All-Party Parliamentary Group on Science and Technology in Agriculture

FARMING INNOVATIONS TO DELIVER NET ZERO

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About the Group

Established in March 2008, the All-Party Parliamentary Group on Science & Technology in Agriculture (APPGSTA) aims to promote debate among UK politicians and other stakeholders, not only to understand the role of science and technology in 21st Century agriculture, but also to identify any policy, knowledge-based or regulatory barriers to its adoption.

The Group's activities are supported by a range of food, farming and research organisations including: Agricultural Industries Confederation (AIC), agricultural biotechnology council (ABC), British Society of Plant Breeders (BSPB), CropLife UK, Maltsters Association of Great Britain (MAGB), UK Flour Millers, National Farmers' Union (NFU) and NIAB.

Introduction by Julian Sturdy MP

In late 2022, the All-Party Parliamentary Group on Science & Technology in Agriculture launched a call for evidence into the farming technologies, innovations and practices which can help deliver on the UK's Net Zero commitments.

The starting point for the inquiry was that climate change should be tackled by encouraging new green technologies and scientific innovations, rather than by imposing measures which might harm economic growth and living standards, and ultimately reduce domestic food production.

Policy developments under discussion in other countries, such as the imposition of emissions reduction targets, livestock culls, and even the buy-out and closure of farms, suggest that agriculture can be seen as a soft target for climate action.

Indeed, Defra chief scientist Professor Gideon Henderson referred to ruminant livestock as the 'low hanging fruit' for short-term greenhouse gas (GHG) reductions when he spoke to the All-Party Group in January 2022.

But agriculture is possibly unique in its relationship to climate change – at the same time a major cause, victim *and* a source of solutions.

It is therefore disappointing that the narrative around climate change and agriculture is often negative in tone, particularly in relation to livestock farming, diverting attention from the enormous opportunities for agricultural innovation to contribute positively to the climate agenda.

We must also recognise that climate change cannot be tackled in isolation. War in Ukraine has exposed the fragility of the world's food system, and the precarious balance which exists between global supply and demand.

Estimates from the UN Food and Agriculture Organisation suggest that the world needs to increase food production and availability by up to 70% by 2050 to keep pace with the food needs of a rapidly expanding global population.

This is particularly relevant to the development of farming systems in temperate regions such as the UK, which organisations such as the Intergovernmental Panel on Climate Change (IPCC) predict will be less susceptible to the production-limiting effects of changes in temperature, rainfall and increasing weather extremes.

In meeting our Net Zero commitments by 2050, therefore, the United Kingdom also has a global responsibility to optimise its own food production capabilities, and reduce our dependence on food imports, so minimising our food system footprint in parts of the world where farmers may be more vulnerable to the effects of climate change.

This report highlights many exciting examples of how advances in areas such as plant and animal breeding, precision agriculture, alternative proteins, feed additives, indoor farming and other sectors can address these policy goals, supporting increased domestic food production and economic growth while delivering on the Net Zero agenda for British agriculture.

Julian Sturdy MP
Chair, APPG Science & Technology in Agriculture

Scope of the report

This brief report is not intended to be comprehensive or exhaustive, but draws on the written evidence submitted to the inquiry from a range of organisations and individuals, as well as presentations made to the All-Party Group by experts from different sectors.

It highlights **eight key areas of innovation** with the potential to transform British agriculture's climate impact.

In seeking to deliver an ambitious goal of reaching net zero in UK agriculture by 2040, the **NFU** has identified three key pillars of activity:

PILLAR 1

Farm-level innovations to improve productivity and reduce GHG emissions

PILLAR 2

Enhancing and maintaining farmland carbon storage in soils and vegetation.

PILLAR 3

Boosting renewable energy and the bioeconomy to displace GHG emissions

While Pillars 2 and 3 are integral to the farming industry's drive to reduce its carbon footprint, this report focuses primarily on Pillar 1, and the potential contribution of science, technology and innovation not only in improving the productivity and resource use efficiency of farming systems, but also in directly reducing GHG emissions.

Of course, reducing climate impact per unit of food output by increasing yields and resource use efficiency also contributes significantly to the objectives of Pillar 2 by freeing up more land for carbon sequestration measures such as tree planting or peatland restoration.

Furthermore, this report recognises, but does not focus on, the significant contributions already being made on farms across the country to reduce and mitigate UK agriculture's climate impact, for example through increased uptake of precision farming and GPS tools, minimum tillage systems, cover cropping, hedge and tree planting, installation of solar panels, anaerobic digestion plants and wind turbines etc.

A word about metrics

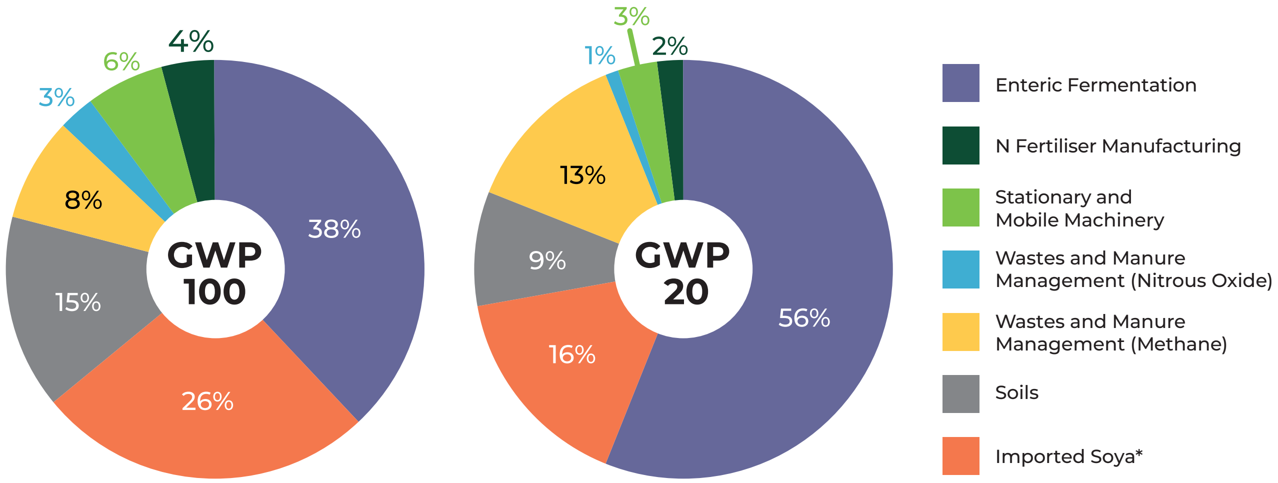
A number of submissions to this inquiry highlighted the importance of metrics, and the need to ensure a consistent and meaningful approach to measuring GHG emissions from UK agriculture, particularly in relation to enteric methane emissions from livestock.

The IPCC – the United Nations body responsible for overseeing the science of climate change – uses a measure of Global Warming Potential over a 100-year timescale, known as GWP-100. However, the use of a shorter-term measure, or GWP-20, has also been considered by IPCC in view of the rapid and dramatic weather extremes and natural disasters associated with climate change which have taken place in recent years.

However, over a 20-year period, the warming potential of methane is estimated[1] to be 84 times more potent than CO_2, and using a GWP-20 metric would substantially increase the contribution of methane as a key source of UK agricultural emissions.

Agriculture accounts for around 10% of GHG emissions in the UK, of which 38% are accounted for by methane emissions from livestock under the established GWP-100 measure. As the following graphic demonstrates, applying the shorter GMP-20 metric would increase the contribution of livestock methane emissions to 56% of the total.

Breakdown of GHG emissions by source within UK agriculture using GWP-100 and GWP-20



* 'Soya' represents direct production emissions as well as Scope 3 emissions from imported soya deforestation 7 and reforestation 'carbon opportunity cost'.

Source: Innovation for Agriculture, *Reducing Greenhouse Gas Emissions at Farm Level*

Others, such as the **Commercial Farmers Group (CFG)**, have suggested that an alternative metric, known as GWP*, which accounts for the different properties of greenhouse gases including their relative lifespan in the atmosphere, would be a more appropriate measure, taking account of the fact that methane has a much shorter lifespan than N_2O or CO_2.

When grazing livestock numbers remain stable, the **National Sheep Association (NSA)** points out that the natural biogenic cycle ensures enteric methane emitted by ruminants is recycled into carbon in plants and soil within a relatively short (~12 year) timeframe.

Academic proponents of the GWP* metric, including Professor Myles Allen[2] at the University of Oxford, contend that constant ongoing methane emissions cause relatively little additional warming. In contrast, every tonne of CO_2 emitted causes the same amount of warming whenever it occurs.

Sustainable intensification and metrics

Alongside the debate over how to measure GHG emissions from agriculture, there is an urgent need to adopt meaningful, science-based metrics for sustainable agriculture more widely – ie including but not confined to carbon footprint or GHG emissions.

The All-Party Group has long advocated the need to embed data science and sustainability metrics at the heart of a policy agenda focused on securing the optimum balance between food production, resource use and environmental impact (see for example this Westminster Hall debate[3]).

Access to metrics capable of objectively and consistently monitoring that balance will be essential to set targets and measure progress for sustainable, efficient production, to develop coherent research and development programmes, to understand and advise on best practice throughout the industry, to inform the policy agenda, and to provide meaningful information to consumers about the sustainability impact of each unit of food produced, whether that is a litre of milk or a kg of potatoes.

Focusing exclusively on GHG emissions, rather than including GHG emissions as one measure in a basket of sustainability indicators, may lead to unintended impacts elsewhere. For example, *Farmers Weekly* reported[4] in 2020 that the National Trust's flagship Wimpole Hall Farm had gone 'carbon negative' in its organic wheat production, but this required double the amount of farmland, and cost twice as much to produce. Can that be regarded as sustainable? Meaningful measures of agricultural sustainability must take account of a broad balance of resource use and environmental impact parameters, related to the quantity of food produced.

Farming innovations to deliver Net Zero

This report focuses on eight key areas of farming innovation with the potential to transform British agriculture's climate impact:

Genetic innovation in crop breeding

- Increased crop yields and resource-use efficiency
- More climate resilient crop varieties
- Nitrogen fixation and improved photosynthetic efficiency

Precision farming technologies

- Improved productivity and input use efficiency
- Enhanced monitoring and decision-making tools
- Natural resource conservation, eg water for irrigation

Genetic innovation / Improved control of endemic disease in livestock

- Improved productivity and disease resistance, reduced morbidity and mortality
- Improved feed use efficiency and reduced methane emissions
- Climate resilience traits in livestock

Vertical farming and controlled environment agriculture

- Increased food output per land area
- Significant potential to reduce pesticide, fertiliser and water use
- Reduced transport emissions and food waste by growing locally, year-round and on-demand

Novel protein sources for animal feed (eg insect meal)

- Low carbon, high protein feed source
- Reduced food and agricultural waste
- Source of low carbon, high value fertiliser (insect frass)

Green fertilisers and controlled release fertilisers

- Reduced carbon footprint in N fertiliser manufacture using renewable energy
- Development of alternative fertilisers using industrial and agri-food waste streams
- Reduced nitrous oxide emissions

Strategic development of home-grown protein crops

- Significant opportunity to reduce N fertiliser use in UK arable rotations
- Home-grown alternative to imported proteins (eg soybean)
- Additional healthy-eating, soil health, economic benefits

Methane reducing feedstuffs and feed additives

- Reduced methane emissions in ruminant livestock
- Potential to reduce overall feed intake

INNOVATION AREA 1

Genetic innovation in crop breeding

Genetic improvement through advances in plant breeding is the single most important factor driving gains in crop productivity and resource use efficiency. These gains translate into significant GHG savings at the farm level.

For example, the **British Society of Plant Breeders (BSPB)** points to independent socio-economic impact research[5] by **HFFA Research GmbH**, published in 2021, which concluded that, between 2000 and 2020, progress in plant breeding accounted for two-thirds of the productivity gains in UK arable crops. An earlier peer-reviewed study[6], led by **NIAB** scientists in 2011, found that for the UK's main cereal crops (wheat and barley), the contribution of genetic improvement to yield gain was closer to 90%.

Without the contribution of improved varieties over the past 20 years, the HFFA study found that UK crop yields would be 19% lower, and 1.8 million hectares of additional land would be needed here or in other parts of the world to meet our food needs, placing additional pressure on scarce global resources and causing more than 300 million tonnes of additional GHG emissions.

A range of breeding targets contribute to improved crop productivity, from increases in physical yield potential allowing more crop to be harvested using less land and fertiliser, to more durable pest and disease resistance, preventing crop losses and allowing reduced use of crop protection inputs. These breeding targets translate directly into GHG savings both at farm level and in terms of input manufacture and distribution.

However, the HFFA study also highlighted the challenge of maintaining current rates of yield and productivity improvement. It underlined the critical importance of access to novel sources of germplasm, and new breeding techniques such as gene editing, with the potential to accelerate the underlying rate of progress in crop innovation.

These technologies can also improve plant breeders' ability to develop more climate resilient crops (eg capable of withstanding more extreme conditions of drought, heat, cold or waterlogging), and have the potential to target characteristics which can directly reduce the volume of warming gases in the atmosphere.

In one report[7] shared with the Group, for example, the US-based **International Technology and Innovation Foundation (ITIF)** highlighted a number of crop biotech research projects taking place globally with the potential to reduce the amount of excess carbon in the atmosphere, estimating the impact each innovation could have if adopted and deployed at scale. These are summarised in the table below:

Project description	Lead institute	Potential GHG reduction at scale (gigaton carbon dioxide emissions equivalent – $GtCO_2e$)
Modifying stomatal density in rice to reduce water requirements	University of Sheffield	1 $GtCO_2e$ per year
Blocking conversion of excess nitrogen fertilisers into GHG emissions by improving nitrogen use efficiency in crops	University of Alberta	1.6 $GtCO_2e$ per year
Boosting photosynthetic efficiency by engineering better RuBisCO enzymes	Harvard University	1.1 $GtCO_2e$ per year
Reinventing photosynthesis	Max Planck Society	>3 $GtCO_2e$ per year
Engineering faster growing trees to sequester atmospheric carbon and reduce emissions	Futuragene	2.4 $GtCO_2e$ per year

Genetic improvement of forage crops to improve energy and digestibility can also contribute to reduced methane emissions in ruminant livestock, for example by improving conversion of plant protein into meat and milk. Improved digestive efficiency results in less methane emitted, and less nitrogen excreted.

There are many other examples of how crop genetic technologies such as gene editing can help unlock opportunities to deliver Net Zero in agriculture – see, for example, here[8], here[9], here[10], here[11], and here[12].

The significance of these opportunities, and the urgency of the climate crisis, underline the need to ensure the regulatory framework established by the Genetic Technology (Precision Breeding) Act delivers on the UK Government's objective to encourage UK-based investment and innovation in these technologies.

Ministers must ensure that the implementing rules currently in development for precision bred products, particularly in relation to food and feed marketing, are proportionate, non-discriminatory and enabling, and reflect the Genetic Technology Act's underpinning rationale that such products introduce no new or additional risks compared to their conventionally bred counterparts.

The All-Party Group also welcomes the Government's recent announcement[13] of up to £30m to unlock the potential of precision breeding, and the establishment of a working group to bring plant breeders, food manufacturers and retailers together to agree an approach that enables these products to reach our shelves.

However, given the evidence identifying crop genetic innovation as the single biggest driver of productivity gains and emissions reduction in agriculture, alongside Professor Jane Langdale's 2021 UKRI review[14] of the UK plant science sector which concluded that major opportunities for crop improvement are being lost due to fragmented and short-term funding tranches, the All-Party Group reiterates its call[15] for a more coherent and long-term R&D strategy for crop genetic improvement which ensures promising new genetic discoveries, for example in model plant species, have a clear translational pathway into crops and products of value to UK farmers and consumers.

INNOVATION AREA 2

Genetic innovation / Improved control of endemic disease in livestock

In livestock farming, one of the most effective ways to reduce GHG emissions per unit of production is to reduce morbidity and mortality in livestock caused by endemic disease, for example through the development of new vaccines, application of new vaccine technology, and greater uptake of existing vaccines, as well as enhanced animal husbandry and management practices.

Continued genetic improvement in farmed livestock, for example to improve performance, health and resilience, is another key factor in reducing agriculture's climate impact.

Professor Geoff Simm, Director of the **Global Academy of Agriculture and Food Systems** at the University of Edinburgh, notes[16] that incremental improvements in livestock performance over time generally lead to reductions in feed and other resources used per kg of product, and hence in associated GHG emissions.

For example, Professor Simm cited a comparison of US dairy systems in 1944 and 2007, which estimated that modern systems required 21% of the animals, 23% of the feedstuffs, 35% of the water, and only 10% of the land per billion kg of milk produced. The 2007 systems also produced 24% of the manure, 43% of the methane, and 56% of the nitrous oxide per billion kg of milk compared with 1944 systems. Similarly, selection of chickens bred for meat production is estimated to have reduced feed required per kg of weight by around 35% over 25 years, with corresponding savings in land use and GHG emissions per unit of product.

The **NFU** points to modern livestock breeding as a vital tool not only for addressing disease, health and welfare challenges, but also in helping farmers select for sustainability traits, for example through the development of a genetic index for breeding cows which produce the least GHG emissions over their lifetime, or breeding sheep for enhanced resilience to climate change.

Working closely with animal breeding companies, techniques developed at the **Roslin Institute** in Edinburgh are estimated to have saved over 600,000 tonnes of animal feed, through improvements in feed use efficiency.

Much of Roslin's work is also focused on the development of genetic solutions to control infectious diseases, which represent a major barrier to Net Zero as they are directly

associated with high rates of mortality in farmed animals and with an increase in resources required to maintain a high health status. Examples include the use of genome editing techniques to confer resistance to porcine reproductive and respiratory syndrome (PRRS) in pigs, and avian influenza in poultry.

Most of the climate impact from animal production is due to methane emissions, which contribute around 70% of all livestock-related GHG emissions. As previously discussed, because methane's warming potential over a short period is much more potent than CO_2, the impact on warming is not gradual build-up over time but from relatively recent years. Reducing methane emissions is therefore one of the most effective ways to slow down warming.

But that does not necessarily mean scaling back livestock production. Work is under way to develop a better understanding of the relationship between the rumen microbiome and methane emissions in cattle. The integration of rumen microbiome data into breeding programmes will help predict and select for lower methane-producing cattle. Scientists at the **University of California, Davis**, also recently announced a $70m project using CRISPR gene editing technology to engineer the microbes themselves to produce less methane.

In November 2022, the All-Party Group issued an open statement[17] signed by leading organisations and individuals across the scientific, breeding, farming, veterinary and input supply sectors, welcoming the inclusion of farmed animals in the Genetic Technology Act, recognising the contribution of more balanced breeding programmes to improved animal health and welfare on Britain's farms, and highlighting the potential of new breeding technologies such as gene editing to support even more sustainable, high-welfare production by delivering genetic solutions to some of the more intractable disease challenges in farmed livestock.

Once again, Ministers must ensure that the implementing rules currently in development for precision bred products are proportionate and enabling, and support the potential to improve farmed animal health and welfare by encouraging UK-based investment and innovation in these technologies.

INNOVATION AREA 3
Novel protein sources for animal feed

According to the **Agricultural Industries Confederation (AIC)**, switching to alternative and novel feed materials, ranging from marine algae, single cell proteins from carbon capture and insect proteins to the use of co-products and former foodstuffs otherwise treated as waste, could offer significant opportunities to reduce agriculture's carbon footprint.

Keiran Whitaker, director of **Entocycle** and a founding member of **Insect Industry UK**, told the All-Party Group in March 2023 that the development of insect protein as feed is set to become an $8- 12bn global market by 2030. He explained that 95% of the global insect industry is focused on the black soldier fly, which is hungry and fast-growing, increasing in size 8000x in 14 days; it is omnivorous, eating a wide range of substrates; and it provides a very low carbon alternative, reducing GHG emissions compared to other protein feed sources.

The potential Net Zero benefits of farming black soldier fly larvae include local production on a small area of land, turning waste material into a valuable resource, producing a low carbon, high protein feed (40-60% protein when processed), while also helping to reduce the carbon footprint of crop production by using the remaining insect frass (excrement) as a source of fertiliser.

However, **Insect Industry UK**, **AIC** and **NFU** have warned that because the UK Food Standards Agency has not yet approved insect protein for feed use beyond pet and aquaculture diets, Britain risks falling behind other parts of the world and even the EU, which approved insect meal for use in pig and poultry feed in 2021, having already approved its use in aquaculture and pet food in 2017.

Similarly, because insects are classified as farm animals, post-BSE restrictions mean that certain animal by-products cannot be fed to the insects, limiting overall feedstocks and growth potential for the insect protein sector, even though it would be entirely natural for the insects to feed on this material. Accessing new feedstocks, especially from supermarket and supply chain waste, would be transformative in terms of growth potential and reduced costs for the farmed insect industry, and for the prospects of insect meal becoming a viable cost-competitor to fishmeal and, in the longer term, soybean meal, both of which can have significant environmental impacts.

Thirdly, the ability to use raw frass as a nutrient-rich fertiliser is currently blocked in the UK due to the lack of a legal definition and conditions for its application. Here again, the EU is ahead of the UK, requiring frass to be sterilised at 70°C for one hour or composted. The same legislation could be adopted in the UK, enabling frass to be used as an alternative to synthetic fertiliser.

Having previously been a world leader in the science of insect farming, the UK is now falling behind due to regulatory barriers not constraining the insect industry elsewhere. Government action to address each of these three challenges could accelerate the uptake of insect protein, reducing current feed sector carbon emissions, increasing supply chain resilience by reducing import dependence, and providing a diversification opportunity for farmers. With the right incentives, the UK still has the opportunity to regain its global lead in the farmed insect sector.

INNOVATION AREA 4

Strategic development of home-grown protein crops

A number of submissions to the APPG inquiry (**NFU**, **AIC**, **NIAB**, **IAR Agri Ltd**) highlighted the potential Net Zero benefits of increasing nitrogen-fixing pulse and legume cropping in UK arable rotations, both to reduce the demand for Nitrogen fertiliser and to provide a home-grown alternative to imported protein supplies (primarily soybean).

The prospective health benefits of an increase in consumption of pulses was also highlighted, with potential savings to the taxpayer in healthcare costs.

James Wallace of **IAR Agri Ltd** noted that when comparing a typical three-year arable rotation in the UK (eg winter wheat/winter barley/oilseed rape) with one that includes pulses as a break crop, N fertiliser use would be approximately one third less, with additional benefits in terms of reduced energy and pesticide requirements, improved soil health and soil structure.

However, the UK pulse crop remains a relatively niche and neglected sector in terms of public sector R&D funding, private sector plant breeding and applied agronomic research activity. As a result, peas and beans are much more variable in yield and performance than cereal and oilseed crops, and the UK pulse area has declined in recent years.

In March 2022, the All-Party Group hosted a session with experts from the pulse research community including **PGRO**, **John Innes Centre** and **NIAB**, exploring opportunities to foster innovation to unlock the sustainability, healthy-eating and climate change benefits of UK pulses.

The meeting highlighted the potential for a more co-ordinated programme of pre-breeding and agronomic research in pulses to deliver improvements in key in-field performance characteristics such as consistency of yield and resistance to pests and diseases, as well as the opportunity for the UK to take a leadership role in the high-growth sector of plant-based food innovation.

The All-Party Group welcomes the recently announced £5.9m Nitrogen Efficient Plants for Climate Smart Arable Cropping Systems (NCS) project, which has a goal of increasing pulse cropping in arable rotations to 20% across the UK – currently 5% – by improving on-farm agronomy, measurement of greenhouse gas emissions, and testing new feed rations. This is a major boost for a much-neglected area of public good research.

However, a more strategic end-to-end approach is needed in the medium to longer term, for example including trait development and pre-breeding, development of improved varieties and new pulse cropping options, alongside investment in the development of new food market outlets, to unlock the full potential of more climate-friendly home-grown pulses and legumes.

The All-Party Group supports calls for the Government to show leadership in developing a sector-specific UK pulse strategy as part of the UK's commitment to delivering Net Zero, providing a joined-up, end-to-end R&D programme to unlock the economic, health, sustainability and climate change potential of home-grown pulses, building on Britain's research strengths in terms of crop genetics, smart agronomy and food science.

INNOVATION AREA 5

Precision farming technologies

Precision agriculture covers a range of digital and engineering technologies which can help farmers and growers improve their productivity through enhanced decision-making tools and more efficient use of inputs. Technologies involved in precision agriculture include image analysis, sensors, drones, GPS, autosteer, variable-rate application and robotics.

The **NFU** notes that precision farming can contribute to improved yields, animal health, profitability and reduced environmental impact through better efficiency, helping farmers select and apply the right inputs at the optimum time and scale.

For example, satellite imaging and Unmanned Aerial Vehicles (UAVs), or drones, using hyperspectral sensors, are now being used to monitor growth and detect the early onset of disease and stress in crops, and to help develop GPS guided maps to optimise the precision application of fertiliser and crop protection inputs at variable rates across each field.

Soil moisture sensors and weather-related data are also being used to optimise irrigation schedules in crops such as potatoes to conserve precious water resources.

The Water Efficient Technologies (WET) centre, a demonstration hub for the soft fruit sector developed by **NIAB**, collects real-time data to match water supply to demand, using a fully automated precision irrigation system to maintain moisture at the optimal levels for crop development at each stage of the growing season.

Crop establishment, input application, selective harvesting and crop scouting have all been identified as areas of potential for robotics, which already has a growing role in livestock production, automating routine activities such as milking, health monitoring and feeding.

A recent report[18] from the **Social Market Foundation** think-tank, supported by **MSD Animal Health**, which was launched in Parliament at a meeting of the All-Party Group in January 2023, also highlighted how more widespread adoption of Precision Livestock Farming (PLF) technologies such as monitoring collars on cattle, computerised feeding systems, farm management software and apps, and electronic ID tags can all help improve productivity in terms of input use efficiency, animal health and environmental impact.

Jonathan Halstead of **Syngenta** also told the All-Party Group how technological innovation is continuously delivering opportunities for more targeted and site-specific application of pesticides and fertilisers, moving from field-map application informed by satellites and drones, right through to optical spot spraying of single plants within a field. Such advances in precision application technologies should be taken into account as risk-mitigation factors in the regulatory process for assessing new crop protection products, he suggested.

Despite the benefits of precision farming technologies in improving productivity and reducing emissions, both the **NFU** and the **Social Market Foundation** identified the capital costs of such technology as a potential barrier to uptake, alongside concerns over who owns and can use the data collected in precision farming activities.

To help deliver on the Net Zero agenda, Government should consider more targeted incentives to encourage uptake of precision farming technologies, for example through productivity-enhancing grants or 'green' investment-focused capital allowances in the tax system.

An agreed system of farm-level sustainability metrics capable of objectively and consistently monitoring the balance between food production, resource use and environmental impact is also urgently needed to quantify the value and contribution of such investments.

INNOVATION AREA 6

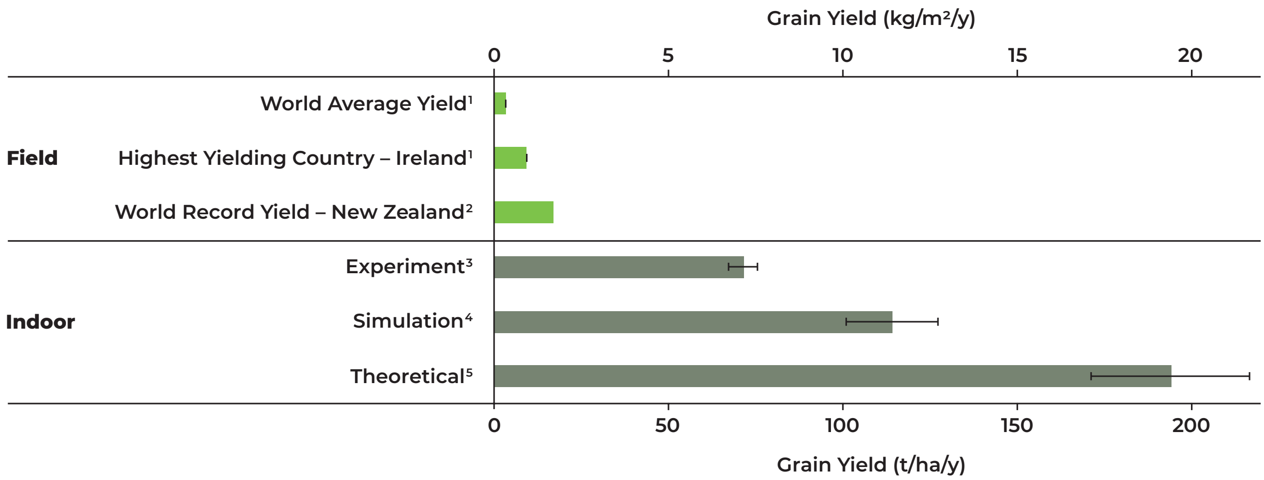
Vertical farming and controlled environment agriculture

In separate presentations to the All-Party Group, two successive Defra chief scientific advisers, **Professor Sir Ian Boyd** and **Professor Gideon Henderson**, have highlighted the potential Net Zero contribution of moving crop production indoors through vertical farming systems and controlled environment agriculture, freeing up land for other uses, reducing input requirements, and using renewable energy rather than fossil fuels to grow food.

Vertical farming is the practice of growing crops indoors in vertically stacked layers, with the potential not only to reduce the land area needed to produce food but also, by incorporating controlled-environment agriculture and soil-less farming techniques such as hydroponics, aquaponics and aeroponics, to significantly reduce other inputs such as water, fertiliser and crop protection products.

Because vertically farmed crops are produced indoors, they are less susceptible to unexpected weather events or extremes of climate, which appear to be affecting traditional outdoor agriculture with increasing frequency. Vertical farming, which can take place in a range of locations including disused buildings, shipping containers and tunnels, can also help reduce transport emissions and food waste by enabling produce to be grown locally, year-round and on demand.

The theoretical potential for vertical farming to increase future food production on a much smaller area of land was highlighted in a 2020 study[19] by Asseng *et al*. published in the *Proceedings of the National Academy of Sciences* (PNAS), which estimated that a 10-layer indoor vertical facility could produce between 700 and 1,940 t/ha of grain annually under optimised temperature, intensive artificial light, high CO_2 levels, and a maximum attainable harvest index. Such yields would be 220 to 600 times the current world average annual wheat yield of 3.2 t/ha, as shown in the graph below:



Despite these potential benefits, however, the development of commercial-scale vertical farming has to date been relatively slow, reflecting the extremely high capital set-up costs and energy required compared to traditional outdoor crop production. The NFU suggests that these constraints may restrict its near-term potential to high value crops such as fresh herbs and salads that benefit from being grown relatively close to consumers.

The PNAS study referred to above also acknowledged that although indoor wheat farming is unlikely to be economically competitive with current market prices in the near future, it could play a key role in hedging against future climate or other unexpected disruptions to the food system, and that future technological innovations could reduce capital and energy costs in such facilities.

INNOVATION AREA 7

Green fertilisers and controlled release fertilisers

Nitrogen-based fertilisers are essential to maintain agricultural production at the levels required to feed a growing global population, but the production and use of synthetic fertiliser are major contributors to the greenhouse gas emissions causing global warming.

In February 2023, an analysis[20] by two Cambridge University researchers, Yunhu Gao and Andre Cabrera Serrenho, published in ***Nature Food***, found that the production and use of Nitrogen fertilisers account for approximately 5% of global greenhouse gas (GHG) emissions – more than global aviation and shipping transport combined.

In addition to the plant breeding and precision farming technologies already discussed which can help farmers to optimise their fertiliser use, manufacturers are also adopting greener production methods and developing innovative new fertiliser products to curb greenhouse gas emissions.

The ***Financial Times*** recently reported[21] that Norwegian fertiliser company **Yara International** is seeking a substantial reduction in its carbon footprint by producing ammonia with green energy. This involves splitting water molecules using electricity from renewable sources, rather than by extracting it from a fossil fuel such as natural gas. According to the FT, the company expects the carbon footprint of this green fertiliser to be 80-90% smaller.

Another UK cleantech start-up, **CCm Technologies**, is using captured carbon dioxide from industrial power generation to stabilise a wide variety of organic materials, such as sewage sludge or food industry waste, and using these to create new fertiliser products with significantly lower (-90%) carbon footprint compared with conventional fertiliser production methods.

The NFU also points to the potential to reduce post-application emissions through controlled release fertiliser (CRF) technology which helps suppress the activity of nitrifying soil bacteria and provides crops and grassland with nutrition at a rate that matches the plants' needs.

Urease inhibitors are designed to prevent leaching and volatisation, for example, by blocking the urease enzyme found in soil and plants which breaks down urea into ammonium. Nitrification inhibitors also prevent soil bacteria converting nitrogen in the fertiliser into nitrous oxide.

Urease and nitrification inhibitors can be applied as a coating on granular fertilisers, injected into the soil with liquid fertilisers, and mixed into slurry before application.

However, the **NFU** adds that CRF technology is expensive, and has not yet shown a consistent economic benefit to farmers through yield gain. Policy incentives to encourage the use of CRF technologies would therefore be needed, pending greater clarity on the effectiveness of inhibitors under different circumstances.

INNOVATION AREA 8

Methane reducing feedstuffs and feed additives

Enteric fermentation in ruminant livestock is a major contributor to UK agriculture's greenhouse emissions. Methane-reducing feed additives and supplements may offer an innovative way to reduce emissions in livestock production.

According to **Defra**, methane suppressing feed products typically work through the regulation, inhibition or disruption of methane producing micro-organisms in the rumen, thus reducing the volume of methane produced. A broad range of products and groups of products claim to provide methane suppressing properties, including:

- **Methanogenesis inhibitors** (e.g., 3-nitrooxypropanol (3-NOP), bromoform, nitrate, urea) include a range of products that evidence shows can reduce methane formation by disrupting enzymes or blocking methane production

- **Probiotics or live microorganisms** (e.g., live yeast or bacterial cultures) have been shown to promote a rumen biome that is less prone to methane production.

- **Essential oils** may be able to suppress methane production by a range of actions, including by reducing the number of methanogens in the rumen.

- **Organic acids** (e.g., fumaric Acid, malate, aspartate) have been shown to reduce methane formation by diverting hydrogen. One example, fumaric acid is commonly used as a preservative.

- **Seaweeds** (e.g., Asparagopsis). Naturally occurring bromoform in certain species of seaweed may inhibit methane production during digestion. Seaweeds are typically dried or powdered before being added to the animal feed.

- **Antimicrobials or Ionophores** are bio-active substances used to affect ruminal fermentation in cattle and have been shown to reduce the activity of methanogenic gut flora.

- **Garlic** demonstrates some anti-microbial properties and has been shown to reduce presence of methanogenic microbes within the rumen, reducing methane produced during digestion.

In August 2022, Defra and the devolved administrations launched a joint call for evidence[22] into the current and potential role of methane suppressing feed products in UK agriculture, to seek feedback on the potential barriers to their introduction. Although the consultation closed in November 2022, the Defra website indicates that a summary of the 213 responses received will not be published until the end of 2023.

This paucity of action by Defra reflects wider industry concerns expressed by **AIC** and **NFU** that the UK may already be falling behind other countries in its access to methane reducing innovations in the feed sector. In February 2022, for example, Bovaer – a feed additive developed by the Dutch company DSM – was granted formal marketing approval in the EU. According to DSM, the additive reduces enteric methane emissions by approximately 30% for dairy cows and as much as 90% for beef cows. A further potential benefit is reduced overall feed intake since 10% of a cow's energy is consumed in generating methane. Bovaer is still awaiting FSA approval for use in the UK.

When he spoke to the All-Party Group in January 2022, Defra chief scientific adviser Professor Gideon Henderson was highly critical[23] of the lack of progress by the UK farming industry in reducing GHG emissions compared to other sectors such as manufacturing, construction, fuel and electricity supply. He stressed the importance of reducing emissions from meat and dairy production if the UK is serious about its Net Zero target. In view of the potentially significant contribution of methane-reducing feed additives such as Bovaer, it would seem reasonable to expect Defra to treat this issue with greater urgency, and to consider a fast-track approach for the approval of feed additives which may favourably affect the environment and Net Zero.

Summary of Recommendations

This report highlights many exciting examples of how advances in areas such as plant and animal breeding, precision agriculture, alternative proteins, feed additives, indoor farming and other sectors can help address the Net Zero agenda, while at the same time supporting increased domestic food production and economic growth.

The report also identifies a number of potential and actual barriers to these innovations reaching Britain's farmers.

To address these barriers, eight recommendations for Government, covering regulatory, policy and R&D actions, are summarised below.

1. **Ensure the implementing rules for precision bred products, particularly in relation to food and feed marketing, are proportionate and non-discriminatory, and reflect the Genetic Technology Act's underpinning rationale that such products introduce no new or additional risks compared to their conventionally bred counterparts.**

2. **Develop a more coherent, long-term R&D strategy for crop genetic improvement which ensures promising new genetic discoveries, for example in model plant species, have a clear translational pathway into crops and products with the potential to reduce farming's carbon footprint.**

3. **Ensure the implementing rules for precision bred livestock products are proportionate, science-based and enabling, and support the potential to improve the health, welfare and climate impact of farmed animals by encouraging UK-based investment and innovation in new breeding technologies.**

4. **Remove current regulatory roadblocks to the development of the UK insect farming industry by fast-tracking the approval of insect meal as a feed ingredient, facilitating access to new feedstocks currently prohibited by post-BSE regulations, and providing conditions for the use of insect frass as a high-quality fertiliser.**

5. **Initiate a sector-specific UK pulse strategy as part of the UK's commitment to delivering Net Zero, providing a joined-up, end-to-end R&D programme to unlock the economic, health, sustainability and climate change potential of home-grown pulses, building on Britain's research strengths in terms of crop genetics, smart agronomy and food science.**

6. **Consider more targeted incentives to encourage uptake of precision farming technologies, for example through productivity-enhancing grants or 'green' investment-focused capital allowances in the tax system.**

7. **Support the adoption of an agreed system of farm-level sustainability metrics capable of objectively and consistently monitoring the resource use, climate and environmental impact for each unit of food produced.**

8. **Attach much greater priority to the ongoing Defra review of methane reducing feed products, and consider a fast-track approval process for feed additives already approved for use in other countries.**

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All-Party Parliamentary Group on
Science and Technology in Agriculture

All-Party Group contacts:

Chair
Julian Sturdy MP
House of Commons,
London SW1A 0AA

julian.sturdy.mp@parliament.uk

Co-ordinator
Daniel Pearsall
Front Foot Communications Ltd

daniel.pearsall@frontfoot.uk.com

www.appg-agscience.org.uk

@appg_agscience