HM Government

Non-Road Mobile Machinery Decarbonisation Options

Call for Evidence: Summary of Responses

January 2025

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Introduction

To help inform the policy development, the Department for Energy Security & Net Zero (DESNZ), the Department for Environment Food & Rural Affairs (Defra), and the Department for Transport (DfT) published a joint call for evidence on non-road mobile machinery (NRMM)[1] decarbonisation options.

The call for evidence sought to gather industry and stakeholder views on NRMM decarbonisation, 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 when determining whether there is a case for further government intervention to support NRMM decarbonisation.
- The call for evidence also included, in Part II, questions on aspects and assumptions of DESNZ commissioned research. The purpose of this section was to validate or improve upon these assumptions.

The departments would like to thank all those who provided a response to the call for evidence. This document provides a summary of the responses received and does not constitute government policy.

The call for evidence should be read alongside this document, as there are references to information from the call for evidence throughout.

https://www.gov.uk/government/calls-for-evidence/non-road-mobile-machinery-decarbonisation-options

[1] Off-road machinery broadly refers to any mobile machine, transportable equipment or vehicle not intended for carrying passengers or goods on the road and is installed with an internal combustion engine. In scope of the call for evidence were the machines included in the industrial off-road mobile machinery, commercial off-road mobile machinery, and the agricultural mobile machinery categories in UK Carbon Budgets. While these machines have been referred to collectively to date as non-road mobile machinery (NRMM), including in the call for evidence and in this summary of responses, government intends to use the umbrella term ‘off-road machinery’ in future. This is to avoid any potential confusion with the regulatory definition of NRMM (Regulation (EU) 2016/1628) which remains unchanged.

Executive Summary

The call for evidence was published on 21 December 2023 and closed on 26 March 2024. The call for evidence received 95 responses from a range of stakeholders during this period.

Breakdown of respondents by category

The table below provides a breakdown of the respondents to the call for evidence by market actor category.

Category of respondent	Number of responses
Trade association or other industry body	31
NRMM original equipment manufacturer (OEM)	13
NRMM parts supplier	8
NRMM rental/hire business	7
NRMM user	6
Public sector body	5
Consultant	4
Fuel supplier	3
Non-governmental organisation (NGO)	3
Private individual	3
Other	12
Total	**95**

Key Findings

Identified below are the key findings from the responses to each section of the call for evidence.

Part I, Chapter 1: The role of NRMM in the economy

Chapter 1 sought 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.

Respondents reported that NRMM is deployed in a range of different environments across multiple sectors with a variety of demands, often in rural or remote locations with limited infrastructure. It was also reported that NRMM often has multiple lives through repair and remanufacture, with the importance of residual machine values highlighted as integral to current business models, alongside export markets and the rental sector.

Part I, Chapter 2: Decarbonisation options

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

Respondents reported that machine efficiency improvements are required to enable fuel switching due to the often lower energy density of fossil fuel alternatives, however efficiency savings varied greatly by sector, environment and machine type.

Respondents reported that there is no single substitute for fossil fuels to decarbonise NRMM, with electric, hydrogen and biofuel technologies (including internal combustion engine technologies) all expected to play an important role. The suitability of, and the ability to deploy, fuel switching options are predominantly determined by the use case and site characteristics.

Part I, Chapter 3: Deployment considerations

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

It was reported that low and zero carbon NRMM can cost significantly more to purchase and operate than incumbent technologies, caused by higher input costs and the price of alternative fuels. The cost of installing recharging infrastructure was also raised as a barrier.

Certain regulations were flagged as not having kept up with technology developments or requiring further clarification.

Part I, Chapter 4: Policy considerations

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

Respondents generally regarded existing and planned policies as non-specific to NRMM and insufficient to decarbonise NRMM in line with net zero targets.

The majority of respondents agreed with the policy principles as set out in the Industrial Decarbonisation Strategy, with technology neutrality emphasised as highly important, in particular not misaligning with the policy approaches taken in key export markets.

Part II

In Part II, respondents provided views on DESNZ's detailed modelling assumptions for industrial NRMM including about patterns of use, the appropriateness of grouping of machines into archetypes, the efficiency of different power trains, and the cost of fuel and infrastructure for fossil fuel alternatives.

Next Steps

Responses to the call for evidence will be used to help inform the development of policy to support the decarbonisation of off-road machinery. Further details of which will be shared in due course.

Methodology

This document provides a summary of the views and evidence submitted in response to the call for evidence. In Part I, there were 49 questions across four chapters. In Part II, there were 18 questions. Some notes and caveats on the methodology used to prepare this document:

- A number of respondents provided either a general submission or did not respond to individual questions. Evidence from these submissions has been included in the summary of responses against questions where the information provided was deemed to be most relevant.
- Where a response to a specific question was considered to answer a different question, the information provided is summarised alongside the question deemed most appropriate.
- A number of similar themes were expressed by respondents across a range of questions. To avoid repetition, these views have either been summarised against the question deemed most appropriate, or the summaries of the relevant questions have been grouped together in this document.
- Categories are used to give an indication of the proportion of respondents that expressed certain views in relation to the number of responses to a specific question. These categories are as follows:
- 'Majority' is used when referring to 50 percent or more of respondents to a particular question;
- 'Many' is used when referring to 25 to 49 percent of respondents to a particular question;
- 'Several' is used when referring to 10 to 24 percent of respondents to a particular question; and
- 'A few' or 'a small number' are used when referring to less than 10 percent of respondents to a particular question.

- The above categories may be expressed in terms of a particular sector and/or market actor type to distinguish between the views of that group compared with the views of respondents in general (for example, ‘several OEMs’ or ‘a majority of construction sector NRMM users’).
- The summary of responses aims to reflect the balance of views and evidence submitted in response to a question. It is not practicable to detail every view or piece of evidence provided, however, all responses have been reviewed and considered by government in full.
- The views expressed by stakeholders in response to the call for evidence are not government policy, and the information submitted has not been corroborated nor independently verified during the drafting of this document.

Responses to questions 1 to 13 are not summarised in this document, beyond the breakdown by respondent category above, as these relate to identifying information about the respondent.

Chapter 1 – The role of NRMM in the economy

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

Number of responses: 48

Summary of responses:

A majority of respondents discussed lifecycle management factors of machinery. Respondents generally agreed with the lifecycle as presented in the call for evidence but reported that the turnover rate of machinery is dependent on different factors such as access to servicing, intensity of use, environmental conditions, and whether the machine is a specialist machine. However, some respondents explained that the introduction of new technologies or safety standards might result in the earlier retirement of assets. Respondents noted that where machinery is used intensively, such as in the mining and quarrying sector, serviceability and remanufacturing are particularly important.

Respondents reported that second hand and international sales of machinery are common and that this impacts the calculations for the total cost of ownership (TCO) and lifecycle CO_2 emissions of a machine. Although it was noted that this is not currently true for nascent technologies such as hydrogen fuel cell machinery. It was also noted that hydrogen fuel cell generators are often sold as part of an energy service, with the fuel provided at the same time.

Many respondents discussed end of life factors of machinery. A number of respondents reported that the high export rate of machinery meant that a lot of end of life considerations happen in other markets, with machines not usually scrapped in the UK. While some respondents highlighted the potential to recover valuable materials, such as batteries, from decommissioned machinery to recycle in the UK. Others noted that old machinery is sometimes bought back by OEMs to be repurposed or to sell parts separately.

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

Number of responses: 52

Summary of responses:

A majority of respondents highlighted the multiple use cases of machinery. Respondents explained that a range of factors determine what the best machine or powertrain is for a task including: site location, type of work, duty cycle and profile, energy demand, cost, climate, site constraints, operator, and rate of loading. Respondents also explained that machinery, such as excavators and generators, are deployed across a range of different economic sectors and can perform various different functions. Others also noted that a machine might be deployed across various sites during a day, for example machinery used on road maintenance. Respondents explained that a machine's use should not be considered to be limited to specific sectors only.

Mining and quarrying respondents reported that their sector in particular was uptime sensitive and that any pause in use of machinery, such as to refuel or due to a breakdown, impacts upon revenues. In contrast, a number of construction sector respondents reported significant rates of machine idling within their sector, while agricultural sector respondents reported that their use of machinery is often seasonal with varied operating hours.

Several respondents discussed the importance of infrastructure access. A number of respondents explained that access to the electricity grid is a key factor in determining what types of NRMM are used on site, especially for generators.

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?

Number of responses: 52

Summary of responses:

Several respondents agreed that the main sectors which use NRMM were listed in the call for evidence. However, a majority of respondents noted additional sectors that were either a significant source of NRMM use or were particularly dependent upon NRMM for their operations. These sectors include:

- Airports
- Emergency services
- Environmental protection and disaster relief
- Highways
- Landscaping
- Material handling
- Military
- Municipal
- Outdoor events and festivals
- Telecommunications
- TV and film

Respondents also noted that machines can be deployed across multiple sectors. In particular, generators were highlighted as common across a large number of sectors and that they could be used either for: primary power supply, temporary power, back-up power, or outdoor power. Some respondents also noted that the machinery listed in the call for evidence should not be considered exhaustive.

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?

Number of responses: 29

Summary of responses:

A majority of respondents discussed cost and financial considerations when deciding what machine to procure and whether to buy outright or rent or lease. These factors include the upfront cost of a machine, the TCO of a machine, business cashflow, potential for staggered payments, and policy incentives (such as capital expensing or renewable transport fuel certificates).

Respondents noted that the decision as to whether to purchase or rent a machine was often defined by its expected level of use. If it was expected that a machine would not be used sufficiently, or if its usage was uncertain, then it would more likely be hired than purchased. Other factors such as limited financing options and the residual value of a machine were also cited.

A majority of respondents also discussed factors related to the deployment requirements of a machine as influencing this decision. In particular, the performance, durability and reliability of a machine were cited. It was noted that these factors also impact the financial considerations as downtime and maintenance requirements have a cost. Other factors highlighted include the safety of a machine, how secure it is against theft, how comfortable and straightforward it is to operate, its compatibility with existing fleet, its fuel consumption, and air quality emission standard. For low and zero carbon machinery, the availability of alternative fuels and recharging times were also considered.

Some respondents explained that hiring (where a machine is purchased speculatively to meet anticipated demand) and leasing (where a contract is agreed with a customer and then a machine is sourced to fulfil said contract) are distinct business models and should not be considered collectively. Respondents noted that hire firms determine what to stock by market demand for a product and sometimes will hire a machine, for example from a partner firm, if it is not on their books and then re-hire it out to the customer. Others also reported that a hire-purchase model is sometimes preferred where a machine is hired with service and maintenance contracts, and then is retained afterwards. The importance of the distinction between hiring and leasing was made in response to several questions throughout the call for evidence.

Some agricultural respondents also mentioned factors such as location of dealership, aftersales support, and brand loyalty.

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 which you are interested?

Number of responses: 42

Summary of responses:

A majority of construction sector respondents agreed that the split between hired and owned machinery was broadly correct for their sector. Other sectors which reported mostly hiring machines include TV and film, events and festivals, and material handling.

Sectors which reported mostly owning machines outright include mineral products, waste, and agriculture.

As well as a sectoral split, respondents noted that the ownership of a machine can be influenced by the machine type, its size, and application.

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?

Number of responses: 53

Summary of responses:

Many responses discussed the potential for machine efficiency measures. Some respondents highlighted the improvements made to engine and powertrain efficiencies in recent years, while others noted that further such improvements would still be required to enable fuel switching to less energy dense fuels. The opportunity for further machine efficiency gains beyond the powertrain, for example from the hydraulics, was also highlighted. Several responses relating to transport refrigeration units (TRUs) suggested that the integration of advanced batteries in TRU systems could reduce the reliance on diesel engines.

Many responses also discussed process efficiency measures. These included the importance of using the correctly sized machine for a task, the use of telematics and other software to optimise energy use, and the importance of site design and layout.

A small number of responses discussed operator efficiency measures, noting the need for operators to be trained to use machinery more effectively and emphasising the importance of correct and timely maintenance of machinery.

Respondents also emphasised the importance of efficiency in terms of uptime or the time taken to execute a task, and that energy efficiency measures should not cut across these measures of task efficiency.

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?

Number of responses: 51

Summary of responses:

A majority of respondents noted that some form of machine efficiency improvements had been implemented in their respective machine types. Respondents reported that newer machines, as a matter of course, tended to be more efficient and that their deployment was supported in certain instances by company policies or local regulation such as the London NRMM register. Some respondents also highlighted the installation of start/stop technologies to reduce machine idling, although only applicable to certain machine types. The implementation of energy recovery systems and smart technologies for machinery use optimisation were also highlighted.

A majority of respondents also discussed process efficiency measures that had been implemented in their sector(s). The use of technologies such as telematics and digital twins was reported to improve how machines are used onsite and to identify the correctly sized machine for a task. One response explained how cloud-based monitoring, for example,

allowed for predictive and preventative maintenance to take place. A number of responses noted how combining generators with energy storage systems or renewable onsite power generation could significantly reduce the time that generators were operating at below peak power, when they are less efficient.

Several responses discussed measures implemented to improve operator efficiencies. Measures included training of operators on how to better utilise equipment and to reduce idling of machines when not in use.

The beneficial impacts observed across the different efficiency measures included: reduced fuel consumption and, therefore, cost savings; reduced air quality emissions; and reduced maintenance requirements.

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

Number of responses: 60

Summary of responses:

A majority of respondents broadly agreed with the estimated emissions savings range for the different efficiency measures. Some noted that process efficiency savings might even be greater, depending on the sector in question. Generators in particular were highlighted as having a high potential for emissions reductions through efficiency measures, with generators often not operating at peak load (when they are most efficient). Possible measures included the chaining of smaller generators and combining generators with energy storage systems.

Many respondents disagreed with the estimated emissions savings range, however, including a majority of agricultural sector respondents. Some respondents considered that machine efficiency estimates were too low, for example given the current low efficiency of hydraulic systems, whereas other respondents considered the estimated emissions savings range too high. Agricultural respondents highlighted that the sector has already adopted many efficiency measures and that seasonal usage patterns can limit the scope for further efficiency measures adoption. Respondents also noted that realising efficiency gains was dependent upon the availability of skilled operators. One agricultural sector respondent, for example, estimated that 10% to 15% in fuel use variation could be attributed to the skill of an operator. Additionally, some respondents also noted that any efficiency measures had to be balanced against the potential impact on onsite productivity.

A small number of respondents disagreed with efficiency measures being calculated individually and suggested, instead, that a whole system approach should be adopted, for example using lifecycle analysis, to understand the energy consumption across the whole supply chain.

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

Number of responses: 57

Summary of responses:

A majority of respondents considered that market forces would result in the implementation of efficiency measures to a certain extent. Reducing the TCO of machinery was pointed to as driving the implementation of efficiency measures. Competition among OEMs drives machine efficiency measures, and the cost of fuel incentivises users to use machines more efficiently. A number of respondents, however, reported that the cost of fuel has a limited impact on the implementation of efficiency measures due to split incentives. It was highlighted that the operator of a machine might not be responsible for the cost of its fuel and therefore not incentivised to limit idling for example.

Many respondents reported that there might be a role for government to support the implementation of efficiency measures and increase the rate at which they are adopted. Product labelling and public procurement were given as possible policy examples. Some respondents also noted that the removal of the red diesel rebate might have delayed the uptake of newer, more efficient, machines as funding previously allocated to CAPEX was reallocated to cover higher fuel costs.

A few respondents discussed the need for greater awareness of efficiency measures and increased skill levels to increase their adoption.

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?

Number of responses: 48

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?

Number of responses: 23

Summary of responses:

A majority of respondents could identify possible process changes specific to a machine type or sector where used which could reduce emissions. Replacing generators with onsite renewable energy generation, in particular solar, was highlighted as an option across industrial sectors. Some construction sector respondents also highlighted the potential for off-site manufacturing and design changes which could reduce the need for NRMM onsite. Agricultural sector respondents highlighted minimum till or no till farming and other regenerative techniques, which have significant co-benefits for soil health as well as reduced machinery use. The potential to use autonomous machines was also identified by some construction sector and agricultural sector respondents. Some respondents with an interest in TRUs reported the potential use for solar and energy recovery to reduce the need for auxiliary engines to cool cargos.

However, many respondents could not identify, or were unaware of, possible process changes that could be implemented to reduce emissions from NRMM.

Where process changes had been implemented, many respondents reported positive impacts, notably reduced fuel consumption and, therefore, reduced costs and emissions. Some agricultural sector respondents highlighted that this helped to support the transition to regenerative farming practices.

Several respondents reported negative impacts where process changes had been made. These included increased operational complexity and costs for one TRU operator. Other respondents explained that process changes can negatively impact on overall site efficiency.

Several respondents provided a neutral view on the impacts of process changes.

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.

Number of responses: 75

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

Number of responses: 57

Summary of responses:

A majority of respondents reported fuel switching to biofuels, including all agricultural sector respondents. Hydrotreated vegetable oil (HVO) was the most commonly referenced biofuel, with fuel switching to fatty acid methyl ester (FAME) blends, bio-methane, and bio-LPG also reported.

A majority of respondents reported fuel switching to electric machinery had been attempted. Primarily to battery electric machinery, with tethered electric, hybrid electric, and solar all also switched to.

A majority of respondents reported fuel switching to hydrogen powered machinery, both fuel cell and internal combustion engine (ICE) technologies.

Many respondents reported fuel switching to renewable fuels of non-biological origin (RFNBOs) including renewable dimethyl-ether (rDME), synthetic fuels in general, and ammonia.

A small number of respondents had either not attempted to fuel switch or were unaware if such attempts had been made.

A majority of respondents reported positive impacts of fuel switching. Reduced carbon and air quality emissions in particular were highlighted. Fuel savings were also reported for example from electric machinery. Other positive impacts included reduced noise emitted from operation and reduced maintenance requirements. HVO was reported to be an effective drop-in replacement for diesel, without impacting on performance, however, concerns about the sustainability of the source of HVO were also expressed.

A majority of respondents also reported negative impacts of fuel switching, primarily related to the higher cost of alternative fuels compared to fossil fuels and the lack of supporting

infrastructure to enable the deployment of certain fuels. Negative impacts on operations were also reported including long recharging times for electric machinery and reduced efficiency of drop-in alternative fuels.

A few respondents expressed a neutral view on the impact of fuel switching options.

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?

Number of responses: 58

Summary of responses:

Many respondents pointed to other promising fuels which had not been explicitly included in the call for evidence. These fuel switching options were:

- Hydrogen dual fuel ICE
- Ammonia (as a fuel and as a carrier for hydrogen)
- Methanol
- Ethanol
- Solar
- Higher biodiesel and FAME blends

One respondent highlighted interchangeable batteries to enable battery swapping in electric machinery. Another suggested that hydrogen's cold energy presented an opportunity to decarbonise TRUs. Some respondents also reported that research into fuel switching options and alternative powertrains is ongoing and that further research should not be limited by policy.

Many respondents agreed that all promising fuel switching options had been listed in the call for evidence.

A few respondents did not know whether or not other promising fuel switching options exist.

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?

Number of responses: 75

Summary of responses:

A majority of respondents considered electric machines to be necessary fuel switching options. Primarily battery electric, but also tethered electric, hybrid electric, and solar.

A majority of respondents also saw hydrogen powertrains as necessary fuel switching options. The number of responses which raised hydrogen ICE and hydrogen fuel cell technologies as necessary fuel switching options were broadly similar. A small number of respondents also highlighted hydrogen dual fuel technologies.

A majority of respondents reported that biofuels were necessary fuel switching options for NRMM. HVO was most commonly cited, other biofuels reported were FAME blends (including higher blends than B20), biomethane, bio-LPG, and ethanol. Respondents noted that certain biofuels have the advantage of being drop-in replacements that can be used in existing machinery.

Many responses considered other low carbon fuels to also be necessary to decarbonise NRMM. These included RFNBOs such as rDME, synthetic LPG, and ammonia.

A number of respondents also expected that ICE technologies would be used over the long term, requiring ongoing access to low carbon liquid and gaseous fuels.

Overall, views on necessary fuel switching options were fairly consistent across industrial, agricultural and transport sector respondents.

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?

Number of responses: 31

Summary of responses:

A majority of respondents had decided to reduce emissions from the machines which they either owned, hired out, or operated. Corporate responsibility, towards the environment and their workforce, combined with environmental sustainability and governance (ESG) targets, was highlighted as one motivating factor. Business models were another factor, some businesses are dedicated to the provision of low carbon fuels or NRMM, whereas others saw a cost reduction by reducing their emissions. One agricultural respondent reported that on-farm biomethane offered long-term revenue saving for the farmer. Others cited growing demand by customers for low carbon alternatives, although with the caveat that customers were not always willing to pay a premium for this. Regulatory compliance was also highlighted, for example the London NRMM register.

Many respondents reported that they had decided not to reduce emissions from their machines. The higher cost of low carbon alternatives and their lack of availability were commonly referenced as reasons by respondents. One respondent reported that they had switched to HVO but operational issues meant that this decision was reversed. Another respondent highlighted the lack of incentive for fuel suppliers to switch to alternative fuels when the cost of incumbent fuels is far lower.

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?

Number of responses: 57

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

Number of responses: 48

Summary of responses:

The majority of respondents agreed with the opportunities and potential co-benefits to the deployment of NRMM decarbonisation options as presented in the call for evidence. Many respondents emphasised the export opportunities for UK based manufacturers and for the UK to lead on the global transition to low and zero carbon machinery, promoting the creation of skilled jobs within the green economy. Many also noted integrated energy solutions as an opportunity, aligning with fuel switching options and infrastructure in other sectors, such as marine, for example. Some respondents highlighted the opportunity for increased energy security, citing both a reduced reliance on imported fossil fuels and the possibility of battery electric NRMM serving as mobile energy storage units. A small number of respondents also mentioned that decarbonising NRMM would reduce downtime due to a reduction in maintenance requirements. Some respondents explained that an increase in the use of electric machinery would also result in fewer fuel deliveries to sites, reducing the number of refuelling trucks on the road and their associated emissions. Respondents also suggested that reduced noise levels were also a health benefit in and of themselves for those working with machinery.

Agricultural sector respondents, in particular, highlighted the potential for onsite production of biomethane from waste which could then be used to power machinery, feed into the gas grid, or sold to other end users. Some agricultural respondents also reported that improved soil health was a potential co-benefit from reducing the number of passes over fields by a machine.

Many respondents disagreed, however, that these were the main opportunities and potential co-benefits to the deployment of NRMM decarbonisation options. Some respondents disagreed that fuel switching would result in significant reductions in noise pollution from the operation of NRMM, explaining that the work undertaken by a machine generates greater levels of noise than its powertrain. Others argued that limits on air quality emissions are already regulated for, and so there was less opportunity for these to reduce through machine decarbonisation.

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?

Number of responses: 63

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

Number of responses: 59

Summary of responses:

A majority of respondents agreed that the main technical barriers to the deployment of NRMM decarbonisation options had been identified in the call for evidence. Several respondents commented that while fuel cell technologies may exist, they are challenging to operate in off-road settings. These respondents noted that, although the automotive and NRMM sectors shared similar incumbent technologies, possible decarbonisation options were not necessarily common to both.

Many respondents disagreed that these were the main technical barriers to the deployment of NRMM decarbonisation options. Several respondents argued that the technology readiness levels (TRLs) were considered to be too low in the call for evidence and provided examples of alternatively powered machinery that is already commercially available.

A majority of responses, including the majority of agricultural sector respondents, scored the technical barrier category as either ‘important’ or ‘extremely important’. Responses primarily reported that alternatively powered machinery was either lacking in their sector or, where available, was not as effective compared to incumbent technologies. Some reported a need for R&D support to develop the decarbonisation options required in their sector. While others reported a need for new technologies to be proven to work before they would be adopted at scale. Agricultural respondents also reported that the weight of a machine was an important factor due to considerations related to soil compaction.

A number of OEMs did not consider technical barriers to be a significant barrier to the deployment of NRMM decarbonisation options, arguing that the technologies were ready, or near ready, and that production could be increased to meet customer demand, given sufficient lead times. It was also suggested that not all decarbonisation options would reach commercial maturity and that those which made use of existing supply chains and components were better placed to do so.

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?

Number of responses: 72

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

Number of responses: 64

Summary of responses:

A majority of respondents agreed that the main financial and economic barriers to the deployment of NRMM decarbonisation options had been identified in the call for evidence. Several respondents disagreed that the main financial and economic barriers to the deployment of NRMM decarbonisation options had been identified in the call for evidence. Several respondents neither agreed nor disagreed, or did not know, if the main financial and economic barriers to the deployment of NRMM decarbonisation options had been identified in the call for evidence.

A considerable majority of respondents scored the financial and economic barrier category as either ‘important’ or ‘extremely important’.

Respondents noted that the majority of NRMM sales are business to business and that businesses are not sufficiently incentivised currently to pay a premium for low and zero carbon NRMM, in particular for those sectors which operate on low margins and are at risk of being undercut. It was also noted that machinery is often hired out, with the depreciation of the asset determining the cost at which the machine is rented. Uncertainty over the residual value, and demand for, certain low and zero carbon NRMM (such as battery machines) means that rental costs for these machines are likely to be higher than incumbent technologies. It was suggested by some that the cost of certain fuel switching options would reduce as production volumes increase, however, others explained that NRMM manufacturing lacks the economies of scale of the automotive sector and, therefore, that costs might not reduce to parity with incumbent technologies. This might apply more to certain fuel switching technologies and end use sectors which use specialist NRMM. Limited access to insurance and limited financing options for novel technologies was also cited as a barrier to their adoption.

The higher cost of alternative fuels was also highlighted as a significant issue. This applied to both drop-in fuels, such as HVO, and fuels for alternative powertrains such as hydrogen. The installation of alternative refuelling, and recharging, infrastructure was reported as a financial barrier. It was also explained that the company operating the NRMM might not have the ability to install the necessary infrastructure, for example where they did not own the land where the work was being undertaken. Split incentives were also highlighted as a potentially limiting factor on the efficient use of fuels in machinery. For example, the operator might not be the person who pays for the fuel.

Respondents also highlighted policy factors as having an impact on financial and economic barriers to NRMM decarbonisation. Some reported that greater certainty over future alternative

fuel supply was required to enable private investment in decarbonisation options. The uncertainty around the eligibility of certain hydrogen fuel cell NRMM to claim renewable transport fuel certificates was highlighted by a number of respondents. Others explained that policy support was required to help with the purchase of low and zero carbon machinery, such as capital allowances or low interest rate loans.

A few respondents reported that the additional cost of any decarbonisation measures must also be considered against the benefits realised through their deployment, such as reduced carbon and air quality emissions.

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 financial and economic barriers exist?

Number of responses: 76

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

Number of responses: 64

Summary of responses:

A majority of respondents agreed that the main infrastructure and fuel supply barriers to the deployment of NRMM decarbonisation options had been identified in the call for evidence. Several respondents disagreed that the main infrastructure and fuel supply barriers to the deployment of NRMM decarbonisation options had been identified in the call for evidence. A small number of respondents neither agreed nor disagreed, or did not know, if the main infrastructure and fuel supply barriers to the deployment of NRMM decarbonisation options had been identified in the call for evidence.

A considerable majority of respondents scored the infrastructure and fuel supply barrier category as either ‘important’ or ‘extremely important’.

Regarding infrastructure and supply barriers for electrification technologies, respondents noted that NRMM is often operated at remote or rural sites, such as farms and quarries, which lack a grid connection. Respondents reported that connecting these sites to the grid often presented significant challenges such as cost. In addition, it was highlighted that the temporary nature of certain sites limited the ability to install a grid connection, as well as the rationale to do so. Others pointed out that the nature of certain deployment scenarios, such as disaster relief work or moving sites, meant that grid connections were not possible. Grid capacity was also highlighted as a limiting factor, both in terms of capacity to individual sites and in terms of total grid capacity for all machines in the current fleet to electrify. It was suggested that solar, or other onsite renewable power sources, could be used to alleviate some grid connectivity and capacity issues, however, it was also highlighted that the planning system can sometimes act as a barrier to the installation of such measures.

Regarding infrastructure and supply barriers for hydrogen technologies, respondents reported that the current lack of hydrogen production and supply is a significant barrier to the

deployment of hydrogen powered machines. Respondents called for greater certainty for investment in hydrogen supply chains to increase. It was also noted that it was particularly challenging to provide hydrogen infrastructure to remote or transient sites. The planning system was also highlighted as a potential barrier to the onsite production of hydrogen using electrolysers.

In addition to hydrogen, a lack of supply of other low carbon fuels was also highlighted as a barrier. Some respondents considered alternative fuels to play an important role, in particular where electrification and hydrogen were not available or viable. The higher cost of HVO, compared to diesel, and concerns over the sustainability of its supply were also reported as potential barriers to its adoption.

For TRUs, it was noted that they are often reliant upon progress in heavy goods vehicles (HGVs) decarbonisation, with access to alternative refuelling or recharging infrastructure deployed at HGV depots.

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 financial and economic barriers exist?

Number of responses: 70

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

Number of responses: 61

Summary of responses:

A majority of respondents agreed that the main operational barriers had been discussed in the call for evidence. Many respondents disagreed that the main operational barriers had been discussed in the call for evidence. A small number of respondents neither agreed nor disagreed, or did not know, if the main operational barriers had been discussed in the call for evidence.

Many respondents, including a majority of agricultural respondents, scored the operational barrier category as either ‘important’ or ‘extremely important’.

Safety and space requirements were highlighted by respondents as important considerations and potential barriers to the deployment of decarbonisation options. It was noted that smaller sites might not be able to install electric chargers with the correct spacing requirements, for example. The safe use of alternatively powered machinery was also reported as a potential barrier, for example the handling of different fuels or the use of high voltage cables on site. Some respondents explained, however, that limited space is already a challenge for incumbent technologies and that certain liquid and gaseous fuels do not pose any additional safety or space requirements for their use and storage.

It was commented upon that the operational barriers cited in the call for evidence do not necessarily apply to all decarbonisation options and that the extent to which operational barriers are a factor can depend on machine type and usage profiles.

Some respondents highlighted additional weight of machinery, such as battery electric machines, as an operational barrier. For TRUs, reduced payloads were reported as a potential issue, and soil compaction issues in agricultural settings were also raised. However, for other applications, such as excavators, it was reported that greater weight was a potential benefit.

The performance of certain fuel switching technologies was also noted as a potential operational barrier, in particular in sectors where machines are used intensively and where usage is weather dependent, such as agriculture. There was concern among certain respondents that electric machines might not be suitable for these types of deployment scenarios due to operational factors such as longer charging times. Concerns around adequate technical and maintenance support were also expressed.

Some respondents noted that behavioural and cultural changes would be required to adopt decarbonisation options and that this might be more challenging for smaller firms, in particular where additional training was required.

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 financial and economic barriers exist?

Number of responses: 66

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

Number of responses: 60

Summary of responses:

A majority of respondents agreed that the main regulatory barriers had been discussed in the call for evidence. Several respondents disagreed that the main regulatory barriers had been discussed in the call for evidence. A few respondents neither agreed nor disagreed, or did not know, if the main operational barriers had been discussed in the call for evidence.

A majority of respondents scored the regulatory barrier category as either ‘important’ or ‘extremely important’. However, many respondents did not score the regulatory barrier this way.

Respondents highlighted the need for regulatory clarity and certainty. Uncertainty over hydrogen storage regulations and over support for hydrogen fuel cell usage under the Renewable Transport Fuel Obligation (RTFO) were both highlighted as examples where further clarity could be provided. A lag between technological advancements and regulatory changes was also highlighted as a potential barrier, in particular for hydrogen transportation and storage. International alignment with UK export markets was also reported as highly important for future investment, with some respondents pointing to the difference of approach taken to date between the EU and UK on the use of hydrogen ICE in on-road transport settings.

Some agricultural sector respondents reported that the red diesel rate should also apply to other lower carbon fuels to help incentivise decarbonisation. While other respondents reported

that the continued existence of the red diesel rebate for fossil fuels was a barrier to decarbonisation. Some respondents explained that the fuel efficiency of machinery should be clearly reported and be comparable across different products, to support consumers to purchase or rent the most efficient machines. One respondent noted that any such regulation should focus on emissions per unit of work completed and not output of power delivered at the flywheel to account for energy losses elsewhere in the machine, such as the hydraulics.

Of the respondents who did not score the regulatory barrier category as either 'important' or 'extremely important', some explained that there are no such barriers preventing the deployment of certain decarbonisation options such as solar or battery technologies.

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 financial and economic barriers exist?

Number of responses: 64

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

Number of responses: 62

Summary of responses:

A majority of respondents agreed that the main knowledge and information barriers had been discussed in the call for evidence. Several respondents disagreed that the main knowledge and information barriers had been discussed in the call for evidence. A few respondents neither agreed nor disagreed, or did not know, if the main knowledge and information barriers had been discussed in the call for evidence.

Many respondents scored the knowledge and information barrier category as either 'important' or 'extremely important'.

Respondents reported that a lack of familiarity with new technologies and alternative fuels was a barrier to their adoption. In particular, respondents noted a lack of information regarding what decarbonisation options are available to them and what the emissions savings of different options are, with concerns cited around HVO in particular. Further, respondents noted that the prioritisation of machinery uptime and reliability meant that users were less likely to take a perceived risk by using an unfamiliar technology. Respondents also explained that there was a lack of information internationally. The need for clear information on decarbonisation options and the demonstration of alternatives was highlighted as important to reducing the impact of this barrier.

Respondents also reported that a lack of skills was an issue for the deployment of alternatively powered machinery, both in terms of its operation and delivery of fuel to sites, but also in terms of design and procurement.

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?

Number of responses: 55

Summary of responses:

Many respondents thought that there were additional barriers to the adoption of NRMM decarbonisation options which had not been included in the call for evidence. On the other hand, many other respondents did not think that there were any additional barriers which had not been included in the call for evidence. A few respondents did not know whether there were any additional barriers.

Additional barriers reported by respondents included a lack of broader international initiatives and collaboration. Respondents also noted that a general lack of clarity and certainty over future policy on NRMM decarbonisation and access to low carbon fuels was a barrier. A need for cultural changes in certain sectors, in terms of accepting and implementing changes to current practices, was also highlighted.

In addition to concerns around the sustainability of certain fuels, such as HVO, some respondents also reported concerns around the ethical or sustainable sourcing of materials required for battery electric technologies, suggesting that this might limit their uptake.

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

Number of responses: 43

Summary of responses:

A majority of respondents reported that the current usage and ownership structure of NRMM in the UK presented challenges to decarbonisation. The cost of low and zero carbon NRMM and of alternative fuels was consistently highlighted by respondents as an issue. Respondents noted that rental firms cannot be cost competitive if offering low and zero carbon NRMM options versus firms offering incumbent technologies. Further, the hire price of a machine is often determined by its upfront cost and residual value. Therefore, a more efficient machine that is more expensive to purchase would likely cost more to hire and might not be selected by the consumer who would otherwise save on fuel costs. Similarly, the uncertain residual value of battery electric and fuel cell machinery means that their rental costs are often higher. Further, it was noted that users are not paid more for work undertaken with low and zero carbon machinery and so have little incentive to hire them.

Split incentives were also highlighted in the rental market as a potential challenge. For example, some rental firms also sell the fuel used to the hirer of the machine and therefore might not be incentivised to hire out the most efficient machinery or to ensure that the customer does not hire a machine which is larger than what is required for the task. It was also reported that rental firms might seek to purchase low and zero carbon machinery which can be deployed in the majority of circumstances, rather than increasing their fleet size to cover more eventualities, and that this might limit the availability of low and zero carbon machinery for certain applications. How to dispose of machines no longer in use or no longer compliant with regulations was also raised as a concern.

Many respondents reported that opportunities also exist. These included the opportunity for firms to meet their ESG targets or similar sustainability goals through the decarbonisation of NRMM used by them or their contractors, particularly in the construction sector where the end customer determines the approach taken. However, it was noted that this applied more to larger firms. A further opportunity cited was the flexibility of the rental sector to supply low and zero carbon machinery where needed, and that regular fleet turnover meant that change could happen quickly. However, it was also noted that the NRMM hire sector currently lacks policy support to do so.

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?

Number of responses: 72

Summary of responses:

A majority of respondents did not consider the policies outlined in the call for evidence to provide sufficient support for NRMM decarbonisation. Respondents noted that many of the policies presented in the call for evidence are not specific to the barriers to NRMM decarbonisation. In addition, some respondents explained that, where policies did exist, these were too granular in approach and that they did not provide a long-term whole system approach. While others noted that certain NRMM using sectors had not been included in NRMM specific policy measures to date.

A majority of respondents reported that additional policy support was needed to help address the cost of low and zero carbon NRMM and the cost and supply of low carbon fuels, as well as access to recharging infrastructure. Respondents noted that, while policies to increase grid connections and rebalance electricity costs against gas prices might help, they do not address the fundamental issues around lack of grid connections and capacity, especially to remote and rural sites, as well as the high costs to address them.

Regarding hydrogen, some respondents considered that policy support for hydrogen is focused on the production side without the equivalent focus on its use. Others flagged that hydrogen fuel cells are not currently supported under the RTFO and that this was inhibiting their adoption. One respondent reported that the Net Zero Hydrogen Fund was a positive contributor to the scaling up of hydrogen production and use. However, others reported that more support for smaller volume hydrogen supply was needed.

A number of respondents discussed how the uptake of HVO could be incentivised. Cost was cited as a major barrier to its wider deployment and suggested reviewing the relative taxation applied to HVO, and other drop-in fuels, compared with fossil fuels.

Many respondents reported that regulatory measures were either lacking or in need of updating to support NRMM decarbonisation. For example, some respondents highlighted that requiring a new Written Scheme of Examination when hydrogen powered machinery is relocated is a challenge, in particular given a potential lack of qualified persons to assess machinery as more machines enter the market. Others suggested that regulation could be used to increase demand for low and zero carbon machinery, such as requiring its use in urban areas, alongside other demand side measures such as public procurement.

Several respondents, including a majority of agricultural sector respondents, discussed the need for policies to support further innovation and development of decarbonisation options. Some respondents welcomed the Red Diesel Replacement competition as a positive step towards supporting low and zero carbon NRMM development. The Industrial Energy Transformation Fund was also cited by one respondent as having been well received by the sector.

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

Number of responses: 42

Summary of responses:

Many respondents highlighted further policies which have or are expected to have a positive impact on NRMM decarbonisation. The London NRMM register was highlighted as driving changes within the construction sector and was suggested as an approach that could be adopted in other locations. Construction sector stakeholders also highlighted the Construction Playbook, associated guidance, and the BSI PAS 2080 as measures that incentivise the use of NRMM decarbonisation options that are most appropriate to a project. It was also noted that such measures were a good example of an ecosystem approach to decarbonisation.

Support for the development of low carbon fuels was also highlighted, such as the need for a published Low Carbon Fuels Strategy and the ongoing policy work on biomethane production. Others reported that the introduction of the zero emission HGV and infrastructure strategy could have a positive impact on TRU decarbonisation.

Many respondents also discussed policies which they considered might have a negative impact upon NRMM decarbonisation. Several respondents discussed hydrogen policy and regulation. Concerns included limitations of the hydrogen business model and allocation rounds for risk taking intermediaries and the emissions classification of hydrogen engines. A small number of respondents reported that the removal of the red diesel rebate had not driven efficiency savings, but rather delayed the purchase of new and more efficient machinery. The Green Gas Support Scheme was also highlighted as incentivising the sale of biomethane into the gas grid over its use onsite to decarbonise operations where produced. Planning regulations were also cited as having a potentially negative impact on the installation of small-scale renewable energy generation.

Several respondents did not know of any other policies that might impact NRMM decarbonisation.

43. Are the Industrial Decarbonisation Strategy (IDS) policy principles appropriate in relation to NRMM decarbonisation?

Number of responses: 63

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

Number of responses: 56

Summary of responses:

A majority of respondents agreed that the policy principles set out in the IDS, published by the previous government, were appropriate in relation to NRMM decarbonisation. Several respondents disagreed that the IDS policy principles were appropriate and many respondents did not know whether the IDS policy principles were appropriate or not. Of the respondents who disagreed that the IDS policy principles were appropriate, some explained that a focus was also needed on efficiency measures and fuel switching options for incumbent machinery.

Of those who agreed with the IDS policy principles, several respondents emphasised the importance of technology neutrality, explaining that a variety of fuel switching options is required due to the range of use cases of machinery. A number of respondents also discussed the importance of taking a lifecycle emissions approach and that policy should set targets based on lifecycle emissions rather than emissions at the tailpipe. The need for alignment with international markets was also reported by a number of respondents, to ensure that policy does not negatively impact upon the competitiveness of UK businesses.

Others underlined the importance of fairly sharing the costs between industry, consumers and taxpayers. A few respondents also highlighted the need for government to play a role in the delivery of large infrastructure projects, such as alternative refuelling infrastructure. Agricultural sector respondents, while generally agreeing with the IDS policy principles, noted that they were not specific to agriculture.

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

Number of responses: 63

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

Number of responses: 41

Summary of responses:

A majority of respondents discussed the need to address the cost difference between incumbent technologies and alternatively powered machinery and their fuels. In particular, respondents highlighted the need for policy support to increase the supply of low carbon fuels, as well as improve electricity grid access to sites. Respondents also emphasised the need to create demand for low and zero carbon machinery to help reduce their cost and suggested leveraging public procurement in the construction sector to achieve this.

Many respondents advocated for regulation to incentivise or require the use of low and zero carbon NRMM. Options put forward included the use of low emission zones where only certain NRMM types could be deployed, and also product labelling and accreditation schemes to help inform customers of machinery to select the most efficient machine for example.

Several respondents also suggested measures to help address knowledge and information barriers. These included a role for government in the demonstration of new technologies, and the sharing of best practice or guidance on NRMM decarbonisation options. It was noted that public procurement could play an important role in demonstrating new technologies and evidencing best practice.

Several respondents discussed the need for policy support for innovation and technology development. A small number of respondents discussed the need for policy support for battery recycling and other circularity measures.

Some respondents suggested that policy should target certain machine types, for example the most common or the largest machine types, or certain market actor types such as rental companies. While others suggested that a holistic approach was required.

Respondents generally saw the role of government at the start to set a policy framework that provides certainty for investment in decarbonisation options. Respondents suggested that the role for financial support and incentives was greatest initially to help establish the market for new technologies, alongside the demonstration of these technologies. It was explained that any regulatory measures, for example requiring the use of new technologies, should be signalled clearly in advance and should come after earlier policies to help establish these markets. Respondents expected that the role for government would then reduce over time once the costs of new technologies started to fall, while there would be an ongoing need to monitor the impacts of policy and to review approaches taken internationally.

Some respondents highlighted the need for effective collaboration across all levels of government, including with local authorities and devolved administrations, as well as working closely with industry and seeking to build upon initiatives where these already exist and are effective.

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

Number of responses: 49

Summary of responses:

Many respondents reported the need for a sector specific approach to policy design, explaining that what might be applicable to the construction sector might not work for the agricultural sector, for example. Several respondents explained that the full lifecycle emissions should be considered, including fuel production and machinery end of life. Several respondents also emphasised the importance of taking a technology neutral approach, explaining that the variety of NRMM and the breadth of its use meant that there would not be a single solution. Respondents explained that policy should be flexible, enabling the development and deployment of new technologies, rather than prescribing a solution.

Several respondents explained that policy should consider how the costs and impacts are distributed across different market actor types, such as OEMs and NRMM end users, to ensure a fair approach. A few respondents noted that wider social and environmental impacts, such as air quality emissions, should also be taken into account when designing policy. A few respondents also reported the need to ensure that policy makes NRMM decarbonisation cost effective, otherwise it is unlikely to happen. A small number of respondents emphasised the need for clear signalling of policy, taking a long-term approach, while others reported the need for policy to be implemented quickly.

Other factors raised included the importance of international markets, the need for further R&D and demonstrator projects, ensuring that policy is enforceable, and that existing policies such as the RTFO are optimised to enable NRMM decarbonisation.

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

Number of responses: 38

Summary of responses:

A number of policies were highlighted, both international and UK schemes. International policy examples included subsidies for the purchase of zero emission machinery, for example in the Netherlands and California, as well as municipal level regulations on the use of machinery or procurement standards, for example in Oslo. The schemes cited tended to relate either primarily or exclusively to the construction sector.

Schemes to support the development and production of low carbon fuels were also highlighted, such as tax relief for synthetic fuels in Germany, hydrogen production in the Netherlands, and biomethane production in various European countries.

In the UK, the London NRMM register was highlighted as an example which government could adopt more widely, as was the subsidy for electric HGVs.

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

Number of responses: 30

Summary of responses:

A range of additional information was provided in response to this question and others in the call for evidence. Some respondents highlighted that the transportation of NRMM to sites also needs to be decarbonised. Others that the enforcement of policy is important, with some respondents reporting that some contractors might bid on the basis of using low and zero carbon NRMM but then not deliver on this during the work. One respondent emphasised that smaller firms need to be considered when making policy, as their ability to implement changes might not be the same as larger companies. Others suggested that a national register of NRMM was required to help monitor the impact of policy and identify where policy should be targeted. A number of respondents emphasised the need to consider the lifecycle emissions of machinery and their fuels, such as the sourcing of biofuels or how hydrogen is produced. Some agricultural respondents highlighted the need to work more closely with farmers to transition to low carbon NRMM. Others highlighted that the largest gains for net zero in agriculture will lie outside of fuel switching options for NRMM, in areas such as soil management, fertiliser use, and livestock methane emissions.

Part II – Industrial NRMM detailed modelling assumptions

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. - Evidence on typical hours and pattern usage?

Number of responses: 23

Summary of responses:

Many respondents explained that usage patterns vary by use case, with factors such as sector, site location, season, and task undertaken, all impacting the hours of use. As such 'typical' hours of machine usage do not exist. It was also noted that using averages fails to reflect the use cases at the extremes which are important to consider when determining feasible decarbonisation options. A few respondents discussed the use of certain types of machinery, either providing a detailed use case summary or examples of typical hours. While many others offered to provide further information upon request.

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?

Number of responses: 14

Summary of responses:

Many respondents listed sectors or use cases, outside of construction, where sites are temporary, these included:

- Disaster response
- Festivals
- TV and film
- Forestry
- Agriculture
- Road rehabilitation
- Generators used as emergency back-up power

Many respondents reported that machines are not present onsite for the duration of the site, explaining that the machine will only stay onsite for the period of time that it is required. One

respondent said that this was especially true for larger machinery. Respondents also noted that machines can move day to day between sites and that some sites might only be open for a day.

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?

Number of responses: 20

Summary of responses:

A majority of respondents reported that this can also be true of long-term sites, where financial barriers might prevent the installation of infrastructure in the first place. Many respondents also noted that short-term sites in urban areas also face difficulties in accessing fuel switching infrastructure. Many respondents explained that connecting to the grid, or upgrading a grid connection, is also a barrier. Several respondents noted that recouping investment costs on the installation of infrastructure would be challenging. One respondent also reported that the supply of hydrogen to sites is a problem.

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?

Number of responses: 34

Summary of responses:

A majority of respondents either disagreed entirely or disagreed with caveats that the industrial NRMM archetypes set out in the call for evidence form an appropriate grouping for modelling purposes. Other factors highlighted were:

- Infrastructure availability and proximity to it
- Climatic conditions
- Duty factor
- Hours of use per day
- Light or heavy use
- Site specific factors

Many respondents considered the use case of a machine to be of greater, or equal, importance to its technical specification. Several respondents reported that more than one powertrain option would need to be available across an archetype and that government should not mandate a technology per archetype. Several respondents also suggested that analysis should be on an individual machine level, not a generalised approach at archetype level. A small number of respondents reported that the sector in which a machine is used will have an

impact. One respondent noted that there were no biogas options in the archetype mapping, and another noted that the 'hard to deploy' use cases were not included in the archetype mapping either. On the other hand, many respondents agreed with the archetypes, with a few respondents acknowledging the difficulty involved in modelling these machines.

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.

Number of responses: 39

Summary of responses:

The number of respondents who agreed and disagreed with the assessed suitability of the alternative powertrains for the archetypes set out in the call for evidence were broadly similar. Several respondents either provided a neutral response or did not have a view.

Of the respondents who disagreed, several reiterated that the use of archetypes was unsuitable. Some respondents highlighted that certain biofuels and RFNBOs, such as biomethane and rDME, had not been included in the table. Other respondents noted that HVO can be used across all archetypes. One respondent considered tethered electric to be unsuitable for mobile machinery, while another considered its TRLs to be higher than presented. Some respondents reported that hybrid machines, while commercially available, can have a limited impact if used at a high power continuously.

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

Number of responses: 39

Summary of responses:

A majority of respondents disagreed with the years of availability assumed for each archetype in the call for evidence. Many respondents reported that some hydrogen fuel cell machinery, such as generators, are already commercially available and so should be assumed to be available sooner. Many respondents also noted that hybrid technologies are already available and should be assessed at TRL 8+ across archetypes. Several respondents considered that hydrogen ICE should be assumed to be available sooner, with some suggesting by 2030. Several respondents explained that biomethane is already at a TRL level of 8+ and is currently used in tractors in the medium power rating band and in generators. Several respondents reported that the TRLs for electric machinery should be higher, mostly for low to medium archetypes. A few respondents reported that lead times to procure technologies should also be factored in.

Many respondents agreed with the years of availability assumed for each archetype, or certain archetypes, with several respondents either providing a neutral response or answered that they did not know.

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

Number of responses: 39

Summary of responses:

Many respondents disagreed with the assessment of the efficiency of the powertrains listed in the call for evidence. Respondents considered diesel ICE efficiency to be higher, between 37% and 45%, with the most common view being 40% efficiency. The same also applied to HVO and B20 used in diesel ICE machines. It was also noted that hybrid technologies applied beyond just diesel.

Many respondents discussed hydrogen fuel cells, with some reporting that efficiencies could be over 50%. While others explained that the efficiency of a hydrogen fuel cell depended on factors such as its load or the ambient temperature, with efficiency dropping as low as 20% under certain conditions. Many respondents reported that hydrogen ICE efficiency levels were similar to that of hydrogen fuel cells of around 45% to 50%.

Several respondents explained that the whole system efficiency should be considered, not just that of the powertrain.

Several respondents agreed with the assessment of the efficiency of the powertrains listed in the call for evidence. Many respondents did not provide a view.

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

Number of responses: 37

Summary of responses:

A majority of respondents agreed with the definition of hard to deploy as set out in the call for evidence. A few respondents did not provide a view and many respondents disagreed with the definition.

Several respondents reported that the use case of a machine was the deciding factor in the most appropriate fuel switching option. While several respondents noted that the approach implies an equal challenge to deploy electric and hydrogen technologies in hard to deploy scenarios, which is not always the case. With some suggesting that electric options would be the more challenging of the two to deploy.

Several respondents disagreed that two of the conditions need to be met for the hard to deploy scenario to apply, while others explained that in an urban setting, electricity infrastructure might not be available.

Other characteristics suggested for inclusion in the definition included the availability of trained personnel, energy consumption, location of site, and number of machines on site.

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. - Do you agree with these estimates?

Number of responses: 26

Summary of responses:

Several respondents agreed with the estimates of the percentage of hard to deploy machinery across the different industrial sectors, while many respondents did not provide a view. However, many respondents disagreed with the estimates.

A majority of respondents thought that the estimate of 15% for construction was too low, with several respondents suggesting that the estimate should be around 90%. Many respondents discussed mining and quarrying and considered 76% to be too high, given that these sites are fixed locations and should therefore be more able to install permanent infrastructure. Respondents also noted that this was true for seaports and waste sites.

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?

Number of responses: 35

Summary of responses:

Many respondents agreed with the assumption that fuel switching options within the hard to deploy category will face a delay in becoming commercially available and that 10 years is a reasonable assumption for this time period. A few respondents did not provide a view, while a majority of respondents disagreed with the assumption.

Many respondents thought that some of the challenges to decarbonise machinery in the hard to deploy category could not be resolved by waiting. However, some agreed that a delay is a sensible approach for hydrogen infrastructure which is expected to develop overtime. Others suggested that, in many instances, the infrastructure required for electrification would not be deployable at any point.

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

Number of responses: 13

Summary of responses:

A majority of respondents considered that the costs associated with electric options appeared to be too low. Many respondents noted that the calculation did not take into account a scenario where a machine is replaced by more than one other machine. Many respondents suggested alternative values.

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?

Number of responses: 34

Summary of responses:

A small number of respondents agreed with the estimated cost of an electric cable and the assumption that this would remain constant up to 2050. Many respondents either did not know or provided a neutral response, while a majority disagreed.

Several respondents reported that 20 metres of cable was too short, with one respondent suggesting that 1km to 2km of cable would be required with an estimated cost of £60,000 to £120,000. Many respondents explained that the cost of a cable would not remain the same over time and that it would vary depending upon the costs of input materials, such as copper. Many respondents considered the cost of other factors, such as an electricity grid connection, to be more important. While many respondents reported that tethering was not a suitable fuel switching option to start with.

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 the contrary.

Number of responses: 38

Summary of responses:

A majority of respondents either did not know or provided a neutral response to whether they agreed or not with the assumed infrastructure costs for on-site hydrogen deployment. A few respondents did agree with the assumed costs, while many respondents disagreed with the assumed costs and reported that it should be higher with current values ranging between £15 and £200 per kilogram.

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.

Number of responses: 33

Summary of responses:

A majority of respondents either did not know or did not provide a view on whether the assumed cost of battery infrastructure was fit for purpose. While the numbers who agreed and disagreed with the assumed costs were broadly similar. Several respondents reported that the cost of a grid connection or upgrade far outweighed the cost of installing chargers onsite and that this needs to be accounted for.

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.

Number of responses: 40

Summary of responses:

Many respondents agreed with the assumed overnight period for battery recharging and the ability of a battery to carry out a day's work on a single charge. A small number of respondents either did not know or did not provide a view on this assumption. However, a majority of respondents disagreed with these assumptions.

Respondents explained that the assumption was unsuitable because either battery machines are not capable of doing a full day's work on a single charge yet, or because machines are used for longer than 16 hours a day. Respondents also noted that the performance of batteries will vary by machine type and use case, as some machines might be able to recharge during breaks in work. Respondents also noted other factors which should be considered, including: battery degradation, climatic conditions, power availability, and the weight of the battery.

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).

Number of responses: 27

Summary of responses:

Almost all respondents reported that drop-in fuels such as HVO, other biofuels, and synthetic fuels, would be required. Views differed on the timeframe that drop-in fuels would be required for, with some reporting that they would eventually be replaced by other technologies, while others explained that drop-in fuels would be required in the long-term for scenarios where electrification and hydrogen were not deployable.

A majority of respondents considered there to be a role for battery electric machinery, particularly for static machines (where the battery weight matters less), small and medium machines, or those with lower daily utilisation. Respondents acknowledged, however, that challenges remain for these types of machine around charging times, charging infrastructure, and cost. Access to charging infrastructure is also a challenge for tethering which many respondents considered would play a role for stationary and low mobility machinery. Although some respondents noted that tethering options have been commercially available without much uptake to date. Several respondents also saw a role for hybrid machinery.

A majority of respondents saw a role for hydrogen ICE, with many respondents also seeing a role for hydrogen fuel cell technologies. However, respondents noted the challenges around hydrogen production and distribution to sites, as well as additional operational challenges to do with hydrogen fuel cells.

Several respondents saw a role for efficiency measures, predominantly machine efficiency measures. While many respondents explained that a range of decarbonisation options is

required, each coming with their own relative strengths and weaknesses, depending on the machine and its use case.

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

Number of responses: 16

Summary of responses:

Respondents noted that the study, and modelling in particular, are on a large and complex area with significant limitations as set out in the report itself. Further limitations reported by stakeholders included:

- TCO is not always the deciding factor in which machine is purchased, rented, or deployed, in part due to ownership structures;
- The use of machinery archetypes does not sufficiently represent the use cases of the machines;
- HVO, B20, and other drop-in fuels can be adopted immediately, rather than waiting for the sale of new machinery as currently modelled; and
- Several sectors which use the same or similar machinery are not considered in the report.

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?

Number of responses: 21

Summary of responses:

Broadly, respondents reported that the research study should be considered a valuable first step to assessing ways to achieve NRMM decarbonisation, though reservations were expressed around the use of archetypes and limitations in the scenarios explored. Additionally, respondents noted that the exclusion of agriculture (and other sectors) from the scope of the research was regrettable. Several respondents expressed a desire to input further and be involved in any future discussions.

Glossary

BSI PAS – British Standards Institution publicly available specification

B20 – 80:20 diesel-FAME fuel blend

CAPEX – capital expenditure

CO_2 – carbon dioxide

Defra – Department for Environment, Food & Rural Affairs

DESNZ – Department for Energy Security & Net Zero

DfT – Department for Transport

ESG – environmental, sustainability and governance

EU – European Union

FAME – Fatty acid methyl ester

HGV – heavy goods vehicle

HVO – hydrotreated vegetable oil

ICE – internal combustion engine

IDS – Industrial Decarbonisation Strategy

LPG – liquified petroleum gas

NRMM – non-road mobile machinery

OEM – original equipment manufacturer

rDME – renewable dimethyl-ether

R&D – research and development

RFNBO – renewable fuel of non-biological origin

RTFO – renewable transport fuel obligation

TCO – total cost of ownership

TRL – technology readiness level

TRU – transport refrigeration unit

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