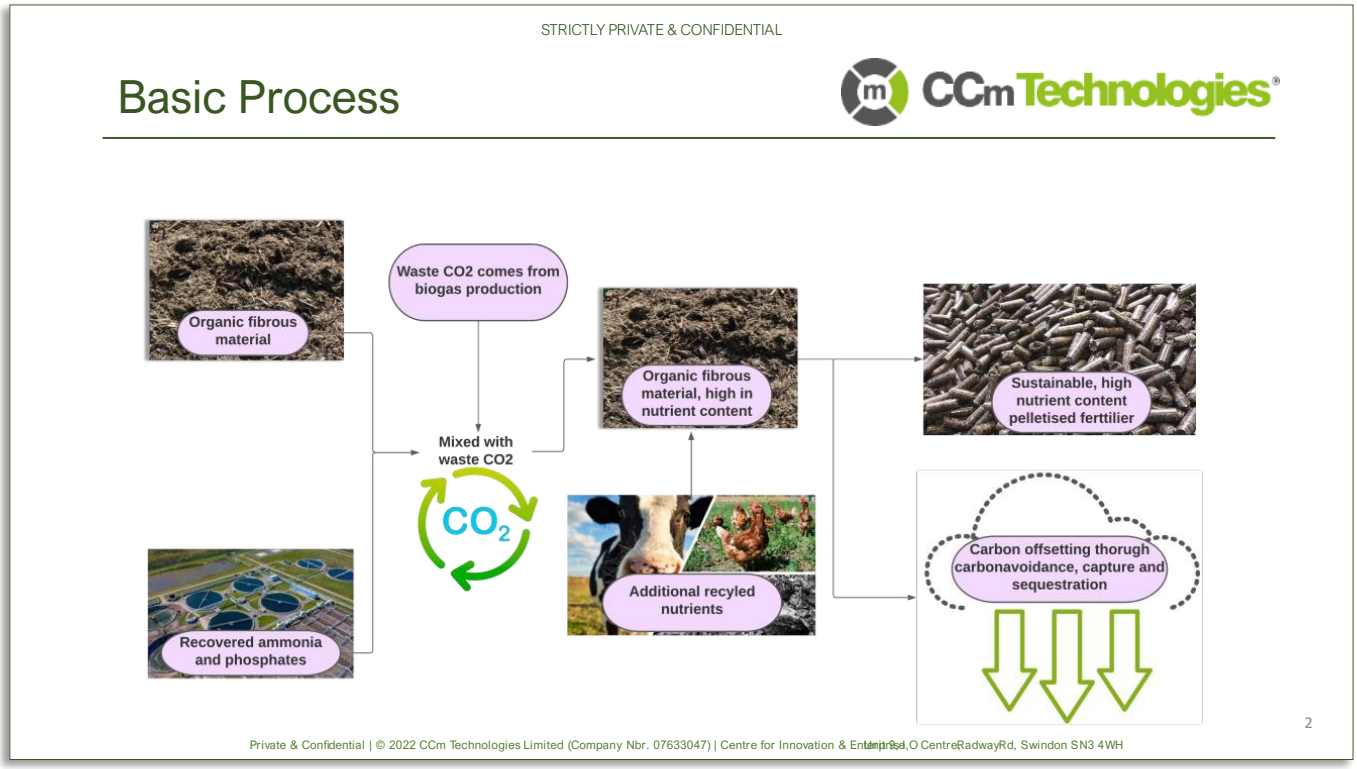
Technical Review - CCm Technologies' Low Emission Fertilisers

Background

CCm have developed a range of low emissions technologies based around a core Carbon Capture and Utilisation platform. The technology applications include Heat Storage, Power Generation, Functional Plastics and Fertilisers. This document describes the current product readiness and outlines the plans for capacity scale-up for the fertiliser materials.

CCm Fertilisers

CCm has been developing its fertiliser technology since 2014. Initial work concentrated on mimicking conventional fertiliser formulations in terms of nutrient content but importantly containing additional organic and carbonate resulting from the application of CCm's core processing technology which is set out below.



Initial trials were very successful and CCm decided in 2016 to make the development of its fertiliser system, the company's main priority.

The development programme saw the increasing use of waste materials, including those from energy, wastewater and food based digestates.

An extensive trial programme has been undertaken to ensure that the fertilisers produce excellent performance in terms of yield, utility, particularly in terms of spreading capability and critically in economic competitiveness. It has always been central to our development plan that the fertiliser would be a viable, low emissions alternative to conventionally produced compound fertilisers.

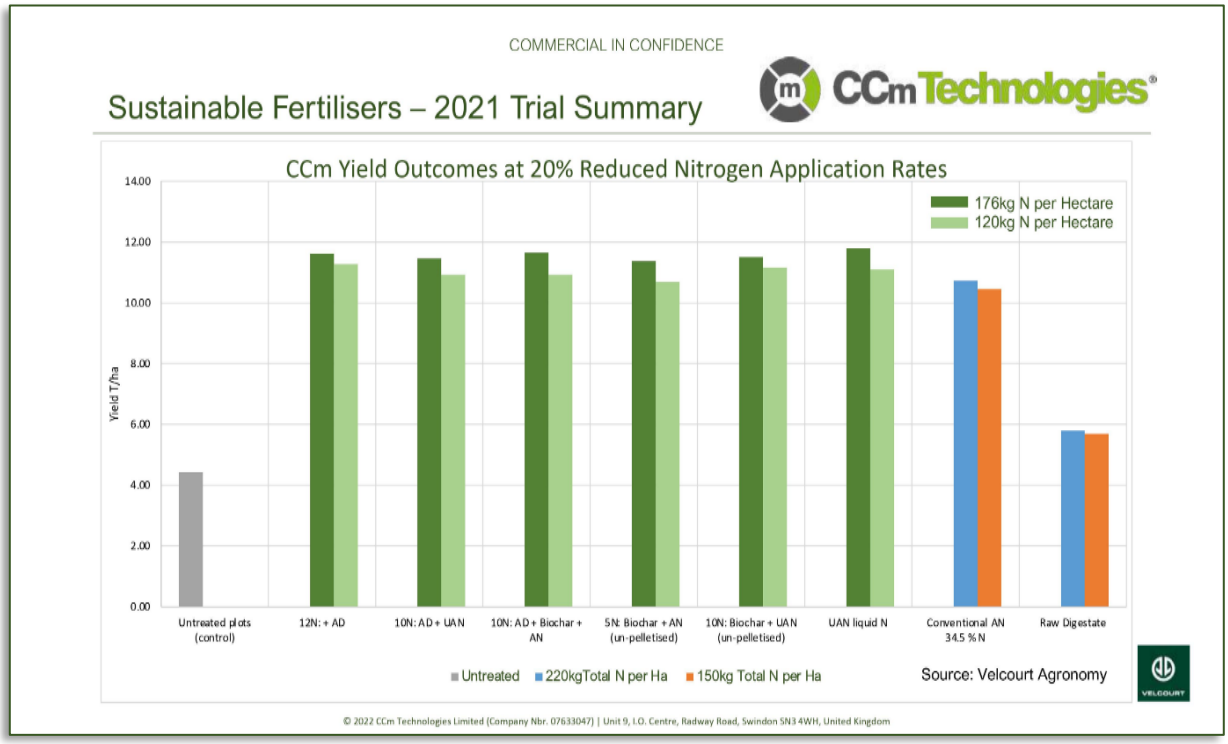
The development of the fertiliser as a product has been underpinned by a range of independent research programmes carried out as follows:

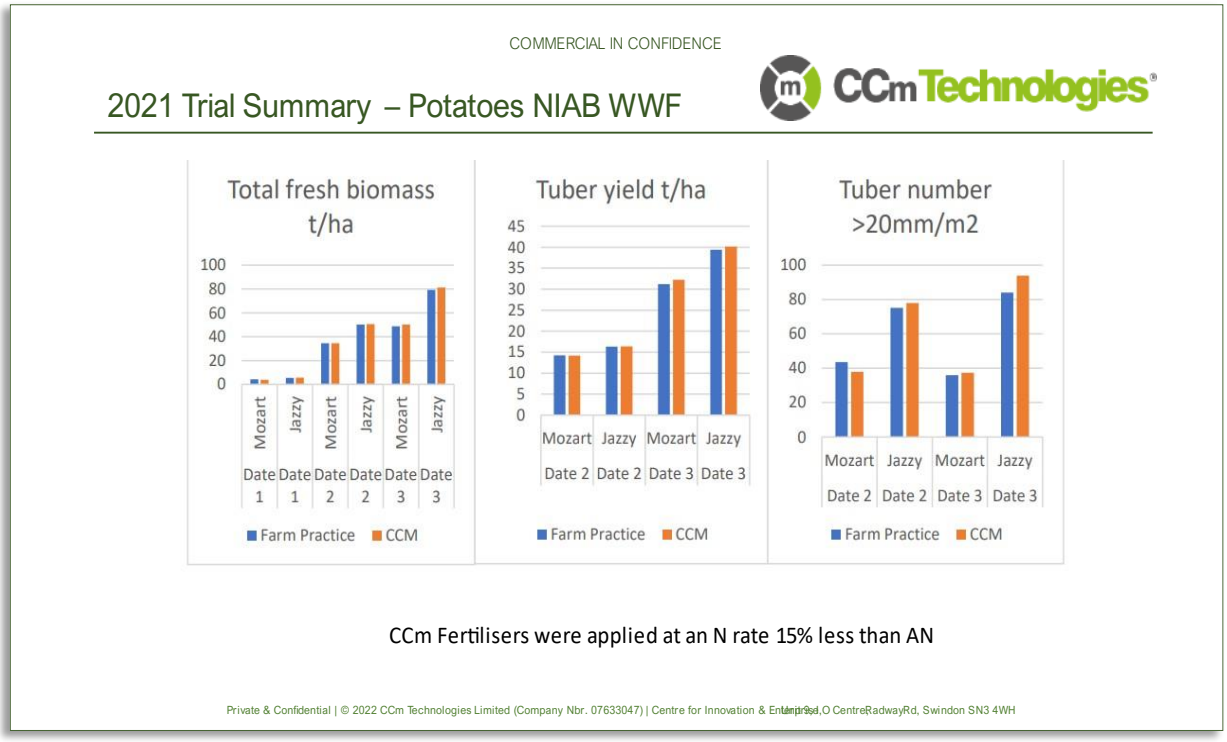
- RAU (Cirencester) - Grass trials (2015 to 2018),
- Harper Adams and Crowne Farms - Cereals (2016),
- University of Sheffield - Environmental assessment (2017),
- Velcourt Agronomy - Cereals and Oil Seed Rape (OSR) (2018-2022),
- Cranfield University - Cereal and Environmental Evaluations (2020),
- NIAB and WWF - Potatoes (2020), and
- Independent commercial trials with UK and global agri-food businesses focusing on potatoes and oats (2019 to present).

The trial results have been consistent and successful throughout and the programme clearly demonstrates yield parity or better is being achieved through applying the CCm materials.

Critically since 2020, it has been apparent that various underlying material efficiencies significantly reduce Nitrogen and other losses from the growing system.

This reduction in nutrient loss has allowed CCm to investigate the potential of applying lower nutrient levels to crops. The extensive programme has delivered key field data which show how CCm fertilisers can dramatically affect the efficiency of nutrient delivery to crops. The following two slides illustrate the effect of reduced nutrient application rates on both Cereals and Potatoes:





These results have been repeated in trials carried out by our commercial partners and have resulted in their decision to reduce nutrient application rates to their crops by 20% in 2023.

Spreading requirements – target delivery 220 kg N /Ha

CCm materials contain high levels of organic materials to maximise in field performance. This means that it is necessary to apply higher application rates in the first instance, however, if best practice is maintained - in terms of organic matter application the total quantity of material taken to the field is actually reduced.

Fertiliser	% N	kg N/t	kg/ha of product	-20% kg/ha	% organic	kg O/ha	kg FYM with equiv. kg O as CCm	kg CO2eq/kg	kg CO2eq/ha
Urea	46	460	478		0	0	0	5.22	2497 [1]
AN	34.5	345	638		0	0	0	2.89	1843 [1]
CCm 15N-U [2]	15	150	1,467	1,173	61.73	724	2,897	-5.429	-6,370
CCm 12N-U [2]	12	120	1,833	1,467	67.71	993	3,972	-5.162	-7,571
CCm 10N-U [2]	10	100	2,200	1,760	71.69	1,262	5,047	-4.984	-8,772
CCm 5N-U [2]	5	50	4,400	3,520	81.65	2,874	11,496	-4.539	-15,979
FYM	0.6	6	36,667		25	9,167	0	0.175	6417 [3]

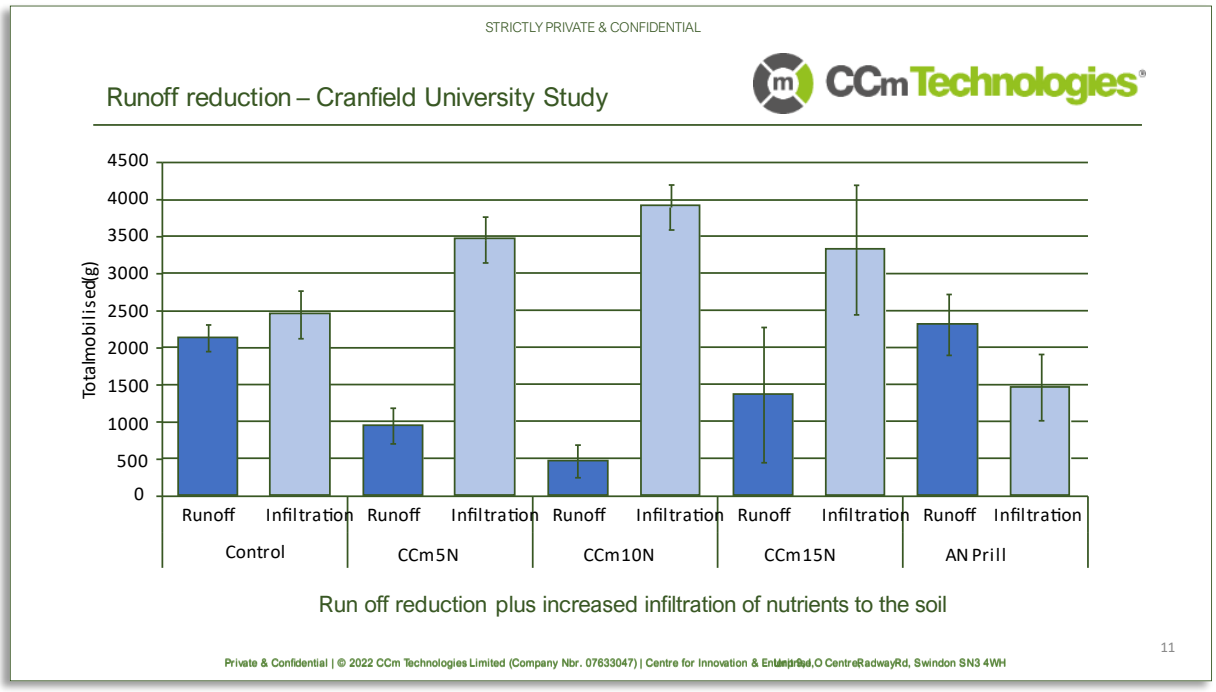
Sources: [1]Fertilizers Europe Carbon Footprint Calculator for Fertilizer Products, [2]CCm LCAs, [3]MDPI paper

Application of CCm fertiliser requires between 2 and 3.5 times as much application to the field to deliver the same level of N/Ha. However, when applying CCm material, the equivalent of between 3 and 5 tonnes of FYM is also delivered to field. In order, to achieve the same soil benefits using conventional fertilisers, there is a need to apply additional material to land. Therefore, to deliver the equivalent of 1.76t/Ha of CCm fertiliser, a total of 5.6t/Ha AN/FYM or 5.5t U/FYM would need to be spread.

Nutrient loss reductions

Whilst we do not fully understand all the mechanisms that reduce losses from the CCm fertilisers we have been able to gather some good indications from some initial experimental programmes carried out either internally or in conjunction with Cranfield University.

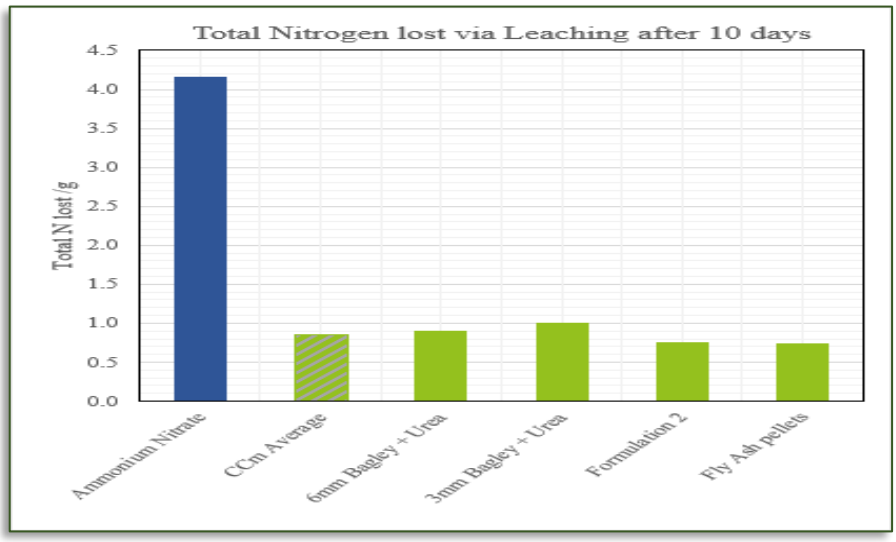
The investigations have focused on the most likely areas where nutrient losses can occur CCm fertiliser minimises run of losses from the moment it is applied; this study by Cranfield University shows how CCm products reduce initial losses.



We believe that this effect is largely associated with the physical properties of the pellet and its high organic content and reduces N lost in run off by around 50%.

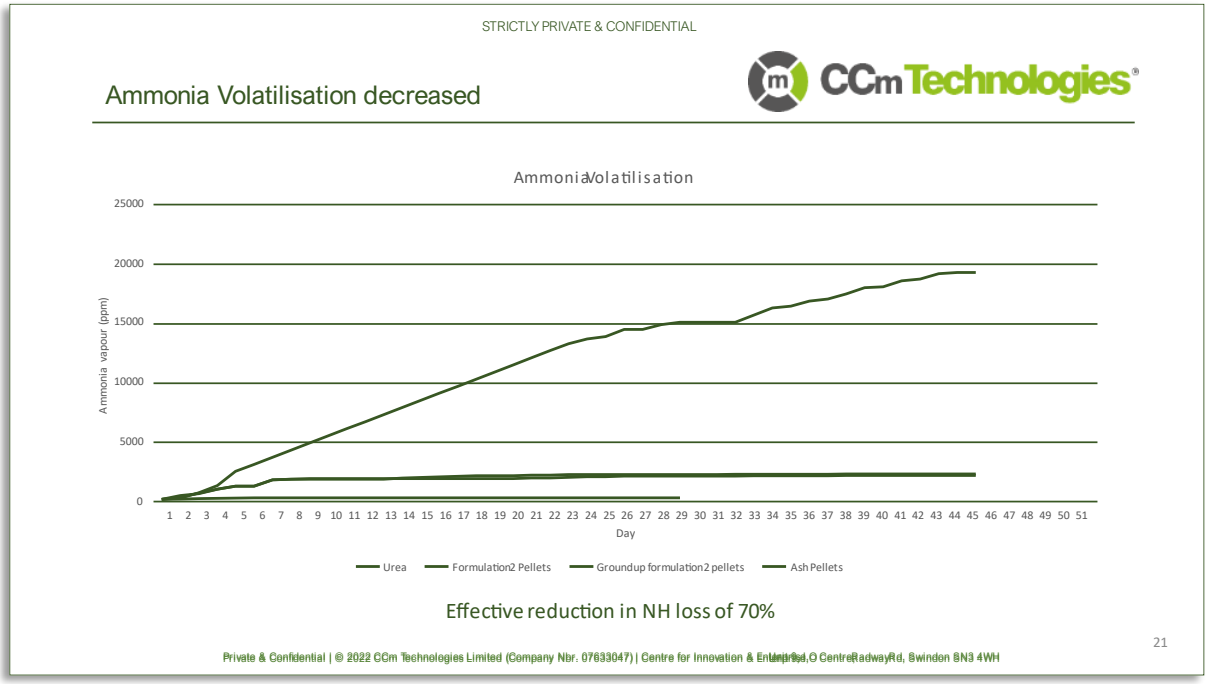
Leaching Reductions

Here we are looking at how much N leaves the growth zone over a period of 10 days:



These effects are most likely due to physiochemical effects in the pellet slowing the release of the nutrients giving the plants time to use them so that less Nitrogen is lost from the root zone.

Losses to air (volatilisation) are also reduced



These reductions are physiochemical in nature but primarily due to lignin and ligno-cellulosic interactions with Ammonia species.

These effects of reducing Nitrogen losses to air are small but significant as they prevent the production of harmful Nitrous Oxides.

Additional Benefits

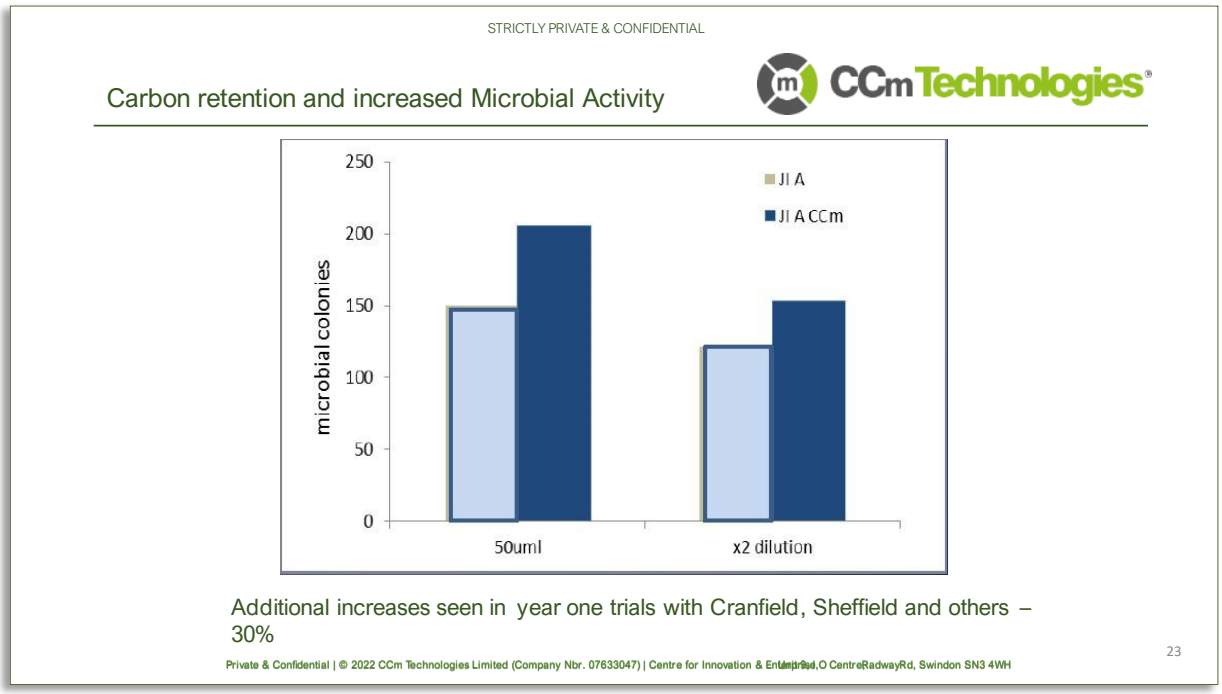
Whilst the ability of the CCm fertilisers to reduce system losses is very important there is significant evidence that the CCm manufacturing process produces additional benefits that ultimately increase the effective delivery of nutrients to plants. These benefits are manifested in several key outcomes.

Nutrient Stabilisation

We understand that ligno-cellulosic effects on ammonium/ureic release profiles, combine with the physical effects associated with organic materials in the pellet to reduce net losses and ensure that viable nutrients remain available to plants for longer.

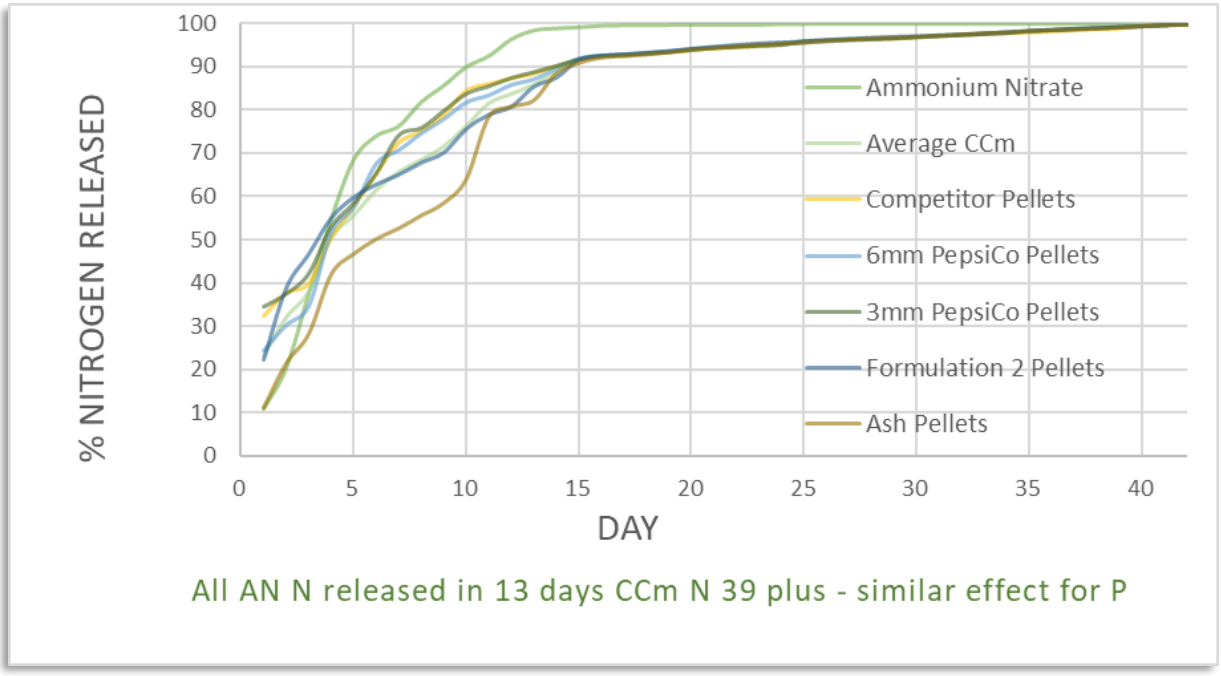
Activation

The pellets directly boost soil microbes which can assist plant utilisation of nutrients:



We further believe that CCm's manufacturing process also Improves the availability of organic Nitrogen based molecules through the combined effects of partial hydrolysis and mechanical action in high pH environments. We are currently developing analytical methods to quantify these effects.

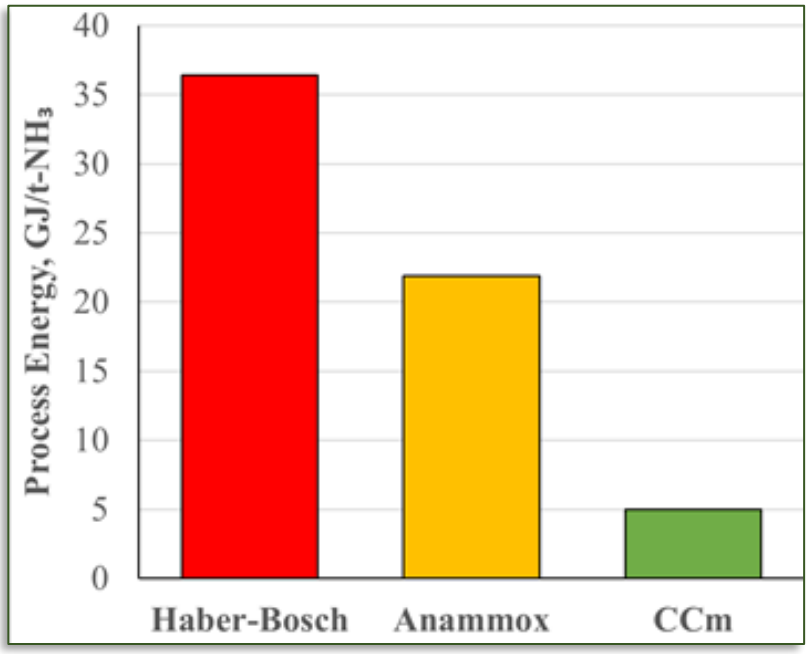
The combination of reduced losses and the physio-chemical effects of the organic materials in the pellet combine to ensure that nutrients are available to the plants for longer.



CCm's intention is to expand our research programme over the coming years with the aim of developing new agronomic approaches which maximise the effective use of combinations of organo-mineral and conventional fertilisers to drive down the Carbon impact of agricultural production.

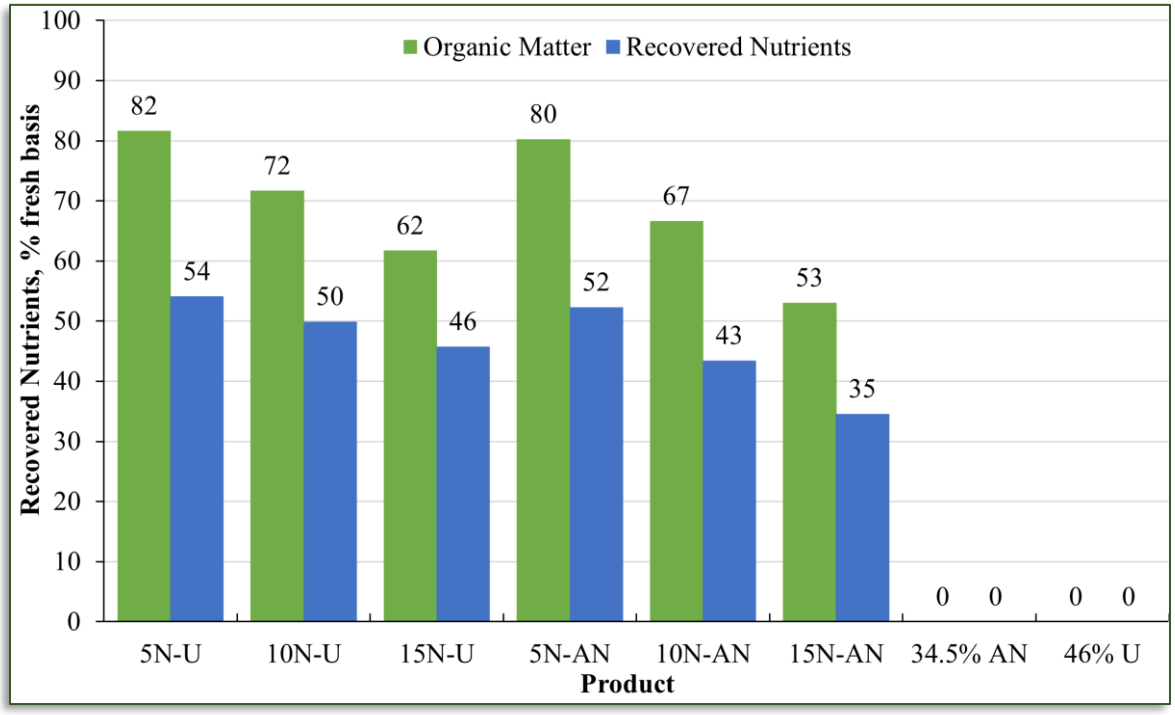
Manufacture

All CCm formulation are produced through low energy production systems which significantly reduce CCm's end-to-end Carbon footprint from the outset.

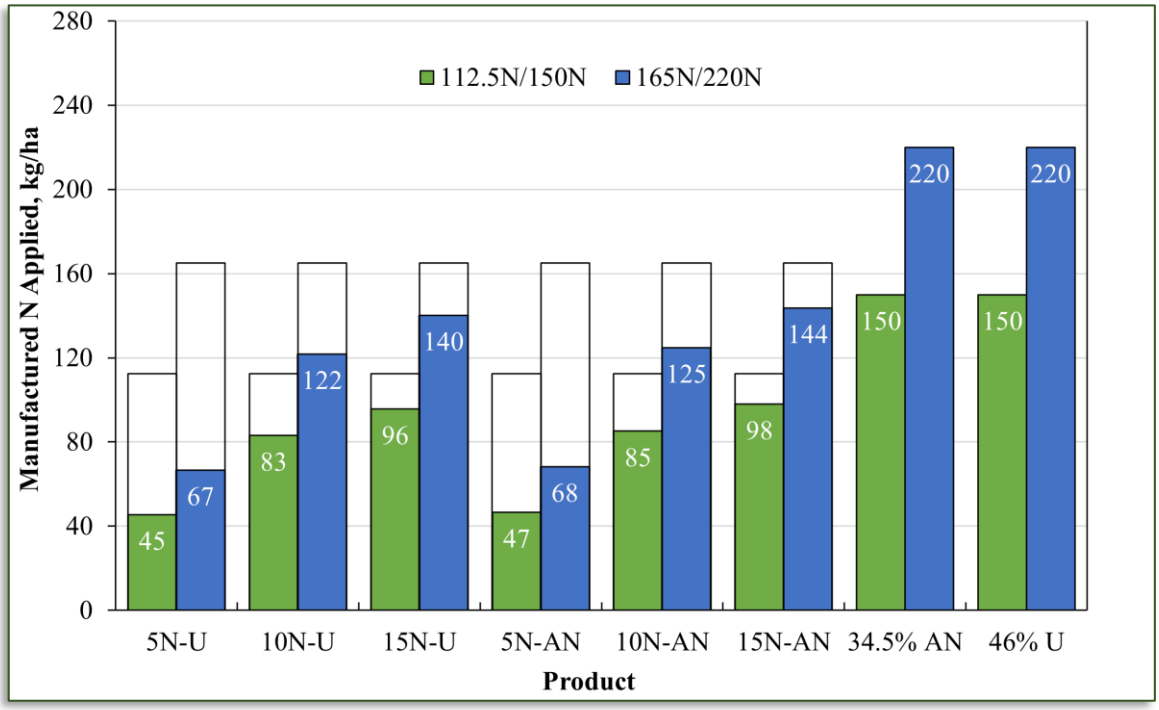


This minimises the amount of energy needed to produce the fertiliser in the first instance and ensures that the ultimate Carbon footprint of the materials is very low.

The Carbon impact of production is further reduced by the extensive use of recovered heat and renewable electricity during the manufacturing process.

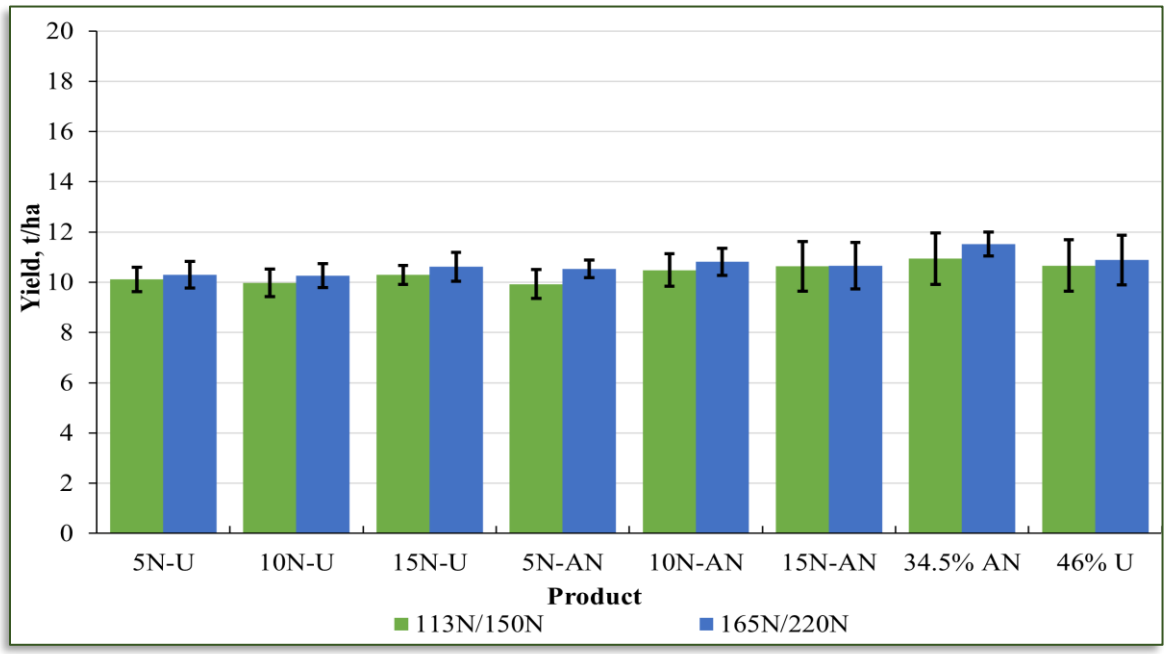


The use of recovered nutrients means that all CCm formulations contain low levels of manufactured N helping to reduce the Carbon footprint of the range.

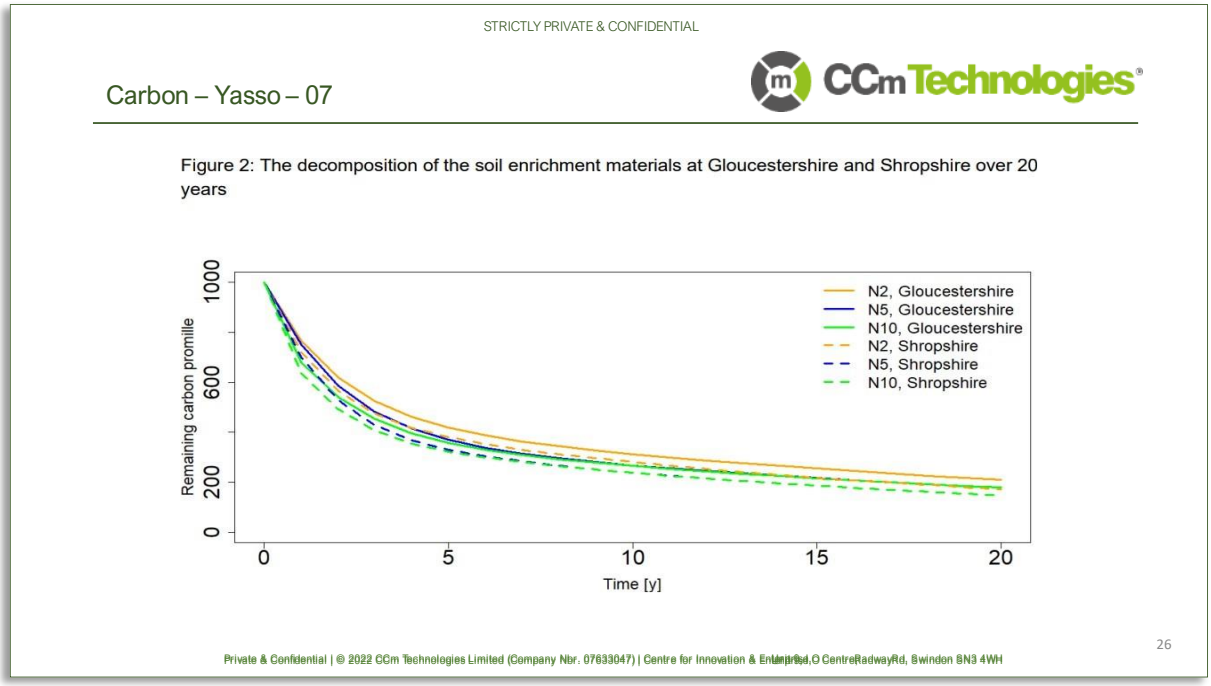


2022 Field trial results

All the CCm fertilisers were applied at Nitrogen rates 25% lower than either the standard ammonium nitrate or urea trial sites and again demonstrated that these low impact materials produced the same yield with a far lower Carbon impact. Critically all formulations contain high levels of recalcitrant Carbon, which are independently verified to remain in the soil for decades.



In addition to the impacts associated with low Carbon manufacturing the CCm fertilisers also help to return organic Carbon back to the soil. All formulations contain high levels of recalcitrant Carbon which are independently verified to remain in the soil for decades.



Professor Peter Hammond
Chief Technology Officer
27th October 2022