ROYAL AGRICULTURAL SOCIETY of ENGLAND

FARM OF THE FUTURE: JOURNEY TO NET ZERO

Pre-COP26 Briefing Paper – October 2021

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FARM OF THE FUTURE: JOURNEY TO NET ZERO

What could UK farms look like in 2030 and beyond?

As stewards of much of the UK's landmass, farmers have the resources to increase carbon sequestration in soils, grasslands, hedges and trees and at the same time 'farm carbon' to produce food.

Agriculture is therefore key to reducing emissions and helping the UK meet its climate targets. However, this will require systemic change in farming practices and across the food supply chain.

Increased investment in research and development into innovative systems and technologies applied to livestock and crop husbandries will enable farm businesses to reduce greenhouse gas (GHG) emissions e.g. methane mitigation strategies, diesel fuel replacements, carbon sequestration techniques, precision crop treatments using AI and robots.

Rural decarbonisation involves enhancing soil and water quality, boosting biodiversity and reducing food (and food waste) miles.

Improving food security whilst protecting rural livelihoods and farm incomes will require changes in the way we farm and must involve reduced reliance on fossil fuels, as well as land management practices which sequester carbon.

As high-carbon fuels - including diesel, LPG and heating oil - are phased out, alternative clean and adoption-ready on-farm energy technologies will pave the way for zero-emission fuels. On-farm renewables, combined with battery storage and smart applications of robotic machines and digital systems will challenge established farming practices.

Across agri-food supply chains, more circular resource-use models will replace wasteful disposal of bio-materials and residues found in current 'linear' systems.

British farmers are well-positioned to deliver the transition to a more sustainable low-carbon agri-food economy. Their commitment and innovation deserves the nation's full support.

KEY MESSAGES

Each section of the 'Farm of the Future: Journey to Net Zero' Pre-COP26 Briefing Paper – October 2021 has a **vision** of how farming might adapt to the wider challenges posed by climate change, followed by a narrative and policy insights on: farm and land resource management; low carbon and renewable energy options; agricultural vehicles and agritech; and farm enterprises and novel crops. It concludes with some general policy insights.

The following key messages summarise the policy approaches required to fulfil the vision for the Farm of the Future:

- Effective systems to provide **sound economic valuation of natural capital** will help support the UK's decarbonisation goals and enhance food security, as well as action to restore soil health, increase biodiversity and better manage valuable land and water resources.

- Farmers, responsible for managing a large percentage of the UK's landmass, have **a vital part to play in** the implementation of **the country's low carbon transition plans**, both in terms of sequestration through land management and renewable energy generation. Following COP26, policies should place agriculture at the heart of these plans - to mobilise farmers and land managers in delivering "systems change" whilst maintaining a vibrant rural economy.

- Agriculture is at the core of a food supply chain driven by consumer choice. As consumers become more aware of the environmental impact of their food (and food waste) choices this will encourage and drive the economics of change. **Standardised environmental labelling on food (including carbon)**, supported by standardised farm-level emissions accounting, would inform consumer choice, promote low carbon initiatives and improve the economics of local growers.

- More enlightened long-term, consistent cross-sectoral **rural, energy and carbon transition policy integration** and leadership is required, particularly with regards to circular resource use and measures to boost decarbonisation in rural areas.

- With so many systems choices and technology solutions available, farmers and land managers need access to timely, independent and cost-effective **advice, on-farm demonstrations and information** related to nature-friendly farming practices and renewable energy options. RASE experience has shown that on-farm demonstration sites and practical events such as those run by Innovation for Agriculture (IfA) and Groundswell represent the best way to drive change and inform learning. These activities deserve Government support and funding.

- The job of caring for land resources, whilst supplying food and remaining profitable, is a complex one in itself: **policy and regulation should be designed to engage** with farmers and other relevant stakeholders to ensure they are accessible, deliverable, user-friendly and avoid unnecessary 'red tape' wherever possible.

1. INTRODUCTION

The **'Refuelling the Countryside'** report[1] published by the Royal Agricultural Society of England (RASE) in 2014 assessed options for reducing fossil fuel use on UK farms and highlighted the potential for sustainable farm transport and on-farm renewable energy generation. It followed the Society's 2011 report **'A Review of Anaerobic Digestion Plants on UK Farms'**.[2]

The 2014 report included three on-farm fuel scenarios – electric, biogas and hydrogen – to indicate how farms might move towards a level of energy self-sufficiency in powering farm operations and fuelling vehicles and machinery.

In 2021, the role of agriculture in decarbonisation is wider than simply energy transition. It also includes:

- building and sequestering carbon in soils, improving biodiversity and more effectively managing water resources;
- maximising value from bioresources through adopting circular economy principles;
- adopting emerging business models and technologies, e.g. robotics, artificial intelligence and hands-free farming, where applicable;
- working with supply chain partners including feed suppliers, supermarkets and consumers to reduce greenhouse gas (GHG) emissions.

"Climate change is systems change."

This Briefing Paper offers stakeholders and policymakers a vision of the future farm. It provides policy insights to help enable this transition, presenting current and likely solutions in areas such as resource management, renewable energy, low emission agricultural vehicles and digital agritech.

The Briefing Paper is also an introduction to the more detailed RASE 'Farm of the Future: Journey to Net Zero' study which will include contributions from industry specialists and case studies of good practice. The study will highlight current and near-term planet-friendly practices and technologies that will help implement the 'vision' for a healthier, more resilient and nature-friendly rural food supply system.

It will also examine options to decarbonise specific farm sectors (dairy/ruminants, cereals, intensive livestock and horticulture), and suggest practical steps towards a more circular and resource efficient rural economy. The report, aimed primarily at farmers, is due to be published in March 2022, but will also take account of deliberations and agreements reached during COP26.

[1] https://www.rase.org.uk/reports
[2] https://www.rase.org.uk/reports

2. FARMING 2021: THE TIME FOR CHANGE?

"A sustainable future for UK agriculture may only be achieved by balancing economic viability, environmental responsibility and social acceptability through the adoption of new and existing management practices.

Sustainability is not a peak that can be conquered without further improvements, as the tools, technologies and systems that were sustainable in the past or present may not be so in future. For example, science relating to livestock health, welfare and environmental impacts has resulted in considerable changes to the ways that livestock are housed, fed, bred and managed over the past three decades.

A clear and immediate need exists however, for the UK livestock sector to demonstrate dedication to reducing negative environmental impacts, and to do so in an evidence-based manner that allows progress to be benchmarked and communicated. It is crucial to set appropriate targets, with greenhouse gas (GHG) emissions being the most urgent area of focus."

- Prof . Judith Capper, Harper Adams University

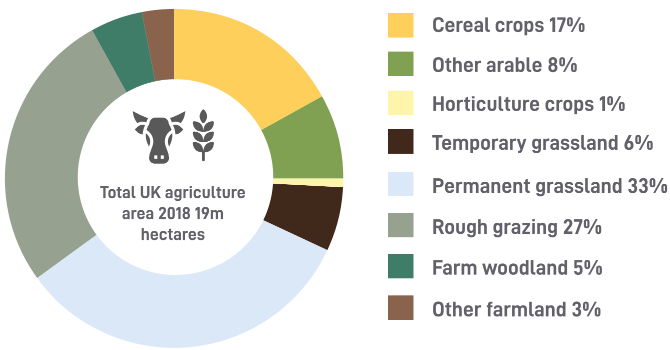
Agriculture, both in the UK and globally, faces a significant period of change over the next two decades – not least through the 'threat multiplier' effects of climate change, turning what were often regarded as 1 in 100-year predictions into more regular and sometimes extreme events, including flooding, drought and pest inundations. This is in addition to the other challenges that farmers have to manage – many of which lie outside of their control.

"Each farmer has different pains and gains."

In addition to weather uncertainties, UK farmers and land managers face other issues: a new subsidy/grant regime (largely as a result of Brexit and changed trading conditions); supply chain adjustments to meet consumer demands; multiple policy and regulation changes; labour and skills shortages; market fluctuations and unexpected crises such as the Covid-19 pandemic. With a reputation for resilience, farmers, land managers and rural communities tend to adopt a long term (multi-generational) view of the future.

Farming activity covers some 43m acres (17.4m hectares) occupying around 71% of the UK landmass. As such, it constitutes a vital part of the UK's rural, agri-food and bioresource economies[3]. Defra estimated that UK farming produced a total income of £4.1bn in 2020[4]. Some 219,000 UK agricultural holdings (66% of which are less than 50 ha)[5] provide more than half (64%) of the nation's food[6].

Agricultural land use in the UK, 2018



Source: *Defra (2018) Agriculture in the UK, CCC analysis*

Some observers might regard farming as an inconsequential contributor to the UK economy. However, linked to the food and drink industry, UK farming is an integral part of the agri-food supply chain worth over £120 billion, employing over 4 million people[7]. It has a wider impact on rural communities and the natural environment than other economic sectors.

Farming activity plays an important role in sustaining rural livelihoods, managing the local environment, as well as supplying the nation's food needs. To continue to achieve this within changing economic and environmental conditions, farm businesses must remain viable, providing a living income for farming families and contributing significantly to the rural economy.

The National Farmers Union (NFU) reported in 2019[8] that greenhouse gas (GHG) emissions from UK farms amounted to 45.4 million tonnes of carbon dioxide equivalent (CO_2e) in 2018 – about 10% of the country's total emissions.

However, in contrast to other industrial sectors, agriculture contributes only 1% of total UK CO_2 emissions (mainly from fuel and energy use) – whereas the industry is responsible for around 70% of the UK's nitrous oxide (N_2O) emissions (mainly from artificial fertilisers) and 50% of methane (CH_4) emissions (mainly from ruminant livestock).[9]

[3] The future farming and environment evidence compendium - September 2019 edition https://www.gov.uk/government/publications/the-future-farming-and-environment-evidence-compendium-latest-edition

[4] Defra - Total Income from Farming in the United Kingdom, first estimate for 2020. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/989701/agricaccounts-tiffstatsnotice-27may21.pdf

[5] Agriculture in the United Kingdom 2019, Defra, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/950618/AUK-2019-07jan21.pdf

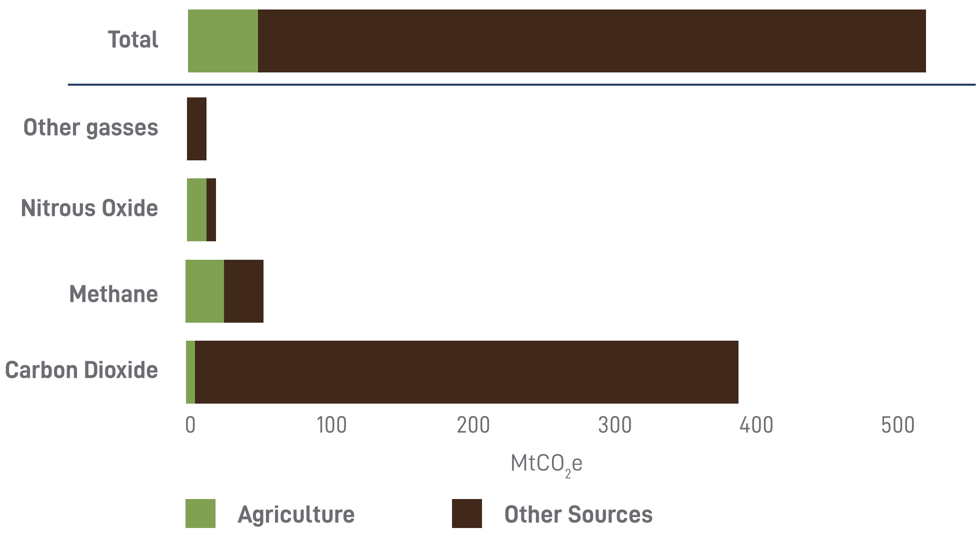
[6] How can the UK be more self-sufficient in food, The Grocer, https://www.thegrocer.co.uk/sourcing/how-can-the-uk-be-more-self-sufficient-in-food/653103.article

[7] Contributing to the economy, https://www.countrysideonline.co.uk/food-and-farming/contributing-to-the-economy/

[8] Achieving Net Zero, Farming's 2040 goal, NFU, https://www.nfuonline.com/nfu-online/business/regulation/achieving-net-zero-farmings-2040-goal/

[9] The Future Farming and Environment Evidence Compendium, Sep 19 Update, Defra https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/834432/evidence-compendium-26sep19.pdf

UK Greenhouse Gas Emissions (2017) in CO_2 Equivalents



Source: *Defra - The future farming and environment evidence compendium 2019*

Although not directly a greenhouse gas, agriculture is also responsible for 88% of the UK's ammonia emissions[10], produced when organic manures (e.g. slurry, manure, sludge, compost, digestate) come into contact with air (wind) and warmth and when both organic and inorganic fertilisers are spread.

Ammonia emissions adversely affect the quality of air, soil and water, ecosystems and biodiversity. So, whilst agriculture urgently needs to address its emissions, it also has the land area to curb its emissions and sequester more carbon through improved nature-friendly farming practices, as well as reducing fossil fuel reliance by helping to produce various forms of renewable energy. Farming is therefore a key part of owning, framing and claiming the solution in rural Britain.

> "The climate, nature and our waistlines are telling us we need fundamental change now."

Following withdrawal from the European Union, UK farmers are moving away from a 40-year-old system of top-down area-based subsidy under the Common Agricultural Policy (CAP) and towards different 'post-Brexit' agricultural policies covering the devolved regions of Scotland, Wales and Northern Ireland – for example, the Environmental Land Management Scheme (ELMS) which applies in England.

This policy shift is an opportunity to drive more agro-ecological, regenerative farming and nature-based solutions on diverse types of farmed land, placing carbon sequestration and carbon reduction at the heart of future plans for farming, land management and the evolving food supply chain.

Although the impact of this transition will be significant, there is little clarity around what the potential income benefits for agricultural businesses might be, making future investment decisions, particularly those around decarbonisation, even more challenging.

[10] Code of good agricultural practice (CoGAP) for reducing ammonia emissions https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/729646/code-good-agricultural-practice-ammonia.pdf

The Vision
Key Messages
1. Introduction
2. Farming 2021
3. Farm & land resource management
4. Low carbon & renewable energy options
5. Agricultural vehicles & fuels
6. Farm Enterprises & Novel Crops
7. General policy insights

Farm business viability is key to farming's critical functions in providing rural livelihoods, managing the environment and meeting emerging market demands. The core economic role of farming is to harness natural resources and to do so, where possible, at a commercial profit.

However, Defra report that between 2015 and 2018, only the top 25% of UK farm businesses made a clear profit from agricultural activity alone. Many others made little or no profit from their core agricultural activities – relying on additional income from farm and environmental diversification, along with the contribution from direct EU payment subsidies.

> "Farmers cannot be green if they are in the red."

It is estimated that 42% of UK farms will be loss-making when the Basic Payment Scheme ends, necessitating cost cutting by 10% to compensate[11]. The nature of farm businesses is that they are 'price takers' (with limited ability to influence the value of their output) unless they sell to customers directly, e.g. on-line or at markets and fairs.

There is consensus that British farmers produce food to some of the highest standards of hygiene, animal welfare and environmental protection in the world[12 13]. As such, UK farms are well positioned to address widening global demand for premium sustainably produced products.

> "Trade deals on cheap food imports should not disadvantage UK farmers working to higher standards."

Such opportunities are even more relevant following the UK's exit from the EU, with anticipated opportunities for farmers and processors to be innovative and supply new international markets. It is vital to ensure that post-Brexit trade deals on food imports do not disadvantage UK agriculture in favour of cheap food produced to lesser welfare and environmental protection standards.

There is no doubt that over the next decade and beyond, farm businesses, operating within an ever-diversifying rural economy, will need to adapt to meet regulatory pressures and supply food and public goods whilst delivering against national targets on emissions reduction.

Agriculture needs to reduce emissions from production activities, and increase its potential to sequester carbon, both directly on land and indirectly, by increasing productivity and reducing demand for land[14]. To do this and to enable better planning and on-farm investment decision making, diverse UK farming businesses need to have a clear and dynamic vision for the way forward.

There is an appetite to understand the parameters for practical change at farm and water catchment level and to develop or refine both technical and operational solutions which are available now or will emerge over the next few years.

[11] Briefing Note: Food after Brexit, April 2021, Rural Policy Group, https://ruralpolicygroup.com/wp-content/uploads/2021/07/RED-X-Food-Wars-2-Food-After-Brexit-Briefing-Note.pdf

[12] Animal health and welfare, Countryside Online https://www.countrysideonline.co.uk/food-and-farming/animal-health-and-welfare/

[13] https://redtractor.org.uk/

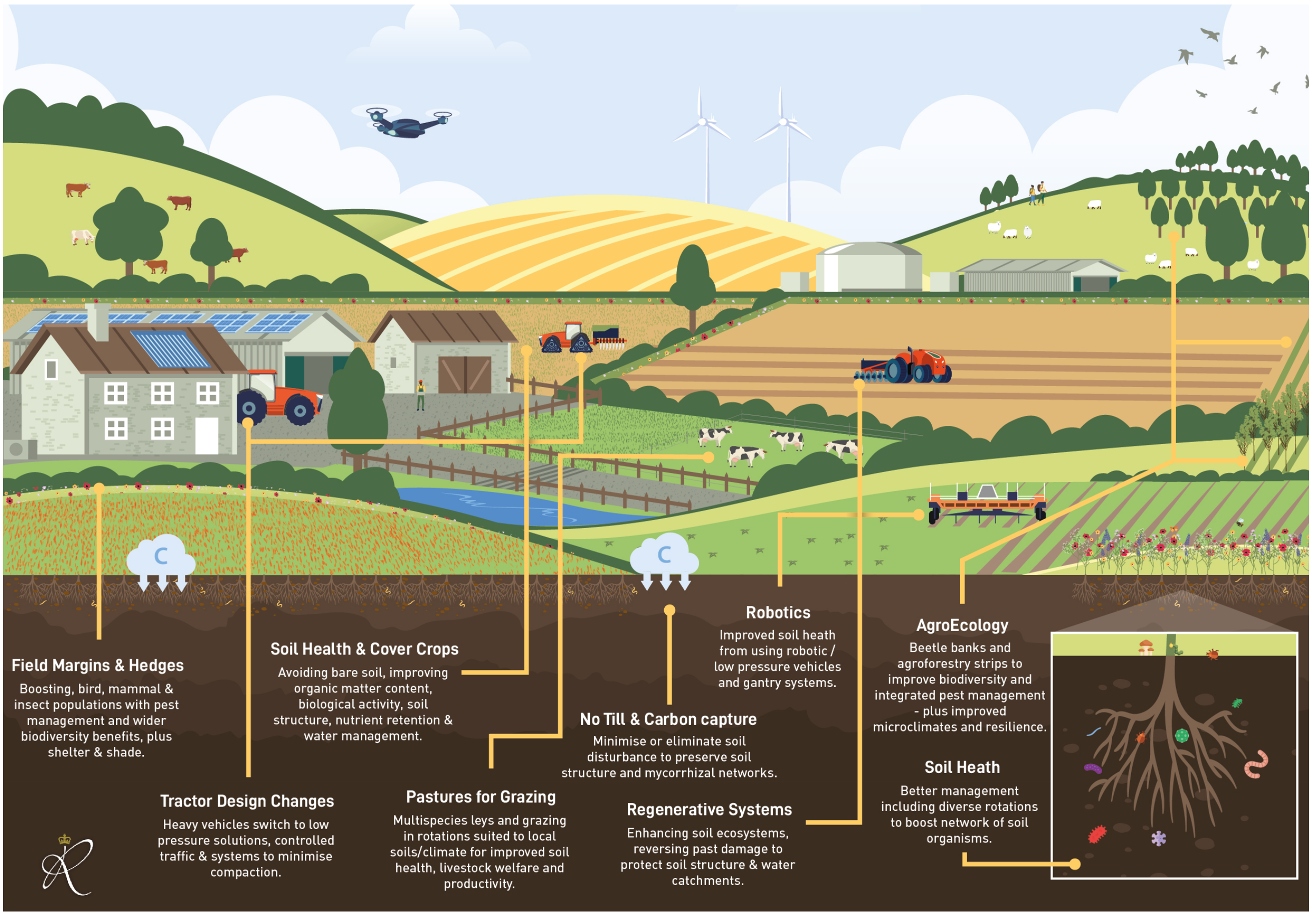
[14] Non-CO_2 abatement in the UK agricultural sector by 2050: https://www.theccc.org.uk/wp-content/uploads/2020/12/Non-CO2-abatement-in-the-UK-agricultural-sector-by-2050-Scottish-Rural-College.pdf

3. FARM AND LAND RESOURCE MANAGEMENT: SOILS, WATER AND BIODIVERSITY

Increased adoption of nature-friendly practices such as regenerative farming and agroforestry will improve soil carbon sequestration, increases in pollinator numbers, a trend in improvement in plant, fungal and animal biodiversity and reduction in fossil fertilisers (reducing agricultural emissions), herbicides and pesticides.

The primary role of a farmer, a forester and land manager is essentially to harvest sunlight, mix with carbon dioxide, oxygen and water, and 'grow carbon'. The above-ground carbon is then harvested and sold or consumed as a food source by other on-farm enterprises whilst the accumulated below-ground carbon is either sequestered as long-term stable humus or partially consumed and cycled through the soil microbial biomass as a food and energy source.

Jump to policy insights

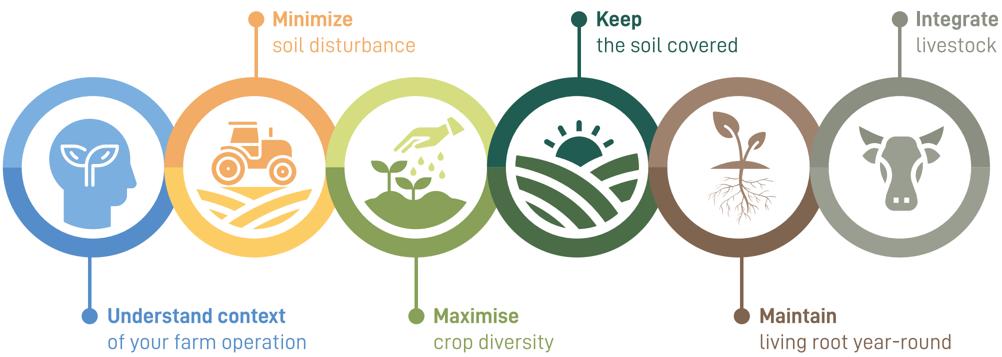


3.1 Regenerative Agriculture

There is increasing adoption of and migration towards farming systems such as regenerative agriculture. As shown in the Groundswell[15] graphic below, key regenerative agriculture principles which can be applied within the context of the farm business include:

- Minimise disturbance of the soil, both physically and chemically.
- Keep the soil covered, either with living plants or a mulch of crop residue.
- Maintain living roots in the soil for as much of the year as possible.
- Maintain as much plant diversity as possible.
- Reintroduce livestock into the system.

6 Core Principles of Regenerative Agriculture



***Graphic courtesy:** Paul and John Cherry, Groundswell*

3.2 Soil Improvement

A critical aim of such systems is to better harness more sustainable and sensitive farming practices to capture carbon in soil and above-ground biomass, thereby helping reverse current global trends of atmospheric accumulation.

Biodiverse woodland, hedgerows and buffer strips can help sequester carbon. However, central to the decarbonisation process is a reduction in soil degradation and, in particular, to reverse past losses of critical in-built carbon resources. The UK Government's 25-Year Environment Plan[16] refers specifically to soil health, setting a goal of improving soil management outcomes by 2030. Loss of soil carbon, of which soil microbes are a living part, is a primary indicator of soil degradation.

> "A 1% increase in soil organic matter is approximately equal to 1.5T CO_2 sequestered/ha/yr, potentially worth £100-£200/ha/yr on C sequestration alone, disregarding other benefits."

[15] Groundswell – the Regenerative Agriculture Show and Conference, https://groundswellag.com/
[16] 'A Green Future: Our 25 Year Plan to Improve the Environment' HM Government 2018

It is estimated that a conventional arable farm with 65 tonnes of carbon per hectare could double the organic carbon in their soils within about 5 years by following nature-friendly practices, although the ability to achieve this is dependent on many factors[17].

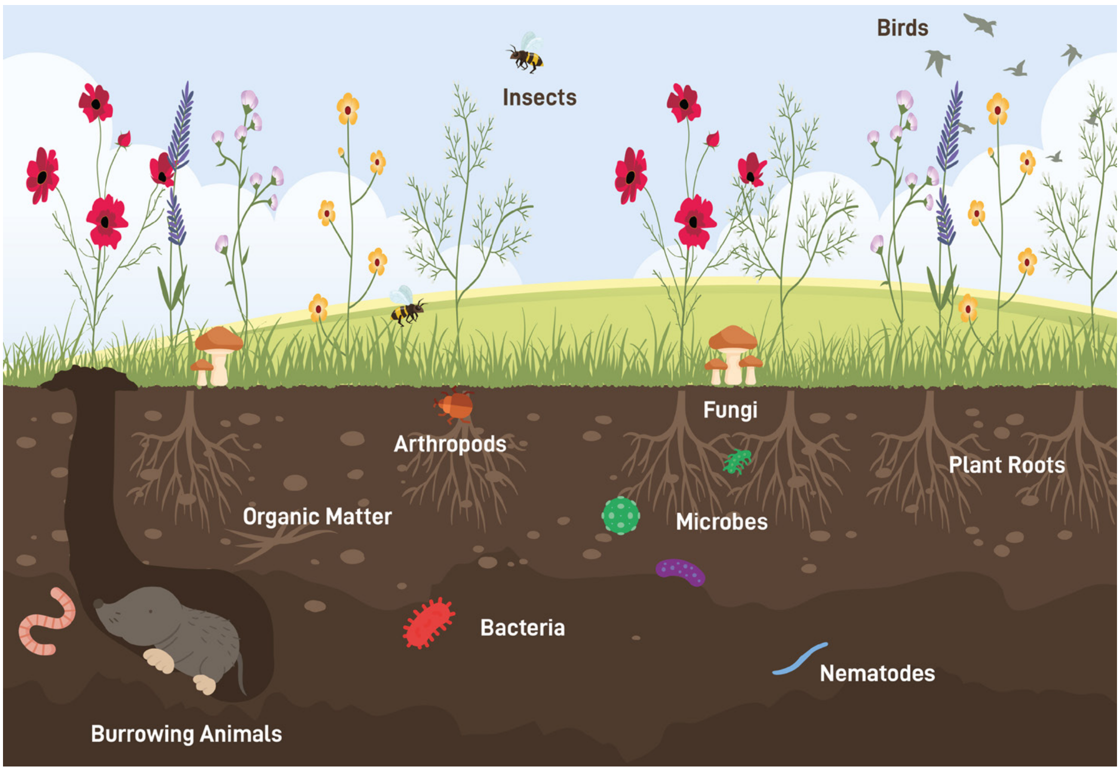
For many decades intensive farming practices have resulted in less carbon being put back into soils than is taken out. The result has been declining soil carbon (soil organic matter) and with it, a corresponding decline in long term resilience and productive potential. Conversely, replacing organic matter improves storage and supply of plant macro- and micro-nutrients, increases water holding capacity (to mitigate against drought/flood events), and improves soil structure, helping prevent compaction and erosion[18].

Regenerative systems which include greater focus on soil health are gaining traction. Practices like covering open soil with previous crop residues or living plants, plus greater diversity in rotations, minimising use of chemicals/synthetics will have a major impact on soil ecosystems.

The organisms in the soil range from minute one-celled bacteria, algae, fungi, and protozoa, to more complex nematodes and micro-arthropods and visible earthworms, insects and small vertebrates. As these organisms move through soil, they contribute to supplies of clean water and clean air, with healthy plants and moderated water flows.

They prey on crop pests and help decompose organic materials including roots, manure, plant residues and even pesticides - preventing them from entering water as pollutants. Some sequester nutrients or fix nitrogen from the atmosphere, making it available to plants. Others enhance soil aggregation and porosity, increasing water infiltration.

Soil health and biodiversity



[17] Farming with Nature: The Cholderton Way: https://youtu.be/-Bd_wzyq6r8

[18] What does organic matter do in soil? Noble Research Institute, https://www.noble.org/news/publications/ag-news-and-views/2001/august/what-does-organic-matter-do-in-soil/

Most agricultural soils are degraded to some extent, but they can be regenerated by more sympathetic farming practices which promote a diverse and abundant soil microbial community, including the extensive eco-systems of bacteria and fungi. Thus, better soil management must be a clear goal for all farmers and should be supported by policy mechanisms.

These systems highlighted above can be assisted by the repurposing of organic and inorganic materials from on-farm and off-farm sources to enhance carbon-sequestering in soils. Such materials include manures, composts, bio-solids, bio-chars and anaerobic digestates. This is a virtuous intention, but due consideration must be given to any potential toxic/polluting effects, as well as life-cycle assessment of GHG emissions.

The recovery of wastes, recycling of products, by-products and co-products into systems like on-farm anaerobic digestion, with land application of denatured (clean) residues has already demonstrated the value of this technology to reduce the environmental footprint of food produced within a more circular rural economy.

Fundamental to reducing GHG contribution of agriculture is improved nitrogen use efficiency. So, whilst these practices can reduce or eliminate the need for fossil fuel fertilisers, careful husbandry of nutrients from both organic and inorganic fertilisers (where used) is essential to reduce agriculture's high contribution to the UK's nitrous oxide and ammonia emissions.

Increasingly stringent regulations will mandate covering stores of organic fertilisers such as slurries and anaerobic digestates (due to their high readily available nitrogen levels) and applying them with low-emission spreading equipment (e.g. trailing shoe, shallow injection) to minimise losses.

Precision fertilization using soil testing and crop sensors can improve the effectiveness of timing and spatial targeting of applications, to meet crop requirements. Timings should be informed by medium-range weather forecasting and soil moisture assessments to minimize risks of nitrous oxide (N_2O) losses from nitrate fertilizers and ammonia (NH_3) losses from manure and slurry applications.

There are significant opportunities across arable and livestock farming to reduce emissions, while improving efficiency and reducing costs and environmental impacts of agrochemical inputs. Future pest, disease and weed management practices will need to be less reliant on chemical and technological solutions that require use of fossil fuels, and more reliant on ecological strategies to build resilience.

3.3 Agroforestry

These 'nature-friendly' climate practices outlined above come under many labels and with numerous manifestations from highly intensive solutions which rely on technology utilisation through to low input systems and possibly even re-wilding of areas to suit the farm business and geography.

In addition hybrid systems such as agroforestry can contribute to CO_2 reduction - enhancing landscape and biodiversity whilst maintaining food productivity. Agroforestry essentially involves combining agriculture and trees, a practice which decreased in the UK as farming became industrialised[19].

[19] Simply put, agroforestry means combining agriculture and trees, Soil Association, https://www.soilassociation.org/causes-campaigns/agroforestry/what-is-agroforestry/

Agroforestry systems include ‘silvopasture’ where animals are grazed under trees; or ‘silvoarable’ where crops are grown beneath trees spaced in such a way as to allow the crops to be tended. This can include use of hedges, buffer strips (including nature corridors and beetle banks) or forest farming. The trees in such hybrid systems provide root systems at different levels to the crop, sequester carbon and house natural predators, potentially reducing the need for pesticides. The trees themselves can provide a crop, potentially producing wood, nuts or fruit, acting to stabilise soils. Trees help reduce soil erosion, the potential for localised flooding and nutrient leaching.


© Courtesy Stephen Briggs farm

3.4 Farmer Engagement

Farm cluster groups, first piloted by the Game and Wildlife Trust in 2012, enable farmers to collaborate, helped by a facilitator, to collectively deliver landscape benefits for wildlife, water catchments and soils - with the additional benefits of knowledge exchange, social contact, practical support and more.

The numbers of such groups have grown rapidly and they have been remarkably successful at driving positive environmental changes in their localities and engaging with local stakeholders and community groups, supported by facilitation funding, sponsorships, subscriptions and fund-raising.

> “If we take ownership of the problems, we can then shape and claim the solutions. The best defence for farming is to stop being defensive”

To support this activity there is a need to benchmark, measure and value/encourage ‘natural capital’ in such diverse areas as; water quality and biodiversity improvements; increases in carbon sequestration in under and above-ground biomass; reduction in GHG and ammonia emissions; farming provision of ‘public goods’, without disadvantaging those at different stages of the journey.

Also, it is necessary to avoid making the reporting process excessively complex or favouring one size or type of farm business over another and offer flexibility to respond to improved knowledge and practice.

Farmer engagement in shaping post-CAP agricultural policies across the UK will be critical – and with more than 2000 farmers expressing an interest in England’s Sustainable Farming Incentive (SFI) pilot, there appears to be a healthy appetite to be at the heart of a co-designed process.

3.5 Policy Insights: Farm and Land Resource Management

a) The use of a variety of **nature-friendly farming systems** (e.g. regenerative systems, silvopasture, and rewilding) should be incentivised and valued. Such systems increase biodiversity and focus upon building carbon stores in soils and above ground (plants, hedges, woodland), whilst curbing emissions from excessive fertiliser use and soil disturbance. It is also essential that the farmer's administrative burden associated with post-Brexit agricultural policy is not excessive.

b) **Standardised reporting** with farmer-friendly evaluation and measurement of farming systems should be implemented, and reviewed regularly to account for improvements in knowledge, practice and equipment. This should align with supply chain CO_2 emissions reduction reporting and be done in an evidence-based manner that allows progress to be benchmarked and communicated. The Global Warming Potential (GWP) model that relates to emissions from ruminants should be adjusted to take account of the invaluable role of grazing animals in sequestering carbon into soils.

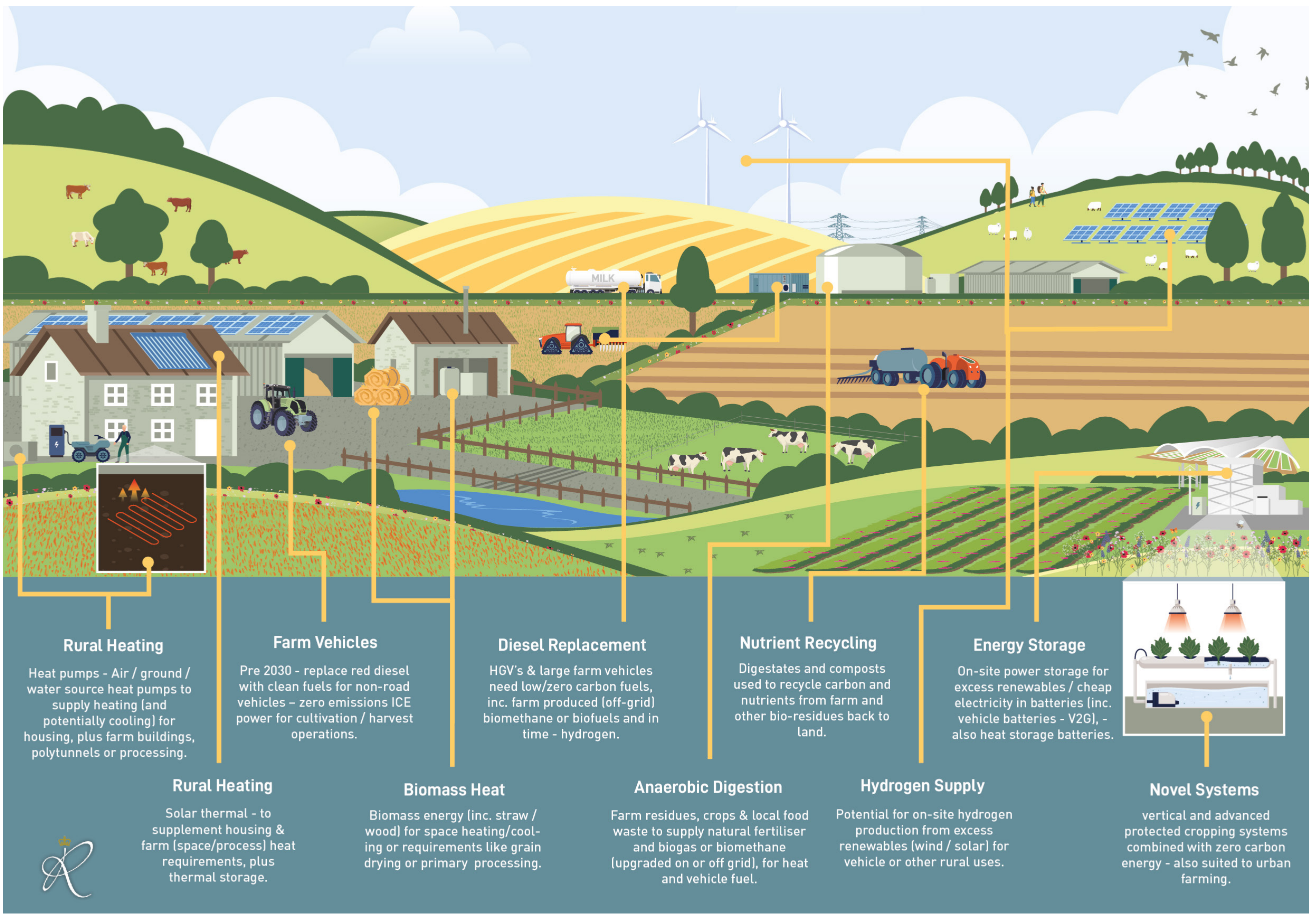
c) On-going financial support is needed to bolster and establish more **collaborative farm cluster and innovation groups**, where collective action, practical demonstration activities, information exchange, experimentation and shared responsibility can help mitigate flooding, protect water catchments, restore landscapes, improve soils and create biodiverse nature corridors or amenity land. Collaboration could even extend to shared or aggregated cluster/community investment in renewable energy generation and storage projects.

4. LOW CARBON AND RENEWABLE ENERGY OPTIONS

Solar PV farm installations continue to grow. Small on-shore wind has regained popularity due to its ability to extend generation throughout the year with addition of battery storage for use on-site and at peak times in an increasingly flexible grid.

As heat pumps become more price competitive, installation has increased. Small scale off-grid biomethane production from farm residues is supplying on-site heat and fuel. Adoption of slurry cover rules is also enabling smaller AD plants to supply off grid or inject aggregated gas to the grid. Carbon capture, utilisation and storage is more common, with numerous plants also providing food-grade CO_2.

Many farms will use different power trains and supply increasing amounts of low carbon energy.



Although UK agriculture does not produce many of the country's direct CO_2 emissions from energy use, exposure to volatile or increasing energy prices will adversely affect the profitability of farm businesses and their costs of production. Pricing issues are likely to become more common as countries decarbonise or where climate-related events such as flooding or prolonged cold affect fossil fuel supply chains.

Jump to policy insights

On-farm energy generation should therefore be promoted as a way of increasing resilience and as an untapped rural investment opportunity - an essential part of the process of decarbonizing agriculture. With the trend towards electrification where possible, distributed, 'behind-the-meter' (i.e. on-site) energy production can present some attractive new opportunities for farm businesses.

On-site electricity generation also helps to minimise the demand on weak rural electricity grids. UK farms must continue to invest in appropriate renewable energy technologies for heat, electricity and fuel: e.g. solar photovoltaics, wind turbines, heat pumps, solar thermal, biomass, anaerobic digestion (AD) of farm residues, plus battery storage and micro-/pico-hydroelectric. Integration of multiple technologies is important as it can increase the times that intermittent renewables can be used, e.g. photovoltaics/wind/battery for electricity or solar thermal/heat pump/solar PV for heat.

Rural areas need higher installation rates of small-scale renewable technologies (e.g. solar thermal, biomass and heat pumps) for renewable heat in rural locations, and particularly for those off the gas grid[20].

Community energy initiatives such as those supported through the Rural Community Energy Fund (RCEF)[21] need continued support to make important contributions in identifying and addressing specific rural community needs, particularly for those not connected to the mains gas grid or where housing stock is poor. Community groups facilitate much more than just energy generation: they support skilled rural jobs, provide wider social benefit, act as a knowledge hub and engage people in the drive to net zero.

Although technology is still developing, the UK is in a favourable position with its increasingly 'smart' and 'flexible' electricity grid, which uses technologies such as artificial intelligence (AI) and smart devices to match demand with supply increasingly sourced from distributed electricity generation from intermittent renewables (e.g. wind and solar) and storage (e.g. batteries; pumped water storage). Such innovation enables farm businesses to adjust their electricity requirements to take advantage of on-farm generated and stored power or cheaper off-peak tariffs at times of cheapest electricity.

This is particularly important in rural areas where many farms and communities still lack a resilient electricity supply. Grid flexibility is a vital component in a low carbon farm energy system where electricity is increasingly sourced from on-farm renewables and demand is balanced using storage, smart equipment and pricing incentives.

On-farm control equipment such as smart and bi-directional electric vehicle chargers (Vehicle to Grid or 'V2G') or heat pumps can operate and batteries can charge when electricity is inexpensive. When it is expensive (e.g. during peak demand and at times with little wind or sun), battery storage can provide electricity for on-site or even export purposes. New business models such as time-of-use (TOU) tariffs and companies that aggregate renewable production from small-scale generators may provide further opportunities.

[20] Renewing Britain: The changing landscape of homegrown energy 2008-2021, Microgeneration Certification Scheme (MCS) https://e.issuu.com/embed.html?d=mcs_renewing_britain_report&hideIssuuLogo=true&logoImageUrl=https%3A%2F%2Fdevbyfuture.co.uk%2Frenewing-britain%2Fassets%2Fsvg%2Fglobal%2Flogo-mcs.svg&u=mcscertified
[21] 'Rural Community Energy Fund' https://www.gov.uk/guidance/rural-community-energy-fund

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4. Low carbon & renewable energy options
5. Agricultural vehicles & fuels
6. Farm Enterprises & Novel Crops
7. General policy insights

On-farm power generation needs to be recognised, encouraged, accounted for and valued within the carbon accounting for farms and as a way of cushioning against volatile energy prices. After all, the farm is creating energy in yet another form: instead of turning the sun's energy into food energy, renewable technologies turn one form of energy into another: both help to lower the farm's carbon footprint.

4.1 Solar Photovoltaics (PV)

Since the demise of the Feed in Tariff scheme, the number of small scale (i.e. sub 50 kWe) solar and wind power installations on farms has declined significantly. However, reduced component costs (e.g. solar panels) combined with a steady increase in grid electricity costs and more cost-effective farm and grid scale battery storage technologies will enable farms to continue to capitalise on the opportunity to supply 'home grown' or decentralised energy.

Solar PV and plant biodiversity

Use of farmland for larger solar parks continues to expand – supplying the national power grid or directly feeding into heavy electrical or transport demand hubs. But this also needs more emphasis on good installation practice demonstrating a balance between technology, plant diversity and integrated livestock grazing.

4.2 Farm Scale Onshore Wind

In the period 2010-2019, renewable electricity generation in the UK from wind power grew from 2.7% to 19.8%, with offshore wind exceeding onshore production towards the end of 2019. By 2020, onshore and offshore wind together generated 75,610 GWh of clean electricity, accounting for 24% of the UK's total electricity output, with onshore wind accounting for 11%[22] - much of this located on farmed or managed land. This technology will continue to play an important part in the UK's renewable energy mix – and provide an additional source of farm income and opportunity for business and community investment.

On-farm wind turbines

It can also be economic to combine solar PV, a farm-scale wind turbine (under 50 kWe) and battery storage for use on-site or for grid export. The addition of wind to solar PV systems can increase renewable generation over the year and better match the demand cycles as many areas experience more wind in the winter months when solar PV output is minimal.

[22] Wind Energy in the UK: June 21, Office for National Statistics https://www.ons.gov.uk/economy/environmentalaccounts/articles/windenergyintheuk/june2021

4.3 Power Storage

On-farm battery storage provides a practical opportunity to meet some daily demand for electricity – balancing out peaks of on-farm generation with rural demand cycles on- and off-farm. This is of particular relevance to intensive production systems (pigs, poultry and dairy, plus glasshouses) where energy demand is high.

Containerised battery storage systems are appearing on some farms – serving as decentralised grid buffer stores, feeding the grid via power aggregation networks or for direct on-farm usage, storing excess renewably generated electricity (e.g. on-farm solar or wind) to power drying and cooling equipment, intensive livestock units or charging electric vehicles.

Electric vehicles (EVs) can also provide battery storage capacity via the use of bi-directional vehicle-2-grid (V2G) chargers – the EV being essentially a 'battery on wheels'. Smart charger management and the integration of vehicle-2-load electricity export facility built into some vehicles enables the vehicle battery to power equipment and lighting and serve as an emergency supply during a power outage.

With costs of battery technology falling steadily and with smart digital control technologies emerging for energy and transport, the progress to on-farm energy self-sufficiency is real.

On-farm battery storage

4.4 Green Hydrogen

The UK government published its hydrogen strategy to great fanfare in August 2021. However, it remains to be seen whether hydrogen will play a major role in rural areas as it likely to require large-scale, expensive (and green) hydrogen production as well as transmission infrastructure (for rural access). Planning for future hydrogen use rightly tends to favour industrial clusters and large-scale fossil fuel users, such as the steel or glass industry, as well as heavy transport.

However, it is worthy of note that one of the winners of the 2021 Earthshot Prize[23] was Enapter – an Italian start-up company which has developed modular small-scale (500 NL/hr) anion-exchange membrane (AEM) electrolyser technology to turn renewable electricity into green hydrogen gas.

Here in the UK, a campus demonstrator unit has been established at Keele University in Staffordshire – the 'Hydeploy' demonstration project[24] led by Cadent Gas which is heating 100 homes and 30 faculty buildings through a 20/80 hydrogen/natural gas blend. Hydrogen is clearly gaining traction as an alternative, zero emissions heating and transport fuel with prospects for rural applications.

[23] https://earthshotprize.org/london-2021/the-earthshot-prize-winners-finalists/climate/

[24] Hydeploy, Keele University, https://www.keele.ac.uk/sustainable-futures/ourchallengethemes/providingcleanenergyreducingcarbonemissions/hydeploy/

The Energy Network Association has ambitious plans to create a hydrogen production capacity of 5GW by 2030. Part of this plan includes the injection of up to 1% hydrogen in Wales & West Utilities Swindon gas grid, with plans to work towards blending up to 20% hydrogen by 2023.

There are also plans to replace some of the fossil gas in the network with bio-substitute natural gas, produced by a local waste-to-gas facility. Due to initiatives such as these, it is likely that some farming businesses with access to the gas grid will have a percentage of hydrogen over the next decade.

It is possible to utilise electrolysers to create hydrogen and biologically transform it to methane by putting it into an AD plant in a process known as 'in situ' biomethanisation or power-to-gas. Microbes in the digester adapt to use hydrogen as a feed and thus the methane in the biogas will be increased to 90%-95% instead of the usual 50%-60%. Hydrogen and bio-methane work flexibly as complementary fuels since each can be derived from the other.

Small-scale hydrogen production on-farm is likely to be challenging over the next few years, due to pricing and market uncertainties. These include the cost of electrolysers and associated equipment; the availability of excess renewables; higher diesel prices (and eventual removal of the red diesel subsidy); increases in electricity prices; the cost, availability and reliability of hydrogen; the production of affordable fuel-cell vehicles (e.g. farm tractors) that run on 100% hydrogen.

4.5 Anaerobic Digestion (Biogas and Biomethane)

Despite over 15 years of efforts to promote biogas with generation incentives, farm scale anaerobic digestion, based on livestock, local and crop residues, has largely failed to deliver multiple on-farm AD plants, tailored to the needs of local communities.

With the UK's Net Zero commitment and increasingly volatile energy prices, it is time for the reassessment of the role of smaller-scale on-farm biogas sites, which can be carbon-negative, particularly when manures/slurries and local rural food wastes are used as feedstock. Because AD is part of the carbon cycle, returning recalcitrant carbon back to land and intercepting volatile carbon in the form of energy, it is a perfect way to capture and utilise carbon emissions which would have been emitted anyway via uncontrolled biodegradation.

The role of biogas in the transition to greater resource efficiency in the agri-food sector has been understated. GHG mitigation is only one benefit of on-farm biogas. Apart from energy supply, other significant benefits include fossil fertiliser replacement, weed seed reduction and improved animal health, with treated digestate spread on grazing land and not raw slurry. Rural areas can benefit from reduced food waste miles if local organic wastes are used to supplement slurry/manure feedstocks.

At this smaller, more 'human' scale, it is also easier to work with the community to minimise food waste contamination (e.g. plastics), producing a cleaner digestate, supporting the 'proximity principle' with a circular economy practice and recycling the nutrients back to land.

The biogas is used to produce 24/7 electricity and heat through a combined heat and power (CHP) unit, or heat only through a boiler - or it can be upgraded to biomethane. Off-grid upgrading for use as a vehicle fuel or to replace natural gas in applications such as heating is feasible and less complex than grid injection. Some plant designs include piping biogas/biomethane to a central injection point.

The agricultural sector offers a unique opportunity for biomethane within a more circular economy, as an adoption-ready option to deliver early diesel replacement for tractors and HGVs. Incentivising adoption-ready technologies is important in reducing emissions now, whilst other technologies catch up. Also, on-site biomethane offers a route to the phasing out of the red diesel subsidy prior to 2030.

Unlike many off-site carbon capture and storage projects using dilute CO_2 streams, on-farm biomethane upgrading offers a perfect opportunity to further improve the GHG credentials of its production since it is straightforward to capture the CO_2 produced in the process. This CO_2 can be cleaned up to food grade standard or it can be compressed and injected underground to sequester it.

4.6 Heating and Cooling

Heating and cooling forms a large component of farming's fixed costs, particularly for dairy and intensive livestock, glasshouse production, crop drying, storage and processing. Much of this is currently provided from carbon emitting fossil fuels (natural gas, bottled gas, oil and diesel).

Heating and hot water has been hard to decarbonise, not least because heat use is highly seasonal, and the fabric of building stock is often poor. With space heating accounting for 17% of UK's emissions[25] (37% with industrial processes, hot water and cooking), it is a priority for decarbonisation.

Rural fuel poverty is a particular issue that cannot be ignored, often characterised by low income, poor housing stock and expensive off gas grid heating options.[26] Hence, there is a need to support rural community heat initiatives.

Heat pumps are a well-established solution that extracts heat from a medium: typically, air (air source heat pump - ASHP) which has a varying temperature; ground (GSHP) or water (WSHP) whose temperature varies less than air. Conversely, some types can also be designed to 'run in reverse' for cooling, useful in many applications including vegetable storage or alongside greenhouses.

Heat pumps are most efficient when there is a relatively fixed heat requirement. They run at lower temperatures than gas boilers, so pipes and 'emitters' (radiators) must be sized appropriately, and a well-insulated buffer tank (e.g. a hot water tank) is usually recommended. It is critical that heat pumps are properly designed to fit the exact application. Training for design and install of such technologies is key to adoption and can only be supported by long-term initiatives supporting wider heat pump use.

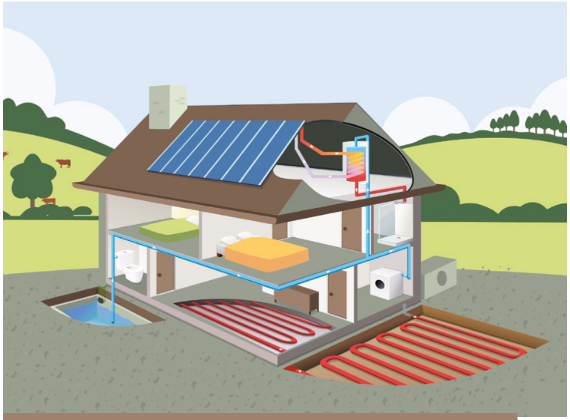
The Wales and West 'Freedom' project[27] converted 75 houses to use a combination of heat pump and gas boiler, coupled with a smart controller which predicted the user's needs. By switching between gas and electricity, this avoids electricity use at peak demand and can benefit from time-of-use pricing.

This principle of utilising various renewable energy sources in a smart and flexible cost-effective manner, coupled with thermal storage (e.g. an insulated hot water buffer tank) has great potential for farm applications. Hot water boilers powered by biogas or biomass, solar thermal cylinders

[25] Guide: Decarbonisation of Heat: Why it needs innovation, Energy Systems Catapult https://es.catapult.org.uk/brochures/decarbonisation-heat/

[26] Statistical Digest of Rural England: Fuel Poverty, Defre, August 2021 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1013323/Individual_fuel_poverty_section_-_word_final.pdf

[27] Freedom: the key to carbon, comfort and cost in home heating, https://passivuk.com/case-studies/freedom-the-key-to-carbon-comfort-and-cost-in-home-heating/



Rural multi-source renewable heating example

heated directly from plate or tube collectors, and immersion tanks heated by wind and solar electricity can be combined in multi-source thermal stores for on-farm use.

The move to more sustainable sources for heating and cooling will require support for energy efficiency measures, coupled with a shift towards more integrated deployment of technologies which may include AD, ground/air/water source heat pumps, solar PV, biomass, wind turbines, solar thermal, hydroelectric, energy storage and heat extraction/recovery.

4.7 Policy Insights: Low Carbon and Renewable Energy Options

The potential for on-site bioenergy to boost agri-food sector resource efficiency has not been fully recognised at a policy level and in the development of the new post-Brexit agricultural subsidy regimes, which offers a once in a generation opportunity to initiate fundamental change. The extremely diverse agri-food sector needs to be involved in the creation of a wider vision for their low carbon future.

a) **Carbon accounting:** monitoring and measuring renewable energy systems should align with those for farming systems and be farmer-friendly, accredited, standardised and regularly reviewed in light of new equipment and practices. A mechanism to value farm carbon could be used to encourage farm energy decarbonisation (wind, solar thermal and PV, storage, biomass, AD, heat pumps, hydroelectric, etc.) with a farm payment scheme for carbon – whether saved, stored or possibly offset.

b) **Biomethane:** there is a widespread misunderstanding that the supply of biomethane is limited to large, expensive AD systems which inject it into the gas grid. Because it is funded by a tax on natural gas, the new Green Gas Support Scheme (GGSS) does not support off grid biomethane production with no support for smaller on-farm AD and no impetus to valorise local bioresources, such as slurries, manures, waste feed and local food wastes. A new approach is needed to stimulate small scale (modular) AD plants on farms, plus local community and rural SME food processing sites. A dedicated scheme would support small off-gas-grid biomethane supply. The gas could be used directly to fuel tractors or HGVs or transported to an injection hub or to discrete village gas grids.

c) **Community Energy integration:** Working with communities to develop local (and off-grid) solutions should include extending the scope of the Rural Community Energy Fund and the establishment of a fair playing field for community generation[28]. As noted above, farm cluster group collaboration could also extend to shared or aggregated investment in renewable energy generation and storage. UK farms and rural areas can produce an appreciable proportion of their fuel needs. This must be embraced in renewable energy policy.

[28] Community Energy, State of the Sector Report 2021, Working together towards net zero https://communityenergyengland.org/files/document/523/1624438045_UKSOTSReport.pdf recommendations page 19ff

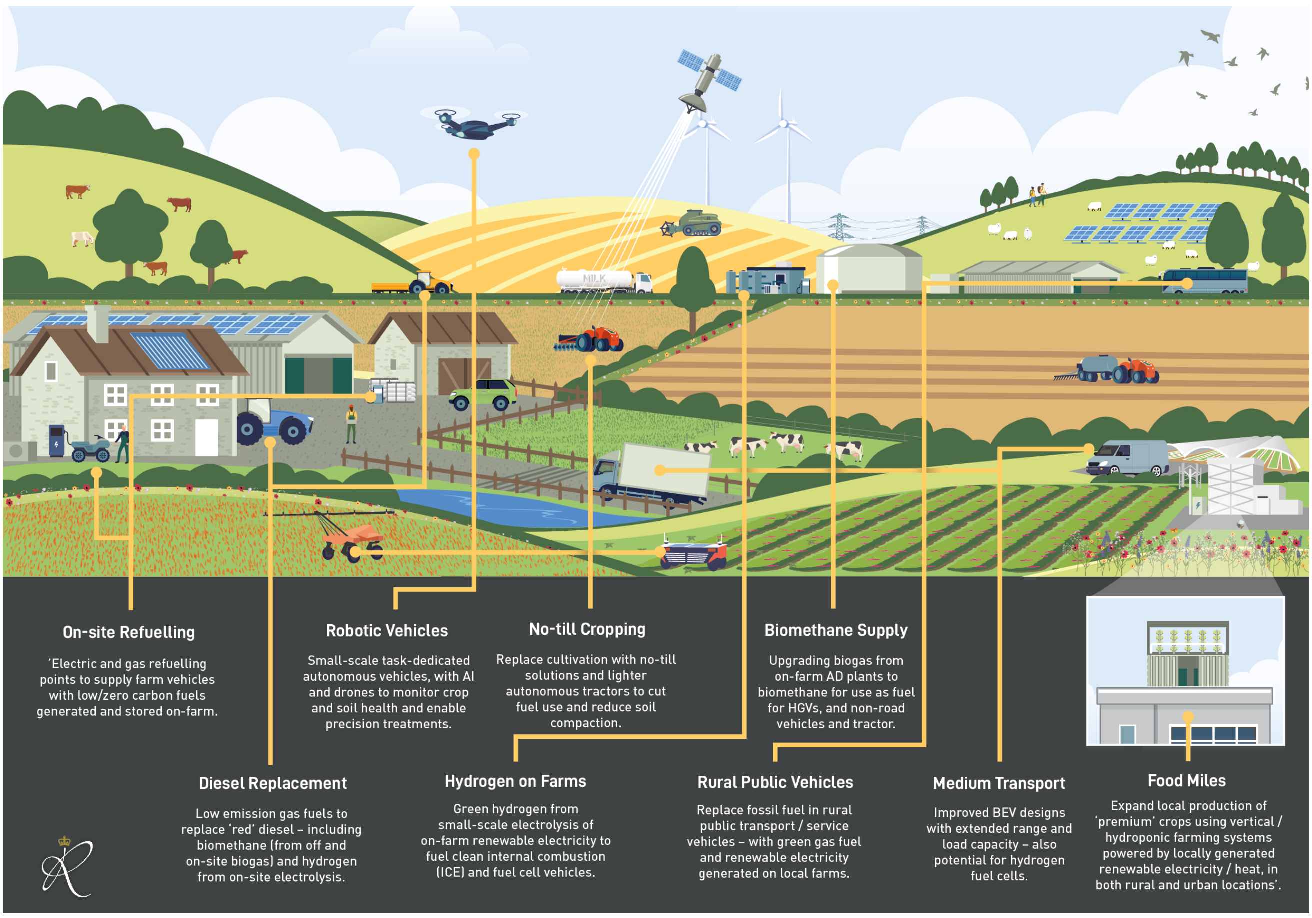
5. AGRICULTURAL VEHICLES AND FUELS

As diesel tractors become more expensive to run due to recent price rises as well as the eventual removal of the red diesel subsidy, biomethane tractors have started to appear, particularly on farms producing biomethane.

Smaller electric farm vehicles, such as quad bikes and telehandlers are increasing in number, joining the family's electric car. Where hydrogen is available, some fuel cell, hydrogen ICE and hydrogen/diesel tractors are also in use. Off-grid biomethane production in some areas has grown a network of rural re-fuelling for local farms and haulage.

Farm transport represents another significant component of farming's fixed cost ledger, dominated by investment in tractors and machinery. In addition, dependence on use of diesel contributes to the overall greenhouse gas emissions from farming in the form of CO_2 and particulate emissions.

Jump to policy insights



The agricultural sector currently gains real economic benefit from the red diesel rebate that enables farmers to compete with food producers in major supply countries such as the EU, US and Canada - which also provide their agricultural sectors with a lower fuel duty on red diesel, affecting the pace of change to low-carbon alternatives (which also provide their agricultural sectors with a lower fuel duty on red diesel).

After the 2020 Budget and subsequent Finance Bill 2021, several industrial sectors such as construction will have the red diesel subsidy removed from April 2022 to help meet UK climate change and air quality targets. Although the Bill included an exemption for vehicles used in agriculture, horticulture, fish farming and forestry, it may not be sustainable for much longer.

The UK government has made no formal announcement, but it seems unlikely that the red diesel subsidy will still be in place by 2030. If it is not removed before 2030, it could harm farming's reputation and carbon reduction ambitions. Ending this subsidy will have a significant economic impact on farmers and other land managers. But a transition package linked to support for adoption-ready low carbon replacements like biomethane, hydrogenated vegetable oil (HVO) and increasingly, hydrogen, would facilitate their adoption.

In 2021, a £40m funding scheme[29] was created to develop future fuel for non-road sectors and agricultural vehicles should have been included in this scheme. Development of new fuels for such uses needs to reflect the economics of the sector and will need be cost comparable to diesel. JCB, for example, is investing in a hydrogen internal combustion engine (ICE) and solutions for non-road heavy vehicles should include ICE adaptions and fuels like biomethane.

Farmers need access to alternative solutions to red diesel for their conventional large internal combustion engine powertrains. Tractor and HGV manufacturers are designing vehicles powered by low carbon fuel options: biodiesel and HVO, biomethane, and in time, with hydrogen and battery electric. All future farm fuels will also need to reflect the low margins under which farms and other users operate.

Biomethane Tractor spreading digestate

Transition to 'non-diesel' farm power trains will not happen quickly: vehicle and infrastructure asset replacement cycles will impact on transition. Many farm vehicles have working lives of 15 to 20 years. With long replacement cycles, and the relatively low volume of new tractor sales (circa 14,000 units in the UK in 2018[30]), there are limited opportunities for technology transitions between now and 2050 and the industry will need support for this. It is highly likely therefore that farm vehicles powered by internal combustion technology will remain in use on farms up to 2040 and beyond.

[29] https://www.gov.uk/government/publications/red-diesel-replacement-competition. £40 million Red Diesel Replacement competition to support development/demonstration of low carbon fuel and system alternatives to red diesel for the construction, and mining and quarrying sectors – but agriculture is excluded.

[30] 2018 UK Tractor Market Shares by Manufacturer and Brand, https://www.farmersguide.co.uk/2018-uk-tractor-market-shares-by-manufacturer-and-brand/

But innovation – combining new field practices, smart control systems and redesigned vehicles – is already well into prototype stage of development. There are a number of adoption-ready systems that can be deployed by vehicle original equipment manufacturers (OEMs) and it will be essential that they work closely with farmers to understand the requirements of on-farm traction and likely impact of switching to non-till systems. The need for change is generating considerable interest in agritechnology – or 'agritech' - and the potential for micro and robotic farm vehicles.

5.1 Biomethane and Biofuels

With the path to zero emission tailpipe vehicles still relatively unclear for large vehicles, biofuels and biomethane offer the opportunity to reduce carbon emissions immediately using these current proven farm-scale technologies which in best practice primarily utilise the carbon energy from wastes and residues which would otherwise produce uncontrolled emissions on degradation.

The next 10-20 years are an opportunity for biofuel (biodiesel and biomethane) deployment to reduce CO_2 emissions; waiting for fully 'zero-carbon' alternatives is no justification for inaction in terms of fuel and engine innovation and lack of policy support for the early farming transition away from diesel.

5.2 Battery Electric Vehicles (BEVs)

The use of battery powered vehicles on farms is growing, with smaller on- and off-road vehicles and robotics, where the battery does not unbalance the weight-to-power ratio. In larger vehicles (e.g. tractors or combines) this ratio is critical. Where duty cycles are long, BEV solutions are much less likely. Purchase costs of BEVs is also a real issue. However, this is changing, with predictions (McKinsey 2020)[31] that BEV operating costs will be 50% lower than equivalent diesel vehicles by 2050.

For many farmers, the adoption of electric vehicles will still rely upon at least some power being sourced from the electricity grid – even where farm renewable generation and battery storage technologies are installed. However, the electricity grid in the rural UK is less dense than in urban areas and it does not extend across farms. Battery swapping technology and in-field charging may provide options for smaller BEV solutions or some robotics applications.

5.3 Agricultural Technology (Agritech) Innovation

Flexible robotic machinery, coupled with GPS and artificial intelligence (AI) are being used in multiple applications such as precision planting, harvesting, and weed/disease notification and control. Autonomous vehicles and robotics use 'service' business models, as well as outright purchase or lease.

[31] Reducing agriculture emissions through improved farming practices, May 2020, McKinsey and Company, https://www.mckinsey.com/industries/agriculture/our-insights/reducing-agriculture-emissions-through-improved-farming-practices

Since at least 2014, the increase in use of digital technologies, drones, precision farming techniques, robotics, automation and artificial intelligence (AI) has been astonishing, mirroring the speed and influence across society of the internet and mobile communications.

Many critical farm operations now rely on global positioning satellites (GPS), smart vision systems, and laser guidance. Agritech innovation can reduce overall energy use in crop production applications while simultaneously increasing yields and improving environmental management.

Systems Innovation also offers the opportunity to replace labour intensive work, improve soil structure and reduce costs of tillage and crop inputs through targeted applications of herbicides (or non-herbicide weed control), pesticides and fertilisers. It should be noted that effective use of AI technology and related equipment often depends on wireless connectivity (e.g. 4G and 5G) which is currently sparse in rural Britain – and therefore may be regarded currently as a potential design constraint to such development.

Controlled traffic farming (CTF) is a concept based on operating field equipment repeatedly on the same routes through the crop, made possible through use of Global Navigation Satellite Systems (GNSS) and solutions like gantry farming systems. Research has shown crop yields can increase 9%-16% in un-trafficked soils, with enhanced benefits in soils prone to compaction.

CTF will be enhanced through the emergence of autonomous (i.e. driverless) crop equipment. This not only has the potential to address concerns over some farm labour shortages, but can deliver a wider range of benefits including energy and fuel saving, intensification of crop management, more timely field operations, reduced soil compaction, greater precision and greater field biodiversity.

Crop monitoring and weed control robots

The use of robotic i.e. driverless machines operating in field and glasshouse operations enables accurate crop and plant monitoring combined with targeted precision treatments – and is set to revolutionise crop husbandries. Digital technology pinpoints areas and individual plants that require treatments as shown below – saving time and cost and avoiding excessive use of control applications.

Connected and autonomous vehicles (CAV) prototype testing and demonstration projects are already taking place in several farming regions. In 2016, Harper Adams University[32] established the first fully autonomous farm plots - successfully planted and harvested without human intervention in the field.

[32] HandsFree Hectare, https://www.handsfreehectare.com/

In livestock systems, dairy farmers have utilised robotic milking for over a decade, enabling an increase in herd size with corresponding lift in yields and animal health. Intensive livestock enterprises such as pigs and poultry operate in increasingly controlled environments using sensors and monitors within enhanced disease control systems that can boost productivity.

5.4 Policy Insights: Agricultural Vehicles and Agritech

a) Instead of its focus upon 'zero tailpipe emissions', the Department for Transport (DfT) policy should **fully account for the carbon intensity** emissions (well-to-wheel) of fuels used (gCO_2e/MJ). Fuel type alone does not determine its carbon credentials e.g. grey hydrogen produced from fossil fuels without CCS. For instance, biomethane supplied from wastes captures and utilises carbon that would otherwise be emitted in an uncontrolled fashion.

b) The **red diesel subsidy** is a major impediment to the move away from diesel on farms. Agriculture should be part of current research into low emission fuels for non-road vehicles (i.e. construction and mining) even if the adoption timeline is different. Funding for research and fuel development will deliver better value if it supports all non-road heavy vehicles. With key OEMs based outside the UK, developing alternative power train technologies depends on international supply chains. Replacing diesel is key to meeting the Net Zero 2050 target, but this requires cumulative emissions reduction, using existing lower cost technologies– rather than reliance on future promise. Adoption-ready on-farm solutions (such as biomethane from AD) that can deliver affordable progress to reduce carbon must be supported, with more emphasis given to on-farm energy production and use.

c) The UK's approach to reducing transport emissions must make full use of **solutions that are available now** (including biodiesel, HVO & biomethane), so that efforts to move to longer-term solutions do not delay progress. Policy should fully embrace the ability of biomethane to lead the transition, as reflected in the 2020 Cadent (Element Energy[33]) report on fossil fuel replacement in heavy haulage. This also applies to farm vehicles. It suggests more rapid deployment of biomethane will cut HGV emissions by 38% over 10 years - waiting for hydrogen or electric trucks will limit the reduction in this period to 6%.

d) Replacement of the existing (ICE) stock in rural and non-road heavy vehicle sectors may require **retrofit solutions** that do not impose excessive costs on low margin sectors like farming, forestry and bulk haulage. But adaption of the ICE power train to new fuels must also be encouraged.

Hydrogen Power on the farm

e) Adoption of advanced technologies needs **increased funding for research**, including trials of novel approaches such small robotic vehicles which can undertake specific tasks and coupled with no till/minimum till cultivations, hasten the end of the need for heavy farm tractors and other vehicles. This includes precision farming systems, especially in field and crop operations such as autonomous weeding and targeted non-chemical treatments.

[33] The Future Role of Gas in Transport: Green Gas Transport Pathway, Cadent Gas, http://www.element-energy.co.uk/wordpress/wp-content/uploads/2021/04/20210325-CADENT_HYDROGEN_TRANSPORT_REPORT.pdf

6. FARM ENTERPRISES AND NOVEL CROPS

Agriculture does not operate in isolation, so the main 'Farm of the Future: Journey to Net Zero' report to be published in 2022 also explores four main product sectors – dairy (and ruminants), cereals, horticulture and intensive livestock - as exemplars of how decarbonisation is impacting on agri-food supply chains and how the interaction of different farm sectors and farming activities can enhance carbon saving opportunities.

With more than 60% of UK land being grassland - best suited to livestock grazing and supply of high-grade protein, livestock will remain part of UK agricultural production. Switching to more intensive indoor systems will increase methane and nitrous oxide emissions, but these could somewhat be mitigated by shorter production cycles, with slaughter at younger ages.


© Courtesy Innovation for Agriculture

Extensive pasture-based grazing systems, with lower methane and nitrous oxide emissions are best suited to the UK's grassland regions, but the longer production cycles can increase these emissions. It is therefore imperative that improving efficiencies in grass-based production cycles is given a high priority both in relation to research and on farm innovation.

Some of the changes that need to be made at a farm level are summarised below:

a) **Dairy (and ruminants):** there is a need for increased investment in measures that curb emissions from dairy farms, including choice and design of feed rations, use of methane-curbing additives /techniques and installation of covered slurry stores sized for reduced spreading windows. However, the Global Warming Potential (GWP) model related to ruminant emissions should take account of how grazing animals can sequester carbon into soils. Livestock farmers and trade bodies need to develop ways of measuring and benchmarking emissions and carbon capture.

b) **Cereals:** regenerative farming systems can improve negative impacts on arable farms. Farmers and contractors must be incentivised to replace fossil fuels power trains as quickly as possible, particularly in relatively high-turnover vehicles (some arable and farm contractor's vehicles are replaced after about 4 years). Replacing fossil fuel-based crop protection products must include adoption of novel pest and disease control systems.

c) **Horticulture:** In addition to reducing fossil energy demand (particularly in protected/controlled environment systems), the sector also needs help to improve soil health in field systems. Incentives for investment must be combined with better engagement from regulators and planners, as too often they are thwarting efforts to decarbonise existing production systems.

d) **Intensive livestock:** Intensive pig and poultry operations often do not have the land base to spread their slurries and manures, so more consideration should be given to facilitate the use of covered storage, as well as the local valorisation of these of these products (e.g. through AD) to minimise their environmental impact and make better use of nutrients.

In addition to sector-specific issues, challenges include fossil fuel use in the product processing and distribution chain, some of which fall under the remit of the farm or are undertaken in the local area.

There are increasing opportunities for **novel crops and systems**, particularly in the context of mixed farming operations or as part of carbon efficiency or sequestration. Examples include:

a) **Fruit/nut trees** as part of silvopasture, but also to provide an additional crop, some varieties of which may do increasingly well in a warmer, wetter UK climate[34].

b) **Novel or high value crops** including pulses[35], ancient grains (e.g. spelt, einkorn)[36], saffron[37] and hemp[38]. In addition to medicinal use, from some hemp species the entire plant can be used for plastic-free, sustainable and durable products, including fabric[39].

c) **Meat substitutes** - With a gradual policy-supported consumer shift to eating less meat, there will be increasing opportunities for growing plant-based options, at both small and large scale.

d) **Insect proteins** offer low environmental impact protein sources for animals or people. Edible insect production can be undertaken at small scale on farms. Some models use insects as a high protein animal feed and frass (excrement) as a chitin-rich fertiliser.

e) **Vertical farming** presents an opportunity for local production of high value crops that may currently be imported (adding to food miles) but systems can be located in urban sites, closer to processors, using zero carbon power supplies to ensure commercial and emissions viability.

[34] Growing Almonds and Apricots in the UK, Soil Association, https://www.soilassociation.org/causes-campaigns/agroforestry/growing-almonds-and-apricots-in-the-uk/
[35] Hodmedods, https://hodmedods.co.uk/pages/our-farmers
[36] Ancient grains deliver top prices for organic farmer, Farmers Weekly, 4 Dec 19, https://www.fwi.co.uk/arable/crop-selection/market-opportunities/ancient-grains-deliver-top-prices-for-organic-farmer
[37] Farmer revives lost art of saffron growing, Farmers Weekly, 13 Aug 14, https://www.fwi.co.uk/business/farmer-revives-lost-art-of-saffron-growing
[38] British Hemp Alliance, https://britishhempalliance.co.uk/about-hemp/
[39] The Hemp Shop (clothing) https://www.thehempshop.co.uk/clothing.html

7. GENERAL POLICY INSIGHTS

It is widely accepted that meeting emissions targets will require significant changes across the agri-food supply chain. Rural decarbonisation also requires fundamental change for many rural communities. In addition, across rural areas, hidden deprivation can be exacerbated by disruption from external factors. Hence, a more balanced and equitable transition is essential. Investment in social capital should become a higher priority, particularly for vulnerable areas and more marginal communities.

For too long, the financial, food supply, and wider leisure and community contribution of rural Britain has been taken for granted. Its contribution to natural capital has been undervalued. Hence, the infrastructure needed to facilitate change is less well developed in remoter areas.

The following general policy insights do not fall under the land resource management, renewable energy, agricultural vehicles or agritech opportunities identified in previous sections.

a) **Rural Engagement:** communities and rural businesses should be consulted on their role in delivering emissions reduction in a way that facilitates change and promotes innovation. If farms, land-based business and rural communities are to play their part in emissions reduction, they must be fully engaged in developing solutions to suit their needs.

b) **Skills training:** the industry needs trained people whose skills are properly recognised and valued. There is an enhanced role for rural colleges and skills centres to provide practical and on-going training for workers in low carbon farming systems and technologies.

c) **Advice, information and demonstration:** With so many new operational and technology options for such diverse farming businesses, the need for sound, independent and cost-effective advice and information is urgent. Along with professional advice, farm cluster groups, and nature groups, technology demonstration sites should be established and funded to help farmers to meet decarbonisation objectives.

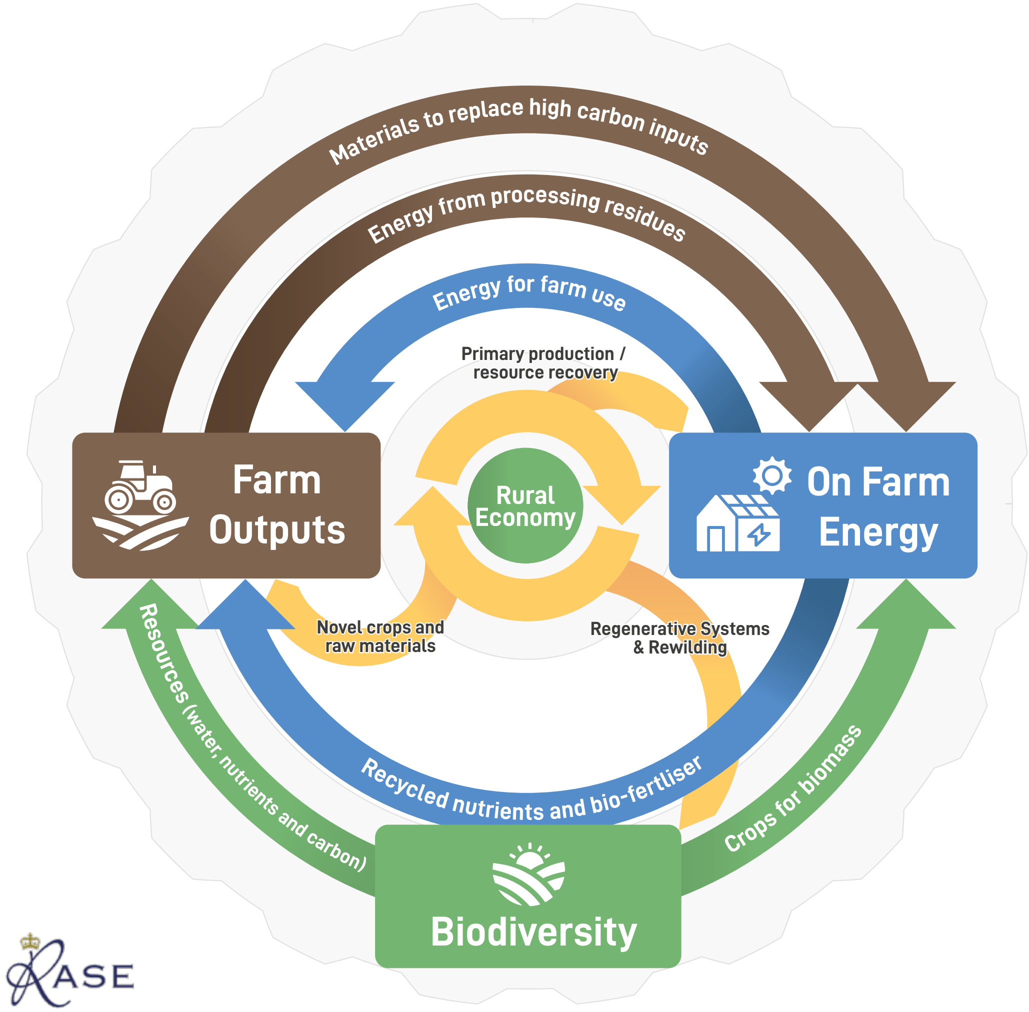
d) **Rural Infrastructure:** With the lower priority that has been given to rural infrastructure such as power grid capacity, lack of access to the gas grid and poor broadband, there is an urgent need for Government investment in a green rural infrastructure ‘catch-up’ fund.

e) **Consumer education:** as public awareness of food supply chain issues grows, expectations are being reflected in purchasing choices and views on waste and recycling.

f) **Research priorities:** a stronger science base is vital to improved measurement and understanding of sustainable production, novel biomaterials, improved pest and disease management, enhanced plant and livestock genetics, training, software development and resource use. R&D funding must help boost UK food self-sufficiency and efforts of rural businesses to improve national food security.

g) **Circular economy:** to encourage delivery of better resource management, policies must support private investment across the agri-food sector in resource efficiency and the avoidance of waste, including recycling of nutrients, water and other natural resources.

Farm circular economy overview



The farm sector should play a leading role in rural decarbonisation but this needs a more ambitious and better coordinated vision, with stronger Government leadership and a willingness to work closely with the industry. This requires solutions and technologies that reflect the commercial realities of incredibly diverse farm sizes and activities, to deliver far-reaching change across the rural sector.

In addition, at a time when there are multiple pressures on public finances, it is crucial that the historical failings of departmental coordination are avoided. To provide the foresight and leadership that is needed, officials from BEIS, DEFRA, DfT, HM Treasury, the Ministry of Housing, Communities and Local Government need to work together when setting policy. Departments also need to engage with and take account of the concerns of farmers, land managers and rural communities who will be expected to deliver the required changes.

If farmers, land managers and communities are to make a full contribution to decarbonisation of the rural economy, there is a requirement for a more coordinated approach across the agri-food sector to deliver full 'systems change'. Cross-sector solutions will also help stimulate investment in low carbon technologies, protect critical food supply chains and drive down costs for farmers. There is a need for better collaboration between the research base, farmers, their supply chain and food processors.

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