelopment

### Use description:

Excavating basements and moving materials in city centres, operating at low intensity for 10 hours a day.

### Machine employed:

20 tonne excavator with 125 kW diesel engine. Fuel consumption is typically 80 L of diesel per day (or equivalent to battery capacity of 250 kWh).

### Decarbonisation pathways:

Battery electric (or possibly direct electric) is a feasible and practical pathway as electricity is available onsite and there is time for battery charging. Alternatively, Internal Combustion Engine (ICE) machines using renewable fuels.



### Evaluation Criteria

### Use Case Evaluation

| Evaluation Criteria                 | Use Case Evaluation  |
|-------------------------------------|--|
| Energy use                          | Low <input type="range" value="50"/> High  |
| Work intensity                      | Low <input type="range" value="50"/> High  |
| Type of use                         | Sporadic <input type="range" value="50"/> Continuous                                   |
| Availability of electricity on site | Available <input type="range" value="10"/> Not available                               |
| Predictability of deployment        | Pre-planned <input type="range" value="50"/> Un-planned                                |
| Location of site                    | Adjacent to infrastructure <input type="range" value="10"/> Remote from infrastructure |
| Time on site                        | Extended <input type="range" value="50"/> Short  |
| Required machine mobility           | Low <input type="range" value="50"/> High  |
| Minimise refuelling/recharging      | Infrequent <input type="range" value="50"/> Fast                                       |

# Construction

## Example 4: Heavy Machines in a Large Quarry

### Use description:

Extraction and processing of large quantities of rock. Excavators and loading shovels load rocks into dump trucks that move the rock around site for further processing. Loading shovels load rock into tipper trucks for transport off site. The quarry site is in use for a decade or longer.

### Machines employed:

Large excavators (> 50 tonne) at the quarry face; smaller excavators for processing (30–50 tonne); dump trucks (30–60 tonne); loading shovels (> 5 m<sup>3</sup>).

### Decarbonisation pathways:

If electricity is available from the grid or onsite microgrids, direct electric or battery electric machines could be a viable option. ICE powered machines using renewable fuel could be used where microgrids are not available.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="85"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="85"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="85"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="15"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="15"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="15"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="15"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="50"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="50"/> | Fast                       |

# Industrial and Other Sectors

## Example 1: Large Dump Truck for Open Cast Mining

### Use description:

Carrying mined ore from the lower level to the upper edge of open cast mines for processing. High intensity when going up fully laden, and low intensity when descending empty.

### Machine employed:

**100 tonne** dump truck powered by an ICE or ICE electric powertrain of **600 kW**. The combined energy from fuel and battery is used on the way up and energy recovered to the battery during descent.

### Decarbonisation pathways:

ICEs running on low carbon fuels, moving to renewable, liquid or gaseous fuels. A battery and energy recovery system can be added to the ICE electric powertrain to improve efficiency and reduce emissions. If there is high power, electrical infrastructure or a microgrid onsite, this can be used to supplement energy recovery to batteries, minimising fuel use for plug-in hybrids.

Alternatively, a pure battery electric powertrain could be used if there is time for charging or a system for charging on the move. With an average vehicle lifespan of over 30 years, low carbon and net zero drop-in fuels will be important to decarbonise the existing machine fleet. New powertrains will also need to be as durable as current machines.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="85"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="85"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="85"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="50"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="15"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="50"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="15"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="85"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="50"/> | Fast                       |

# Industrial and Other Sectors

## Example 2: Telescopic Handler for Industrial, Construction and Farm Operations

### Use description:

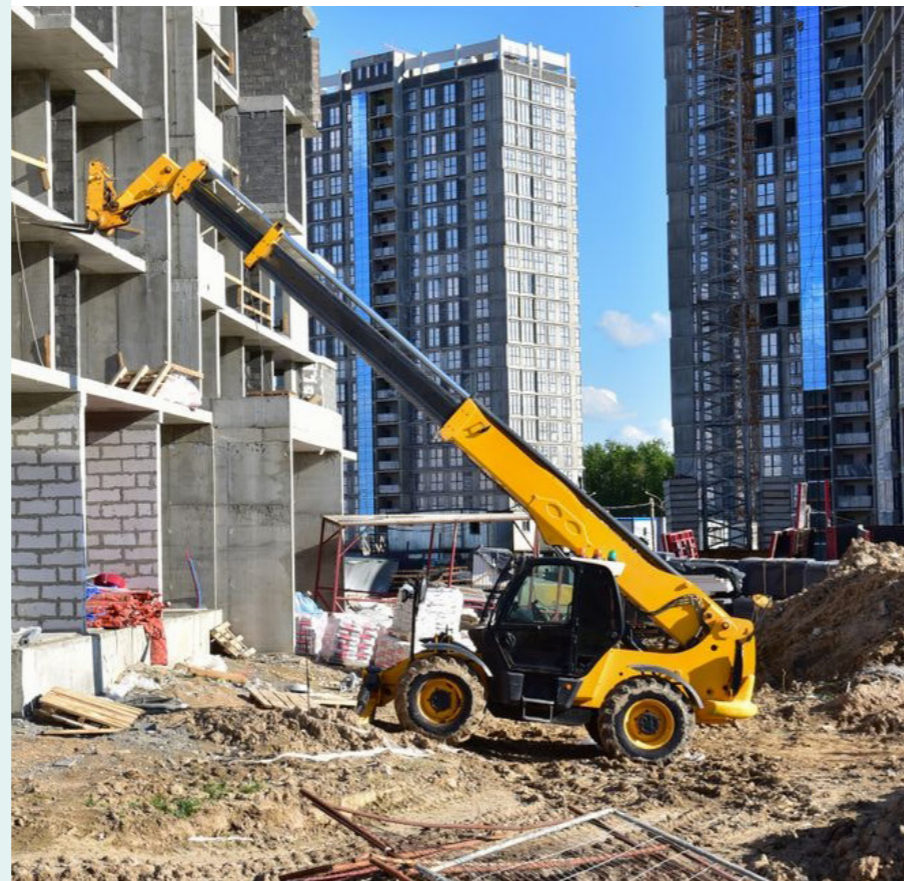
Moving materials around construction sites, industrial sites and farms. It has many use cases and operates anywhere from 1 to 20 hours a day at intensities ranging from 10-80%.

### Machine employed:

Telescopic handler. < 3 to > 10 tonne machine with diesel engine of 35-120 kW. Energy consumption varies from < 20 to > 500 kWh per day (equivalent to < 7 to > 150 L diesel).

### Decarbonisation pathways:

All technologies offering pathways to decarbonisation will need to be applied to cover the wide range of use cases and energy carriers available in different locations. Low carbon liquid or gaseous fuels, moving to renewable fuels are suitable for high-intensity use over long periods. Battery electric is viable for lower-intensity short use where electricity is available onsite. Renewable gaseous fuels including hydrogen are also feasible where production and distribution networks are available.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="50"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="50"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="50"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="50"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="75"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="50"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="75"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="85"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="50"/> | Fast                       |

# Industrial and Other Sectors

## Example 3: Warehouses and Distribution Hub Management

### Use description:

Moving goods around warehouses and loading and unloading trucks and vans, working continuously at 25% intensity.

### Machine employed:

Forklift truck with a **35 kW** engine using diesel or LPG, or battery electric using removable battery packs. Energy consumption of around **200 kWh** per day.

### Decarbonisation pathways:

Battery electric is a feasible solution if using interchangeable battery packs and off-vehicle charging stations, or when there are other vehicles to take their place while they are being charged. Hydrogen fuel cells could be used with onboard tanks depending on the availability of onsite hydrogen refill stations.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="75"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="50"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="75"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="10"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="15"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="85"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="80"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="10"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="75"/> | Fast                       |

# Industrial and Other Sectors

## Example 4: Refrigeration of Trailer Units

### Use description:

The refrigeration unit keeps the contents of the trailer at the required temperature such as -20°C. The trailer may be parked for extended periods, sometimes in remote locations. The unit will start and stop based on the temperature inside the trailer.

### Machine employed:

Diesel engine powered refrigeration unit. Engine powers range from **10–25 kW**. Plug in direct electric units are also used (where electricity supply is available) as well as hybrid versions.

### Decarbonisation pathways:

Diesel and hybrid versions can use low carbon fuels, moving to renewable fuels. Plug-in direct electric can use renewable electricity. Batteries could be used for short/medium distance journeys, recharged by regenerative braking or solar panels



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="25"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="25"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="75"/> | Continuous                 |
| Availability of electricity on site | Available                  | <input type="range" value="75"/> | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="25"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="50"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="75"/> | Short                      |
| Required machine mobility*          | Low                        | <input type="range" value="50"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="75"/> | Fast                       |

\*Including the trailer refrigeration unit.

# Mobile Generators

## Example 1: Prime Power for Small Music Festival or Sporting Event

### Use description:

The provision of 24-hour power for outdoor events in off-grid locations with average electricity demand of 150 kW and peak demand of 400 kW.

### Machine employed:

500 kVA ICE mobile generator. Producing 3.6 MWh of electricity per day. Using 1,000 L of diesel.

### Decarbonisation pathways:

Low carbon liquid or gaseous fuels transitioning to renewable fuels, including hydrogen.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="80"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="50"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="80"/> | Continuous                 |
| Availability of electricity on site | Available                  | Not available                    | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="50"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="80"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="50"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="10"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="80"/> | Fast                       |

# Mobile Generators

## Example 2: Electrical Power for Small Site Facilities

### Use description:

Provision of electricity on smaller sites. Average demand of 10 kW with a peak demand of 75 kW.

### Machine employed:

Hybrid mobile generator with **25 kW** engine and battery pack modules of **20 kWh**. Energy consumption of approximately **200 kWh** (equivalent to **60 L** diesel) per day.

### Decarbonisation pathways:

Low carbon liquid and gaseous fuels moving to renewable fuels, including hydrogen. Fuel cells could provide efficient generation when running at low loads, with batteries providing peak power.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="75"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="25"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="85"/> | Continuous                 |
| Availability of electricity on site | Available                  | <b>Not available</b>             | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="50"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="85"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="50"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="25"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="85"/> | Fast                       |

# Mobile Generators

## Example 3: Electrical Power for Low Level Power Demand in Urban Settings

### Use description:

Provision of electricity to low demand sites, using less than about 50 kWh per day.

### Machine employed:

50 kWh battery pack. Battery packs are swapped daily and charged offsite.

### Decarbonisation pathways:

Use renewable electricity to charge battery packs.



### Evaluation Criteria

### Use Case Evaluation

|                                     |                            |                                  |                            |
|-------------------------------------|----------------------------|----------------------------------|----------------------------|
| Energy use                          | Low                        | <input type="range" value="25"/> | High                       |
| Work intensity                      | Low                        | <input type="range" value="25"/> | High                       |
| Type of use                         | Sporadic                   | <input type="range" value="25"/> | Continuous                 |
| Availability of electricity on site | Available                  | Not available                    | Not available              |
| Predictability of deployment        | Pre-planned                | <input type="range" value="75"/> | Un-planned                 |
| Location of site                    | Adjacent to infrastructure | <input type="range" value="75"/> | Remote from infrastructure |
| Time on site                        | Extended                   | <input type="range" value="75"/> | Short                      |
| Required machine mobility           | Low                        | <input type="range" value="25"/> | High                       |
| Minimise refuelling/recharging      | Infrequent                 | <input type="range" value="25"/> | Fast                       |



# Conclusion

The wide range of machines employed in this sector are often high-powered and used intensively in remote and rural areas, consuming large amounts of energy.

This energy, or fuel, is almost universally taken to the machine at its place of work. Some machines work less intensely on sites where electricity infrastructure exists and may be able to use electric powertrain solutions. Policy and regulation needs to be technology-neutral, and acknowledge these diverse requirements.

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.

# 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.



# Appendix: Definitions

**Life Cycle Analysis (LCA)** is a method of calculating the total CO<sub>2</sub>e emissions from a product, including other emissions such as nitrous oxide (N<sub>2</sub>O) and methane (CH<sub>4</sub>), 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<sub>2</sub> and water from burning a hydrocarbon fuel).

**GHG Emissions** CO<sub>2</sub> is the predominant Greenhouse Gas for this sector, but this also encompasses other GHGs such as nitrous oxide and methane, normally defined as CO<sub>2</sub> equivalent (CO<sub>2</sub>e) when using the GWPI00 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.



## Acknowledgements

This paper has been developed with the valued support and contributions of member companies of The European Association of Internal Combustion and Alternative Powertrain Manufacturers (EUROMOT). Their expertise, insights, and active engagement have been instrumental in shaping the content and ensuring its relevance and quality.

## Disclaimer

This paper is provided for general informational purposes only and may be updated or revised in the future. It's based on the information available at the time of publication. Technology is advancing and future developments may alter the conclusions made here.

Neither the European Association of Internal Combustion and Alternative Powertrain Manufacturers (EUROMOT) nor any of its member companies provide professional services through the publication of this paper.

The content of this paper is not intended to serve as a basis for business, financial, or other decisions, nor for the execution of any

related actions. For such purposes, readers should consult a qualified professional advisor.

No representations, warranties, or guarantees, whether express or implied, are made regarding the accuracy or completeness of the information contained in this paper. Neither EUROMOT nor any of its member companies, nor their employees, shall be held liable for any loss or damage of any nature, whether direct or indirect, incurred by any individual or organisation as a result of reliance on this paper.

EUROMOT and its member companies operate as legally autonomous and independent entities.

---

## Contact

### **EUROMOT aisbl**

The European Association  
of Internal Combustion Engine  
and Alternative Powertrain  
Manufacturers  
Rue Joseph Stevens 7  
1000 Brussels  
Belgium

**Email:** [secretariat@euromot.eu](mailto:secretariat@euromot.eu)

**Web:** [www.euromot.eu](http://www.euromot.eu)

**EU Transparency**

**Register ID:** 6284937371-73

All rights reserved.

© March 2026

© Pictures: Adobe Stock, iStock, Shutterstock, Pexels, EUROMOT member companies