UK Research and Innovation

Driving the Electric Revolution in AgriFood

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Summary

To achieve UK's net-zero ambitions there is an urgency for the agriculture and food (AgriFood) sector to move to cleaner technologies. The UK government is investing £80 million in electrification technologies through the Driving the Electric Revolution Challenge to support this move.

The aim of the consultation summarised in this report was to identify opportunities and challenges related to adoption of Power Electronics, Electric Machines and Drives (PEMD) in the AgriFood sector. PEMD are the technologies that enable the control and delivery of electrical energy.

The consultation consisted of an online questionnaire (20 respondents) and 15 interviews, with various stakeholders (from farmers to construction and agricultural machinery companies) representing 33 organisations.

The AgriFood sector is an extensive and very diverse sector, and though in some parts of the sector electrification is widely adopted (like food manufacturing, glasshouses) when it comes to mobile agricultural machinery (for example tractors, combine harvesters) there is little to no adoption.

The main reason is a lack of electric alternatives. Affordable, reliable, and high autonomy battery technologies that can provide the power and long duty cycles of conventional tractors are nonexistent. The weight of such batteries is also of concern since they can lead to soil compaction with detrimental impacts to crop growth.

Swarm robotics was seen as a potential alternative to current technologies, but hydrogen and methane powered tractors were also noted.

The jury is out and policy changes, funding the development of new technologies as well as subsidies for the uptake of greener technologies, might hold the key for less carbon based agriculture.

Introduction

To reach net-zero carbon emissions the agriculture and food (AgriFood) sector must move to cleaner technologies, and electrification underpins much of this. Electrification is the process of powering by electricity and, in many contexts, the introduction of such power to replace a carbon based power source, such as fossil fuels, commonly used in the internal combustion engine.

Across every sector of society, from energy generation for our homes, to how we move around and how we make things, electrification is creating a massive need for next-generation Power Electronics, Electric Machines and Drives (PEMD). These are the technologies that enable the control and delivery of electrical energy, and these technologies are growing fast and are used across many sectors.

Their use in electrification is a major contributor to economic growth and reduction of carbon emissions.

This field is critical to the decarbonisation of the AgriFood sector, and has the potential to make a real difference in helping governments worldwide reach their net-zero target.

The UK government is investing £80 million in electrification technologies through the Driving the Electric Revolution Challenge. The investment will support the UK's push towards a net-zero carbon economy and contribute to the development of clean technology supply chains. To help understand priorities, KTN has been appointed to identify opportunities and challenges related to adoption of PEMD, from people working in the AgriFood sector.

Survey methodology

From July to August 2021, KTN consulted its AgriFood networks regarding the state-of-the-art, challenges and opportunities of the implementation of PEMD to the AgriFood sector. This consultation was done in two stages:

1st stage: Online questionnaire – disseminated via the KTN's AgriFood and PEMD webpage and newsletters (10,000+ subscribers), via a dedicated marketing list campaign (243 members), and via the AgriFood LinkedIn groups run by KTN. In total 20 individuals from various organisations responded to the survey. These included companies dedicated to:

- farm digital mapping
- aquaculture technology
- meat food production
- farming, construction and agriculture machinery
- agriculture dedicated AI and robotics
- farming analytics software
- power electronics design and consultancy
- agri-food consultancy
- food manufacturing automation
- biotechnology
- vehicle manufacturing consultancy
- project managing
- vehicles and railway PEMD design and manufacturing
- manufacturing and agri-tech centres.

2nd stage: In person interviews – in total 15 interviews were carried out. The stakeholder interviewees included academics, agricultural producers, agricultural cooperative representatives, agricultural robotics engineers, agricultural and construction machinery experts, funding and levy body representatives, food manufacturing experts, and agri-tech consultants. All those interviewed were known by the interviewers to be experts in their field.

Across both stages 34 individuals from 33 organisations were consulted and their views compiled in this report.

Online questionnaire

AgriFood is a large and diverse sector, therefore considering electrification of the sector as a whole is a challenging task. In the UK the sector can be divided into three subsectors:

- Primary production
  - Plant based agricuture
  - Crop based agriculture
  - Livestock
  - Aquaculture (production systems based on animals)
- Food processing
- Manufacturing

Within these sectors there are also marked sub-sectors, for example within livestock and aquaculture there are sub-sectors such as dairy, poultry, salmon etc.

As mentioned earlier, 20 people responded to the online questionnaire representing various subsectors of the AgriFood sector (Figure 1). In total 25% represented the livestock and aquaculture subsector, 58% the plants and crop subsector, and 17% the food processing and manufacturing subsector.

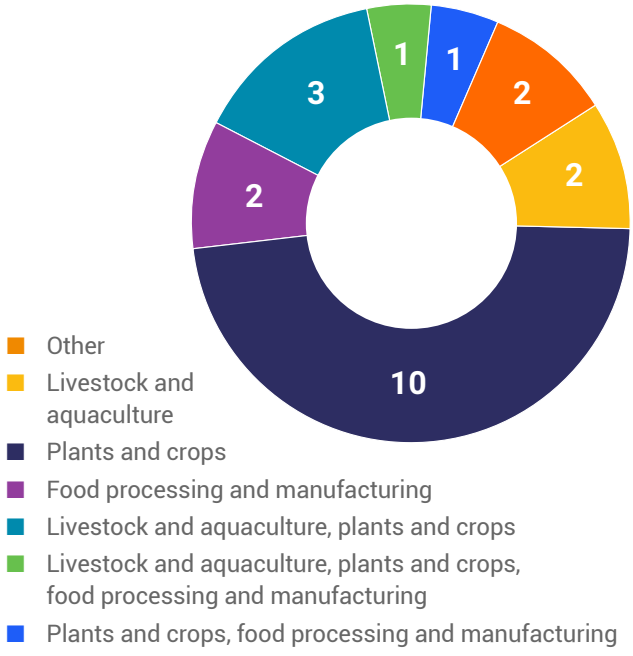
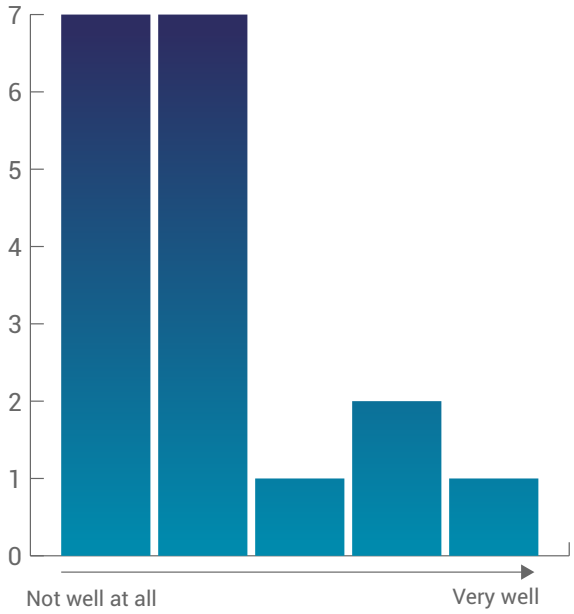


Figure 1. AgriFood sectors represented by the respondents to the questionnaire.

When asked about the adoption of electrification in their sector and supply chain, most respondents agree that the level of adoption is low (Figure 2). However, with AgriFood being such a wide and diverse sector, it is not a surprise that some respondents think that in parts of the sector the adoption is high. Furthermore, the data might also reflect the fact that most respondents were from the plants and crops subsector where there still is some lack of electric alternatives.

How well adopted is electrification in your sector?



How well adopted is electrification in your supply chain?

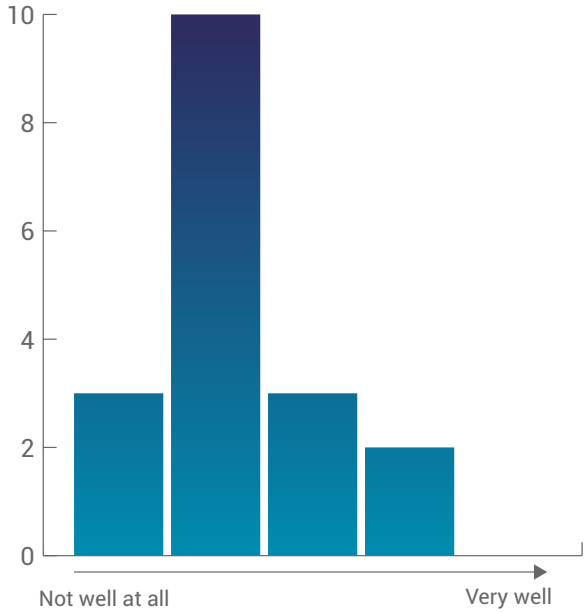


Figure 2. Responses to the adoption questions.

Accordingly, to the people questioned the AgriFood sector is rather mixed. Food manufacturing is largely driven by electric power, wherein processing equipment, variable speed drives, cool chain, and even some forklifts trucks are electric. However other parts of the sector, for example steam generation, still tend to be gas fired due to the need to maintain low costs, and road transport is, for the most part, diesel powered.

In agriculture, for example, glasshouses and vertical farming, have quite a degree of electrification, and even seed dryers that were typically diesel powered now have electric alternatives. Vehicles are still largely powered by diesel, although the major manufacturers are developing their first ranges of electric vehicles (for example, John Deere). A few new players in the market have been or are developing robots, and though early adopters exist, most are on trial.

When asked about barriers to adoption of electrification in the sector, most respondents indicated that cost, charging time and battery life were the major reasons. But range, infrastructure and performance scored relatively high too (Figure 3).

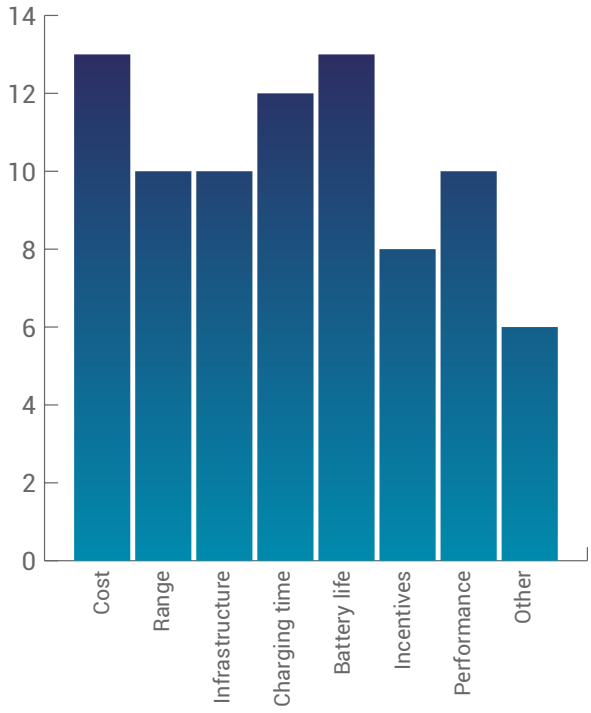


Figure 3. Scoring of the major barriers to the adoption of electrification in the AgriFood sector.

Other barriers mentioned were:

- Weight of battery-powered vehicles
- No government incentives
- Lack of funding to prove concept
- Lack of a national strategy
- Availability
- Electrification may require simultaneous adoption of new vehicles, autonomy, and new farming practices
- No confidence and knowledge of new processes.

Regarding the question 'How is net-zero encouraging adoption?', the general view was 'Not well at all' to 'Somewhat' (Figure 4).

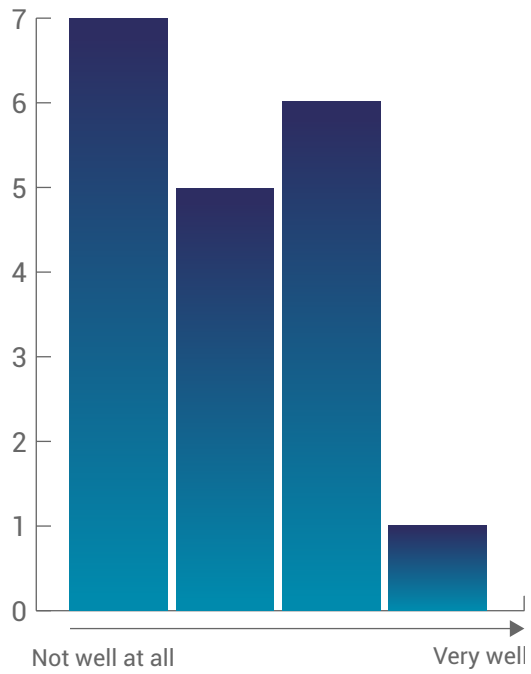


Figure 4. How strongly is net-zero encouraging adoption.

Views regarding how net-zero is driving adoption differ dramatically accordingly to the people consulted. Some see it as having a positive drive to reduce carbon emissions, leading businesses to search and adopt electric and other alternatives (like hydrogen) to replace traditional fossil fuels. However, it was recognised that implementation in some AgriFood areas has been low due to a lack of, or weak technology and infrastructure to deliver electrification. It was also mentioned that adoption might be quicker if incentives to de-risk are provided.

Some of the respondents were very critical about the net-zero concept, regarding it as a slogan created by politicians and activists, or a confusing concept difficult to define and understand. There is a need to qualify and standardise its definition, to make it more useful to everyone. In much of the agriculture subsector the general opinion is that it is still unknown how net-zero can be achieved and that the main focus is still on productivity and efficiency. This reveals a lack of clear vision around the best strategies and most effective routes to achieve the goal.

Most efforts around net-zero have been focussed on reducing waste and improving efficiency of energy usage and on-farm power generation (for example wind turbines, solar panels, and anaerobic digestion).

The largest consumption of fossil fuels was agreed to be in vehicles involved in arable crop production and logistics, however currently there is a lack of reliable alternative options.

Autonomous robots, transport and industrial vehicles were seen as the main opportunities for electrification in the AgriFood sector (Figure 5).

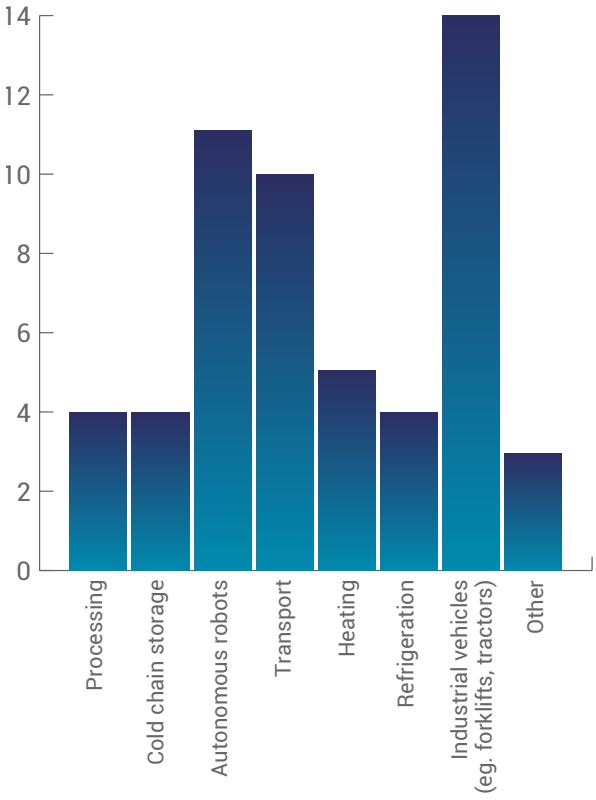


Figure 5. What are the best opportunities for electrification in the AgriFood sector.

In terms of opportunities for PEMD manufacturers, intra- (on site) and extra-logistics (between sites) and agriculture machinery is where most opportunities lie. For example forklifts, tractors, HGV, as well as boats and barges. Particularly the development of battery technologies that can lead to lighter and higher range battery for vehicles. This will rely on the development of a reliable electric infrastructure combined with onsite renewable energy generation (wind and solar), and the development of high-capacity battery storage will be needed. However, large land-based solar schemes might not be desirable, since it can lead to a reduction in the available agricultural land area, pushing food production overseas and increasing net emissions at the global level as a result. In terms of on-farm machinery, the use of small autonomous vehicles to replace heavy and long duty cycle tractors is also seen as an opportunity for PEMD manufacturers.

In person interviews

As previously mentioned in the 'Survey Methodology', 15 people affiliated with 13 organisations were interviewed. The individuals that contributed to this stage of the consultation are listed in the acknowledgments.

Key findings

In the interviews conducted by KTN the main bottleneck identified for electrification of the AgriFood sector is the electrification of heavy vehicles, mainly tractors, used in agriculture. As one of the interviewees said, tractors are a very expensive, heavy and power hungry means of transport and even more so when you connect them to an additional piece of machinery (like a plough). Tractors are key to modern agriculture and current row cropping would be impossible without these machines. However, they pose the highest challenge to decarbonisation of the agriculture subsector particularly with regards to electrification.

The biggest challenges pointed out by the various stakeholders interviewed are summarised in the table below:

Biggest challenges to the adoption of PEMD in agriculture
Constraints of the electricity network in rural areas, particularly lack of charging stations.
Power requirement for harvesting/combining, ploughing and other high energy tasks require too much energy for a conventional tractor etc (use of extended power cable akin to a slurry spreading 'umbilical cord' not practical).
At peak times, such as harvest, high power vehicles must run continuously for 12-15 hours, not allowing for any down time to recharge batteries, creating a barrier to adoption.
Low power density of current batteries, therefore large and multiple heavy batteries are needed to achieve the same as combustion engines. This will result in heavy machinery, leading to detrimental soil compaction.
Lack of engineering back up/knowledge/infrastructure to repair on-farm, and in current tractor dealers/garages.
Apparent lack of vision to redesign the tractor, with a reliance on mimicking the electric car model of simply replacing the energy source.
Poor internet connectivity in rural areas: reliable and large mobile and cable internet bandwidth may be required for modern advanced technologies for agriculture production, e.g. for the control of autonomous vehicles, data gathering and send to servers in support of precision farming, smart grid control.
Some small electric alternatives exist for agricultural machinery, however they tend to be more expensive and some would say less robust than the fossil fuel powered ones.
Lack of robust and reliable mid-size vehicles for on-farm tasks (e.g. inexistence of pickup trucks).

Though the electrification of the agricultural sector has various challenges, various opportunities were also identified by the experts interviewed, these are listed in the table below:

Opportunities for PEMD manufacturers/suppliers in the agricultural sector
High precision tasks such as spraying are better served with electric motors and can lead to a reduction in over applying fertilisers and crop protection products which will contribute to net-zero reductions.
Autonomous electrified robotic solutions (including swarms) undertaking tasks such as weeding, precision application of fertilisers and crop protection products, health monitoring and cleaning (plants and livestock). Adoption of robotics for soft fruit disease prevention (mildew) is now established and has the ability to be continuously used by exploiting northern and southern hemisphere seasons, improving the return on investment.
On-farm energy generation and storage (e.g. solar, wind and anaerobic digestors) for closed loop production systems and wider electrified power solutions (i.e. heating, ventilation and lighting in poultry sheds, dairy parlours, etc).
Electric appliances for tractors: tractors with combustion engine to carry a high voltage generator to power tractor implements (e.g. drills), these tend to be more efficient, contain less parts and have a more precise control than their mechanical and hydraulic counterparts.
On-farm charging stations to be available to the wider rural community and others. Possibly connected to farm shops, this could increase the rural tourism and farm income. This can also be undertaken in farm machinery yards of farm machinery contractors.
Use of bidirectional chargers (currently very expensive) on farm to make use of the battery of farm vehicles to stabilise the grid, taking energy from or supplying energy to the grid when required.
Electrification of small and 'light' vehicles with low duty cycles (e.g. forklifts, telehandlers, quad bikes, pickup trucks).
Developments in direct drives for tractors indicate that smaller tractors for smallholders is possible now but better suited to markets such as India where farm sizes are much smaller but with higher farm numbers.

During the interview process, a series of threats to the adoption of PEMD in the agricultural sector were identified by the interviewees, these range from alternatives to fossil fuels to user know-how, these are listed in the table below:

Threats to the adoption of PEMD alternatives in agriculture
Cost of adoption.
Hydrogen alternatives.
Gas powered alternatives.
Potentially more difficult to repair in-situ by farmers.
Autonomous alternatives may require new expertise, in terms of the user as well as repairing.
Lithium mining green credentials.

Due to the small size and low margins of the agricultural machinery market, and the threats described above, the sector might not lead the adoption of PEMD per se, and instead follow more popular and larger markets like the ones described below:

Sectors that could help the adoption of PEMD in agriculture
Business to Consumer (B2C) companies with long standing expertise in batteries and motors such as Dyson, DeWalt and Bosch are considered to have technologies that could make electrification more appealing, although there are concerns that margins in AgriFood will not be inducive.
Advances in marine and aviation sectors for alternatives to fossil fuels should be monitored and be readily adopted when proven.
Heavy duty vehicles industry (e.g. HGV and construction) adoption can potentially lead the uptake of such technologies in the agricultural machinery segment.

Throughout these interviews, the general opinion was that setting out net-zero goals for the AgriFood sector and in particular the agriculture subsector without appropriate support for technological advancements, accompanied by policy change and appropriate support to farmers will fall short of the goals set. The list of interventions identified that can lead to a faster adoption of PEMD is summarised in the table below:

Interventions that can help the adoption of PEMD in the agricultural sector
Policy.
Set out standards early on, to move from the exponential growth phase to the plateau phase of technology development sooner rather than later.
Grants for development of electric alternatives.
Subsides/incentives for adoption of electric alternatives.
On-farm demonstrations (e.g. in universities and research centres).

Final considerations

The AgriFood sector bottleneck in the adoption of PEMD alternatives to fossil fuels is on-farm mobile Agriculture machinery. These are expensive, long duty cycle, pieces of equipment usually with a long-life expectancy. The general view of the people consulted was that there is a lack of reliable alternatives to current equipment. However, various companies are trying to come up with suitable replacements to the commonly used machinery and their hydraulic and mechanical implements, These include swarm robotics, electric tractors, and electric implements.

Swarm robotics

Typically, electric powered lightweight autonomous pieces of equipment that do one or very few functions (for example, powered weeders, crop monitors, precision application of plant protection products). Swarm robotics, are now available but the challenge is scale up (investment) and battery cost. If these barriers can be overcome, then there is a significant global market opportunity with several leading companies based in the UK.

Electric tractors

Replacement of fossil fuel powered internal combustion engines represents the biggest opportunity to reaching net-zero in agriculture but is also the toughest challenge to crack in the UK. The complete redesign of the tractor and further advances in electric drives could go some way to creating a fit for purpose tractor for UK-size farms. The more realistic target would be overseas markets (such as India) where farm/tractor size is more easily addressed. Add to this the small number of R&D centres working on this in the UK and the market opportunity is low.

Electric implements

Quoting one of our interviewees: “A tractor is a very expensive and inefficient means of transport until you connect it to an implement". Typically implements are hydraulically and/or mechanically powered pieces of equipment. Replacing those with electric drives provides the opportunity to increase precision application of plant protection productions and weeding/harvesting similar to swarm robotics. They also have less parts and therefore potentially harder to break (though more difficult to repair by the user). The application in conventional large-scale equipment attached to tractors has many benefits from adoption (resistance to change and capital costs with retro fitting) to net-zero and productivity. It is anticipated that through collaboration with other sector companies such as Dyson, Bosch and DeWalt, translation of their learnings in motors and batteries innovation could be rapidly adopted in this area. However, modifying implements to electric might not have a big impact to net-zero if these are to be powered by a generator onboard of aa fossil fuel powered tractor.

AgriFood encompasses a huge and diverse sector. From farm-to-fork, there are multiple opportunities for PEMD, and during this consultation it was noticeable that the “easy” targets have been or are being successfully addressed (for example, vent control of glasshouses, food production and cool chain, and milk extraction tend to be electric). However, there are a lack of reliable and robust alternatives to fossil fuel powered tractors. Alternatives are being developed, but they require a new set of expertise, investment and possibly a rethink of the UK farm. In Table 1, the potential net-zero impact of such alternatives as well as their market opportunity are summarised.

The agricultural machinery market is small and of low margins when compared to other markets, therefore public investment to the development of new and greener technologies, as well as incentives to the adoption of such technologies by users may be needed. PEMD is not the only alternative to fossil fuels, hydrogen and methane powered tractors are seen by some interviewees as more viable replacements, and possibly greener.

PEMD alternative	Net-zero impact	PEMD usage	Market opportunity
Swarm robotics	Medium	Medium	High
Electric tractors	High	High	Low
Electric implements	Low	High	Medium

Table 1. Net-zero impact, PEMD usage and market opportunity of electric alternatives to current fossil fuel mobile agricultural equipment.

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Jim Booth (SAOS)

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Keston Williams (Barfoots)

Mark Stewart (AB Sugar)

Paul Fishpool (AB Sugar)

Parmjit Chima (Harper Adams)

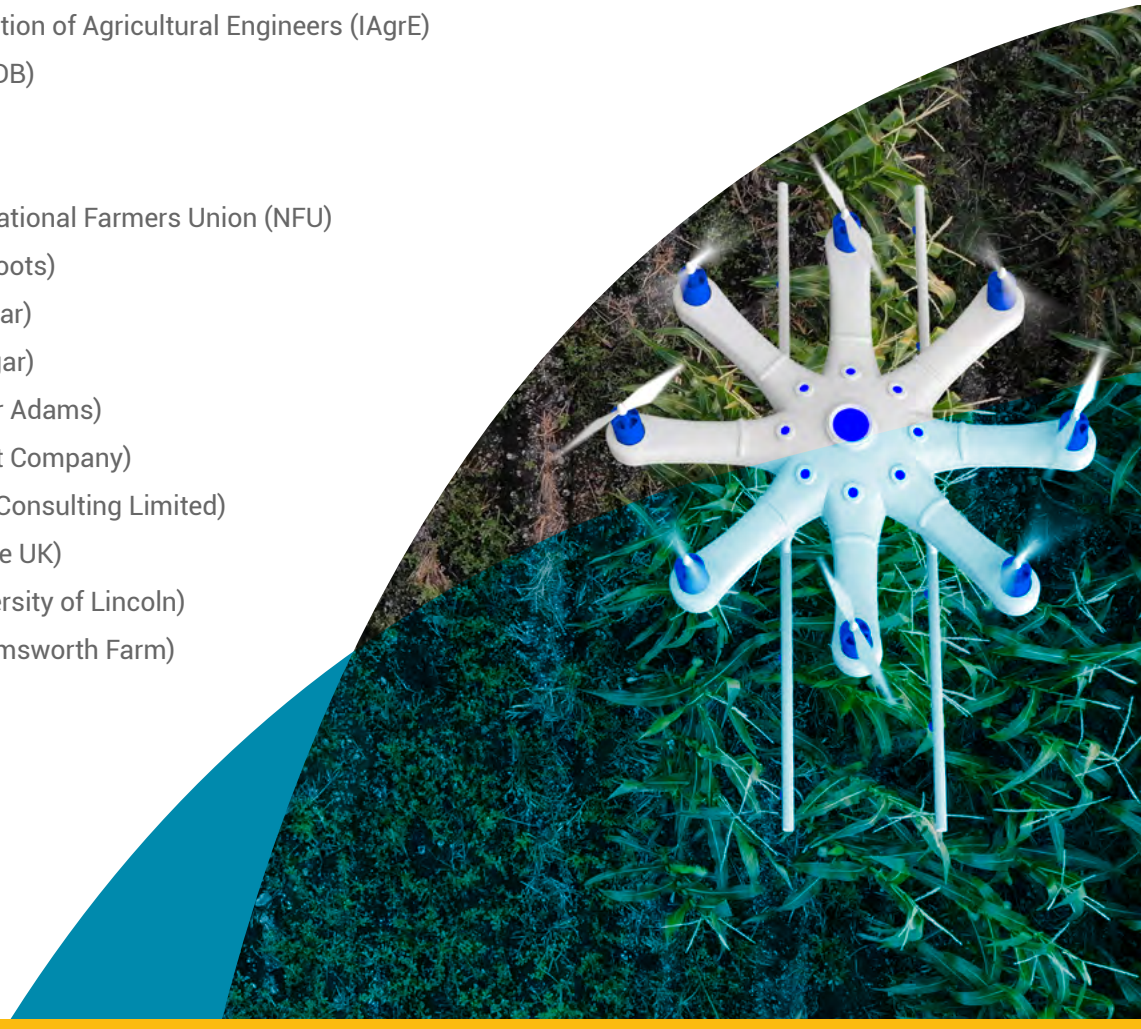
Ray King (Small Robot Company)

Rob Merrall (Merralls Consulting Limited)

Robert Crook (Innovate UK)

Simon Pearson (University of Lincoln)

Sophie Alexander (Hemsworth Farm)



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For more information about this report
please contact the authors:

Dr Pedro Carvalho, KTN-AgriFood
pedro.carvalho@ktn-uk.org

Simon Baty, KTN-AgriFood
simon.baty@ktn-uk.org

For more information about
Driving the Electric Revolution, please contact:

DER@Innovateuk.ukri.org