HM Government

Non-Road Mobile Machinery Decarbonisation Options

Call for Evidence

Department for Energy Security & Net Zero

Department for Environment Food & Rural Affairs

Department for Transport

Closing Date: 26 March 2024

Executive Summary

In 2019, the UK became the first major economy to pass a net zero law to end its contribution to climate change by 2050. The UK has made significant progress in reducing its greenhouse gas (GHG) emissions. Between 1990 and 2021 we've cut emissions by 48% while growing our economy by 65%, decarbonising faster than any other G7 country.[1] However, achieving net zero will require further ambitious emissions reduction across all sectors of the economy, including from the use of non-road mobile machinery (NRMM). NRMM broadly refers to any mobile machine, transportable equipment or vehicle which is not intended for carrying passengers or goods on the road. Examples of NRMM include excavators, forklifts, generators, and tractors. Emissions from NRMM constitute approximately 11.4 million tonnes of CO_2 equivalent ($MtCO_2e$) per year (2021)[2], equivalent to 2.7% of total UK GHG emissions.

Addressing GHG emissions from NRMM can also deliver important co-benefits: reducing air and noise pollution, benefiting the health and well-being of those who work with machines and those who live and work nearby. NRMM decarbonisation also presents economic opportunities for the UK. As a significant manufacturer and exporter of NRMM, the UK can lead the world in the development and deployment of zero emission NRMM technologies.

In Powering up Britain: The Net Zero Growth Plan, published in March this year (2023), government announced that it will publish a cross-government strategy to decarbonise NRMM. The responses to this call for evidence will inform the development of a NRMM decarbonisation strategy. This call for evidence is a joint publication by the Department for Energy Security & Net Zero (DESNZ), the Department for Environment Food & Rural Affairs (Defra) and the Department for Transport (DfT) that seeks information to inform the strategy, including with respect to:

- How NRMM is currently used across different sectors of the economy;
- What efficiency measures, process changes, and fuel switching technologies might be required to decarbonise NRMM;
- What issues may affect the development and deployment of NRMM decarbonisation options;
- Whether existing policies are sufficient to decarbonise NRMM in line with net zero; and
- Whether the policy principles of the Industrial Decarbonisation Strategy should also apply in relation to determining whether there is a case for further government intervention to support NRMM decarbonisation.

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1 Powering Up Britain: Net Zero Growth Plan https://www.gov.uk/government/publications/powering-up-britain

2 Final UK greenhouse gas emissions national statistics: 1990 to 2021 https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2021

This call for evidence is split into two parts. Part I seeks to strengthen the government's evidence base on NRMM decarbonisation options according to the following themes:

Chapter 1 seeks to develop our understanding of the NRMM product lifecycle from manufacture or import to end of life disposal, before seeking evidence on how NRMM is utilised across different sectors of the economy.

Chapter 2 sets out NRMM decarbonisation options such as efficiency measures and fuel switching. It requests evidence to further develop our understanding of these options including their potential role across different types of machines, usage scenarios, and sectors of the economy.

Chapter 3 seeks evidence on the opportunities and barriers to the development, deployment, and utilisation of the decarbonisation options discussed in Chapter 2.

Chapter 4 seeks views on possible high-level policy approaches to determine the case for potential government intervention. It also sets out existing government initiatives that stakeholders can access to support NRMM decarbonisation and seeks evidence on the impact of these.

We invite all respondents to answer questions in Part I.

Part II of this call for evidence covers detailed aspects and assumptions of DESNZ commissioned research (link). The purpose of this section is to validate or improve upon these assumptions. We ask that only those with relevant experience, such as industrial NRMM OEMs or industrial NRMM users, respond to questions in Part II.

Contents

General information

Why we are issuing this call for evidence

This call for evidence will help strengthen the government's evidence base on the role of NRMM in the economy, the decarbonisation options available to NRMM, the opportunities and barriers to their deployment, and possible policy approaches. It builds upon the findings of the DESNZ commissioned Industrial NRMM Decarbonisation Options: Techno-Economic Feasibility Study.[3] The information gathered will inform the development of government future policy on NRMM, including the NRMM Decarbonisation Strategy that the government committed to publish in the Net Zero Growth Plan. Government welcomes that significant innovation in support of NRMM decarbonisation is underway in the UK and overseas, with new evidence on technological developments regularly becoming available. It is important that the government evidence base reflects these developments through this call for evidence.

Alignment with other government policies

NRMM decarbonisation relates to a range of sectors and possible technology solutions, some of which are covered by separate existing policies and ongoing policy development. These are listed below, and we encourage stakeholders to respond to related consultations, where appropriate:

- **The Low Carbon Fuel Strategy** will set out the government's vision for the deployment of low carbon fuels in transport, from now to 2050.
- **The Renewable Transport Fuel Obligation** supports the use of low carbon fuels in NRMM.
- **Hydrogen Transport and Storage (T&S) Business Models** are being designed for 2025 to unlock investment and remove market barriers to the build out of transport and storage infrastructure. Government recently published its Hydrogen T&S Government Response to Consultation and Minded To Positions.
- **Enabling Industrial Electrification: a call for evidence on fuel-switching to electricity** sought to build the Government's understanding of the role of electrification in industry, the challenges industry faces when considering electrification options and to test early-stage policy thinking. This will enable the design of an optimal policy framework to overcome barriers and manage interactions with the wider system, such as the review of electricity market arrangements (REMA) and future electricity networks. While industrial NRMM is within the scope of the industrial electrification call for evidence, it does not specifically address NRMM.

[3] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

- **Grid connections**. As the UK moves towards net zero and energy security, including by deploying new low carbon generation and electrifying sectors such as those which use NRMM, there has been a significant increase in electricity network connection applications. This had led to the queue for connections becoming congested and, in some cases, is causing delays to electricity network connections. We are working closely with Ofgem and industry to accelerate building of new network infrastructure to release network capacity alongside action to accelerate connection dates (link). To support this work, we are seeking evidence from NRMM respondents on grid connections and the associated barriers through this call for evidence.

- **The Zero Emission HGV Infrastructure Strategy** will set strategic direction and outline the respective roles and responsibilities of both government and industry to ensure the delivery of the refuelling and recharging infrastructure required to meet the 2035 and 2040 end of sale dates for new non-zero emission HGVs.

- **The Zero Emission Airport Operations Target** will address airport specific NRMM, such as ground support equipment.

- **Seaports decarbonisation** where the government intends to publish a call for evidence on the role of seaports in reaching net zero.

Call for evidence details

Scope:

This call for evidence seeks stakeholder responses on the machines that are included in the off-road mobile machinery and the agricultural machinery categories in UK Carbon Budgets. This categorisation generally refers to any mobile machine, transportable equipment or vehicle which is not intended for the transport of goods or passengers on the road.[4] To illustrate:

- **Industry:** industrial NRMM includes machines that are typically deployed across the construction, manufacturing, mining and quarrying, and waste management sectors, such as excavators, forklifts, and generators.

- **Agriculture:** agricultural NRMM is generally used across the agricultural and forestry sectors, such as tractors, harvesters, and chainsaws.

- **Transport:** transport NRMM is generally used across the logistics, rail, and seaports sectors and includes HGV auxiliary engines such as transport refrigeration units (TRUs), reach stackers, and on rail track plant machinery.

[4] Stakeholders may be familiar with UNECE R96 type approval which defines air quality pollutant limits for the sale of NRMM in the UK. This call for evidence, however, uses UK Carbon Budget categories, as defined in the Greenhouse Gas Inventory (GHGI), as the basis for its scope which includes many, but not all, machines that full under the scope of UNECE R96. It also includes other machine types which do not fall under this regulation, for example agricultural vehicles. The machines within scope of this Call for Evidence are referred to collectively in this call for evidence as 'NRMM'.

The machines and sectors listed above are non-exhaustive. A sample list of machines in scope of this call for evidence is contained in the UK Greenhouse Gas Inventory, which can be found at Annex A. Stakeholders should contact us at nrmm.cfe@energysecurity.gov.uk with any queries regarding the scope of this call for evidence with all our responses published online at www.gov.uk/government/calls-for-evidence/non-road-mobile-machinery-decarbonisation-options.

For the purposes of this call for evidence, we are seeking evidence on the operational (tailpipe) emissions of NRMM. While the principal focus is on the greenhouse gas emissions from the use of NRMM, we encourage stakeholders to also consider broader environmental impacts, including air quality and noise, from the operation of NRMM when responding to the questions in this call for evidence. We are also seeking evidence on the NRMM supply chain, current market dynamics, and how both of these might change over time as NRMM decarbonises.

Audiences:

We are keen to hear from original equipment manufacturers (OEMs) and parts suppliers, NRMM users (such as construction companies, industrial sites, farms, and seaports), lease and rental companies, export companies, waste and disposal companies, academics, technology providers, fuel providers, and anyone else with an interest in this area.

Territorial extent:

The territorial extent of the call for evidence is United Kingdom (UK) wide and responses are invited from all parts of the UK. We will work with the Devolved Administrations to ensure that policy development takes account of devolved responsibilities across the UK.

How to respond

We ask that responses are provided through Citizen Space: https://beisgovuk.citizenspace.com/clean-growth/non-road-mobile-machinery-decarbonisation-cfe. When responding, please state whether you are responding as an individual or representing the views of an organisation.

Your response will be most useful if it is framed in direct response to the questions posed. Please ensure that you cite the appropriate sources and publications in relation to evidence submitted, where relevant, as we may seek commercial and engineering support when considering responses.

There is a question at the end to provide any further comments and evidence which was not covered in the call for evidence but that you consider to be relevant. We will provide acknowledgement of all responses received.

If you have any questions regarding the call for evidence, you can contact the team as set out below at:

nrmm.cfe@energysecurity.gov.uk

Confidentiality and data protection

Information you provide in response to this call for evidence will be subject to UK legislation on public access to information (including the Freedom of Information Act 2000 and the Environmental Information Regulations 2004). Information you provide may be disclosed in accordance with that legislation.

If you consider that information you provide to be confidential, please tell us, but be aware that we cannot guarantee confidentiality in all circumstances. An automatic confidentiality disclaimer generated by your IT system will not be regarded by us as a confidentiality request.

We will process your personal data in accordance with all applicable data protection laws including the Data Protection Act 2018 and the UK General Data Protection Regulation. See our personal information charter and privacy notice for further information.

This call for evidence is a joint publication by the Department for Energy Security & Net Zero (DESNZ), the Department for Environment Food & Rural Affairs (Defra), and the Department for Transport (DfT). Responses may therefore be shared between government departments.

We will aim to provide a high-level summary of the responses to the call for evidence in due course. The summary will include the names of businesses or organisations that responded, but not include people's names, addresses or other contact details.

This call for evidence has been carried out in accordance with the government's consultation principles.

If you have any complaints about the way this call for evidence has been conducted, please email: beis.bru@energysecurity.gov.uk.

Part I – Call for evidence on NRMM decarbonisation options

Questions about your organisation

1. **What is your name?**

2. **What is your email address?**

3. **We usually publish a summary of all responses, but sometimes we are asked to publish the individual responses too. Would you be happy for your response to be published in full?**

4. **How did you hear about this consultation?**

5. **What is the name of the organisation that you represent?**

6. **What is the postcode of your organisation?**

7. **What type of organisation do you represent? Please select one:**

- NRMM original equipment manufacturer (OEM)
- NRMM parts supplier
- NRMM rental business
- NRMM leasing business
- NRMM user
- Trade association or other industry body
- Fuel supplier
- Academic institution
- Non-governmental organisation (NGO)
- Public sector body
- Private individual
- Other (please specify)

8. Do you operate in the UK and, if so, which areas of the UK do you operate in? Please select all that apply:

- North East England
- North West England
- Yorkshire & the Humber
- East Midlands
- West Midlands
- East England
- Greater London
- South East England
- South West England
- Scotland
- Wales
- Northern Ireland
- No UK based operations

9. If you represent a business, what size business do you represent? Please select one:

- Small (fewer than 50 employees)
- Medium (50 to 249 employees)
- Large (250 employees and over)
- Not applicable

10. Please provide the SIC code for the primary activity of your business or organisation (5-digit code if available, otherwise the most granular level).

11. Do you represent or hold expertise on NRMM in a specific sector? Please select all that apply:

- Construction
- Manufacturing site

- Mining and Quarrying
- Waste
- Agriculture
- Forestry
- Seaports
- Road freight
- Rail
- Other (please specify)

12. Do you represent or hold expertise on a specific machine type(s) or technology? If so, please specify.

13. Do you hold data on NRMM used in the UK which you would be willing to share with government? We are particularly interested in sales, usage, and ownership fleet data, although please highlight any other data that you think might be useful. In your response, please provide specifics about the data that you hold and would be willing to share.

1. The role of NRMM in the economy

Economic profile

The UK has a significant NRMM manufacturing base[5] which provides 1.5% (38,000) of all direct manufacturing jobs (2019) and 1.8% (£3.2 billion) of the manufacturing sector's total GVA (2021). In 2022, the UK exported over £4 billion of construction and earthmoving equipment, 47% greater by value than imports of equipment.[6] These economic benefits are spread across the UK, with the majority of NRMM manufacturing enterprises (82%) located outside of London and the South East.[7]

NRMM is used across a range of sectors in the UK, fundamental to the provision of goods and services ranging from construction to farming to waste recycling.

Product lifecycle

The life of NRMM can comprise several different stages of ownership and use involving manufacturers, users, rental companies, secondary markets, exporters, and end-of-life companies.

- **Manufacture and Import**: A number of NRMM units used in the UK are produced domestically by the UK manufacturing sector. This may involve UK-based innovation and development of new technologies, improved designs, and enhanced functionalities for NRMM. There may also be a demonstration phase which might include pilot projects that seek to demonstrate proof of concept and showcase the technology. Alternatively, NRMM might be imported new for use in the UK.

- **Primary UK Market Sales, Export, and Rental:** Following manufacture, NRMM units may be sold directly to businesses that will operate the machines across industry, agriculture, and transport, or may be sold to rental companies. A machine might also be sold new directly into an export market.

- **Usage:** Once sold, rented, or leased, NRMM units are used in a broad range of applications required for the production and delivery of essential goods and services. There is a considerable diversity of use for NRMM units with different operating environments, intensity of use, and power rating requirements.

- **Secondary Market Sales and Export:** At the end of its first life, NRMM is often remanufactured or refurbished to be used again or to enter the secondary market,

[5] SIC codes: 28220 'manufacture of lifting and handling equipment', 283 'manufacture of agricultural and forestry machinery', and 2892 'manufacture or machinery for mining quarrying and construction'. Some of the machines within scope of this call for evidence might be captured under other SIC codes.

[6] Construction Equipment Association (CEA) https://thecea.org.uk/market-info/uk-imports-and-exports-of-construction-equipment-q4-2022/

[7] Inter-Departmental Business Register (IDBR) https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/datasets/ukbusinessactivitysizeandlocation

either domestically or internationally. Multiple lives of machinery are common, often due to high residual values.

- **End of Life:** At the end of their useful life, machines are ultimately scrapped with any remaining functioning parts and valuable materials recovered for further use and recycling.

Sectoral breakdown

Different NRMM types, user requirements and deployment scenarios may have an impact on the suitability of different NRMM decarbonisation options. Evidence is sought on these different characteristics through this call for evidence. Table 1 provides a high-level illustration of NRMM types used across different UK sectors, and possible associated user requirements and deployment scenarios.

Table 1 – illustrative summary of NRMM use cases across the UK

Sector	NRMM Type	Sites and Deployment Scenarios	Potential User Requirements
Agriculture	Agricultural tractors, balers, harvesters, sprayers.	Deployed on farms for tasks such as tilling, planting and harvesting, bailing, and crop maintenance. Other equipment may be used to transport goods and materials on farm.	User requirements vary depending on the task, with some equipment used intensively for short periods on a seasonal basis (e.g. harvesters) while other equipment requires steady, less intense use (e.g. sprayers).
Construction	Bulldozers, cement mixers, compactors, cranes, excavators, forklifts, generators, graders, loaders, pumps, rollers, surfacing equipment.	Used in a wide variety of construction sites for the construction and demolition of infrastructure and buildings, movement of material on-site, road surfacing, and on-site power generation.	Equipment such as large excavators and bulldozers have high power requirements to support intensive use on site. Smaller equipment such as skid-steer loaders and mini-excavators often run for shorter periods on site.
Forestry	Chainsaws, Feller Bunchers, Forwarders, Skidders.	Deployed in forests for tasks such as felling trees, transporting logs, processing, and land clearing.	Tasks such as felling and hauling have high power requirements. Intensity of use varies depending on the specific task.

Sector	NRMM Type	Sites and Deployment Scenarios	Potential User Requirements
Road freight, warehousing & logistics	Forklifts, road sweepers, transport refrigeration units (TRUs).	Used in warehouses for moving goods, and loading/unloading goods vehicles. Road cleaning/maintenance. Refrigeration of goods in transit.	Low power requirements with frequent stop/start patterns of usage. Air quality considerations important.
Manufacturing	Dumpers, forklifts, generators, pumps.	Used in factories for material handling, power generation and driving industrial processes.	Varying power and usage requirements depending on the specific process or task.
Mining & quarrying	Crushers, bore-rigs, draglines, generators, off-highway trucks, mining shovels.	Used in surface and underground mines in support of the extraction, processing, and movement of materials.	High power output and potentially intensive usage requirements given the nature of the site. Noise and air quality considerations important for underground operations.
Rail	Auxiliary railway vehicles, including on track plant machinery, portable transportable mobile machinery, and demountable machinery.	Used on the railway network in support of rail construction, repair and maintenance, as well as measurement and inspection.	Varying power and usage requirements depending on the specific process or task.
Seaports	Forklifts, reachstackers, rubber tyred gantry cranes.	Movement of cargo on-site and to/from ships, warehouses, terminals and freight.	High power requirements for heavy lifting. Usage requirements may have stop/start cycles but need to be available for continuous operations.
Waste	Landfill compactors, material handlers.	Movement and processing of materials on site.	Varying power requirements depending on task.

14. Are you able to provide any additional information regarding the NRMM product lifecycle?

15. Are you able to provide any additional information regarding how NRMM is used in the sectors presented in Table 1?

16. Are there any sectors not listed in Table 1 that constitute a significant source of NRMM use and/or are particularly dependent upon NRMM for their operations?

17. If you own, rent, or lease, and/or operate NRMM, what are the main considerations when deciding what machines to procure and whether to buy outright or rent/lease?

18. DESNZ commissioned research suggests that around 33% of construction machinery is owner operated versus 67% which is either hired or leased.[8] How does this compare to the sector(s) in which you are interested?

[8] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

2. Decarbonisation options

Carbon emissions from NRMM can be abated (reduced) through three main routes:

- efficiency measures which reduce the fuel consumed to complete a task,
- process changes which remove the need for NRMM to complete a task, and
- fuel switching from fossil fuels to low and zero carbon alternatives, including electrification, hydrogen, and other low and zero carbon fuels.

In this chapter we are seeking evidence on these decarbonisation options to reduce greenhouse gas emissions from the operation of NRMM.

Efficiency measures

Efficiency measures reduce the amount of energy (fuel) required to complete a given task. Efficiency measures can be broken down into three further categories: machine, operator, and process.[9] The extent to which efficiency measures apply to NRMM will often depend on the machine type and other factors such as site location and the task that the machine is being used for. DESNZ commissioned research estimates that across industrial NRMM, efficiency measures have the potential to reduce emissions by 5% to 50%.[10] Many operator and process efficiency measures are already deployable using existing machinery and therefore present opportunities to reduce emissions immediately. Whereas machine efficiency measures are expected to continue to develop over time as product designs are improved by OEMs.

We are seeking views on the abatement potential of different efficiency measures for the NRMM types which you are interested in, including how it might vary by sector and machine type.

Machine efficiency

Machine efficiency refers to the optimisation of machine parts (for example, the engine or hydraulics) to reduce energy consumption. To illustrate, such measures might include:

- Replacing a hydraulic transmission with an electric transmission;
- Automatic blade sharpening on a grass harvester used in agriculture; or
- Improved trailer insulation reducing the power demand of a transport refrigeration unit (TRU).

[9] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

[10] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

Operator efficiency

Operator efficiency refers to the more efficient use of machines in operation and improved maintenance of machines when not in use in order to reduce fuel consumption. Examples might include:

- Reduced idling of machinery when not in use. For example, it is reported that some machinery can be idling for up to 45%[11] of the time when in use, presenting a significant opportunity to reduce emissions through behaviour change;

Process efficiency

Process efficiency refers to the optimisation or reorganisation of a process to reduce fuel consumption. Examples might include:

- matching the right machine to the task (for example, avoiding 'over-specifying' the power requirements when hiring a machine); or
- using telematics data to improve site layouts to reduce distances travelled by machinery between and/or during tasks.

Compared to current technologies and practices, ERM's research across industrial NRMM types estimates that emissions savings in the following ranges can be achieved: 5% to 25% for machine efficiency measures; 5% to 30% for operator efficiency measures; and 15% to 50% for process efficiency measures.[12]

The automation of machinery presents opportunities across all three efficiency types. The removal of the operator from a machine can remove the need for associated safety hardware, which could in turn reduce the weight of the machine and its fuel use. Automated machines could also improve the delivery of tasks, for example by reducing the number of journeys required to complete a task through more precise measurements of the work undertaken.

19. Are there any additional efficiency measures that have not been included in this section relevant to the NRMM type(s) and/or sector(s) that you are interested in?

20. What efficiency measures have been implemented in the machine type(s) and/or sector(s) that you are interested in? What were the impacts that you observed?

[11] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

[12] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

21. Do you agree with the estimated emissions saving range of the different efficiency measures as set out above? Please explain your reasoning.

22. To what extent do you think these efficiency savings will be realised through market forces?

Process change

Process change refers to the adoption of alternative processes that remove the need for NRMM to complete a given task, without a corresponding increase in emissions. As with efficiency measures, the potential to reduce emissions through process change is likely to depend heavily on what the task is and what sector the machine is being used in. Examples might include:

- In manufacturing, the replacement of loaders, used to move material around the site, with a conveyor belt system, that is then powered directly from the grid or an on-site renewable energy source;
- In agriculture, a shift away from management practices requiring intensive soil disturbance towards no or minimum tillage (min-till) practices which will generally promote soil health; or
- In TRUs, some units can be powered from the vehicle via an alternator while in transit and via plug-in electrical power when at depots, removing the need for the auxiliary TRU engine (but requiring the vehicle to decarbonise its powertrain still).

23. Can you identify any process change(s) for the NRMM type(s) or sector(s) that you are interested in? What do you see as the abatement potential (possible emissions saving range) for these?

24. What process change(s), if any, has been attempted in the company or sector that you are interested in with the intention of decarbonising NRMM? Did you observe any impacts?

Fuel switching

Fuel switching refers to the replacement of incumbent fossil fuels (primarily diesel but also petrol, LPG, and CNG among others) with alternative low and zero carbon fuels and/or electrification. Some low carbon fuels, known as ‘drop-in’ fuels, can be substituted wholly into existing machinery with no or minimal modification required. Other low carbon fuels require blending with fossil fuels, new machinery with new powertrains, or the significant retrofitting of existing NRMM, to be deployed.

Given the variety of NRMM and applications in which NRMM is used, a range of fuel switching options may be required. Factors that determine which fuel switching options will be feasible include: site location, site duration, machine power requirement, operating hours, range of movement required, and technology availability. Improvements to machine efficiency might also be required to enable fuel switching in certain instances due to the often lower energy density, and higher cost, of low and zero carbon fuels compared to fossil fuel equivalents. Possible fuel switching options are discussed below.

Electrification

The electrification of NRMM can be achieved either with battery technologies or by tethering where a machine is connected to a power source during its use, either by a cable or, less commonly, an overhead powerline (known as a catenary system or bus bars). Battery powered NRMM are already commercially available for certain machine types, including excavators, lifts, and forklifts, with manufacturers continuing to introduce new products to market. For TRUs, government is aware of some experimental zero emission refrigeration systems which use batteries and some use solar cells. Whilst on farm, the electrification of smaller vehicles including light utility vehicles and quad bikes has occurred.

Tethering is already a common technology across handheld and hand operated machinery such as surfacing equipment and pumps. The ERM study suggests that tethering is also a viable alternative for larger machinery with limited range of movement, such as cranes, or for machines that operate on fixed routes on a site, for example in a mine or quarry, where overheard powerlines can be installed.

Electric powertrains are significantly more efficient than fossil fuel equivalents.[13] ERM research suggests that battery electric powertrains are 80% efficient and tethered powertrains 90% efficient. This is compared to 33% efficiency for diesel powertrains. Increased powertrain efficiency can result in cost savings for the user, in terms of reduced operating costs to power the machine to complete a set task. Smaller electric machines could also be used to complete a task that previously required a larger fossil fuel powered machine to complete. However, the cost of electric machinery, in particular battery electric machines, can be greater than that of fossil fuel equivalents. The deployment of electric machines might also be limited by a lack of suitable charging infrastructure onsite.

Electric machinery (both battery and tethered) provides additional benefits including: zero tailpipe air quality emissions, lower maintenance costs, reduced noise, improved operator health and comfort, and avoided risks associated with onsite fuel storage.[14]

Hybrid machines combine an engine with battery technologies and are commercially available across a range of machinery types and sizes. While fuel (typically diesel) is still burnt, the amount of fuel required to deliver a task is reduced due to the higher efficiency of hybrid powertrains, estimated to be 37% to 66% efficient.[15]

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[13] Powertrain efficiency refers to the ratio between the useful kinetic energy provided by the engine or motor and the energy in the fuel or battery consumed. This does not include any energy losses in the rest of the machine outside of the powertrain (for example energy losses from hydraulic systems is not included).

[14] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

[15] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

Hydrogen

Hydrogen can be deployed as a fuel in either an internal combustion engine (ICE) or a fuel cell (FC). A hydrogen FC converts hydrogen into electricity to power the machine. Hydrogen FC powertrains are estimated to be 45% efficient compared to 30% for hydrogen ICE powertrains.[16] For certain applications, such as generators and lighting towers, hydrogen FC machines are already commercially available. As with electric technologies, hydrogen FCs are zero emission (zero greenhouse gas and air quality emissions), and offer reduced noise compared to ICE machines. It is reported, however, that hydrogen FCs might be less suited for use in rugged environments due to potential susceptibility to vibrations.

A hydrogen ICE burns hydrogen as a fuel, in combination with air, to power the machine. According to ERM's research, hydrogen ICEs emit zero greenhouse gas emissions, from the fuel combustion, while emitting a level of air quality pollutants such as NOx.[17] Innovation continues to move at pace on hydrogen ICE, however, with a number of OEMs investing in this technology and significant reductions to NOx emissions in real world conditions may be possible in the future. Hydrogen ICE machines are similar to fossil fuel powered machines to manufacture, maintain, and operate which might reduce the need for retraining and reskilling that might be required for electric and hydrogen FC powertrains. However, new skills are required for the distribution and storage of hydrogen to enable the safe use of both hydrogen ICEs and hydrogen FCs.

Biofuels and other low carbon fuels

Biofuels refer to a range of fuels that are derived entirely from biomass. They are typically blended at low volumes with fossil fuels; using these fuels in higher blends usually requires adaptations to vehicles and infrastructure. "Drop-in" biofuels can be used at 100% to replace fossil diesel without modification of the engine. The main drop-in fuel in the market is hydrotreated vegetable oil (HVO) which is certified for all modern engines, though some kinds of NRMM are able to use higher blends of standard biodiesel. However, the sustainable supply of HVO is limited and the fuel currently costs more than fossil diesel. Another option is FAME (fatty acid methyl ester) which can in many cases be blended up to 20% with fossil diesel (known as B20) and used within existing diesel machines. Biogas can also replace CNG where currently used, for example in forklifts.

On farm, innovative technologies that rely on the use of farm waste products, the capture of methane for biogas and other green fuels could provide a valuable opportunity for decarbonising agricultural machinery.

The greenhouse gas savings biofuels can achieve on a life-cycle basis compared to fossil fuels will vary depending on feedstocks and processing technologies used. When used in internal combustion engines, biofuels typically will not reduce tailpipe emissions.

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[16] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

[17] Industrial non-road mobile machinery: decarbonisation options – techno-economic feasibility study https://www.gov.uk/government/publications/non-road-mobile-machinery-decarbonisation-options-feasibility-study

Low carbon fuels also encompass renewable fuels of non-biological origin (RFNBOs), including some synthetic diesel and methanol, as well as recycled carbon fuels that are fuels produced from fossil wastes and gases that would have been emitted otherwise. Depending on the fuel, these can either be deployed in existing machinery, for example synthetic diesel, or require an alternative powertrain to be produced.

Unlike electricity and hydrogen, many biofuels and other low carbon fuels can also be supplied to sites that use NRMM with incumbent refuelling infrastructure. Though, depending on the fuel and fuel blend used, some adaptations may be required.

25. **Has fuel switching been attempted in the NRMM type(s) or sector(s) that you are interested in? If so, please list the alternative fuels that have been switched to.**

26. **Where fuel switching has been attempted, what have been the outcomes?**

27. **Are there any promising fuel switching options that have not been included in this section relevant to the NRMM type and/or industry that you are interested in?**

28. **What do you see as the necessary fuel switching options for the NRMM type(s) and/or sector(s) that you are interested in?**

29. **If you own, rent/lease, and/or operate NRMM, have you at any point decided to reduce emissions from these machines? If so, what were your main considerations when doing so? If not, why have you not sought to do so?**

3. Deployment considerations

As noted in the previous chapter, certain decarbonisation options are already starting to be deployed, such as the use of electric machinery in construction and the design and production of increasingly efficient machines. However, challenges remain to the deployment of decarbonisation options in many instances. In this chapter we are interested in views on the potential opportunities and co-benefits arising from the deployment of the decarbonisation options discussed in Chapter 2, as well as the potential barriers to their deployment.

Opportunities and co-benefits

In addition to addressing GHG emissions, the development, production, and deployment of NRMM decarbonisation options also present significant opportunities and potential co-benefits. We have grouped these below by category as many might apply across NRMM types and decarbonisation options. We are seeking views on to what extent these apply and what others might exist.

Financial and economic

- Reduced operating costs. For example, through reduced fuel consumption, or through the removal of the need for ancillary equipment to mitigate the emissions from NRMM such as exhaust aftertreatments or ventilation equipment for underground work.

- Export potential for UK based manufacturers. The UK has a significant NRMM manufacturing base and can lead on the global development and deployment of low and zero carbon NRMM, supporting UK jobs and exports.

Operational

- Reduced noise from the operation of low and zero carbon NRMM might allow sites to work beyond current operating hours in urban settings, or be more suited to use in proximity to animals in farm settings.

Air quality and health

- Reduced air quality emissions directly benefit the health and well-being of those who work with NRMM and also those who live and work nearby sites where NRMM is used.

30. Do you agree that these are the main opportunities and potential co-benefits to the deployment of NRMM decarbonisation options?

31. Are there any other opportunities and/or potential co-benefits?

Barriers

As many of the potential barriers might apply across NRMM types and decarbonisation options, we have grouped these below by the following categories: technical readiness, financial and economic, infrastructure and fuel supply, operational, regulatory, and knowledge and information. The barriers listed are not necessarily exhaustive nor applicable to all NRMM types, sectors, and/or market actors. Some are market failures (such as imperfect information, split incentive market structure, limited incentives for R&D investment with impact on commercial readiness, uncosted negative emission externalities) where there might be a stronger rationale for government intervention, while others are barriers that may still need to be addressed in order to enable decarbonisation. We are seeking views on the extent to which these barriers exist and their significance.

Technical readiness

- Limited commercial availability of low and zero carbon NRMM, due to low technology readiness levels (TRLs) of alternative powertrains. While progress has been achieved, with a range of machines brought to market, design challenges can be a particular issue, in particular for higher powered machines that require a range of movement when operating and/or are used for extended operating hours. This is primarily due to the lower energy density of some low and zero carbon fuels, compared to diesel. This therefore requires either machine efficiency gains, increased onboard fuel/energy storage, increased refuelling, or a combination of the three for fuel switching to be achieved.
- Unsuitability of alternative powertrains for use in certain operating environments, for example hydrogen FC technologies which might be susceptible to damage when used in rugged environments.

32. Do you agree that these are the main technical barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant technical barriers exist?

Financial and economic

- Upfront cost (CAPEX) of low and zero carbon NRMM is often higher than fossil fuel equivalent machines, partly due to limited production and higher input costs, such as the cost of batteries.

- Low and zero carbon fuel costs are often greater than fossil fuel equivalent, due to limited supply and/or higher production costs.
- Split incentives. Total cost of ownership (TCO) might be lower if a low or zero carbon machine is used often enough, for example due to lower electricity costs compared to diesel and lower maintenance requirements of a battery machine. However, the ownership model of the machine might mean that TCO is not considered when purchasing, for example when a machine is owned by a hire company. The person operating a machine might also not be responsible for the cost of the fuel consumed, reducing the incentive to use a machine in the most fuel efficient way.
- Difficulties in securing finance and/or insurance for alternatively powered NRMM, in particular where machines are considered novel and/or perceived to have lower resale value.
- Resale value of low and zero carbon NRMM might be reduced if export markets where machines have been traditionally sold into are unable to support the use of alternative powertrains, for example hydrogen machinery.

33. Do you agree that these are the main financial and economic barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant financial and economic barriers exist?

Infrastructure and fuel supply

- Grid connections and grid capacity are limiting factors for the electrification of some NRMM. These can be particularly challenging and costly for remote sites, such as farms or quarries, and/or temporary sites, such as construction sites, to install. Long lead times for grid connections are an issue, particularly for non-permanent sites. Where a grid connection is available, additional charging points might still be required and the connection itself might not be sufficient to support the recharging/use of multiple machines at once.
- The hydrogen fuel supply chain needs to be developed further, including the production, transportation, and storage of low carbon hydrogen. The delivery of hydrogen to remote and non-permanent sites is likely to require transportation of hydrogen by road.
- The supply of sustainable biofuels is limited, and there is competing demand from other transport modes and sectors.
- The supply of other low carbon fuels is limited, due to limited feedstocks with competing demand from other transport modes and sectors, or high electricity demands in the case of synthetic fuels.

34. Do you agree that these are the main infrastructure and fuel supply barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant infrastructure and fuel supply barriers exist?

Operational

- Additional space might be required on-site to enable the use of low and zero carbon NRMM. Certain fuels, such as hydrogen, require more space to be stored, per unit of energy, compared to fossil fuels. Additional or enhanced storage solutions, on-site and on the machine, might also be required to manage safety risks associated with these fuels. Whereas battery electric machines might require minimum distances between them when recharging due to fire risks. This may be a barrier where space is limited, for example on a construction site or at a seaport.
- Where machines are used for extended operating hours, this may require more frequent refuelling of machinery than what currently happens or, in the case of battery electric NRMM, two or more machines operating in shifts might be required to replace a single machine.
- Alternative powertrains, such as the inclusion of battery packs, might increase the overall weight of NRMM. This might be a consideration when transporting units by road or, in the case of TRUs, it might reduce the overall payload of the vehicle or limit the situations in which they can be deployed.
- Overestimating the size of machine required to complete a task or not receiving the appropriately sized machine that has been specified is a barrier to the efficient use of a machine.

35. Do you agree that these are the main operational barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant operational barriers exist?

Regulatory

- Greater investment risk in low and zero carbon NRMM due to lack of policy certainty – the perceived risk of backing a technology which is not favoured by future policy.
- Regulatory position of export markets might also affect decision making on whether to invest in certain low and zero carbon NRMM technologies
- A lack of harmonisation of standards across global markets for low and zero carbon NRMM might depress investment in certain new technologies.

- Regulation around transportation, storage, and use of alternative fuels might deter or restrict their adoption.
- Some alternative powered NRMM need to be made eligible for approval for sale in the UK, known as ‘type approval’.
- Regulation around where alternatively powered NRMM can be used, for example hydrogen powered machines on the road, might deter or restrict their adoption.

36. Do you agree that these are the main regulatory barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant regulatory barriers exist?

Knowledge and information

- While certain decarbonisation options have been adopted, such as biofuels within certain sectors, there remains a lack of awareness of decarbonisation options and sources of reliable information on them. Understanding of decarbonisation options might also be unevenly distributed across market actor types and differently sized organisations.
- A lack of familiarity with new technologies, or processes, might deter users from adopting them due to concerns around the potential impact on the quality of work and/or time taken to complete a task.
- Lack of skills required to produce, operate, and/or service alternative powered NRMM, or lack of skills required for the distribution and the safe handling of alternative fuels.

37. Do you agree that these are the main knowledge and information barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant knowledge and information barriers exist?

38. Are there any barriers to the adoption of decarbonisation options for the NRMM type(s) and/or sector(s) that you are interested in which have not been included in this section?

39. For the NRMM type(s) or sector(s) that you are interested in, please score each barrier category (e.g. financial and economic) in terms of its impact on the deployment of decarbonisation options using the scale below. Please provide a rationale for any scores of 4 and 5, noting where applicable any variation by NRMM type, sector, or decarbonisation option.

0 = Don't know / not applicable

1 = Not at all important

2 = Slightly important

3 = Moderately important

4 = Important

5 = Extremely important

40. How does the current usage and ownership structure of NRMM in the UK present opportunities and/or challenges for decarbonising NRMM?

4. Policy considerations

This chapter seeks views on the extent to which, and how, government should support NRMM decarbonisation. It explores the following topics:

- Whether there are gaps in the existing policy framework that supports NRMM decarbonisation;
- What policy principles should guide our considerations of whether further public support of NRMM decarbonisation is merited, and what the nature of the government's role should be if so; and
- Potential policy approaches to support NRMM decarbonisation.

Existing and planned policies

A range of policies have been implemented or are planned to be implemented to support NRMM decarbonisation, either directly or indirectly, in the UK. We recognise that policies outside of the UK might also impact upon how, and at what rate, NRMM decarbonises.

Table 2: Existing UK NRMM decarbonisation related policies

Existing policy	Description
Renewable Transport Fuel Obligation (RTFO)	Production of low carbon fuels is key to enabling the decarbonisation of all transport modes, including NRMM. DfT supports certain types of NRMM through the RTFO, which considers them as non-road transport. This broadly covers the use of renewable fuels consistent with the wider RTFO in an NRMM context. Government is developing a Low Carbon Fuels Strategy that will set out the government's vision for the deployment of low carbon fuels in transport, from now to 2050.
Removal of the Red Diesel Rebate	In April 2022, the entitlement to use rebated 'red' diesel and biofuels was removed from most non-agricultural users of NRMM to incentivise fuel switching and efficiency measures.
Action Plan on Accelerating Grid Connections	Government recently published a joint Connections Action Plan (link) with Ofgem, which includes measures that will reform the electricity network connections process to accelerate connections for all customers, including sites that use NRMM. Through these reforms, we aim to improve connection timescales so the significant majority of projects can connect in line with their realistic project requirements.

Existing policy	Description
Red Diesel Replacement Competition	The Red Diesel Replacement (RDR) programme provides up to £40 million grant funding to support innovation in the development and demonstration of low and zero carbon alternatives to red diesel for the construction, mining and quarrying sectors. The programme is split into two phases and is funded through the £1 billion Net Zero Innovation Portfolio (NZIP). Phase 1 funded projects to develop component technologies related to distribution, storage and energy delivery systems, equipment component/sub-systems, and fuel development, which were at TRL 4 or above at project start. Under Phase 1, 17 projects were awarded a total of approximately £6.7 million (up to £460,000 per project) over 11 months - find out more about these projects here. Phase 2 supports the physical demonstration of an end-to-end system/solution to replace existing red diesel using technologies on construction, mining or quarrying sites, including engineering design, build, trial, decommissioning, market, assessment and knowledge dissemination. The budget for each demonstration project will be between £1 million and £12 million. Phase 2 closed to applicants in March 2023.
Industrial Energy Transformation Fund (IETF)	The IETF supports industrial sites with high energy use to transition to a low carbon future. The fund targets existing industrial processes, helping industry to cut energy bills by investing in more efficient technologies and reduce emissions by bringing down the costs and risks associated with investing in deep decarbonisation technologies. In autumn 2022, the IETF expanded its scope to include projects that improve the energy efficiency and/or reduce emissions of NRMM. Phase 3 of the IETF, worth up to £185 million, will launch in January 2024. The budget includes £175 million of capital grant funding from the £6 billion announced at the 2022 Autumn Statement to support DESNZ to deliver energy efficiency objectives.
Net Zero Hydrogen Fund	The Net Zero Hydrogen Fund (NZHF), worth up to £240 million, funds the development and deployment of new low carbon hydrogen production to de-risk investment and reduce lifetime costs.
Hydrogen Production Business Model	The hydrogen production business model (HPBM) provides revenue support to hydrogen producers to overcome the operating cost gap between low carbon hydrogen and high carbon incumbent fuel.

Existing policy	Description
Tees Valley Hydrogen Transport Hub	The Hub brings together government, industry, and academia to explore hydrogen use across transport. One of the winning projects is using hydrogen internal combustion engine to power airside vehicles which will inform future policy.
Advanced Propulsion Centre UK (APC)	The Advanced Propulsion Centre UK (APC) provides grant funding and expertise to support and accelerate the development and commercialisation of zero-emission vehicle technologies, from spinout and start-up innovations to late-stage, scale-up collaborative R&D competitions, and capital transformation investment grants, anchoring the future of the UK's strategically important net-zero supply chain.
The Advanced Manufacturing Plan	The Advanced Manufacturing Plan set out our intention to launch an industry taskforce, which will recommend how government could maximise investment opportunities for UK manufacturing of hydrogen propulsion systems. Delivered in partnership with the Hydrogen Innovation Initiative and Innovate UK, and reporting into the Hydrogen Delivery Council, this taskforce will publish recommendations in Spring 2024, considering our manufacturing strengths, the potential of hydrogen propulsion systems across applications, and potential technology developments to 2050.
Driving the Electric Revolution Programme (DER)	The cross-sector Driving the Electric Revolution programme aims to accelerate the capability and growth of the Power Electronics, Machines (motors) & Drives (PEMD) supply chain in the UK.
Farming Innovation Programme (FIP)	The FIP is a £270 million fund to stimulate innovation and boost sustainable productivity in agriculture and horticulture. The fund will help to unlock innovation and pull-through R&D to deliver farmer-led solutions. Rounds of funding have included thematic competitions on automation, robotics, and climate smart farming. The latter included new energy efficient machinery for in-field operations.
Farming Equipment and Technology Fund (FETF)	Part of the £30 million Farming Investment Fund (FIF), FETF offers small productivity grants to support farmers and growers. This includes grants for equipment focussed on improving agricultural productivity and reducing GHGs in line with net zero targets, such as Direct Drills for precision drilling of arable and cover crops.

Existing policy	Description
Clean Maritime Demonstration Competition (CMDC)	The multi-year Clean Maritime Demonstration Competition (CMDC), which provides funding to support the design and development of low to mid technology-readiness levels clean maritime technologies. Clean Maritime Demonstration Competition Round 1 (CMDC1) launched in March 2021, before the full UK SHORE programme was announced. CMDC1 allocated over £23 million to support 55 feasibility studies and technology trials for clean maritime technologies and greener ports across the UK, including Orkney and Belfast. The competition ended on 31 March 2022.
Project TRT-e, seeking to design, develop and manufacture a prototype of zero-emission Trac Rail Transposer, was awarded funding in 2020.	Trac Rail Transposers are used on railway infrastructure for removing and replacing rails. The project aimed to create a working prototype, removing the diesel power unit and developing an electric motor, battery power pack and electronic control system with remote condition monitoring to produce a zero-emission machine.
DfT are currently conducting a research project, investigating the emissions produced by auxiliary engines on HGVs. These can take a variety of forms, with the most common being transport refrigeration units (TRUs).	There are four outputs for the project: • A baseline survey of the number, type and use profile of HGV auxiliary engines in Great Britain; • Establish baseline emission profiles (GHGs, NOx and particulates) for some of the most commonly used HGV auxiliary engines through real world testing and monitoring; • A review of the current level of technological development of low or zero emission alternative engines; and • Recommendations for how Government can promote or incentivise uptake of these new technologies by operators of HGVs that use auxiliary engines.
Critical Minerals Strategy	The UK's Critical Minerals Strategy, published in 2023, sets out the government's approach to critical minerals, including those integral to the production of decarbonisation technologies such as batteries.

Table 3: Planned UK NRMM decarbonisation related policies

Planned policy	Description
Review of Electricity Markets Arrangements (REMA)	This review of electricity market arrangements will identify reforms needed to transition to a decarbonised, cost effective and secure electricity system.
Road use of NRMM fuelled by hydrogen	DfT is preparing legislation to allow the road use of NRMM fuelled by hydrogen where that machinery would otherwise be allowed to be driven on the road if powered by conventional fuels. This will enable, for instance, the movement of hydrogen NRMM, such as diggers, for short distances between construction sites. DfT plan to consult on the draft legislative text in 2024.
Hydrogen Transport and Storage Business Model	The British Energy Security Strategy made a commitment to design new business models for hydrogen transport and storage (T&S) infrastructure by 2025. In summer 2022, government consulted on the high-level design of these business models as well as strategic planning for hydrogen T&S infrastructure. We have set out our preferred high-level designs for the business models for hydrogen transport and storage infrastructure as well as setting out more detail on government approach to strategic planning. We published the minded to positions and government response to the consultation in summer 2023 which can be found through the following link along with the original consultation (link). The business models aim to unlock investment and remove market barriers to support the development of hydrogen T&S infrastructure. We intend to publish the full application guidance for the first hydrogen transport business model allocation round before the first allocation window opens in 2024.
Fuel Price Rebalancing	In ‘Powering Up Britain’, the government accepted the recommendation from the *Independent Review of Net Zero* that government should commit to outlining a clear approach to gas and electricity price rebalancing and should make significant progress affecting relative prices by the end of 2024. We are working to develop our approach to rebalancing to meet these commitments and will provide further information in the coming year.

Planned policy	Description
Zero Emissions Airport Operations Target	In February 2023, DfT published a call for evidence on the 2040 Zero Emission Airport Target. DfT will publish a summary of responses and a government response shortly, which will be followed by a consultation. DfT envision that airport specific NRMM, for example ground support equipment, will be addressed through this target. However, other more general NRMM (such as construction machinery) will be addressed through a broader NRMM context.
Seaports Decarbonisation	DfT has begun scoping on how to better understand the range of solutions for reducing emissions at ports. DfT will publish a Net Zero Ports call for evidence in due course, recognising the need to coordinate with others across government and industry on this work.

41. Do the policies contained in Tables 2 and 3 provide sufficient support for NRMM decarbonisation? If not, what are the gaps in the current policy landscape?

42. Are you aware of any other policies (either current or in development) that could positively or negatively impact NRMM decarbonisation?

Policy principles and approaches

We would welcome views on what policy principles government should have regard to, when considering its role in supporting the NRMM sector to achieve net zero, and what policy interventions may therefore be appropriate in support of this role.

We note that the following principles were contained in the Industrial Decarbonisation Strategy (IDS):

- "government intervention should focus on addressing market failures or barriers to decarbonisation. Intervention should be technology neutral, and fairly share the cost and risk between industry, consumers, and taxpayers."
- "where decarbonisation leads to significant costs that creates carbon leakage risk, it should be supported by targeted intervention to mitigate this risk."
- "government should play a key role in delivery of large infrastructure projects for key technologies (for example CCUS and hydrogen networks) where there is a shared benefit, and the risk or cost is too great for the private sector."

- "government should intervene to deliver specific strategic outcomes in line with wider priorities set out in Build Back Better: our plan for growth" and updated in the Net Zero Growth Plan.

43. Are the IDS policy principles appropriate in relation to NRMM decarbonisation?

44. What additional policy principles should government consider with regards to NRMM decarbonisation?

We also request evidence on potential policy approaches that government could undertake in support of NRMM decarbonisation and address the deployment considerations discussed in the previous chapter. The following list is illustrative, not exhaustive, and not mutually exclusive. We are seeking to understand the potential advantages and disadvantages of different policy approaches.

- **Demand creation.** Government could seek to use its market position in relevant sectors, such as construction, to increase demand for low and zero carbon NRMM, for example as part of the tendering process.

- **Regulate.** Government could regulate to support and enable the deployment of low and zero carbon fuels, such as through type approvals for alternative powertrain machines and amending rules relating to how low carbon fuels can be handled and stored. Regulations that are identified as unsuitable for, or unnecessarily hindering the development and/or deployment of, low and zero carbon NRMM could also be removed. It may also be possible to support the decarbonisation of NRMM through regulation that requires that only low or zero carbon machines are operated in certain locations, for example in urban areas. Similarly, government could develop regulation that requires the sale of new NRMM in the UK to be increasingly fuel efficient or to be low or zero carbon from a certain date.

- **Fund.** Further funding could be provided to support the research, development, and demonstration of new technologies and/or supporting infrastructure. Funding could also be provided to help reduce the cost imbalance between low and zero carbon and fossil fuel powered NRMM and/or the cost of low and zero carbon fuels.

- **Enable.** Government could seek to provide demonstrations of new technologies and techniques and for these learnings to be shared across the relevant sectors, to help reduce information and skills barriers.

45. How could government best contribute to establishing optimum market conditions to increase the rate of NRMM decarbonisation?

46. How might the role of government change over time in aid of NRMM decarbonisation?

47. What factors should we consider when assessing the suitability of different policy options?

48. Are there any existing models or international examples of policy that government could implement to incentivise NRMM decarbonisation?

49. Is there any further relevant information that has not been asked about which you would like to submit?

Part II – Industrial NRMM detailed modelling assumptions

In this part of the call for evidence, we ask a series of questions that discuss detailed aspects and assumptions of DESNZ commissioned research (the ERM report published alongside this call for evidence (link)). The purpose of this section is to validate or improve upon these assumptions. Modelling helps to support policy making by providing an estimate of cost-effective decarbonisation technical potential, under different scenarios. It is therefore important that this modelling is based on accurate and robust assumptions, as far as possible.

Please only respond to this part of the call for evidence if you have experience relevant to the content of this section.

One of the key evidence gaps that ERM's research identified was a lack of site level data. To address this, we are seeking to understand the usage cycles of industrial NRMM better. To inform policy development, we also want to understand the impacts of industrial NRMM use-cases on the availability of decarbonisation options.

Machine utilisation

1. **Can you provide evidence as to the typical hours and pattern of usage of any of the machine types listed in Annex A across an average monthly period? Please specify the sector and situation of use.**

2. **We are interested in the impact that the duration of a site has on the ability of the NRMM used on it to decarbonise. We assume that the construction sector is the only industrial sector to have temporary sites (and that seaports, waste, manufacturing, and mining/quarrying sectors are all located on sites intended for long-term or permanent use). Can you provide any evidence or data covering the duration and location of sites or projects within the construction sector?**

3. **ERM's research suggests that short-term sites will have fewer fuel switching options due to infrastructure availability, particularly outside urban areas. Are there other barriers related to site duration?**

ERM's research established a model to estimate decarbonisation pathways for industrial NRMM based on least-cost technical potential. In the following sections, we are seeking to test some of the key assumptions underpinning this modelling. Decarbonisation scenarios and pathways are key to informing the development of an NRMM decarbonisation strategy.

Archetype mapping

The ERM study mapped industrial NRMM into 14 different archetypes (groupings) in order to simplify the landscape and understand which decarbonisation options may be suitable for which machine types. (For a full discussion, see section 2.1.1 of the published report. Appendix 3 also sets out which archetypes each machinery type corresponds to).

4. **It is assumed that the machines within an archetype share similar characteristics, and are used in a broadly similar manner, such that the decarbonisation options available are the same for all machines within the archetype. This assumption is important to ensure modelling feasibility. Do you think that the industrial NRMM archetypes set out in Table 4 form an appropriate grouping for this purpose? If not, why not?**

Table 4 – industrial NRMM archetypes

Archetype ID	Machinery category	Power rating	Utilisation level
1	Hand-held/hand-moved equipment	Low (<19 kW)	All
2		High (19-56 kW)	All
3	Mobile machinery	Low (<37 kW)	Low (<50%)
4		Medium (37-129 kW)	Low (<50%)
5		High (130-560 kW)	Low (<50%)
6		Medium (37-129 kW)	High (>50%)
7		High (130-560 kW)	High (>50%)
8		Very high (> 560 kW)	High (>50%)
9	Limited movement machinery	Medium (37-129 kW)	Low (<50%)
10		High (130-560 kW)	All
11	Generators	Low (<8 kW)	Low (<50%)
12		Medium (8-74 kW)	Low (<50%)
13		High (75-560 kW)	Low (<50%)
14		Very high (>560 kW)	Very Low (<25%)

Fuel switching option – year of commercial availability

Table 5 below presents our most recent understanding of the Technology Readiness Levels (TRLs) for possible fuel switching options. These have been used to set assumptions on the future years from which commercial availability of a technology is assumed. These are key assumptions in driving transition to decarbonisation technology in our pathways.

Table 5 – TRLs of industrial NRMM fuel switching options

Archetype	Machinery category	Power rating	Utilisation level	HVO	B20	Hybrid	H2 ICE	H2 fuel cell	Tether electric	Battery electric
1	Hand-held/hand-moved equipment	Low (<19 kW)	All							
2		High (19-56 kW)	Medium							
3	Mobile machinery	Low (<37 kW)	Low							
4		Medium (37-129 kW)	Low							
5		High (130-560 kW)	Low							
6		Medium (37-129 kW)	High							
7		High (130-560 kW)	High							
8		Very high (> 560 kW)	High							
9	Limited movement machinery	Medium (37-129 kW)	Low							
10		High (130-560 kW)	All							
11	Generators	Low (<8 kW)	Low							
12		Medium (8-74 kW)	Medium							
13		High (75-560 kW)	Low							
14		Very high (>560 kW)	Low							

Section 3.8.2 of the published report discusses the table in more detail. Note in particular the following section from the report:

The TRL assignment of the abatement powertrain options for each archetype is shown in Table 43 [Table 5 above]. *The current commercial availability of industrial NRMM [discussed in Section 3.4 and Appendix 9.8] were used to determine the overall expected availability of abatement options per archetype. For most cases, the most common TRL rating within an archetype was used. In some instances, the rating was adjusted up to reflect the potential for technology transfer between archetypes, or from other sectors to industrial NRMM.*

We assume that powertrains TRLs would be commercially available according to the dates in Table 6:

Table 6 – TRL descriptions and assumed corresponding year of commercial availability

Key	TRL	Description	Corresponding year of commercial availability
	8+	Currently commercially available as an option.	2025
	6 - 7	Some current availability, expected to become more widely available from 2025 – 2030.	2030
	4 - 5	Some limited current availability (demos/trials). Not expected as a widely available commercial option before 2030.	2035
	1 - 3	Little evidence of current availability, not expected as a widely available commercial option before 2035 – 2040.	2040+
	0	Technically feasible, but no evidence of ongoing development found	NA
	-	Powertrain viewed as incompatible with archetype.	NA

5. **Do you agree or disagree with the assessed suitability of the alternative powertrains for the archetypes set out in Table 5? If you disagree, please provide an explanation and evidence where possible.**

6. **Do you agree with the years of availability assumed for each archetype? If not, please provide evidence to the contrary.**

Powertrain efficiency

It assumed that efficiency of NRMM powertrains is as set out below:

- Diesel ICE: 33%
- HVO ICE: 33% (same as diesel)
- B20 ICE: 33% (same as diesel)
- Diesel hybrid: 37% to 66%
- Hydrogen ICE: 30%
- Hydrogen FC: 45%
- Tethering: 90%
- Battery electric: 80%

7. Do you agree with the assessment of the efficiency of the powertrains listed? If not, please provide evidence to the contrary.

Hard to deploy use cases

The suitability of a fuel switching option might depend, not only on the powertrain and archetype set out above, but also on the use case. While the archetypes account for the mobility requirements of a machine when in use, its power rating, and its total annual hours of use, it is assumed that the following factors can also have implications for the suitability of fuel switching options:

- Size of the site (a larger site might be able to attract more and/or better fuel supply options);
- Duration of the site (machines used on temporary sites might be harder to fuel switch due to lack of dedicated refuelling infrastructure for fuel switching options);
- Location of site (installation of dedicated refuelling infrastructure for certain fuel switching options may be more expensive for more remote sites); and
- Usage cycle (for example, hours per shift, shifts per day, phase of work energy intensity (e.g. ground clearance compared to structural steel work), seasonal variation, and so on).

NRMM that encounter at least two of these factors are classified as 'hard to deploy'. For example, a construction excavator working in urban areas will not be hard to deploy, as there is easy access to electrical infrastructure to recharge a battery powered alternative. Alternatively, the same construction excavator working predominately at remote sites and regularly moving sites is likely to be classed as hard to deploy, as charging/refuelling infrastructure may not be economically viable to install at each site given the remoteness and short-term nature of the work.

8. Do you agree with this definition of 'hard to deploy'? If not, what other characteristics should we take into account?

Based on latest research, it is estimated that 32% of all industrial NRMM is hard to deploy. Mining has the highest proportion of hard to deploy machinery (76%), followed by waste (50%), other (36%, mostly low-powered generators), and construction and seaports (15%).

9. Do you agree with these estimates of the percentage of hard to deploy machinery across different industrial sectors? Please clearly specify the sector(s) that your answer relates to and provide any specific evidence that can validate your view.

It is assumed that the deployment of fuel switching options within the 'hard to deploy' category will face a 10-year delay on the years of availability set out in the previous section.

10. Do you agree with the assumption that fuel switching options within the 'hard to deploy' category will face a delay to becoming commercially available and that 10 years is a reasonable assumed time period for this delay? If not, what alternative would you suggest?

Modelling costs

The modelling in the research study utilises a 'least social cost' approach to identifying decarbonisation pathways. Therefore, the underlying input cost assumptions are important. In this section, we are seeking to test the specifics of the modelling approach to machine CAPEX and infrastructure costs.

CAPEX

The modelling within the ERM report calculates machinery CAPEX as:

Machine CAPEX (£ / machine)

*= Base CAPEX (£ / machine) + (Powertrain cost (£ / kW) * Power rating (kW))*

*+ (Powertrain cost (£ / kWh) * Energy storage (kWh))*

Where Base CAPEX = incumbent machine cost – incumbent powertrain cost.

The costs in Table 7 are assumed for the powertrain cost elements.

Table 7 – powertrain cost elements

Powertrain	Energy Source	CAPEX (£/kW)						
		kW 2020	kW 2025	kW 2030	kW 2035	kW 2040	kW 2045	kW 2050
ICE	Diesel	80	80	80	80	80	80	80
ICE	HVO	80	80	80	80	80	80	80
ICE	B20	80	80	80	80	80	80	80
ICE	Petrol	56	56	56	56	56	56	56
ICE	LPG	56	56	56	56	56	56	56
ICE	Hydrogen	96	96	96	88	80	80	80
HE	Diesel	144	123	107	102	100	97	95
Tethering	Electricity	51	32	21	18	17	15	13
BE	Electricity	51	32	21	18	17	15	13
FCE	Hydrogen	390	305	141	110	105	99	91
Powertrain	**Energy Source**	**CAPEX (£/kWh)**						
ICE	Diesel	0	0	0	0	0	0	0
ICE	HVO	0	0	0	0	0	0	0
ICE	B20	0	0	0	0	0	0	0
ICE	Petrol	0	0	0	0	0	0	0
ICE	LPG	0	0	0	0	0	0	0
ICE	Hydrogen	19	16	11	10	10	9	9
HE	Diesel	0	0	0	0	0	0	0
Tethering	Electricity	0	0	0	0	0	0	0

BE	Electricity	255	233	124	71	49	38	36
FCE	Hydrogen	19	16	11	10	10	9	9

11. Do you have any comments to make about the calculation used to determine the CAPEX of a machine and about the costs set out in Table 8? Where possible, please provide evidence to support your view.

Infrastructure costs

Table 8 – tethering, hydrogen, and battery electric infrastructure costs

Year	Tethering (fixed cost of cable in £)	Hydrogen (£/kg hydrogen delivered to NRMM)	Battery Electric (£/kW of charger power output)
2020	1,200	7.0	500
2025	1,200	6.2	475
2030	1,200	5.3	450
2035	1,200	4.5	425
2040	1,200	3.7	400
2045	1,200	2.8	375
2050	1,200	2.0	350

12. **Latest research suggests that tethered-electric machines would require a cable estimated to cost £1,200 (cable is assumed to be around 20m long). It is assumed that this cost would remain constant up to 2050. Do you consider these assumptions to be fit for purpose in assessing the relative costs of different options? If not, please provide evidence to the contrary.**

13. **Latest research suggests that on-site hydrogen infrastructure costs will start at £7/kg of hydrogen (delivered to the machine) in 2020 and decline linearly to £2/kg in 2050. Do you consider this assumption to be fit for purpose in assessing the relative costs of different options? If not, please provide evidence to support your view.**

14. **Latest research suggests that battery infrastructure costs will start at £500/kW of charger power output in 2020 and decline linearly to £350/kW in 2050. Do you consider this assumption to be fit for purpose in assessing the relative costs of different options? If not, please provide evidence to the contrary.**

15. **It is assumed that machines will have at least 8 hours to charge overnight and that a suitable battery size will be selected such that a full day's work can be performed without needing to recharge during the day. Do you consider these assumptions to be fit for purpose in assessing the feasibility of different options? If not, please provide evidence to support your view.**

Pathways

ERM research estimated potential pathways for industrial NRMM decarbonisation, based on technical potential and least-cost modelling. We are seeking your views on plausible pathways for industrial NRMM decarbonisation.

16. **What do you see as the plausible pathways for the decarbonisation of industrial NRMM within the sector(s) that you are interested in? (Where multiple sectors are relevant to you, please clarify if your response varies by sector).**

17. **Do you have any comments to make on the pathways presented in Chapter 5 of the ERM study?**

Other comments

18. **Are there any other comments or evidence that you would like to provide in response to the content and findings of the ERM study published alongside this call for evidence?**

Consultation questions

Part I – Call for evidence on NRMM decarbonisation options

Questions about your organisation

1. **What is your name?**

2. **What is your email address?**

3. **We usually publish a summary of all responses, but sometimes we are asked to publish the individual responses too. Would you be happy for your response to be published in full?**

4. **How did you hear about this consultation?**

5. **What is the name of the organisation that you represent?**

6. **What is the postcode of your organisation?**

7. **What type of organisation do you represent? Please select one:**

- NRMM original equipment manufacturer (OEM)
- NRMM parts supplier
- NRMM rental business
- NRMM leasing business
- NRMM user
- Trade association or other industry body
- Fuel supplier
- Academic institution
- Non-governmental organisation (NGO)
- Public sector body
- Private individual
- Other (please specify)

8. Do you operate in the UK and, if so, which areas of the UK do you operate in? Please select all that apply:

- North East England
- North West England
- Yorkshire & the Humber
- East Midlands
- West Midlands
- East England
- Greater London
- South East England
- South West England
- Scotland
- Wales
- Northern Ireland
- No UK based operations

9. If you represent a business, what size business do you represent? Please select one:

- Small (fewer than 50 employees)
- Medium (50 to 249 employees)
- Large (250 employees and over)
- Not applicable

10. Please provide the SIC code for the primary activity of your business or organisation (5-digit code if available, otherwise the most granular level).

11. Do you represent or hold expertise on NRMM in a specific sector? Please select all that apply:

- Construction
- Manufacturing site

- Mining and Quarrying
- Waste
- Agriculture
- Forestry
- Seaports
- Road freight
- Rail
- Other (please specify)

12. Do you represent or hold expertise on a specific machine type(s) or technology? If so, please specify.

13. Do you hold data on NRMM used in the UK which you would be willing to share with government? We are particularly interested in sales, usage, and ownership fleet data, although please highlight any other data that you think might be useful. In your response, please provide specifics about the data that you hold and would be willing to share.

Chapter 1 – The role of NRMM in the economy

14. Are you able to provide any additional information regarding the NRMM product lifecycle?

15. Are you able to provide any additional information regarding how NRMM is used in the sectors presented in Table 1?

16. Are there any sectors not listed in Table 1 that constitute a significant source of NRMM use and/or are particularly dependent upon NRMM for their operations?

17. If you own, rent, or lease, and/or operate NRMM, what are the main considerations when deciding what machines to procure and whether to buy outright or rent/lease?

18. DESNZ commissioned research suggests that around 33% of construction machinery is owner operated versus 67% which is either hired or leased. How does this compare to the sector(s) in you are interested?

Chapter 2 – Decarbonisation options

19. Are there any additional efficiency measures that have not been included in this section relevant to the NRMM type(s) and/or sector(s) that you are interested in?

20. What efficiency measures have been implemented in the machine type(s) and/or sector(s) that you are interested in? What were the impacts that you observed?

21. Do you agree with the estimated emissions saving range of the different efficiency measures as set out above [on page 15]? Please explain your reasoning.

22. To what extent do you think these efficiency savings will be realised through market forces?

23. Can you identify any process change(s) for the NRMM type(s) or sector(s) that you are interested in? What do you see as the abatement potential (possible emissions saving range) for these?

24. What process change(s), if any, has been attempted in the company or sector(s) that you are interested in with the intention of decarbonising NRMM? Did you observe any impacts?

25. Has fuel switching been attempted in the NRMM type(s) or sector(s) that you are interested in? If so, please list the alternative fuels that have been switched to.

26. Where fuel switching has been attempted, what have been the outcomes?

27. Are there any promising fuel switching options that have not been included in this section relevant to the NRMM type(s) and/or sector(s) that you are interested in?

28. What do you see as the necessary fuel switching options for the NRMM type(s) and/or sector(s) that you are interested in?

29. If you own, rent/lease, and/or operate NRMM, have you at any point decided to reduce emissions from these machines? If so, what were your main considerations when doing so? If not, why have you not sought to do so?

Chapter 3 – Deployment considerations

30. Do you agree that these are the main opportunities and potential co-benefits to the deployment of NRMM decarbonisation options?

31. Are there any other opportunities and/or potential co-benefits?

32. Do you agree that these are the main technical barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant technical barriers exist?

33. Do you agree that these are the main financial and economic barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant financial and economic barriers exist?

34. Do you agree that these are the main infrastructure and fuel supply barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant infrastructure and fuel supply barriers exist?

35. Do you agree that these are the main operational barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant operational barriers exist?

36. Do you agree that these are the main regulatory barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant regulatory barriers exist?

37. Do you agree that these are the main knowledge and information barriers to the deployment of NRMM decarbonisation options? If not, which barriers listed do not apply and/or what additional significant knowledge and information barriers exist?

38. Are there any barriers to the adoption of decarbonisation options for the NRMM type(s) and/or sector(s) that you are interested in which have not been included in this section?

39. For the NRMM type(s) or sector(s) that you are interested in, please score each barrier category (e.g. financial and economic) in terms of its impact on the deployment of decarbonisation options using the scale below. Please provide a rationale for any scores of 4 and 5, noting where applicable any variation by NRMM type, sector, or decarbonisation option.

0 = Don't know / not applicable

1 = Not at all important

2 = Slightly important

3 = Moderately important

4 = Important

5 = Extremely important

40. How does the current usage and ownership structure of NRMM in the UK present opportunities and/or challenges for decarbonising NRMM?

Chapter 4 – Policy considerations

41. Do the policies contained in Tables 2 and 3 provide sufficient support for NRMM decarbonisation? If not, what are the gaps in the current policy landscape?

42. Are you aware of any other policies (either current or in development) that could positively or negatively impact NRMM decarbonisation?

43. Are the IDS policy principles appropriate in relation to NRMM decarbonisation?

44. What additional policy principles should government consider with regards to NRMM decarbonisation?

45. How could government best contribute to establishing optimum market conditions to increase the rate of NRMM decarbonisation?

46. How might the role of government change over time in aid of NRMM decarbonisation?

47. What factors should we consider when assessing the suitability of different policy options?

48. Are there any existing models or international examples of policy that government could implement to incentivise NRMM decarbonisation?

49. Is there any further relevant information that has not been asked about which you would like to submit?

Part II – Industrial NRMM detailed modelling assumptions

Please only respond to this part of the call for evidence if you have experience relevant to the content of this section.

1. **Can you provide evidence as to the typical hours and pattern of usage of any of the machine types listed in Annex A across an average monthly period? Please specify the sector and situation of use.**

2. **We are interested in the impact that the duration of a site has on the ability of the NRMM used on it to decarbonise. We assume that the construction sector is the only industrial sector to have temporary sites (and that seaports, waste, manufacturing, and mining/quarrying sectors are all located on sites intended for long-term or permanent use). Can you provide any evidence or data covering the duration and location of sites or projects within the construction sector?**

3. **ERM's research suggests that short-term sites will have fewer fuel switching options due to infrastructure availability, particularly outside urban areas. Are there other barriers related to site duration?**

4. **It is assumed that the machines within an archetype share similar characteristics, and are used in a broadly similar manner, such that the decarbonisation options available are the same for all machines within the archetype. This assumption is important to ensure modelling feasibility. Do you think that the industrial NRMM archetypes set out in Table 4 form an appropriate grouping for this purpose? If not, why not?**

5. **Do you agree or disagree with the assessed suitability of the alternative powertrains for the archetypes set out in Table 5? If you disagree, please provide explanation and provide evidence where possible.**

6. **Do you agree with the years of availability assumed for each archetype? If not, please provide evidence to the contrary.**

7. **Do you agree with the assessment of the efficiency of the powertrains listed? If not, please provide evidence to the contrary.**

8. **Do you agree with this definition of 'hard to deploy'? If not, what other characteristics should we take into account?**

9. **Do you agree with these estimates of the percentage of hard to deploy machinery across different industrial sectors? Please clearly specify the sector(s) that your answer relates to and provide any specific evidence that can validate your view.**

10. Do you agree with the assumption that fuel switching options within the 'hard to deploy' category will face a delay to becoming commercially available and that 10 years is a reasonable assumed time period for this delay?

11. Do you have any comments to make about the calculation used to determine the CAPEX of a machine and about the costs set out in Table 7? Where possible, please provide evidence to support your view.

12. Latest research suggests that tethered-electric machines would require a cable estimated to cost £1,200 (cable is assumed to be around 20 metres long). It is assumed that this cost would remain constant up to 2050. Do you consider these assumptions to be fit for purpose in assessing the relative costs of different options? If not, please provide evidence to the contrary.

13. Latest research suggests that on-site hydrogen infrastructure costs will start at £7/kg of hydrogen (delivered to the machine) in 2020 and decline linearly to £2/kg in 2050. Do you consider this assumption to be fit for purpose in assessing the relative costs of different options? If not, please provide evidence to support your view.

14. Latest research suggests that battery infrastructure costs will start at £500/kW of charger power output in 2020 and decline linearly to £350/kW in 2050. Do you consider this assumption to be fit for purpose in assessing the relative costs of different options? If not, please provide evidence to the contrary.

15. It is assumed that machines will have at least 8 hours to charge overnight and that a suitable battery size will be selected such that a full day's work can be performed without needing to recharge during the day. Do you consider these assumptions to be fit for purpose in assessing the feasibility of different options? If not, please provide evidence to support your view.

16. What do you see as the plausible pathways for the decarbonisation of industrial NRMM within the sector(s) that you are interested in? (Where multiple sectors are relevant to you, please clarify if your response varies by sector).

17. Do you have any comments to make on the pathways presented in Chapter 5 of the ERM study?

18. Are there any other comments or evidence that you would like to provide in response to the content and findings of the ERM study published alongside this call for evidence?

Next steps

This call for evidence will close on 26 March 2024. We are committed to ongoing dialogue with stakeholders as we review the responses to this call for evidence and develop our policy thinking in this area. We intend to set out our response to the call for evidence as part of the planned NRMM Decarbonisation Strategy in due course.

Annex A – sample list of NRMM in scope of this Call for Evidence

Trenchers / mini excavators	**Excavators**	**Forklifts**
Telehandlers	**Rough terrain forklifts**	**Dumpers / tenders**
Rollers	**Cement & mortar mixers**	**Cranes**
Rubber tyred gantry cranes	**Pumps**	**Air compressors**
Gas compressors	**Bore / drill rigs**	**Plate compactors**
Landfill compactors	**Loaders**	**Bulldozers**
Asphalt / concrete pavers	**Generators**	**Scrapers**
Graders	**Crushing equipment**	**Aerial lifts**
Sweepers / scrubbers	**Welding equipment**	**Concrete / industrial saws**
Pressure washers	**Tampers / rammers**	**Reachstackers**
Shuttle / straddle carriers	**Port terminal tractors**	**Industrial tractors**
Material handling equipment	**Bitumen applicator**	**TRUs**
Paving equipment	**Surfacing equipment**	**Concrete pumps**
Agricultural machinery	**Agricultural tractors**	**Agricultural telehandlers**
Combine harvesters	**Forage harvesters**	**Root crop harvesters**
Sprayer	**Windrower**	

Interested parties can refer to the “MS 6 Off-Road Machinery” section of the UK Greenhouse Gas Inventory, 1990 to 2021 document, for the full list of machine types that are in scope of this Call for Evidence.
https://naei.beis.gov.uk/reports/reports?repomrt_id=1108

Annex B – glossary of terms and acronyms/initialisms

AQ – Air Quality

Biomass – Organic material from living things

B20 – Fossil diesel blended with FAME in 80:20 ratio

Defra – Department for Environment Food & Rural Affairs

DESNZ – Department for Energy Security & Net Zero

DfT – Department for Transport

CAPEX – Capital Expenditure

CNG – Compressed Natural Gas

FAME – Fatty Acid Methyl Ester

FC – Fuel Cell

GHG – Greenhouse Gas

GHGI – Greenhouse Gas Inventory

HGV – Heavy Goods Vehicle

HVO – Hydrotreated Vegetable Oil

ICE – Internal Combustion Engine

LPG – Liquified Petroleum Gas

NOx – Nitrogen Oxides

NRMM – Non-Road Mobile Machinery

OPEX – Operating Expenditure

PM – Particulate Matter

Power rating – The maximum power that can be supplied by the powertrain.

Powertrain – The part of a machine which powers the operation of the machine. This includes but may not be limited to engines, exhaust, fuel tanks, fuel cells, motors and batteries where applicable.

R&D – Research and Development

rDME – Renewable Dimethyl Ether

RTFO – Renewable Transport Fuel Obligation

Tailpipe emissions – Emissions of greenhouse gases and air pollutants directly from the machine (i.e., from the tailpipe of the machine).

TCO – Total Cost of Ownership

TRL – Technology Readiness Level

TRU – Transport Refrigeration Unit

This publication is also available on our website at www.gov.uk/government/calls-for-evidence/non-road-mobile-machinery-decarbonisation-options

Any enquiries regarding this publication should be sent to us at nrmm.cfe@energysecurity.gov.uk