Founding Member

TECHNOLOGY REVIEW

CCm Technologies have developed a range of processes that realise value across the whole waste inventory.

A unique combination of carbon utilisation and resource optimisation has created a series of environmentally and economically sustainable processes. In developing these processes, CCm Technologies have used captured carbon to trigger very significant carbon retention and avoidance premiums, which ensure that our technologies deliver massive environmental benefits.

CCm systems produce high value, high performance materials from low or negative value inputs. The new materials are targeted at existing growth markets and their efficacy has been proven through independent trials at scale over the last five years. Both the materials and the process that generates them are ready for immediate commercial exploitation and CCm's full-scale demonstration facility is currently engaged on a range of accelerated deployment evaluations.

In addition to the creation of new materials containing high levels of entrained functional carbon, CCm's technology is able to harvest energy from within its own operations through its patented strongly exothermic processes.

This additional capability builds on the material resource efficiency of the core process to simplify the integration of CCm's technology into existing operating systems. This approach magnifies the whole system benefits that can be achieved by the process and allowing increased financial margins and enhanced sustainability to be realised throughout whole systems.

The processes enhanced by CCm's technology all become greater than the sum of their parts.

By drawing on end-of-use materials as substantial inputs into its low energy manufacturing process, CCm has also created a range of materials whose sale price is directly competitive with existing products.

These products are based on the exploitation of existing resource streams and so do not require government subsidies for commercial viability. They do however both confirm the value of resources held within current "waste" streams and, due to the underlying sustainability of both the production process and the materials supply chain, guarantee that value long into the future. Furthermore the CCm process compounds the value of existing upgrading technologies by granting access to new market segments whose growth is extensively underpinned by recent legislation linking product utility to wider sustainability criteria where CCm credentials are unparalleled.

There are three key technology platforms available through CCm and whilst they are built around the same carbon utilisation and resource efficiency platform, they are focused on distinct though potentially overlapping commercial sectors:

- **Plant Nutrient and Carbon Restoration Technology**
- **Low Carbon Heat and Power Management Systems**
- **Low Carbon High Performance Materials**

Basic Process

The process at the centre of the CCm fertiliser production system is simple; it combines and organic fibre, Ammonia and CO_2. The ammonia acts as a Nitrogen source for the plants and allows the capture of CO_2, which in turn stabilises the ammonia allowing to be converted into a more useful form. This step is potentially followed by the addition of further nutrients to supplement those held with the feedstock streams that are feeding the CCm process and allow the production of the desired end formulation of N, P and K.

The following process shows the reaction mechanism at the heart of the CCm fertiliser process. The yield of products depends on the concentration of ammonia and calcium nitrate, as well as the capture conditions - gas concentration, temperature, pressure and reaction time.

Reaction mechanism between ammonia-calcium nitrate and CO_2

$$NH_{3(g)} + H_2O_{(l)} \rightleftharpoons NH_4^+OH^-{}_{(aq)}$$

$$\downarrow CO_{2(g)}$$

$$(NH_4)HCO_{3(aq)} \; ; (NH_4)_2CO_{3(aq)}$$

$$\downarrow Ca^{2+}(NO_3^-)_{2(aq)}$$

$$NH_4NO_{3(aq)} \downarrow + CaCO_{3(s)} \downarrow + H_2O_{(l)}$$

Plant Nutrient and Carbon Restoration

CCm's commercial scale demonstration plant is fully operational. The system currently produces significant quantities of ultra-low carbon-footprint premium fertiliser materials and operates as a pre-deployment optimisation tool for larger systems.

This plant can produce a range of fertiliser products varying in Nitrogen content between 30%N to 4%N; in formats ranging from compound pellets through to organic-based loose material and liquids. The process configuration can be set to favour either a particular fertiliser type or the utilisation of an abundant feedstock, whichever is preferred.

CCm's full-scale commercial unit capable of producing 10,000 tonnes of compound fertiliser

CCm fertilisers and soil conditioners have been extensively tested through five years of independent field trials by commercial agronomists and agricultural academic institutions.

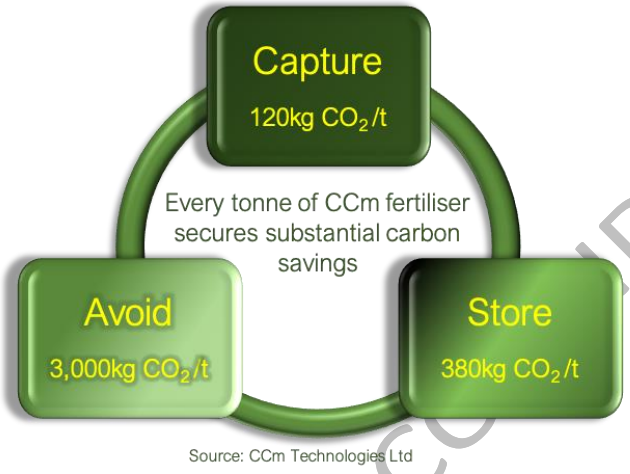
The products created by the CCm process are in essence packages of plant nutrients harvested from existing anaerobic digestion operations. By packaging the nutrients in user-friendly formats bound together by carbon captured from combustion processes, CCm have created a new range of biogenic fertilisers. Importantly these materials are all user friendly and can be delivered using conventional agricultural equipment.

Extensive independent trials have shown that not only do the CCm fertilisers equal or outperform conventional products in terms of yield[1], they vastly exceed them in environmental performance. The environmental benefits of the process are considerable and are based on the creation of beneficial physio-chemical effects in the soil and the carbon capture and utilisation production route used to create the materials.

Carbon

The carbon savings result from the direct capture of CO_2 during the production process; the replacement of high carbon intensity inputs by recovered ones, which produces a large avoidance of primary carbon use; and finally the retention of robust carbon based materials within the fertiliser matrix ensuring high levels of carbon retention in soil.

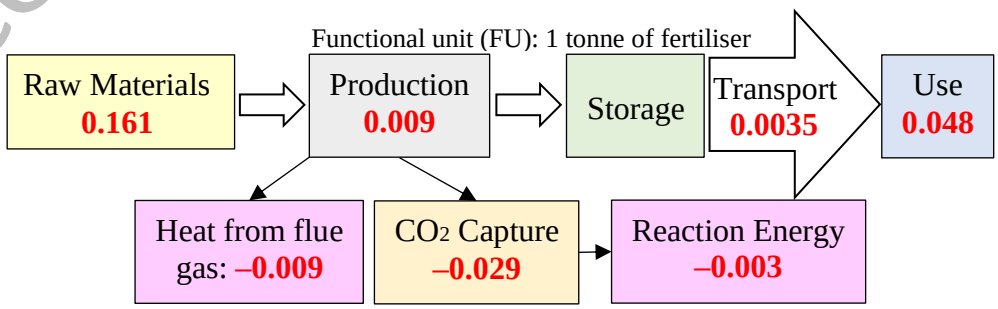
The combined action of the carbon held within the matrix of the fertiliser pellet and the carbonate derived from the captured CO_2 results in the controlled delivery of biogenic nutrients.[2] Every ton of CCm fertiliser generates significant carbon savings – illustrative outcomes from a standard CCm unit producing 10,000 tons of fertiliser per annum:



The process allows the low value materials and wastes currently held within anaerobic digestion or similar operations to be transformed into substantial resources whose real value can be realised by their owners. This step is particularly timely given EU biogenic directive [3] and the move toward direct or indirect carbon pricing in many legislations. The market for these products already exists but legislators are now considerably increasing the size of the market and easing product entry into it [4].

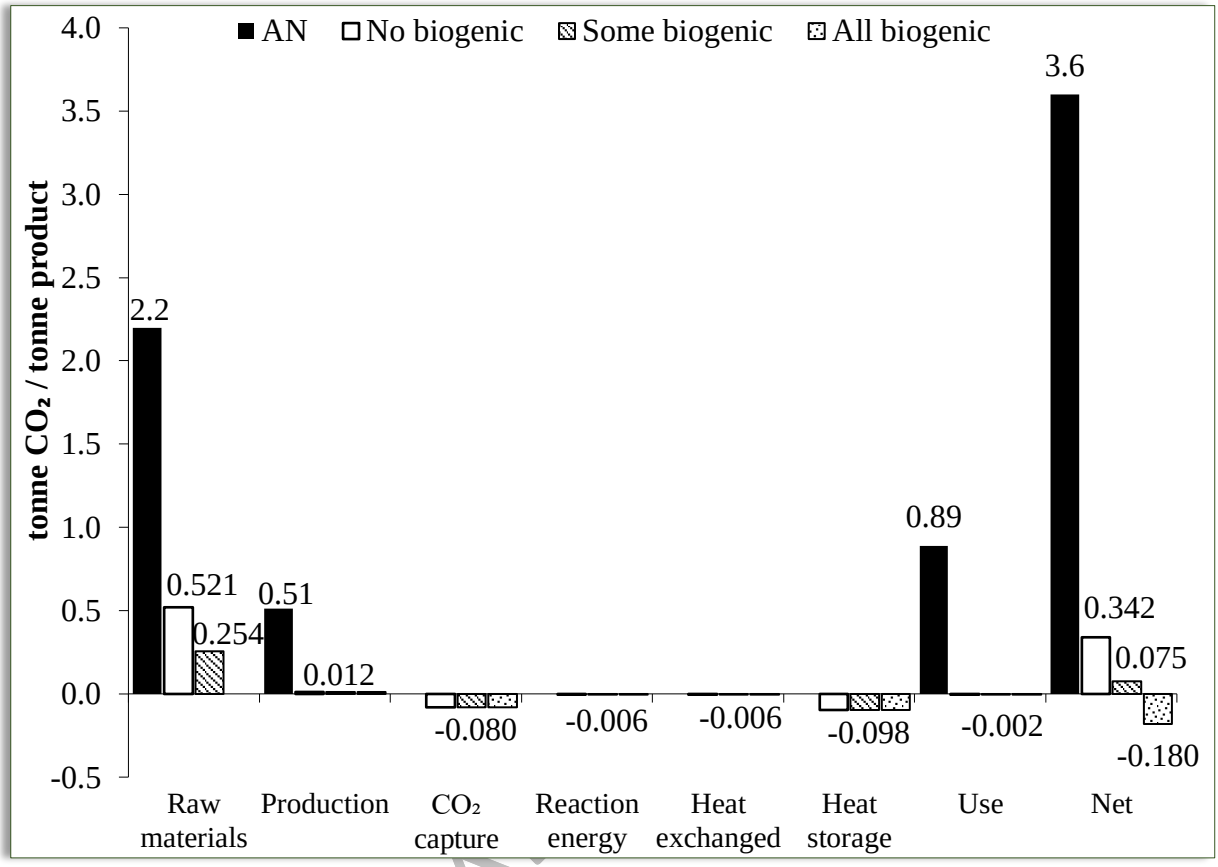
Carbon Footprint

Carbon footprint analysis was carried out for the production of 1 tonne of fertiliser (functional unit - FU) with a NPK of 4:0:0 and based on the fertiliser production plant at Viridor's AD plant at Walpole. The CCaLC software tool was used for the assessment; it follows internationally accepted Lifecycle Assessment (LCA) standards such as ISO 14044 and PAS2050. The production footprint comes from energy to power equipment. Energy recovered from the exothermic CO_2 capture reaction and exchanging heat with flue gases are allocated to substitute burning crude oil, hence their footprints are negative. The transport of fertiliser is based on supplying within a 50-mile radius using 40-tonne capacity lorries. The use stage considers N_2O emissions after fertiliser application.



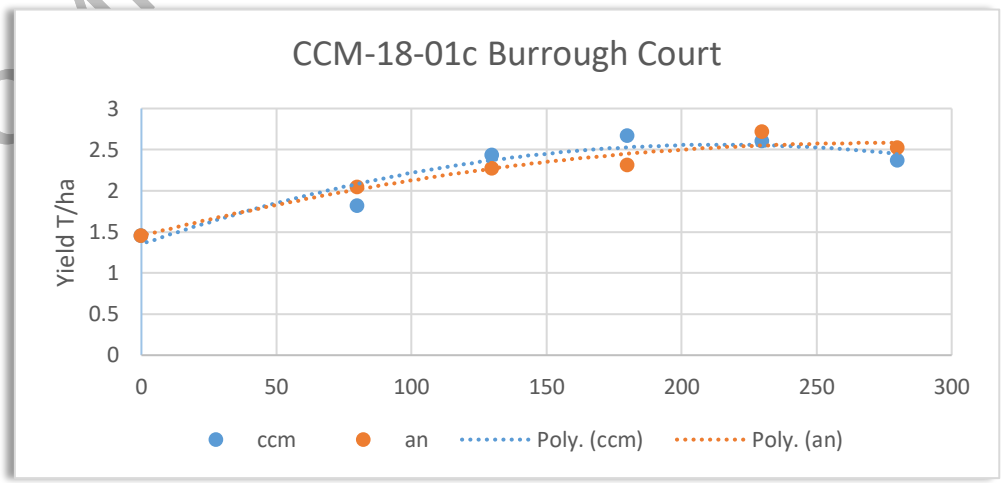
Illustrative Carbon footprint (red) of stages in LCA of fertilisers with varying biogenic inputs

The figure below shows that the net carbon footprint for 1 tonne of CCm fertiliser ranges between 0.342 to 0.180 TCO_2-eq, in excess of 95% lower than that the lowest emission fossil fuel-based producer, Yara (Norway)of an equivalent conventional ammonium nitrate-based fertiliser (Fertilizers Europe, 2011; Yara 2019). This means that for a planned annual output of 7,852 tonnes of product, 1,442 tonnes of CO_2 are avoided.



Field Trials

CCm has carried out fertiliser field trials over the last five years in conjunction with the Royal Agricultural University and Harper Adams University, under the supervision of Professor Philip John from the University of Reading. The growth trials took place at the agricultural universities' sites and on farms across England, where fertiliser was spread using good agricultural practice and standard farm equipment. The results set out below are typical of those achieved using CCm fertiliser:



The field scale trials carried out over the last five years 2015-2019) have focused on cereals, grass and oil seed production. In yield terms CCm materials have always achieved at least equivalence with the industry standard Nitram. Importantly the field trial data has looked beyond simple yield equivalence and has further investigated the benefits which the CCm material brings to the soil. These benefits can be summarised as:

- Enhanced nutrient delivery – allowing the use less N-P-K;
- Enhanced bio-fauna and floral activity – directly contributing positively to overall soil health;
- Carbon (C) retention in soil;
- Enhanced water retention – so contributing to lower N and P run-off reducing pollution in water courses.

These results were recently published by the University of Sheffield in the Journal of CO_2 Utilization (Link).

Key industries that can utilise the CCm process are:

- Anaerobic Digestion based waste treatment operations;
- Food processing systems;
- Agriculture.

Key waste feedstocks that can be drawn from these industries are:

- Carbon, Nitrous and Sulphurous Oxides;
- Fibrous and Particulate Organic waste streams;
- Phosphate and Ammonia rich solid and liquid waste streams.

which are then transferred back into the economy at its starting point.

Professor Peter J. Hammond
Chief Technology Officer

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References:

[1] The results confirm that CCm's fertilisers can be readily applied to a range of agricultural crops and the crop yields are directly comparable with those produced by existing commercial products. These basic levels of directly comparable yield enhancement are a feature of all our independent trials and confirm the commercial utility of our products.

[2] To build on our excellent yield-based trial work, a series of investigations have been launched at the specialist P3, the advanced soil and plant evaluation unit at the University of Sheffield. These results were published in The Journal of CO_2 Utilization - Sustainable soil improvement and water use in agriculture: CCU technologies afford an innovative approach (Lake et al June 2019). (Link)

[3] European Fertiliser Agreement

- http://www.consilium.europa.eu/en/press/press-releases/2017/12/20/eu-fertilisers-council-agrees-terms-of-mandate/pdf -
- European Commission – Circular economy: New regulation to boost the use of organic and waste-based fertilisers. http://europa.eu/rapid/press-release_IP-16-827_en.htm

[4] Food waste collection compulsion in the UK from October 2019.