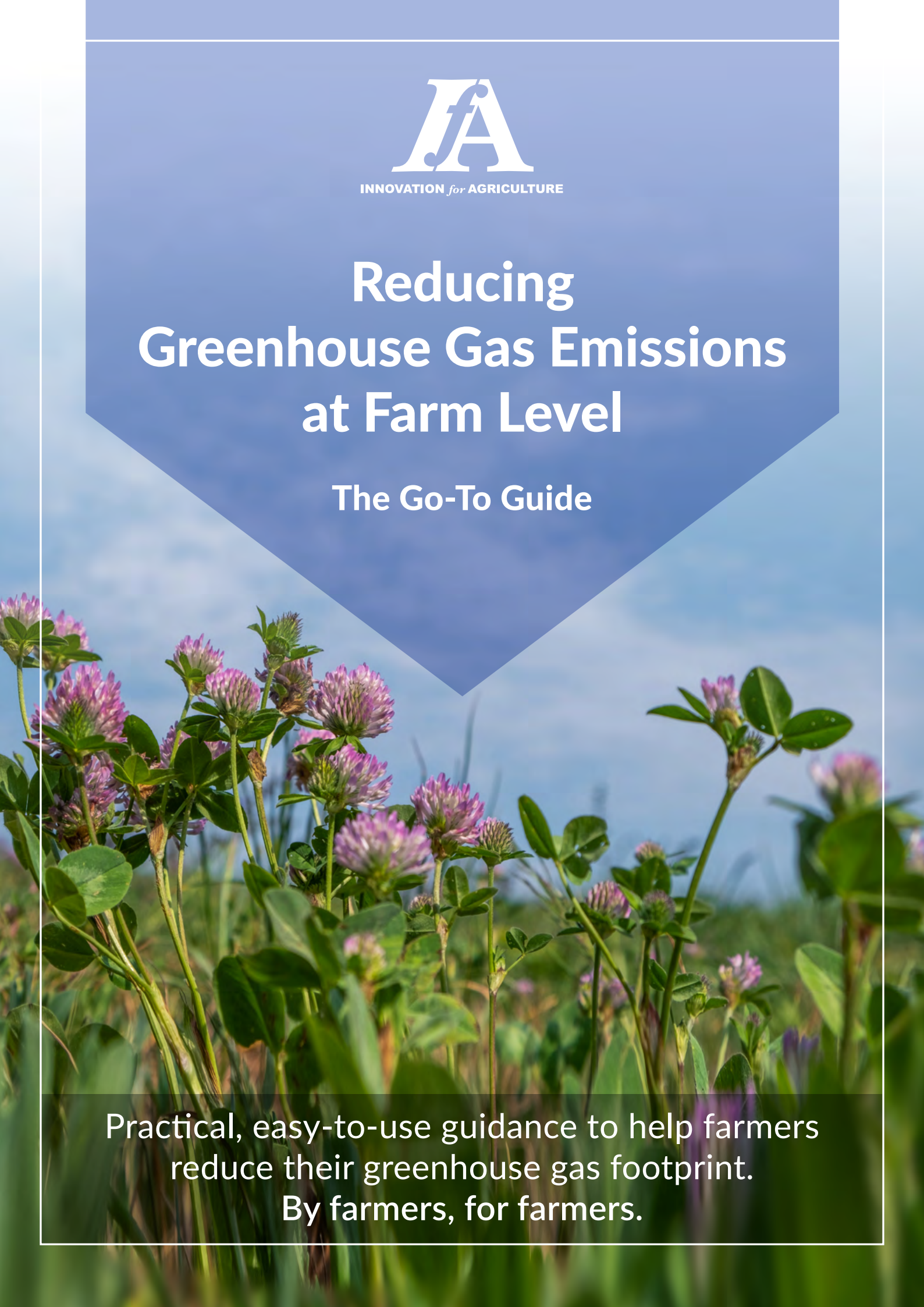
INNOVATION *for* AGRICULTURE

Reducing Greenhouse Gas Emissions at Farm Level

The Go-To Guide



Practical, easy-to-use guidance to help farmers reduce their greenhouse gas footprint.
By farmers, for farmers.

Produced by Innovation for Agriculture, in association with Eunomia Research and Consulting, on behalf of the WWF/Tesco partnership

INNOVATION *for* AGRICULTURE

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Reducing Greenhouse Gas Emissions at Farm Level

The Go-To Guide

Are you interested in the positive impact that your farm could have in tackling climate change?

Are you looking to meet the demand for low carbon farming in a way that is both economically beneficial and environmentally friendly?

Do you want an easy-to-understand, quick reference guide for your farm enterprise which will help you to be part of the solution in reducing global greenhouse gases?

This guide is for you.

WHO IS THE GUIDE FOR?

This guide is for UK farmers, growers and land managers interested in ways to reduce GHG emissions at farm level. The content aims to reflect the range of farming sectors in the UK and will cover:

- Arable cropping
- Horticulture and fresh produce (including glasshouses)
- Upland beef and sheep
- Lowland beef and sheep
- Dairy (extensive and intensive systems)
- Pig (indoors and outdoors systems)
- Poultry (broilers and layers)
- Mixed systems and combinations of above

WHAT THE GUIDE COVERS

The guide has been arranged with easy-to-follow, step-by-step actions for farmers and land managers starting out on the journey of reducing their Greenhouse Gas footprint.

It also includes more aspirational measures for those who are well on their way to transforming their farming business.

The actions presented in this guide are the result of thorough review of the supporting science and subsequent ranking of a long list of measures shown to reduce agricultural GHG emissions. From here a final short list was presented and discussed with a broad, largely representative group of farmers at a farmer-led workshop in June 2021. This short list contains existing measures from the scientific literature with the greatest potential to reduce GHG emissions. The list of measures was then ranked for perceived benefit for cost to the relevant sectors and by the likelihood of implementation – was it feasible now and how palatable is it to those on the ground? This guide is the outcome from this project.

HOW WILL THE GUIDE BENEFIT YOUR FARMING BUSINESS?

This guide aims to make reducing your greenhouse gas footprint easier to understand and implement by:

1. **Providing easy to understand information** for agricultural businesses
2. **Demonstrating a pathway to success** through simple steps that you can take now and into the future with signposting to further resources and tips
3. **Helping you to prioritise what action to take and when**

Contents

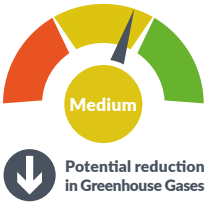
ACTION SWING-O-METERS

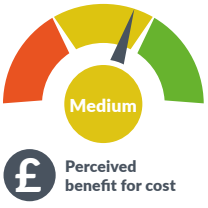
WHAT THEY WILL TELL YOU

The 'swing-o-meters' aim to give you a sense of whether each action has the potential for small or large reductions in GHG emissions.

They also give a sense of whether it has a positive benefit cost ratio for farm business, from a farmer's perspective and not from the scientific literature.

The cost benefit to your farm business is a reflection of the views of a select farmer group and not designed to be an exact figure but a broad representation across relevant sectors.



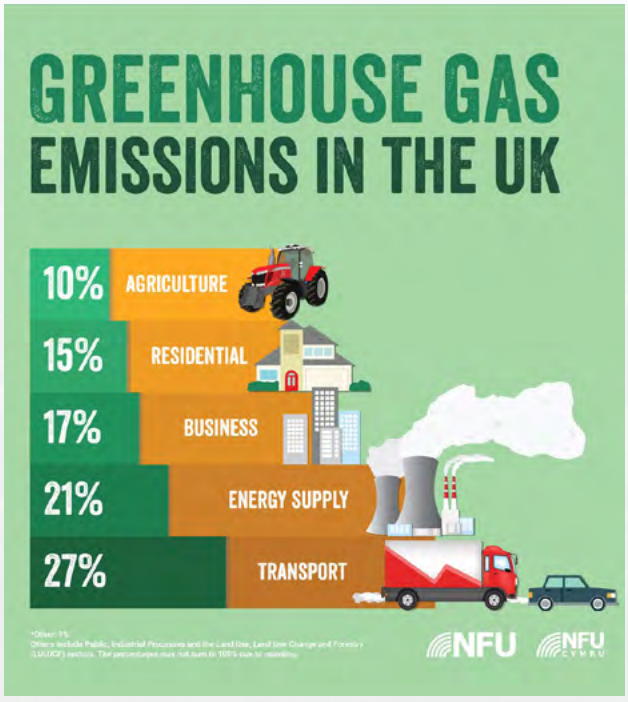


Facts and figures

Climate change is a growing threat to the future of food production, biodiversity and civil society. Increasing emissions of greenhouse gases into the atmosphere means we are not on target to keep a global temperature rise at 1.5 degrees Celsius. This is already having severe knock-on effects to our weather systems and is accelerating climate change.

Greenhouse gases (GHG) act as a blanket around the planet, trapping the heat from the sun and stopping it escaping into space, resulting in Global Warming. GHG include Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O), all of which can be released from on farm activities.

Break down of GHG emissions by industry in the UK*



*Based on Scope 1+2 data (direct/indirect farm-level emissions), not Scope 3 (supply chain emissions)

GHG emissions are measured in units of mass in various ways including CO_2e, GWP-100, GWP-20 or GWP*. Each of these measures has its own set of limitations. Carbon Dioxide equivalence (CO_2e) expresses the impact of different GHG in terms of the amount of CO_2 that would create the same degree of warming. This then gives a single figure measure of a carbon footprint consisting of lots of different gases.

Global Warming Potential (GWP) is a measure of how much heat a GHG traps in the atmosphere over a specific time period, relative to carbon dioxide. The Intergovernmental Panel on Climate Change (IPCC) - the United Nations body for assessing the science of climate change - uses GWP-100. This unit measures how much heat is trapped over a 100-year time frame.

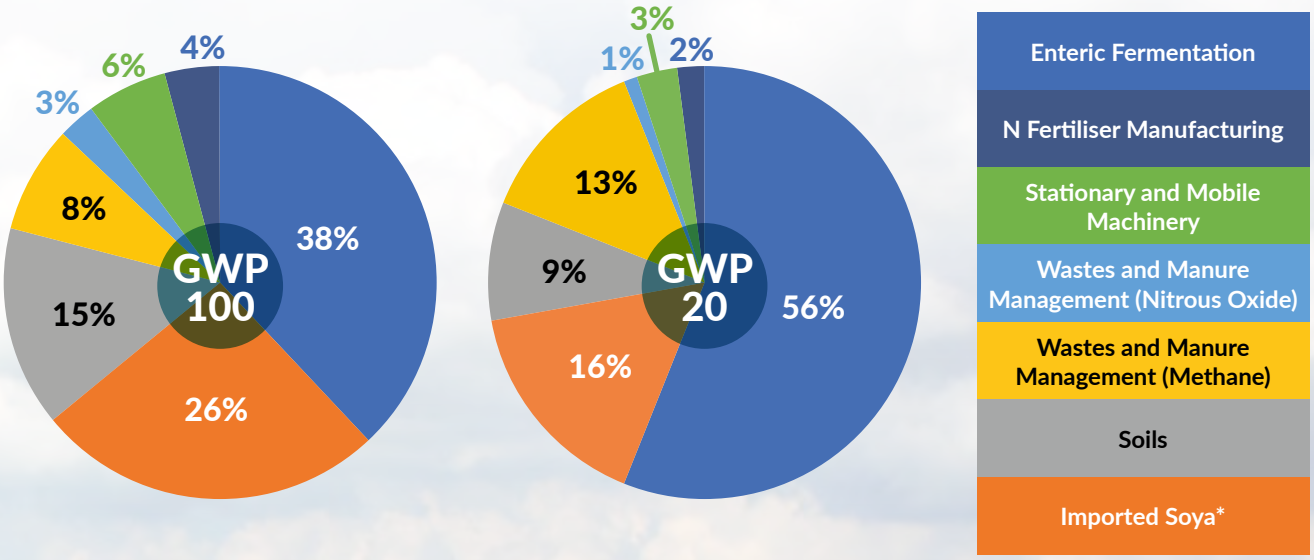
However, the recently released IPCC 6th Assessment report suggests that a focus on a 100-year timescale may be misplaced, considering the dramatic, climate change associated, natural disasters we are witnessing and that a 20-year time horizon is more relevant. Over a 20-year period, methane is 84 times more potent than CO_2. If we use GWP-20 to assess the key sources of UK agricultural emissions, the relative importance of methane is substantially larger.

GWP* is another method for assessing GHG emissions which accounts for the different properties of GHG, their relative time spans in the atmosphere and therefore varied impacts on the climate. Importantly, GWP* accounts for the fact that methane (CH_4) has a much shorter lifespan than CO_2 and N_2O but is a still evolving metric.

Find out more about the IPCC Sixth Assessment report

Follow this link: **tinyurl.com/ReportfromIPCC**

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



More great graphs and data here **tinyurl.com/UK-CO2-profile**

A helpful guide about dairy emissions specifically can be found at this link **tinyurl.com/facts-behind-dairy-emmissions**

The difference between CO_2 and CH_4

It's complicated! CH_4 has a greater warming effect on the planet than CO_2. However, CH_4 starts breaking down after ~9 years, known as its half-life, which means after 30 years, 90% of a given amount of CH_4 has been converted to CO_2 and water, as well as being absorbed and stored in soils as a carbon sink, forming part of a circular carbon cycling system. Emissions of CO_2 stay in the atmosphere for hundreds of years warming the planet for longer.

Plants successfully draw in CO_2 from the atmosphere and ruminants can then digest these plants and covert to nutritionally dense food. If CH_4 emissions remain constant, CH_4 can be absorbed and broken down as fast as it is emitted. However, to limit further global warming, reducing CH_4 can have a significant impact on reducing global temperatures in the short term.

Targets to watch

Climate Change Committee

- Moderate increase in crop yields and 'a more efficient use of N'
- Moderate (5%) increase in stocking rate for grazing animals
- 0.6% /yr increase in dairy productivity between 2020 and 2050
- 10% of horticulture production moved indoors by 2050
- 50% less meat and dairy by 2050
- 50% reduction in food waste (including on farm waste) by 2030 and 70% by 2050

NFU

Net Zero emissions by 2040

WWF

35% reduction in agricultural emissions by 2030 and 51% reduction by 2050 based on 2018 levels

This guide aims to help you understand which actions you can take now and into the future, and where to go for more information. It covers not only direct farm emissions (Scope 1 and 2) but also those from the wider supply chain (Scope 3). It does not cover carbon sequestration (an emerging and rapidly developing area) or ammonia emissions, although some overlap is recognised.

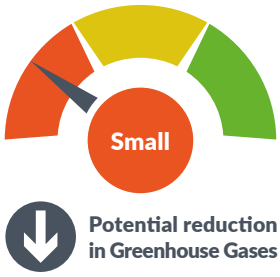
* 'Soya' represents direct production emissions as well as Scope 3 emissions from imported soya deforestation and reforestation 'carbon opportunity cost'.

Cover/Catch crops in arable rotations

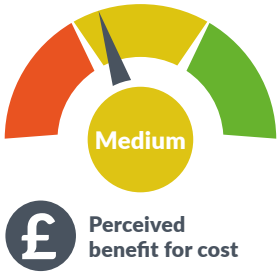
Action 1

Cover crops are usually sown in Autumn/Winter, acting as a canopy to protect the soil, recycle nutrients, help build soil organic matter content, and to combat weeds, pests and diseases. Not only do cover crops increase soil organic carbon content, but they can also improve water retention, acting as a natural flood management system and a buffer for nitrate losses. Crops which include Legumes in the mix have the added benefit of nitrogen-fixation which can lead to less reliance on artificial fertilisers and in turn reduce GHG emissions associated with the manufacture and application of artificial fertiliser. Usually cover crops are not harvested to be sold. Many cover crop varieties can be grazed by livestock. For arable farmers this can provide opportunities for grazing agreements with neighbouring farmers, particularly during periods of forage feed shortages. Alternatively, it could provide opportunities for new enterprises within the business.

Catch crops are a fast-growing cover crop that may be sown to 'catch' nitrogen before it washes out of bare soils, or to replace a failed crop to 'catch' the growing season. Mustard is an example of a catch/cover crop that grows quickly to cover and protect the soil surface, with a strong rooting system to aid soil structure.



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This action is suitable for all growers and livestock farmers managing rotations

- It needs...
  - Ideally late summer/early Autumn establishment
  - Different choice of mixes depending on the end use. Buckwheat, for example, is poisonous to sheep so should not be included in a grazing mix.
  - Tailoring to suit previous and upcoming cropping. For example, you may wish to avoid species with a tap root if your land is susceptible to slugs.
  - A long-term vision of the benefits and an acceptance that there is no immediate financial return.

More information can be found at this link **tinyurl.com/Guide2CoverCrops**

Pathways to success

- For the 2021 growing season farmers are offered £114/ha to grow cover crops under the Countryside Stewardship Mid-Tier or Higher-Tier scheme, option SW6: Winter Cover Crops. Under this scheme you cannot apply any manure or fertiliser to the cover crop.
- Many of the main water companies also offer funding opportunities for cover crops, with Severn Trent, Thames Water, Affinity Water and Cambridge Water all offering different packages. Contact your local water company to find out what packages are available to farmers within their catchment.

It is likely that cover cropping will be included in the upcoming ELM scheme in England.
So keep up to date with the scheme as it develops and be aware of the potential funding opportunities.
Find out more here **tinyurl.com/ELM-overview**

Want to hear from those that have tried it?

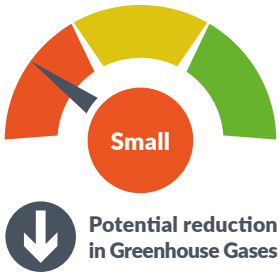
Follow this link **tinyurl.com/covercrop-case-study**

Integrating grass leys into arable rotations

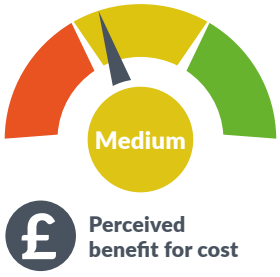
Action 2

Grass leys incorporated into an arable rotation can reduce GHG emissions by reducing losses from artificial fertiliser applications. They can also improve the amount of carbon sequestered (stored) on the farm by boosting soil organic matter. A grass ley can be a useful addition to an arable rotation, by building soil fertility and acting as a break crop to overcome weed burdens. It can be a particularly useful tool for tackling blackgrass when the ley is cut or grazed before the blackgrass goes to head, drastically reducing the seed bank.

Although not an obvious cash crop, there are ways to commercialise a grass ley. Selling the grass as a standing crop to an AD plant can be a profitable option. However, the locality of the AD plant should be taken into consideration as long-distance haulage is costly both financially and in terms of GHG emissions. Alternatively, a cut of silage could be made and sold for livestock or equine feed. There is also the option of renting out the land on a short-term grazing agreement.



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This action is suitable for arable farmers and mixed enterprises.

- It needs...
  - April to October establishment.
  - At least a year in the ground for good establishment and to justify the seed investment.
  - A carefully chosen variety to suit the soil type of the particular field. Tools such as the AHDB 'Recommended Grass and Clover list' may be useful here.
- Expect
  - A high seed cost and a financial return dependant on end use.
  - Reduced artificial nitrogen (N) fertiliser requirement in the following crop from leys containing 30% legumes.

More information can be found at this link **tinyurl.com/grass-leys**

Pathways to success

- If grown for weed control, ensure the ley is cut or grazed in Spring before weeds go to head.
- To sell the ley as a standing crop, ensure that the correct variety for the end use is chosen. High sugar and high digestibility grasses make the best fuel for AD plants for example.
- If for livestock grazing, consider the required infrastructure such as water. Fencing issues can be overcome with temporary electric fencing options.
- Consider utilising the higher-tier or mid-tier options in the Countryside Stewardship Scheme. For the 2021 growing season farmers are offered £522/ha to grow AB15: a two year sown legume fallow. However, under this agreement the sward must not be grazed. Artificial fertilisers are also prohibited. Find out more info here: **tinyurl.com/2-year-legume**
- It is likely that grass leys integrated into arable rotations will be included in the upcoming ELM scheme in England. So keep up to date with the scheme as it develops and be aware of the potential funding opportunities. Find out more here **tinyurl.com/ELM-overview**

Want to hear from those that have tried it?

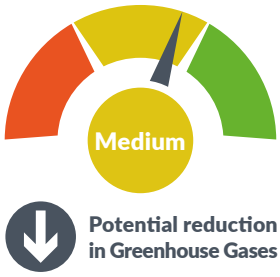
Follow this link **tinyurl.com/farmer-profiles**

Grain legumes in arable rotations

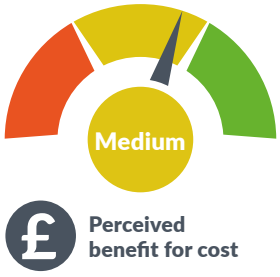
Action 3

Grain legumes include peas, beans and lupins, and can be grown as part of an arable crop rotation to provide a disease break for cereals and OSR. They are best grown in a longer rotation system of 5-6 years to ensure there is not a build-up of pests and diseases. Their nitro-fixing ability supplies nitrogen to the system via a natural source, lowering the reliance on manufactured nitrogen (N) fertiliser. This is particularly important when complying with Nitrogen Vulnerable Zones (NVZ) regulations.

For these reasons, field beans are currently a popular legume crop grown in the UK. They are also a particularly versatile option in terms of establishment and drilling. Growing legumes reduces the need for artificial N fertiliser both during the growth of the leguminous crop and on the subsequent crop due to the residual N. The knock-on benefits include increased biodiversity from flowering crops such as peas and beans. Furthermore, they provide an early entry to subsequent crops, unlike forage maize and sugar beet (both of which are harvested late and can cause subsequent soil damage).



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This measure is suitable for: arable, mixed farmers.

- Growing grain legumes is recommended as part of a 6-year rotation to reduce pest and disease build up.
- Winter beans are better grown on heavier land.
- Beans are suitable for all animal feeds but higher quality crops can be sold for premium markets.
- Grain legumes, as part of a diverse rotation, help to spread the workload on the farm and utilise less labour over a longer period.
- Legumes are of value to increase both the biodiversity and the number of beneficial insects on the farm.

More information can be found at this link:

tinyurl.com/British-pulses

Pathways to success

- Due to the price differential between wheat and some legumes, it may be prudent to consider a 5-year gross margin and benefit from the residual nitrogen rather than a one-year gross margin budget.
- Legumes are beneficial both to the soil and the environment, helping to keep pollinators thriving which boosts on-farm diversity.

Want to hear from those that have tried it?

Follow this link **tinyurl.com/FWI-pulses**

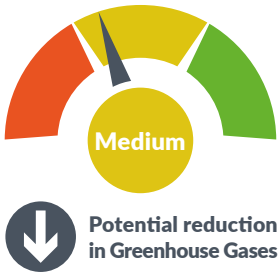
Keeping soil pH at an optimum level for plant growth

Action 4

You can keep pH at an optimum level through liming. There are many benefits to spreading lime on your farm. Lime is a soil conditioner and controls soil acidity by neutralising the effects of acids from nitrogen (N) fertiliser, slurry and high rainfall. Other benefits include an increase in earthworm activity, improvement in soil structure and grass can be more palatable to livestock.

By liming fields, you can achieve the ideal soil pH range which is between 6.0 and 7.0 (neutral). Specifically, plants prefer slightly acidic soils. 6.5 is considered to be the optimum level for nutrient uptake.

The addition of lime helps to release soil nutrients. Fertilisers and manure cannot be fully effective if the soil pH is not optimal. When applied, N is susceptible to losses through nitrous oxide (N_2O) emissions which is around 300 times more potent than carbon dioxide (CO_2) as a greenhouse gas. So, by increasing the potential for N uptake through liming, there is a real opportunity to significantly reduce GHG emissions from agriculture.



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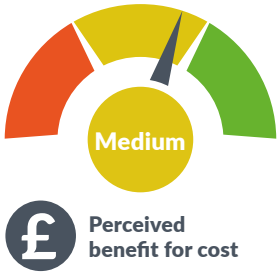


Perceived benefit for cost

How should I approach this?

This measure is suitable for all sectors and systems.

- It needs:
  - A long term view. Soil pH testing should be carried out every 3-5 years to ensure optimum levels are maintained.

More information can be found at this link: **tinyurl.com/facts-on-liming**

Pathways to success

- The cost of the lime can be a disincentive but should be rationalised by improved soil health, nitrogen efficiency and crop yield.
- As a rule of thumb, a 2.5t/ha (1t/acre) application of lime will raise pH by 0.3 units on a medium textured mineral soil, so if the pH is 5.5, an application of 5t/ha (2t/acre) will raise the pH to about 6.0.
- Clay soils need more lime than sandy soils to raise pH by 1 unit – apply at a maximum of 7.5t/ha (3.0t/acre) in one application.
- Slurry application should be avoided for up to three months after lime during drier periods and the same goes for urea fertiliser.
- Liming costs should be considered as a capital investment rather than a gross margin input.
- The longer-term benefits will depend on the sequence of crops in the rotation.

Want to hear from those that have tried it?

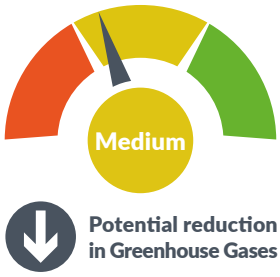
Follow this link **tinyurl.com/liming-benefits**

Minimum-tillage cultivations

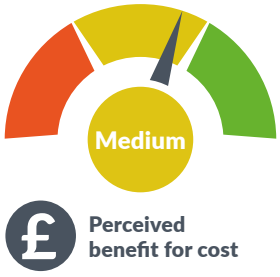
Action 5

Minimum tillage, non-inversion tillage, and reduced tillage are all terms which refer to cultivation techniques that do not include deep inversion ploughing, instead aiming to cultivate as little as possible, only to a depth of 15cm. Direct drilling takes this practice a step further by drilling straight into stubble with no prior cultivation. Minimum tillage practices can reduce GHG emissions through decreased use of fossil fuels in field preparation and also have the added benefit of increasing carbon sequestration in soil.

Many farmers are now turning to minimum-tillage systems as a way to improve soil structure and reduce cultivation and labour costs. By moving as little soil as possible, less dormant weed seeds are chitted which can also help overcome weed burdens such as blackgrass.



Potential reduction in Greenhouse Gases

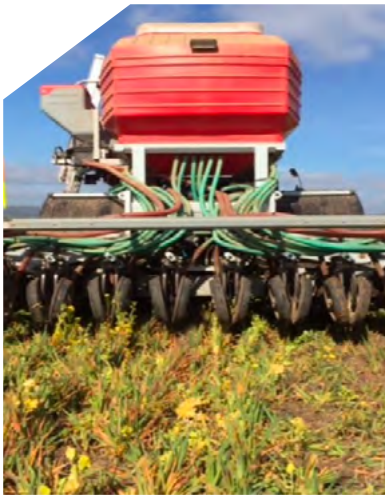


Perceived benefit for cost

How should I approach this?

This action is suitable for arable and mixed enterprise systems.

- It needs...
  - Chemical control of weeds pre-drilling.
  - Level fields post-harvest. A controlled traffic system can help to avoid the requirement for deep inversion tillage to remove post-harvest wheelings. This will avoid ruts across the field caused by corn carts and will ensure a level enough seed bed for the drill. An advantage of minimum tillage is that compaction can be avoided by keeping the tramlines in the same place each year. This is not possible in a plough-based system.
  - As with any cultivation, moist, friable and workable soil is needed. If the soil is worked when it is too wet and is plastic (when it can be moulded like putty) compaction and smearing damage will result. For more advice refer to the following soil guides: **tinyurl.com/UK-soil-initiative**
- Expect
  - A reduction in labour and cultivation costs.
  - An increase in populations of beneficial insects such as predatory ground beetles and parasitic wasps.
  - The increased risk of slug damage from harvest residues and stubble.
  - An initial reduction in yields. Yields normally recover as the level of soil organic matter increases.



Pathways to success

- Ask your farm advisor to help assess your soil type, structure and suitability for min-till or no-till. These methods are more successful on soils with good structure and drainage.
- Consider using cover crops with deep roots such as 'Tillage Radish' as a natural tool within a reduced tillage system to break up deep machinery pans and compaction in heavier soils (see Action1).
- Try before you buy – use contractors or hire machinery to assess how the system works on your soil type and within your current enterprise before making a financial commitment to change farm kit. Alternatively, consider making adaptations to your own drill such as changing to narrower coulters.
- Utilise a diverse rotation, ideally more than 3 crops, to avoid weed build up and resistance.
- It is likely that reduced tillage will be included in the upcoming ELM scheme in England. So keep up to date with the scheme as it develops and be aware of the potential funding opportunities. Find out more here **tinyurl.com/ELM-overview**

Want to hear from those that have tried it?

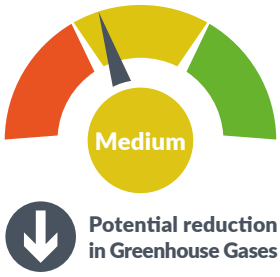
Follow this link **tinyurl.com/no-till-experiences**

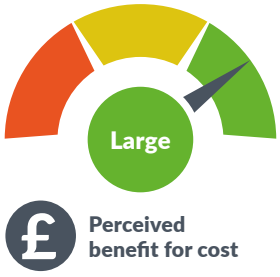
Precision fertiliser applications and avoiding excess nitrogen

Action 6

Nitrogen (N) fertilisers are used to boost crop yields but poor use and application contributes to nutrient loss and indirect GHG emissions. In some cases, only 40-50% of N fertiliser that is applied to crops is taken up. Not only are such losses a waste of financial resources to farmers, but they also have harmful consequences for the environment. The unused N is lost either through groundwater leaching or by volatilisation, the loss of N to the atmosphere as ammonia (NH_3) gas and nitrous oxide (N_2O). Preventing these emissions is hugely important - N_2O, for example, is 300 times more potent then CO_2 as a contribution to CHG.

There are opportunities to improve the efficiency of chemical fertilisers by more accurate timing of application and by applying nitrogen to match specific plant needs. This can be done through Variable Rate Technology (VRT) which allows specific rates to be applied to exact areas of the field based on results from soil testing. Targeting nutrients using soil mapping and VRT does not necessarily mean that you will use less nutrients overall, but it does mean that what you are applying is being used more efficiently.





How should I approach this?

This measure is suitable for: arable, dairy, beef and sheep farmers.

- To utilise VRT you will need to soil test. Initially speak to your agronomist about the various packages available to do this. Monitor soil pH levels to maintain nitrogen uptake. See Action 4 for more detail.

More information can be found at this link: **tinyurl.com/soil-mapping-guide**

Pathways to success

- Utilise the 4 R nutrient strategy (right source, right rate, right time, and right place). This is an accepted protocol for nutrient management which ensures that product, calibration, crop, weather and placement are all considered when using nitrogen fertilisers. The strategy can be accessed here: **tinyurl.com/nutrient-stewardship**
- If a fertiliser spreader has an electronic control, it is possible to convert it to a variable-rate operation for around £500.
- 3-8% is the potential grassland yield benefit from targeted nitrogen application (currently seen on arable, but also likely on grass).
- £34/ha is the benefit of variable-rate phosphate, potash, magnesium and lime compared with flat-rate application (as seen across 1m hectares of grass, arable and vegetables).
- £3-6/ha/year is the rough cost of phosphate, potassium, magnesium application based on soil mapping recommendations. Cost will vary depending on the level of service and detail required.

Want to hear from those that have tried it?

Follow this link **tinyurl.com/precision-fertiliser**

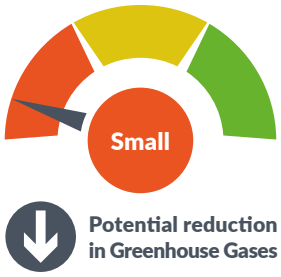
Enhanced efficiency fertilisers (EEFs)

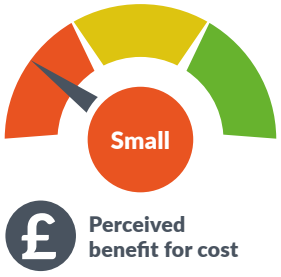
Action 7

The use of artificial fertiliser is a key source of GHG emissions. In some cases, 40-50% of nitrogen (N) fertiliser applied to crops is lost through nitrogen leaching or volatilisation, not only causing environmental concerns but also an inefficient cost to farmers. Urease inhibitors, nitrification inhibitors and slow-release fertilisers, together known as 'enhanced efficiency fertilisers' have emerged as mitigation tools to combat these negative effects.

Inhibitors and stabilizers: These are chemical additives that stop or slow biological nitrogen processes in the soil. There are two types of inhibitors broadly used, the first locks nitrogen in the soil, and the second slows the conversion rate of ammonium nitrate, reducing the amount of urea lost to the atmosphere. The inhibitors can be applied alongside the fertilisers through injection into the soil (for liquid fertilisers), as a coating on granular fertilisers or can be mixed into slurry for application.

Slow-release and controlled-release products: Controlled release fertilisers (CRF) are products that provide readily available N more slowly than conventional fertilisers (over a period of 2-6 months). Using polymer coatings that limit the exposure of the fertiliser to environmental conditions, these physical barriers stop the fertiliser from dispersing immediately, allowing moisture to slowly dissolve the nutrient over a longer period of time. By slowing the release of nitrogen, both inhibitors/stabilizers and slow release products minimise N losses which in turn reduces GHG emissions.





How should I approach this?

This action is suitable for arable farmers and all livestock farmers who are applying fertilisers to grass/forage crops.

- Expect
  - A higher output cost but the potential to reduce fertiliser application rates by up to 20%.
  - Better N-efficiency and a reduced need for split applications.
  - Better water quality, this is particularly important as regulations tighten around Nitrate Vulnerable Zones.
  - Some nitrification inhibitors claim to reduce nitrous oxide (N_2O) emissions by more than 50%.

More information can be found at this link **tinyurl.com/enhanced-fertilisers**

Pathways to success

- Discuss with your agronomist whether this is a cost-effective option for you based on the quantity and timings of your fertiliser applications.
- Shop around. Many Agri-chem companies offer their own version of these products. Ask them how theirs differs in terms of the functionality and the price of the product.
- Have a long-term view. Although the initial price for slow-release fertiliser is still higher than conventional fertiliser, when you take into account the cost savings from decreased nutrient losses, split applications and crop damage, it can become more competitively priced.

Want to hear from those that have tried it?

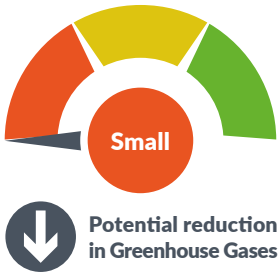
Follow this link **tinyurl.com/enhanced-nitrogen-efficiency**

Manure management: Covering and re-designing slurry stores

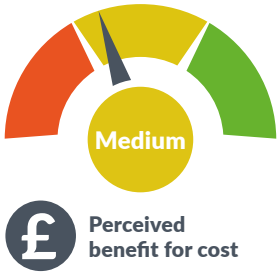
Action 8

This action involves covering your slurry store with an impermeable cover to exclude oxygen. This includes free or fixed plastic floating covers on tanks and lagoons, as well as integral stores and covers in the ground. In the UK, covering and storing slurry in certain ways is a regulatory requirement (known as the 'SSAFO' regulations). You must inform the Environmental Agency of any changes or creation of new slurry stores.

Livestock manure decomposes to form a mixture of carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) during storage, most of which is methane. Reductions in GHG from slurry have been hard to quantify and vary between studies, especially as there is variation in effective covering of slurry stores. Covering certainly helps reduce ammonia (NH_3) and is a regulatory requirement, but NH_3 is not a GHG. The impact on N_2O and CH_4 is less clear but it is likely there is a positive impact and other co-benefits in line with policy developments.



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This measure is suitable for pig, poultry & cattle farmers.

- It needs
  - Notification to the Environment Agency at least 14 days before you begin construction **tinyurl.com/environment-agency-contact**
  - Slurry stores to have lifespan of at least 20 years with maintenance, to be impermeable and meet anti corrosive standards **tinyurl.com/slurry-code-of-practice**
  - To be at least 10 metres clear of inland or coastal waters – you may need a larger 'safety zone' in some cases e.g., near a water supply intake.
  - At least 4 months storage capacity.
  - Planning permission - **tinyurl.com/info-on-planning**
- Expect
  - Penalties for failure to comply.
  - To do calculations based on amount of slurry anticipated and weather conditions - add 25% for wetter-than-average winters.
  - Larger indoor units (pigs) may need permits, see **tinyurl.com/environ-permitting-regulations**

More info can be found at following links:

tinyurl.com/benefits-covering-slurry and **tinyurl.com/info-on-slurry-stores**

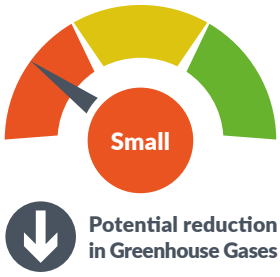
Pathways to success

- Check the above regulatory guidance to understand what you can/cannot do with your slurry.
- Speak to the Environmental Agency and an independent advisor or engineer and they can advise you on covers and building requirements.
- Capital investment for new/improved slurry stores can be overcome by applying for grants from Defra – coming Autumn 2021 **tinyurl.com/farming-investment-fund**

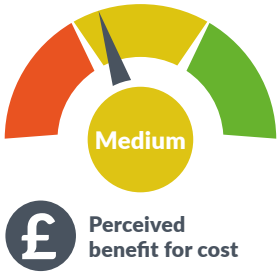
Waste management: Installing and using anaerobic digesters

Action 9

Anaerobic digestion is the decomposition of organic materials (such as manure) in the absence of oxygen, creating biogas (a mixture of methane and CO_2) and fertiliser, known as 'digestate'. Biogas can be used to produce heat or fed into a Combined Heat and Power (CHP) plant to produce both heat and electricity. CHP's can be used 'off-grid' for local heating and power but are typically connected to the electrical grid. Recent policy incentives - Green Gas Support Scheme (GGSS) - have encouraged the upgrading of biogas to biomethane for injection into the gas grid as well as the processing of any CO_2 to pipe into glasshouses (see action 18).



The digestate can be spread on crops 'whole' or separated into a fibre and a liquid. The separated fibre contains more slow-release carbon necessary for improving soils. The liquid contains more readily available nitrogen for use through irrigation systems. Both whole and liquid digestate can easily evaporate creating ammonia emissions so low emission spreading equipment should be used. Digestate stores should be covered in order to minimise GHG emissions, prevent nutrient loss and meet UK government regulation (see Action 8).



Whilst AD is not a zero-carbon technology, it has the potential to recycle nutrients back to the land and add value to waste products. In recent years, AD systems have become much larger with the advent of the feed-in tariff (FIT), which encouraged electricity production from crops. The carbon footprint of growing crops, such as maize, to feed into AD is substantial and reduces the positive impact on emissions compared with using waste products. Growing maize also has negative impacts on soil health.

How should I approach this?

This measure is particularly suited to mixed farms (where there are other organic wastes), arable farms (which can feed in break crops/surplus crops), dairy farms (with need for digestate and CHP systems - see Action 18).

- It needs...
  - Careful independent examination of the economics from project development, operation, refurbishment and end of life.
  - Consideration of the cost of electricity/gas grid connections, odour, regulatory and planning considerations, ongoing permitting costs, maintenance costs (including gas use systems such as CHP and gas removal), digestate storage and use costs..

Pathways to success

1. Speak to farmers/landowners who have AD to find out the challenges, costs and good technology providers. Contact IfA at **info@i4agri.org** to help connect you.
2. Read as widely as possible about the technology - investigate realistic operation and maintenance costs, as well as critical equipment availability (lead times). Be very wary of anyone who says their technology is significantly faster than competitors or can run on your mobile phone!
3. Speak to more than one supplier, ensure they have a good (ideally UK) track record on construction and support and make sure that you back-up their figures with independent advice.

More sources of information:

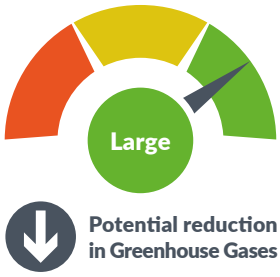
tinyurl.com/info-on-AD **tinyurl.com/RASE-farm-energy** **tinyurl.com/help-on-biogas**

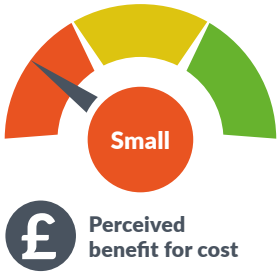
Livestock diets: Feed additives for ruminants

Action 10

Cattle, sheep and other ruminants emit methane (CH_4), a greenhouse gas that warms the planet and contributes to climate change. Ruminants produce this methane when bacteria break down cellulose in their rumen. 6-12% of the energy in cow feed is lost as methane. Altering the fermentation process in the rumen has the potential to produce less methane.

Adding small quantities of a variety of different feed additives (e.g., 3-NOP, nitrate, seaweed, biochar) to ruminant feed can reduce methane without substantially changing diets. Some foods, such as fats and oils, suppress methane release as well, providing non-cellulose sources of energy for ruminants.





How should I approach this?

This measure is suitable for some dairy, beef & sheep farmers

- It needs
  - Willingness to experiment with feed additives and alternative feed ingredients.
  - Data monitoring on DMI, feed digestibility, DM, CP, Nitrogen, LWG etc.
  - A chat with an impartial nutritionist and vet before, during and after making changes.
- Expect
  - Potentially higher feed costs.
  - Livestock health impacts from changes to diets as this is an emerging scientific area.

More regulatory information from the Food Standards Agency can be found at this link **tinyurl.com/animal-feed-additives**

Pathways to success

1. Speak to feed companies and other organisations that sell feed additives that reduce methane emissions – what different products can they offer you?
2. Impartial advice can be sought from advisors/nutritionists not linked to sales of products. Use this link to search feed advisors: **tinyurl.com/reg-feed-advisor**
3. Use data monitoring programmes and your advisors/vets to follow livestock average weight gains, feed intakes and any key diseases before, during and after any changes.
4. Capital investment to help with feeder wagons/feed equipment can be overcome by applying to grants from Defra – coming Autumn 2021 **tinyurl.com/farming-investment-fund**
5. Interested in signing up to a field trial? More info here **tinyurl.com/innovative-farmers**

Want to understand more about altering ruminant diets?

This University of Reading article contains more information and links to a course on climate smart farming **tinyurl.com/climate-smart-agri**

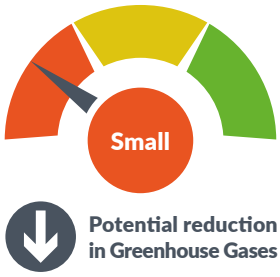
Livestock diets: Low cellulose diets for ruminants

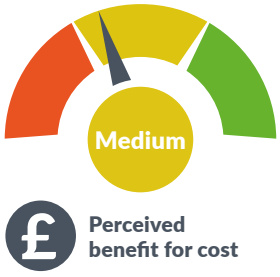
Action 11

Cellulose is a major component of grass that makes up most of ruminant diets. This action refers to reducing the amount of cellulose (i.e. fibre) in ruminant diets by increasing easily digestible starches, sugars and fats, either in feed rations or by modifying the species, variety and type of grass in pasture mixes.

Cattle, sheep and other ruminants emit methane, which is a greenhouse gas that warms the planet and contributes to climate change. Ruminants produce this methane when their ruminant bacteria break down cellulose in their rumen. 6-12% of the energy in cow feed is lost as methane! If ruminants are fed a lower proportion of cellulose (fibre), they will produce a lower quantity of methane but there are implications for rumen health.

Some foods, such as fats and oils, also act as methane suppressing additives as well providing non-cellulose sources of energy for ruminants





How should I approach this?

This measure is suitable for dairy, beef & sheep farmers

- It needs...
  - Willingness to experiment with livestock feed or pasture mixes
  - Data monitoring on feed digestibility, DM, CP, Nitrogen, LWG and metabolic performance
  - A chat with an impartial nutritionist and vet, preferably together

More information can be found at this link:
tinyurl.com/reducing-methane-emissions

Pathways to success

- If you already graze cattle/sheep, consider speaking to grass seed companies about low cellulose species/varieties of grass (i.e., less fibre, more variety)
- Impartial advice can be sought from advisors not linked to sales of products
- Graze livestock on younger grasses or cut silage when grass is at leafier stage than later stage of growth (can achieve 30 % less methane emissions!)
- Trial grazing pasture with low cellulose varieties compared to normal varieties to assess how livestock perform – speak to your vet about risk of metabolic acidosis
- Use data monitoring programmes and your advisors/vets to follow livestock average weight gains, feed intakes, DM and any key diseases before, during and after any changes
- Sign your farm up to a field trial at this link **tinyurl.com/innovative-farmers**
- Capital investment can be overcome by applying to grants from Defra - coming Autumn 2021 **tinyurl.com/farming-investment-fund**

Want to hear from those that have tried it?

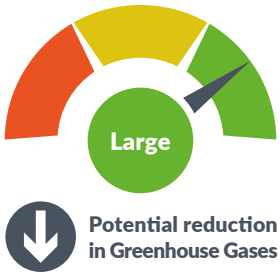
Follow this link **tinyurl.com/changing-cow-diets**

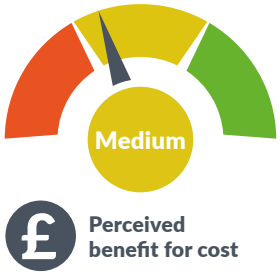
Livestock diets: Replacing imported soya as an animal feed

Action 12

The land and resources used to grow animal feed, such as soya, creates substantial GHG emissions. This is from a combination of direct production emissions, indirect from deforestation and lack of reforestation due to continued soya cultivation, plus emissions from moving soya across the world. Replacing soya with alternatives which have a lower land requirement and are grown/made domestically could substantially reduce GHG emissions, particularly in sectors heavily dependent on soya protein. It would also allow some of the most biodiverse regions of the world (e.g., the Amazon rainforest) to be conserved and even re-established.

Example alternatives: Rapeseed/oilseed meal; Peas and beans; Seaweed; Distillers' grains and other co products. In the future, insect meal could provide opportunities for a high protein, low GHG feed if legislation allows. More information can be found through the link here: **tinyurl.com/future-of-feed**





How should I approach this?

This action is suitable for all livestock farmers who feed soya-based products, especially pig, poultry and dairy.

- It needs...
  - Willingness to experiment with alternative feed ingredients/co products.
  - Data monitoring on feed digestibility, DM, CP, Nitrogen, LWG .
  - A chat with an impartial nutritionist and vet, preferably together.
- Expect
  - Potentially higher feed costs in short term.
  - Huge GHG reductions.

More information can be found at this link **tinyurl.com/reduce-reliance-on-soya**

Pathways to success

- Speak to feed companies and organisations that sell alternative feed products/co products to discuss moving away from soya – what can they offer you?
- Impartial advice can be sought from advisors not linked to sales of products
- Use data monitoring programmes and your advisors/vets to follow livestock average weight gains, feed intakes and any key diseases before, during and after any changes
- Sign your farm up to field trials **tinyurl.com/innovative-farmers**, especially if you want to start growing your own protein crops
- Capital investment can be overcome by applying to grants from Defra – coming Autumn 2021 **tinyurl.com/farming-investment-fund**

> **We use specific amino acids to reduce the overall total crude protein in diets, with the help of specialist species-specific nutritionists. Also use enzymes to maximise nutritional value of other raw materials ...Appliance of science with practice - is the challenge for all sectors.**

Poultry farmer, Elwyn Griffiths, Griffiths family farms , Shropshire

Livestock breeding: Genetic improvement of livestock

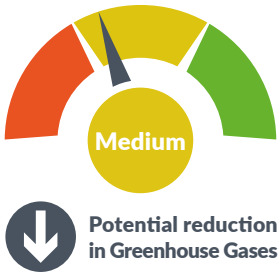
Action 13

Genetic selection of breeding livestock can be used to improve the conversion efficiency of feed to meat or milk and, for ruminants, can be done in ways that also reduce methane emissions. Feed conversion ratios (FCR) are a good measure of the efficiency of livestock production. They are calculated by dividing the weight of the feed intake by the weight gained by the animal over a set period of time. The lower the ratio, the more efficient the animal.

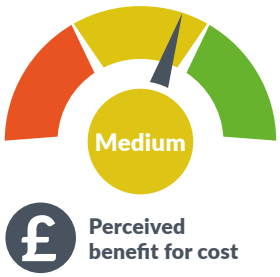
Reducing the amount of feed needed to produce a finished animal reduces the emissions associated with producing that product, such as indirect emissions from growing, manufacturing, and moving animal feed. By recording and selecting animals for higher growth rates and FCRs, it reduces the total number of animals required to produce a given quantity of product. For ruminants, it also reduces direct methane emissions from enteric fermentation and the emissions from manure. This is because they reach slaughter weight quicker, so in their lifetime emit less methane and consume less inputs with a carbon footprint.

Many health traits are also partly inherited, and so genetically selecting for improved health can lower your GHG emissions as outlined in Action 14. Disease rates in dairy cows have been found to decrease by 30% over three generations through selective breeding: **tinyurl.com/disease-resistant-genetics**. Alongside improved immunity, improved health can be selected for through calving/lambing ease, fertility, and conformation.

The breeding support services available will vary depending on the livestock breed. Alongside commercial breeding companies, breed societies may be able to provide more species-specific advice.



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This action is relevant for all livestock farmers

- It needs...
  - Willingness to experiment with different breeding strategies from breed choice up to genomic technology.
  - Upfront investment in data recording technology.
  - Data recording on feed intake and daily liveweight gains.

A place to start: **tinyurl.com/signetdata**

Pathways to success

- Investment in new stock and breeding support services.
- Careful selection and culling process to increase the rate of genetic gain - discuss a breeding plan with your advisor/vet.
- Thorough performance recording including weighing data using an app or computer programme.
- Advice on animal selection and EBVs: **tinyurl.com/breedingforbetterreturns**

Want to hear from those that have tried it?

A case study on performance recording in sheep: **tinyurl.com/recordingcrossbreddata**

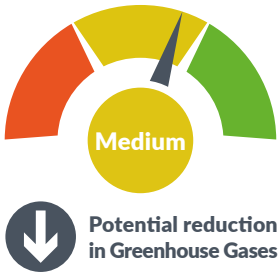
Livestock health and management: Improving livestock health

Action 14

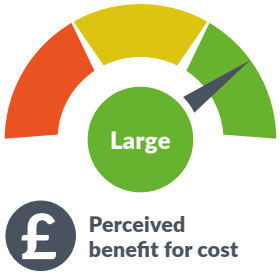
Improving livestock health contributes to a productive herd/flock and means animals are using feed resources efficiently. This can be achieved by active health planning, prevention of diseases, such as diarrhoea and pneumonia, effective biosecurity, improved housing conditions, and improved disease screening and monitoring.

Research has shown that emissions from the production of ruminant meat and milk are sensitive to changes in key production indicators, such as fertility and mortality rates, milk yields and feed conversion ratios. All of these parameters are influenced by an animal's health status, so improving health status can lead to reduced emissions. Animals with disease, even without symptoms, have poorer FCRs and waste costly inputs such as feed. These inefficiencies will have an impact on your farm's GHG footprint and your bottom line.

Healthy livestock = Healthy bank balance = Healthy planet!



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This measure is suitable for pig, poultry, dairy, beef & sheep farmers.

- It needs...
  - Close collaboration with your vet/advisors, preferably together. IfA can help establish a farm health team so you can work together to tackle disease **tinyurl.com/IfA-livestock**
  - Data monitoring on DMI, LWG, production, mortality and disease parameters.
  - An active farm health plan that is reviewed frequently and updated with data and progress.
- Expect
  - Investment in livestock disease monitoring systems whether activity sensors, shed cameras, data recording apps or weigh scales with a crush.
  - Expenditure on medicines such as vaccines and housing improvements.
  - Fewer antimicrobial treatments in the longer term because of healthier and more productive animals!

Follow these links for more information **tinyurl.com/global-research-alliance**
tinyurl.com/farmhealthonline **tinyurl.com/nadis-data**
tinyurl.com/controlling-parasites **tinyurl.com/controlworms-sustainably**

Pathways to success

- Capital investment for new housing/animal sensors etc. from Defra - coming Autumn 2021 **tinyurl.com/farming-investment-fund**
- Use data monitoring programmes to follow animal performance, which helps you pick up disease sooner. Discuss data and trends with your advisors/vets - a free phone call is all it takes!
- Think about any incoming livestock to your farm – can you isolate them for 2-3 weeks and test their health status? Look at this cattle-focused checklist **tinyurl.com/cattle-purchase-checklist** for help deciding what is important before you buy in stock? Better still, could you keep a closed flock/herd?
- Visit similar/nearby farms to see other types of livestock housing and ways to improve for low cost. Get in touch for help: **info@i4agri.org**

Check out videos from farmers who have improved livestock health

Follow this link **tinyurl.com/VideosIfA**

Reducing GHG emissions by tackling endemic diseases*

Endemic diseases are routinely or frequently present in livestock and can result in

- less total product (e.g., milk, meat or wool)
- livestock taking longer to reach their target market weight
- delayed onset and reduced quality of production (e.g., milking heifers failing to calve at 22-24 months)
- lost production (i.e., lambs or calves aborted due to infection)
- premature culling/premature death of animals
- waste of animal products from condemnation at abattoir
- reduced reproductive performance over lifetime

Endemic disease also negatively impacts animal and farmer welfare. GHG emissions from livestock production vary dependent on levels of disease, mortality, fertility and productivity as detailed in the above list. By reducing disease and therefore improving animal health, we can indirectly reduce GHG emissions. Try tackling the following 3 diseases, which have been ranked the most cost-effective and feasible to reduce emissions based on data from Moredun Institute in Scotland.

Neospora

Leading cause of abortion in cattle

What you can do

- Whole herd testing to check for prevalence
- Exclude infected cows from breeding
- Prevent dogs getting to afterbirth etc.
- Educate dog owners on your land to pick up faeces/keep dogs on lead/ avoid cattle feeding areas

Infectious Bovine Rhinotracheitis (IBR)

Cause of respiratory disease and poor fertility/abortion in cattle

What you can do

- Test and diagnose infection
- Vaccinate (using a vaccine that shows infected animals from vaccinated ones)
- Isolate incoming stock and test
- Minimise mixing of stock with neighbouring stock

Parasitic Gastroenteritis (PGE)

Roundworm infection of sheep leading to reduced performance & productivity

What you can do

- Know what worms are present on your farm and their resistance profile
- Isolate and treat incoming stock
- Targeted treatment of infected animals (diagnose through FEC, regular weighing, clinical signs)
- Cull out affected individuals/breed for worm resilience
- Ensure optimal nutrition

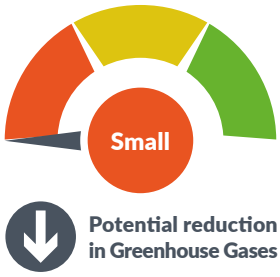
***taken from Livestock Health and Greenhouse Gas Emissions by P.J.Skuce and authors, Moredun Research Institute tinyurl.com/MoredunSkuce**

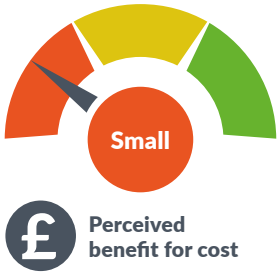
Livestock health and management: Increasing milking frequency

Action 15

Increasing milking frequency, for example from two to three times a day or through installation of robotic milkers, improves the utilisation of amino acids and nitrogen for milk production in the dairy cow. This means less nitrogen is excreted as manure/urine, which reduces N_2O emissions as well as nitrate leaching and ammonia emissions.

An increased milk yield could mean fewer cows are needed so less indirect GHG emissions from feed production. However, higher yielding cows do have increased feed intakes so consideration of the land use requirements of fewer but higher yielding cows needs to be assessed.





How should I approach this?

This measure is suitable for dairy farmers.

- It needs...
  - Upfront capital investment to either install robots or alter your current milking parlour as well as increased labour requirements and parlour maintenance costs.
  - Close collaboration with your vet and milking parlour technicians, preferably together.
- Expect
  - Increased production of ~15% if managed well! The profit per cow can vary dramatically depending on current production, milking hygiene and protocols, staffing levels and existing infrastructure.
  - Improved cow health from reduced SCC and better udder health.
  - Research has estimated major reductions in nitrogen and ammonia emissions 'from getting more from less'.

More information can be found at this link from Michigan State University **tinyurl.com/3xmilking**

Pathways to success

1. Ask yourself and your farm team - is 3 x a day milking for you? Have you got access to enough staff willing to work unsociable hours? Can existing farm infrastructure and equipment cope with the increased throughput? There will be increased power, maintenance and feed costs. Will the potential increased yield offset this? Would robotic milkers be a better option?
2. Visit other similar or nearby farms that transitioned to 3 x day milking or installed robots. Contact us and we can help you connect with UK and international farmers **info@i4agri.org**
3. Capital investment to help with robots or parlour improvements can be overcome by applying to grants from Defra – coming Autumn 2021 **tinyurl.com/farming-investment-fund**

Read this article to work out whether this is the right step to take

Follow this link **tinyurl.com/milking-frequency**

Action 16

Livestock health and management: Grass-legume mixes in pasture

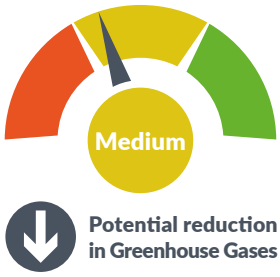
The nitrogen fixing properties of legumes helps to facilitate a reduction in GHG emissions on farm by reducing the artificial nitrogen fertiliser requirement. The addition of legumes to a grass pasture is of further benefit to livestock through an increase in protein content, improved palatability of the pasture and for the anthelmintic properties of legumes.

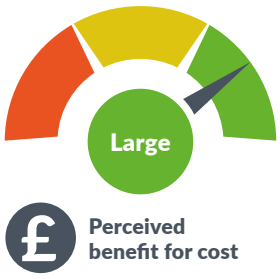
To have maximum GHG reduction impact, the legumes should account for 20-30% of the sward mix.

Key pasture legumes include:

White Clover	Red Clover	Lucerne
Sainfoin	Birdsfoot Trefoil	Vetches

Each legume has its own benefits and limitations which needs consideration before being incorporated into a pasture. For example, the leaf size of a clover variety will affect which grazing system it is best suited to; smaller leaves suit continuous grazing whereas larger leaves are better for cutting. The high protein content of red clover makes it a good option for finishing fattening cattle, but it can affect fertility of breeding ewes at tupping.





How should I approach this?

This action is suitable for all livestock farmers who graze or cut grass.

- It needs...
  - Research into which legumes are most suitable for your needs.
  - An investment in seed.
  - Willingness to experiment with seed mixtures.
- Expect
  - Improved livestock performance.
  - Improved soil health and farmland biodiversity.
  - Cost savings from reduced artificial inputs.
  - Further benefits can be achieved through the incorporation of herbs in the seed mix. Chicory for example is a natural anthelmintic.

More information can be found at this link **tinyurl.com/pasture-improvement**

Pathways to success

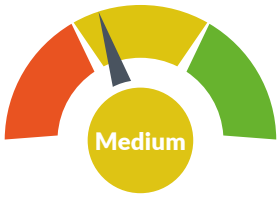
- Impartial advice can be sought from independent advisors.
- The latest grass and clover varieties recommended by the British Grassland Society can be found here: **tinyurl.com/recommended-grass-clover**

Low carbon farm machinery

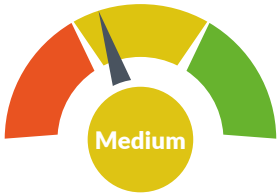
Action 17

This action relates to the machinery used for all on farm operations, such as harvesting, preparing land, herding and moving animals etc. Low carbon machinery will most likely be electric, or potentially in the future, hydrogen-powered. Using low carbon fuels such as electric or even biomethane means burning less fossil fuel, therefore reducing GHG emissions.

Another angle to this action is reviewing and using less on farm machinery (from quad bikes to combines). Older and less efficient machinery could be used less often, which may be better than using low carbon machinery more frequently. Servicing existing machinery more regularly to prolong its life so less new machinery is needed on the farm can also help. Nevertheless, considering the vast majority of agricultural emissions come from nitrous oxide (N_2O) from fertiliser use on soils and methane (CH_4) emissions from enteric fermentation in cattle and sheep, this action will have a moderate impact on farming's footprint.



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This measure is suitable for all farmers.

- It needs...
  - Investment in low carbon farm machinery.
  - Review of when and why machinery is used on farm and whether reductions could be made.
- Expect
  - Small impact on GHG emissions, especially if using biofuels such as biomethane powered tractors.
  - Limited practicality currently due to limited access to electrical charging points in rural areas and low battery range on electric vehicles.

More information on cutting carbon can be found at this link **tinyurl.com/farmcarbontoolkit**

Pathways to success

- Switching energy providers or to a green or renewable energy tariff is a quick and easy first step for your farm business. This is a good step to take at home too!
- Want to hear from other farmers who have made progress in this area? Get in touch and we can connect you **info@i4agri.org.uk**
- Capital investment for new machinery based on low carbon fuels can be overcome by applying for grants from Defra from Autumn 2021 **tinyurl.com/farming-investment-fund**

Want to know more about developments in this area – register to attend the Low Carbon Agriculture 2022 event

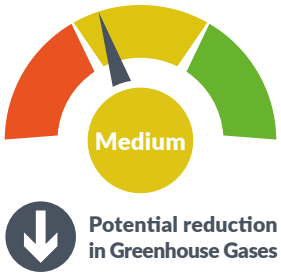
Follow this link **tinyurl.com/lowcarbonshow**

Action 18

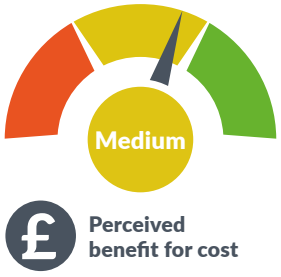
Low carbon heating/cooling in dairies and glasshouses

Keeping bulk milk tanks and related infrastructure cool is a large energy demand on dairy farms and also relies on burning fossil fuels. The majority of glasshouses use gas-fired boilers (fossil fuel energy) to supply additional heat to maintain year-round production of seasonal produce. This action is about replacing fossil fuel use for heating and cooling with low-carbon and renewable alternatives, primarily heat pumps, which require electricity. Heat pumps redirect waste heat from other processes (e.g., nearby wastewater treatment plants) and can also work well with on site or nearby anaerobic digesters. The heat generated by AD can be redirected to glasshouses and used as renewable heating. Any CO_2 emitted from powering the heat pumps can be redirected back into glasshouse production.

Using low carbon heating and cooling means burning less fossil fuel, therefore reducing GHG emissions. If electricity for heating/cooling is already obtained from the grid, then the emissions benefit of low carbon heating is dependent on the fuel mix used to produce the electricity that would have been used. If the grid is already highly decarbonised (i.e., sources a lot of renewable energy), then the emissions benefit will be quite a bit lower because the low carbon heating will be displacing renewable energy.



Potential reduction in Greenhouse Gases



Perceived benefit for cost

How should I approach this?

This measure is suitable for horticulture/fresh produce using glasshouses and dairy farmers.

- It needs...
  - Capital investment to convert heating/cooling infrastructure to heat pumps and low carbon fuel sources.
- Expect
  - Expenditure on technology and infrastructure development.
  - Potential increased revenue if CO_2 produced by CHP plants can be funnelled back into glasshouses increasing yields.

More information on heat pumps can be found at this link **tinyurl.com/guide-2-heatpumps**

Pathways to success

- Visit farms and sites where renewable energy and heat pumps are used to power on farm processes, get in touch and we can connect you **info@i4agri.org.uk**
- Capital investment for new heat pumps/CHP systems can be overcome by applying for grants. If you are already on the Renewable Heating Initiative, then you may be eligible for support (now closed to new applicants), otherwise new grants from Defra are coming Autumn 2021. **tinyurl.com/farming-investment-fund**

Read about exciting developments in this area

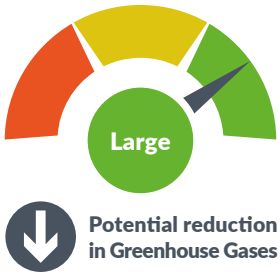
Follow this link **tinyurl.com/lowcarbongreenhouses**

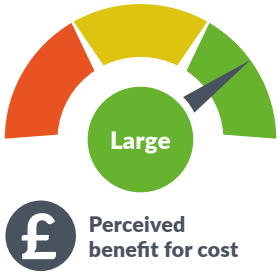
Reducing on farm food waste

Action 19

Substantial amounts of fruit and vegetables are wasted because they are cosmetically imperfect. Data from Germany estimates the proportion of food wasted at farm-level is around 20%. In the UK, 7.2% of all harvested food is either surplus or wasted, this would have a market value of £1.2 billion if sold at farm gate prices. This action aims to reduce the proportion of imperfect products by either changing the way they are grown, broadening the specifications for fruit and veg, or creating new markets such as farmer markets, farm shops, and specialist 'wonky products' retail lines.

By reducing waste on farm, the same quantity of food can be produced from less land with lower inputs of fertiliser and energy, therefore having a significant impact on reducing GHG emissions.





How should I approach this?

This measure is suitable for horticulture/fresh produce growers.

- It needs...
  - Closer collaboration between growers and the food processors, retailers and consumers.
  - Willingness to investigate farm diversification such as farm shops.
  - A longer-term approach is to engage consumers through initiatives such as LEAF (Linking Education and Farming), check them out at this link **https://leaf.eco/**
- Expect
  - Large gains in reducing GHG emissions if successfully manage to reduce out of spec production.

More information on food surplus and food waste at primary production level can be found here **tinyurl.com/foodwaste-production**

Pathways to success

- Speak to your processors/retailer about your contract and their requirements for the products. Are they able to receive products at different times due to limited storage/selling space? How are 'wonky veg' lines being received by consumers and can retailers do more?
- Review how you could reuse out of specification products on farm e.g., sent to a local AD plant or fed to livestock.
- More information on the wider implications of reducing out of specification end products for the food supply chain can be found at the Food and Countryside Commission website **tinyurl.com/food-farming-commission**

Summary

There are many ways you can reduce GHG emissions from on-farm operations and this guide is a useful tool to help you get there. Whether that's changing the way you manage your land and soil, or how you feed and look after your livestock, there is something every farming sector and system can do to make a positive difference. Farming may be a source of GHG emissions, but it can also be part of the solution.

The science underpinning many of these actions can be uncertain and is developing all the time. Nevertheless, we have tried to identify and present the actions that can deliver the most impact on GHG emissions, whilst still being economical. Some actions have added bonuses for biodiversity or for the management and welfare of livestock. The actions presented in the guide were discussed with a group of farmers from across the UK to 'sense-check' the science. Experiences from those already implementing changes on farm have informed the guide to make it as relevant and practical as possible.

There is much debate as to the best way to measure GHG emissions, what's included, what's not included, and the best unit of measurement. A single unit is always problematic and can never capture the whole story. To overcome this, each action was ranked to demonstrate its potential impact on GHG emissions and whether the action is likely to have a small, medium or large economic benefit to farm operations.

Despite this, the key point to conclude is that there is no single silver bullet to reduce GHG emissions significantly. A whole farm approach which selects multiple actions suitable to the specific enterprise will have the biggest impact and longevity.

Climate change is a global threat that affects every one of us and requires urgent action from all sectors and industries. In terms of agriculture, extreme weather such as drought and flooding will become more common.

The steps that the agricultural industry can take to mitigate against climate change will benefit agriculture directly, as well as having a significant global impact.

We hope that this guide has not just informed you about practical changes that you can make on your own farm, but that it will encourage you to act now!

Please get in touch if you have any questions or comments, feedback is most welcome.

info@i4agri.org

About Innovation for Agriculture....

Innovation for Agriculture is an independent charity working to support farmer innovation and practice change in UK farming.

We collaborate with leading researchers and major food and farming companies to connect farmers with the latest developments in science, technology and policy, supporting the transition to more sustainable farming.

Through practical and interactive workshops, farm walks, and on-farm demonstrations, we offer impartial advice where there might be multiple competing interests. Working with industry organisations and farmers, we provide an independent link between the two.

Want to know more? Visit:

www.i4agri.org

INNOVATION *for* AGRICULTURE

About WWF....

WWF is one of the world's largest independent conservation organisations, active in nearly 100 countries.
Our supporters – more than five million of them – are helping us to restore nature and to tackle the main causes of nature's decline, particularly the food system and climate change. We're fighting to ensure a world with thriving habitats and species, and to change hearts and minds so it becomes unacceptable to overuse our planet's resources.

WWF. For your world. For wildlife, for people, for nature.

Find out more about our work, past and present at wwf.org.uk

With food production at the centre of many environmental issues, WWF-UK and Tesco have come together with a shared ambition: to make it easier for customers to access an affordable, healthy and sustainable diet. Through the partnership we aim to halve the environmental impact of the average UK shopping basket. In order to deliver this, we are focusing on three key areas: helping customers to eat more sustainably, restoring nature in food production and eliminating waste.

To learn more about the WWF-UK and Tesco partnership, and our work on sustainable agriculture, at

wwf.org.uk/basket-metric

Working together

TESCO

WWF

Elements of Defra's upcoming Clean Growth for Sustainable Intensification (CGSI) project were used as part of the data analysis that informed the detail of this guide.

We'd like to thank Defra for their collaboration with this work. The results of Defra's CGSI will be published in full this year and further detail on the carbon savings and mitigation trajectories can be found on the DEFRA website once available.