Farm Carbon Calculator

Methodology of the Farm Carbon Calculator

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Glossary

AD	Anaerobic Digestion
CH_4	Methane
CO_2e	Carbon dioxide equivalent
Defra	Department for Environment, Food and Rural Affairs
FYM	Farm Yard Manure
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
N_2O	Nitrous oxide
NH_3	Ammonia
PAS	Publicly Available Standard
SOM	Soil Organic Matter

Document Version

Version	Date	Description
Version 1.0	August 2021	Methodology draft finalised

1. Introduction

The purpose of this document is to share details about the methodology that sits behind our Farm Carbon Calculator, a valuable tool used by thousands of farmers, growers and organisations to inform better decision making.

In a world grappling with the urgent task of rapidly reducing greenhouse gas emissions, we believe transparency in this sector is crucial. By sharing more about how farm-related greenhouse gas emissions are measured, we hope our calculator users and the wider public will have a greater understanding about the priorities and opportunities to make positive change. We also believe transparency will help build a greater trust and engagement with our community, with feedback that will further improve our calculator.

2. About the Farm Carbon Calculator

Started in 2008, the Farm Carbon Calculator is one of the longest running and most popular carbon calculators available in the UK. It is one of the three main carbon calculators for UK farmers and growers which are recommended by the NFU to its members. It enjoys widespread support from its users, both in terms of its comprehensive nature and ease of use.

The Calculator is owned and managed by the **Farm Carbon Toolkit** (FCT), an enterprise that helps farmers and growers to measure, understand and take action to reduce their carbon emissions and increase carbon sequestration. FCT is run by farmers for farmers.

Over the years, the Calculator has attracted interest from other countries as well, showing its potential to positively influence carbon management on farms beyond the UK. From the outset, it has measured carbon sequestration and we remain a strong advocate of the potential for farmers and growers to sequester carbon in soils and biomass.

All users of the Farm Carbon Calculator accept a set of Terms and Conditions which are detailed on our website here: https://farmcarbontoolkit.org.uk/terms.

3. How the Calculator is structured

The Calculator is split into ten sections, each subdivided into various input fields. Users enter data according to the following guidance:

- What is relevant to their business only
- Take a recent point in time and cover everything over the previous 12 months
- Capital items go in the Inventory section (e.g. machinery and buildings) and include everything under 10 years old

4. Calculator Scope

The Calculator has always been designed to be used as a whole farm carbon footprinting tool. However with new features and Key Performance Indicators (KPIs) in 2021, it can also now be used on a per product basis (e.g. wheat, milk, potatoes).

The scope of the footprint is decided by the user and can be one of three options:

1. To farm gate only – i.e. no transport of produce
2. Farm and distribution – i.e. including transport to the customer
3. Farm and distribution through to final customer – i.e. house doorstep

The Calculator covers Scopes 1,2 and 3 in its calculations:

Scope 1	Also known as **direct emissions**, these are emissions that are owned or controlled by the company such as tractors, farm machinery, gas for heating and from change of land use. Additional emissions arise from N_2O released as a consequence of manure storage and application.
Scope 2	These are associated with emissions resulting from the generation of purchased electricity or gas used on the farm.
Scope 3	Also known as **indirect emissions**, associated with the production, processing and distribution of inputs into the farming system. For example, fertilisers and the emissions that occurred in the manufacture of machinery, building materials and other farm infrastructure.

Users are encouraged to be as comprehensive as possible with the data they submit for their calculation, as this gives more assurance in terms of the accuracy of the results.

5. Accuracy of results

The accuracy of the a carbon footprint report is dependent on a number of factors, including:

- Accuracy of emissions factors;
- Whether a factor is based on actual or proxy values;
- Accuracy of both data collection and data input by the user;
- Level of completeness by the user.

We do not offer verification of carbon reports for standard users of the Calculator, as this requires a detailed audit process. As part of our consultancy service, we do support farms and companies with enhanced footprint calculations and verifying the inputs, which provides a level of independent

auditing. However we do not currently provide this service to a Third Party verification standard e.g. an ISO standard.

In the full results of carbon reports we provide a confidence level column. This ranges from 1 to 3, where 3 we have the most confidence in results. This scale is created by us through an understanding of the accuracy of the emissions/sequestration factors, as well as the likely limitations of user accuracy. For example for emissions from diesel we score this as a 3, because the emissions factors are accurate and we would expect users to have good data. However emissions from livestock are scored 1; whilst users should have accurate input data, emissions from biological systems are inherently difficult to have certainty over.

6. References and assumptions

The majority of the emission and sequestration factors that underpin the Farm Carbon Calculator come from peer-reviewed scientific papers and we are transparent about these sources. A full list of current references and assumptions is provided on our website here: https://farmcarbontoolkit.org.uk/carbon-calculator-resources/

Each time we perform a major update to the calculator (typically annually), we review all references and factors; this comprises over 450 data entry lines.

For ease of use, our calculator is divided into the following data input categories and in subsequent sections of this document, we cover the methodology and emission factors used in each:

- Fuels
- Materials
- Inventory/capital
- Fertility
- Inputs (agro-chemicals)
- Livestock
- Waste
- Distribution
- Sequestration
- Processing

Proxy and actual data

Some emissions factors are calculated based on actual data (e.g. litres of red diesel used), and some are based on proxy data (e.g. carbon sequestration in hedgerows). This depends on the availability of data for a particular item, and how practical it is for the user to provide data. Some items offer both approaches – e.g. distribution of produce by lorry.

6. Detailed analysis of emissions factors

6.1. Fuels

Emissions from the use of fuels, electricity, travelling and contractors. These include scope 1 (direct) and scope 3 (indirect – such as processing and transport) emissions, including 'well-to-tank' emissions factors.

Fuels and electricity

All of the items in liquid fuels, electricity, gas fuels and solid fuels are derived from Defra's Greenhouse Gas Conversion factors 2020 (Reference number 1). The exceptions are:

Section	Item	Reference	Notes
Electricity	% renewables in tariff	19	For electricity tariffs with a different amount of renewables in the mix from the grid average of 28.8%. It adjusts to give more or less carbon intensity depending on the % renewables. Includes scope 3 emissions.
	Off grid	19	This is simply a measurement of electricity used, but if it is generated and consumed on site the carbon footprint is 0. Embodied energy in capital equipment is accounted for elsewhere.
	Export to grid	19	Assumed to displace grid average electricity. Treated as a carbon offset.
Gas fuels	Off grid (from AD plant)	38	Accounting for gas burnt on site but generated from AD plant.
	Export to grid (from AD plant)	38	Fed from AD plant in to gas grid. Assumed to displace 'grid gas'. Treated as a carbon offset.
Solid fuels	Bonfires	19	Calculated from 'wood logs' emissions factor from reference 1.
Deliveries	Known carbon footprint	19	To enable users to input a known carbon footprint of an input, such as a delivery. Simply direct input of a CO_2e figure.

Travel

All data is from Defra's Greenhouse Gas Conversion factors 2020 (reference number 1) and includes all scope 3 emissions, including 'well-to-tank' emissions factors. The 'miles per gallon' function for cars is calculated as a function of miles per gallon, fuel used and miles travelled.

Contractors

Data draws from the HGCA Calculator (reference number 37), multiplied by the diesel emissions factor (scopes 1&3) from reference 1. Some Farm Carbon Calculator calculations have been done on hay bales in terms of average numbers of bales per hectare.

6.2. Materials

The embodied energy in a range of materials that may be used on farms, including aggregates, metals, wood and plastics. These are all Scope 3 emissions.

Dara draws from the Inventory of Carbon and Energy, either version 2.0 (reference number 2a) or version 3.0 (reference number 2). A range of metrics are used, including tonnes, kg, m2 and m3. The exceptions to this source are:

Section	Item	Reference	Notes
Stone	Slate & Granite	24	Embodied energy in processing stone
Fencing	Complete fencing options	19	Calculating the posts and wire used in common fencing options, multiplied by emissions factors from the Inventory of Carbon and Energy.
Computers	Laptops & Desktops	15	Proxy emissions factors for embodied energy in computers
Water	Mains water & sewage	1	Scope 3 emissions for water supply and disposal
Water	Non-mains	19	Figure simply recorded as water use. No emissions specifically – any fuel or electricity used in pumping or treatment will be picked up under Fuels.

6.3. Inventory

This section covers the embodied energy in larger items like machinery and buildings (capital items). In a similar principle to financial accounting, these are depreciated over 10 years, so 10% of emissions are apportioned each year. Items over 10 years old are considered to have 'paid their carbon debt' and so are not counted.

Most of the emissions factors are again derived from the Inventory of Carbon and Energy, either version 2.0 (reference number 2a) or version 3.0 (reference number 2), but given only 10% weighting per year. The other data sources are:

Section	Item	Reference	Notes

Vehicles	Cars	15	Proxy for relative carbon cost of the vehicle. Note: data on this is particularly difficult to obtain.
Farm machinery	Tractor, harvesters, etc	3	Based on horsepower of machine – a proxy for emissions
Agricultural buildings		19	This calculation is based on a standard agricultural portal building constructed of concrete floor, steel frame, roof sheets and timber slat walls. Based on a per m2 calculation.

6.4. Fertility and Cropping

This section covers the carbon dioxide and nitrous oxide emissions from fertility and biomass inputs to cropping systems.

Emissions from crops are specifically worked out from the amount of crop (fresh yield) that results in crop residues, using GHG Inventory and IPCC methodology. Crop residues contribute nitrogenous material to the soil, some of which goes through denitrification to N_2O. The fresh yield quantity is directly proportional to the residues, and then the amount of N_2O released.

Section	Item	Reference	Notes
Crops	Agricultural	4	IPCC methodology, and factors from UK GHG Inventory
	Soya & Lupins	20	IPCC methodology but some specific factors provided by Soya UK
	Horticultural	4	IPCC methodology, and factors from UK GHG Inventory
Organic fertility sources	Compost	39	Fresh weight of bought-in compost. Includes both N_2O and CH_4 emissions.
	Manure (composted)	8	An average of annual measured emissions, including both N_2O and CH_4
	Manure – exported	8	A carbon offset/transfer when manure is sold to another farm (which then becomes a carbon emission to them). Same value as composted manure.
Anaerobic digestion	Digestate	38	Bought in digestate – average emissions calculated from AD plants

	Running an AD plant	38	Average emissions of various processes in running an AD plant, including CO_2 and CH_4 emissions. Based on tonnes of biowaste input.
Mineral fertilisers	Lime, rock phosphate, rock potash, K fertiliser, Gypsum	3	Emissions from processing of lime and mineral fertilisers
Green manures	All leguminous green manures	6	N2O emissions as part of the N fixation process. IPCC methodology, and UK specific N fixation rates. Note that this does not take account of any carbon sequestration – this is covered under soils in sequestration page
Plant raising media	(all)	16	Average of emissions for all common plant raising media used in horticulture

6.5. Inputs

The GHG emissions associated with energy input in the production of agro chemicals.

Fertilisers

This is split into two sections: one is for generic fertilisers, such as Ammonium Nitrate, or Urea; these are derived from reference number 14. The second section is for known fertilisers, including those manufactured by Yara, CF and Mole Valley Farmers. These are derived from reference numbers 19, 41, 42 and 46.

The user input figures are based on tonnes of product used.

Two further functions enable users to enter:

1. A specific blend of fertiliser, based on known % of N:P:K, multiplied by tonnes of product used
2. A specific known footprint of a fertiliser, using kg of CO_2e per kg of product, multiplied by tonnes of product used

Overall GHG emissions for fertilisers are based on four processes, and measured in CO_2e:

- Production emissions to factory/plant gate
- Direct N_2O emissions to soil
- Indirect NH3 losses
- Emissions from urea hydrolysis (applies to Urea products only)

Methodology and assumptions

All calculations are based on IPCC methodology. The emissions factors for in field emissions are based on MIN-NO project findings (reference number 47), which are UK specific, and considered an improvement on IPCC methodology because they are more accurate.

Plant gate emissions are based on EU manufactured fertilisers from plants with abatement technology fitted. If fertilisers are manufactured in other places then emissions will be higher.

Application assumed to be by broadcast or application of solution. Nitrogen inhibitors are not accounted for. Guidance is given for conversion of liquid fertilisers to kg or tonne.

Sprays

From reference 40, based on average emissions from four categories of pesticides, and herbicides. Based on kg of active product used, with guidance given for active ingredients found in common products/mixes.

6.6. Livestock

This section covers nitrous oxide and methane emissions from animals' enteric fermentation and manures, and emissions from imported feeds.

Livestock emissions are complex and are based on IPCC calculation methodologies. There are several variables which require user input:

- Category of livestock, by species, age, use and live weight
- Numbers of livestock, on average, per year – both for the current year and the previous year
- Manure handling – the percentage (on an annual basis) of manures handled as slurry, FYM, daily spread, or in field.
- Adjustments for dairy cattle (based on annual milk yield) and beef cattle (based on average liveweight).

All emissions factors are derived from the '2019 UK Greenhouse Gas Inventory' (reference numbers 4 & 4a). We work on Tier 2 methodology, which is UK-specific.

6.7. Animal feeds

These indirect emissions are very important to assess the holistic carbon impacts of livestock production. The list is split into organic and non-organic feeds, and contains a range of common livestock feeds.

The Calculator uses primarily data from the 'GFLI database' (reference number 18). Some further data for non-organic feed is obtained from 'GHG emissions from food' (reference number 17), along with all the data for organic feeds.

Some emissions factors for feed blends have been calculated, based on the known constituents of certain blends. This research has been undertaken by Farm Carbon Calculator, based on discussions with feed companies. Using the constituent parts, and data from the GFLI database, the footprint of certain blends has been calculated.

Emissions factors are based on users entering tonnes of product used on an annual basis.

6.8. Waste and recycling

This section covers emissions from landfill, and the savings from recycling and composting materials. Users enter data on their annual outputs of waste and recycling from a range of specific categories of materials.

Emissions factors for all Landfill emissions, as well as composting and AD emissions are derived from 2019 Defra GHG conversion factors (ref number 1). This source does have emissions factors for recycling as well, but they are very generic and lack specific information; for this reason we have used other sources for recycling.

All recycling emissions and offset figures are derived from reference number 33, which contains a detailed list of emissions factors for a range of goods. This includes effective carbon offsets through energy savings made on using virgin materials for new products post recycling.

Reference number 43 provides emissions from Waste-to-energy plants for combustion of municipal waste.

6.9. Distribution

For businesses that have distribution beyond the farm gate in scope, this section calculates the emissions from distributing and refrigerating food products.

Users can enter actual data on fuel used per year on distribution. If they don't have this data they can use proxy data based on three variables – delivery distance per journey, weight carried per journey, and number of journeys per year.

All the emissions factors are derived from Defra's GHG Conversion Factors (reference number 1). Average values are used, and for road haulage this is based on 50% laden lorries (on a round trip).

Users are encouraged to carefully map and describe the scope of the study, and at what point the responsibility for food transport is passed on to the next actor in the supply chain. This will be different for every business, and may range from farm gate all the way through to the customer's house.

Refrigeration emissions are calculated from refrigerant losses from food storage on the farm (or in packhouses/warehouses/food processing). This is calculated by using reference 12, an online tool to

calculate the accurate emissions from refrigerant gases, per year. This figure from the spreadsheet is entered directly into the Calculator by the user.

Users are reminded not to double count any data entered in the Fuels section in Distribution (and vice versa).

6.10. Sequestration

This section calculates carbon sequestered by perennial plants and soils on the farm.

Data sources: All of the sequestration factors are proxy figures, except for actual Soil Organic Matter (SOM) measurements. A range of sources are used in this section.

Section	Item	Reference	Notes
Soils	Soil Organic Matter	19	Based on actual SOM samples, users enter data on field size, depth of measurement, bulk density and SOM results over a given time period. This is converted in to changes in volume of soil organic carbon and therefore the amount of carbon sequestered (or emitted).
	SOM in grassland	19	From the Soil Carbon Project, average values of soil carbon sequestration in temporary and permanent grassland, according to soil type. This data will be included soon.
	Carbon stocks	19	A log of baseline soil carbon stocks in fields. These results do not impact on the overall carbon balance, they are therefore just for reference.
Peat soils	Cultivated peat soils	21	N_2O emissions from cultivated peat soils. Also CO_2 losses from soils – unless users are able to supply SOM results, in which case only the N_2O changes are accounted for. Average values are used from the source.
Woodland	Detailed analysis	10	Users input the species, age range and area of woodland. Assumptions of average yield class, average spacing, and no thinning is applied. This is the recommended approach.
	Mixed, coniferous and broadleaf	10	Average values per hectare of types of woodland, over a 200 year average.
	In field trees	10	A per m2 value based on average sequestration rates for deciduous woodland.
Hedgerows	Managed	19	Based on the length and width of managed hedges – i.e. those cut on a regular basis. Sequestration factors based on averages from five peer reviewed studies.

	Large growth with trees	19	Based on the length and width of large growth hedges with trees – i.e. those trimmed or laid on an irregular basis, forming large structures with in line trees. Sequestration factors based on averages from five peer reviewed studies.
Perennial crops	Top fruit, stone fruit and nuts	26	Average sequestration values per hectare. Includes biomass only – soil and grass sequestration excluded.
	Grape vines	27 & 28	Average of two studies. Covers sequestration in biomass only, not soils.
	Miscanthus	29	Sequestration rates in biomass and soils
	Willow	30 & 31	Average of two studies, covering sequestration in both soils and biomass
	Poplar	30 & 32	Average of two studies, covering sequestration in both soils and biomass
Field margins	Uncultivated	25	Area of field margins that are permanently uncultivated. Sequestration rates include soil carbon.
Wetlands	Permanent	13	Area of permanent peaty wetland that is ungrazed
Land use change	(various)	23	Changes which result in losses of carbon, such as woodland to arable. This is from carbon losses in soils and biomass. These are considered to be uncommon in a UK setting, but must be accounted for if they occur. These are one off losses. Users should not enter values in here if they have also calculated SOM measurements for exactly these areas of land use change - though this is thought to be an unlikely occurrence.
Habitats	(various)	44	Sequestration in biomass and soils on a continuous basis for various habitats, as defined in the Countryside Stewardship Scheme. Users should not enter data here if they have included SOM measurements of the same area.

7. What farm business information do users enter?

At the start of all carbon reports users are asked to input information about their farm business (or specific carbon report). This includes the following information:

1. **Business category** (multiple can be ticked) - Arable, Beef, Dairy, Fruit, Lowland grazing, Mixed (arable/livestock), Other, Pigs, Poultry - layers, Poultry - meat, Sheep, Upland grazing, Vegetables, Vineyards, Processing, Wineries, Non-agricultural business

2. **Soil type -** Sandy/Light, Sandy Loan, Sandy Clay Loam, Sandy Silt Loam, Loam, Medium Loam, Clay Loam, Clay, Heavy Clay, Silt, Silty Clay Loam, Peat, Chalk

3. **Farm area in hectares** for each of the following:
    - Cultivated land - all arable and horticulture land that involves soil cultivations (or non/min-till systems);
    - Grassland - temporary and/or permanent grassland, generally used for livestock grazing, and/or forage;
    - Non-cropping land - any land not falling under cultivated land or grassland. For example woodland, scrub or other uses which are not generally used for agricultural or horticultural use.

4. **Annual sales of produce** - amount of total produce sold for business category(s) selected. For example 50 tonnes of wheat, 50,000 litres of milk, 30 tonnes of potatoes

5. **Carbon price** - an optional category for including the price a user is paid for any carbon traded, in £ per tonne of carbon. This will likely become more important in the future.

6. **Scope of study** - whether the report covers up to the farm gate only, also Distribution, or right up to the Point of Sale. This is so reports can be made clear where their boundaries are, especially important for comparisons.

7. **Overheads report** - users can create Overheads inventories for their business, which is used specifically when creating reports on a per product basis (e.g. wheat, milk., cauliflower). User guidance is given on how to create Overheads and Produce basis reports.

8. Standards and compliance

We believe there is not currently a satisfactory national or international standard that covers the exact requirements of a farm carbon report. PAS 2050 is widely used to calculate the GHG emissions from various products and services. Its methodology is used in the Calculator, however its scope falls short of what is required for a complete farm carbon footprint, in that it doesn't include Scope 3 (indirect) emissions, and is very limited on carbon sequestration.

We are actively considering alignment with international standards such as ISO 14064 and the GHG Protocol.

9. What's new and what's not included

New developments for each cycle are listed here to enable users to see what's changed.

We also aim to provide a list of what improvements we are working on over the next development cycle of the Calculator. There are often good reasons why certain items are not included, and they usually relate to the lack of available peer reviewed data.

10. Independent Reviews

We believe it's important for any Carbon Calculator to be independently scrutinised. We aim to undertake this on an annual basis or whenever a major update is implemented. Our last review was completed in November 2020 by Dr Russell Layberry of Pilio Group, a company of carbon footprinting experts affiliated to the University of Oxford. The review checked:

- The accuracy of emissions factors
- Quality of references used
- Overall approach and scoping of the Calculator
- Algorithms and assumptions in the calculations

Following a detailed 30 page report and three rounds of discussions regarding corrections and potential improvements, Dr Layberry gave the following assessment:

> *"The Farm Carbon Calculator is an excellent and comprehensive tool for calculating the scope 1,2 and 3 emissions from farm processes. It includes direct energy use, carbon emissions from farm inputs such as fertiliser and sprays, carbon from the production of equipment and buildings, emissions from livestock and sequestration through above and below ground carbon and land use change. Crucially the tool includes the ability to accurately measure carbon sequestration services on farms.*
>
> *The tool, apart from being accurate, up to date and comprehensive, is the best tool by far this reviewer has seen for calculating the environmental impact of farming – part of Dr Layberry's recent work was a comparative analysis of software tools and standards which calculate carbon and biodiversity impacts of farming. Our company is already recommending its use for our current clients who have agricultural emissions which need capturing for their voluntary scope 3 reporting."*

The next independent review will take place in late 2021 and will cover all elements within the Calculator. A specific independent review of our methodology for Soil Organic Matter calculations was completed in June 2021 and a summary of this will be made available on our website in due course.

11. Development cycle

Our development cycle is summarised in the figure below. At a minimum, the Calculator is updated annually. Research into new data, methodologies, and new user functions does continue throughout the year and minor adjustments may be made to the calculator.

As we develop the calculator, we believe it's critical to listen to the views, requests and questions of our users, ensuring we are as relevant, up to date and user friendly as possible. A structured engagement process with users and working groups on particular topics, helps to strengthen the knowledge, feedback, rigour and testing for the Calculator.

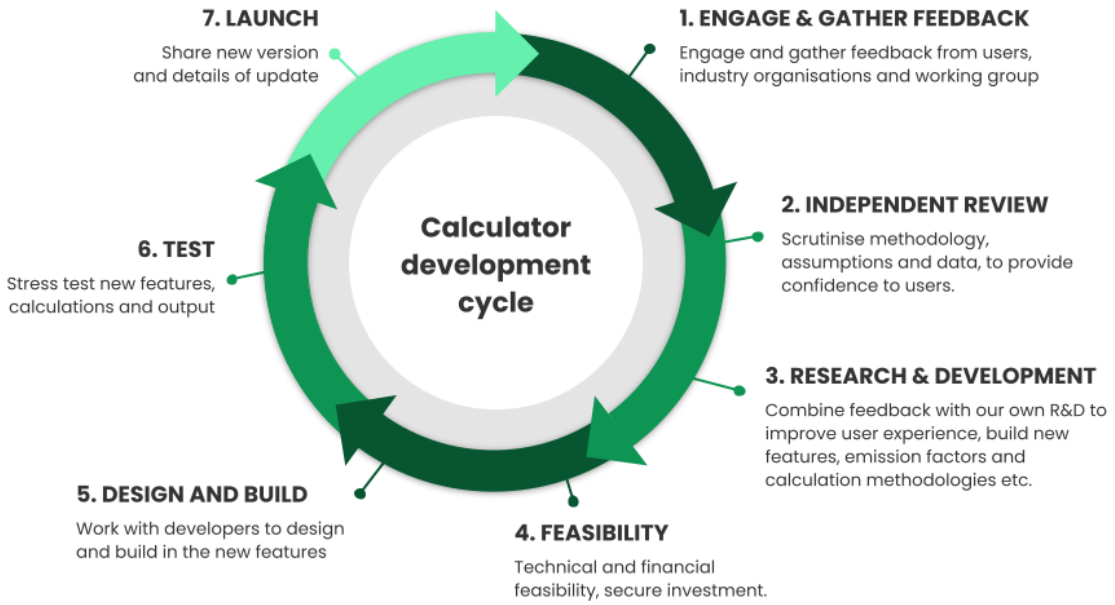

Figure: Our annual calculator development cycle

12. Contacting us

We welcome Calculator users to contact the Calculator team with questions, suggestions and comments at any time. For general enquiries, please email: calculator@farmcarbontoolkit.org.uk or you can contact specific members of staff:

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