Improving energy efficiency in fertiliser production through wastewater treatment resource recovery

Summary

This IEEA funded project saw the construction of a sustainable fertiliser evaluation hub. This facility will ultimately allow the future integration of a broad range of waste recovered feedstocks, harvested from the water industry, to be returned to the economy in a stabilised, value-added form. Unfortunately, due to technical challenges related to onsite recovery of resources at industrial scale, resource recovery elements for CO_2, Ammonia and heat recovery were not integrated within this project as had been hoped but it is expected that these, and other resource recovery processes, will be assessed using the highly flexible evaluation platform that has been put in place.

In collaboration with Severn Trent Water (ST), CCm Technologies (CCm) has deployed a low carbon fertiliser production facility at ST Minworth Waste Water Treatment site (WWT) to combine fertiliser production, sludge management and the recovery of plant nutrients from waste streams to create a high value fertiliser product and reduce energy consumption. Carbon Dioxide (CO_2) derived Ammonium Nitrate produced in the CCm process will be combined with organic cake materials recovered from the semi dry cake at Minworth to create a range of liquid and compound fertiliser formulations. The demonstration plant aims to have an expected maximum output of 30t of fertiliser/day depending on the fertiliser formulation being produced and will utilise digestate cake, CO_2, Ammonia and Heat. Ammonia could be recovered from sludge

The Industrial Energy Efficiency Accelerator (IEEA)

The IEEA programme supports the development of innovative technologies that will help industry reduce energy consumption and cut carbon emissions. It focuses on innovations with large potential cross-sector energy and carbon reduction impact - either new technologies or established technologies applied to new sectors. Over £15 million in public and private funding has been committed to develop solutions through partnerships between technology developers and industrial companies willing to test technologies on-site. The programme is funded by the UK government (BEIS) and managed by the Carbon Trust, with support from Jacobs.

dewatering liquors, and additional Ammonia liquor will also be contained in organic cake inputs; CO_2 could be recovered from the gas to grid separated exhaust stream; and waste heat could be recovered from the onsite CHP hot water loop.

Introduction

CCm's technology focuses on capturing CO_2, potentially from industrial emissions streams, and utilising it to stabilise volatile chemicals such as Ammonia held within waste resources. The stable organic resources produced can be used as market equal fertiliser outputs for use in agriculture.

This demonstration project saw the installation of a 10,000 Tonne per annum CO2 utilisation to fertiliser production unit at Severn Trent Water's Minworth site, one of the UK's largest sewerage treatment works, where the project will produce a pelletised organic fertiliser by enhancing currently available, variable sludge feedstocks. The process has the capability to use captured CO_2 from gas to grid technology, recovered ammonia to deliver additional Nitrogen for crop use, and finally recovered waste heat which can be used to reduce energy consumption of process drying.

The CCm technology could allow the integration of all these recovered resources - CO_2, Ammonia and waste Heat - into one process which then produces a sustainable fertiliser output. This is a novel process and the first demonstration of its kind in the water and wastewater treatment sector. The fertiliser production plant was commissioned using external resources in August 2021 following the project close in June 2021. The IEEA project was closed prior to the point of generated operational results, however since then, batches of fertiliser product have been produced using external sources of Ammonia and CO_2. ST and CCm continue to develop the technology solutions for resource recovery.

Partner technologies can be used to recover Ammonia from wastewater effluent streams, reducing the energy consumption of conventional sludge liquor treatment, activated sludge plants and other ammonia removal techniques currently in use within the WWTW and broader industrial sectors.

Ongoing development and operation of the demonstration will assess the energy reduction achieved at Severn Trent's Minworth site through the integration of combined CO_2, Ammonia and heat recovery for fertiliser production.

About the innovation

The key innovation and benefit within this project is that virtually all the physical inputs for the process; CO_2, Ammonia, and Organic base materials could be drawn from waste resources rather than primary production. The CCm process potentially allows recovered nutrients to be captured in an efficient way and further ensures that their utility as plant nutrients is retained. The bulk nutrient density of the fertiliser produced by this route is 500 times greater than the existing output. Further modelling highlights the potential to produce additional carbon reductions from offsetting carbon intensive mineral fertilisers in the order of 10,000tCO_2 (e) per annum.

The fertiliser product is sufficiently advanced that it could be deployed at scale to prevent increasing Ammonia and Phosphate emissions and leaching into water bodies. Most importantly, the supply chains and delivery mechanisms that currently supply UK agriculture do not need to change to be compatible with CCm fertiliser. This means that the addition of CCm technologies to existing plants could facilitate the whole food sector to make rapid and quantifiable progress toward sustainable productive agriculture. It is hoped that the CCm technology will lead to significant carbon savings from avoided energy intensive fertiliser manufacture and re-use of waste ammonia, CO_2, and heat resources, and ultimately achieve a meaningful effect on the attainment of greenhouse gas

emissions targets. CCm and STW are continuing with the project and intend to quantify these carbon savings using actual operational data.

Fig 1. Reactors, materials handling, mixer

Fig 2. Mixers, hoppers and material handling

The above images Fig 1 and Fig 2 show the CCm technologies CO2 utilisation to fertiliser production plant at Minworth. The reactor units shown in Fig 1 are the entry point for Ammonia (recovered or externally sourced) to be reacted with CO_2. The hoppers feed sludge cake to the mixer where CO_2 derived nitrogen is added. Additional CO_2 is added to stabilise volatile Ammonia held within the sludge cake. Further hoppers are used to add plant nutrients if

required to produce a now predictable fertiliser output with reduced emissions and leaching to conventional sludge and chemical fertiliser outputs.

The demonstration delivered:

CCm and ST completed the installation of a sustainable fertiliser production plant with the capacity to produce 10,000t per annum of fertiliser using digestate sludge from Minworth. This flexible fertiliser hub was designed and built to allow for ongoing integration of recovered resources from within the water industry. Initially these resources include CO_2, Ammonia, and waste heat. Full DSEAR and HAZOP assessments were completed for the fertiliser plant before June 2021. Commissioning started but was not completed within the funded timelines. Energy efficiency modelling focused on two key comparisons:

1. The impact of ammonia recovery technology to reduce on site energy consumption vs conventional nitrification, liquor treatment and additional ammonia recovery technologies

2. The impact of resource recovery integration for production of sustainable fertiliser formulations vs conventional mineral fertiliser production routes

Following the project close in June 2021, CCm and ST have started operation of the fertiliser plant, including the gathering of data to supply actual on-site information for future project energy assessments.

Whilst operation of the fertiliser plant did not take place before project closure, critical learnings were achieved following the funded project to ensure future challenges around drying sludge and recovery of ammonia at scale are reduced. In terms of drying, CCm's knowledge of producing fertiliser formulations using specific nutrient additives and drying parameters will reduce energy consumption of drying phases during fertiliser production. In terms of Ammonia recovery, extensive trials are planned to be carried out with the proposed recovery technology to ensure scale of recovery is achievable. On site heat availability will also be assessed to ensure efficient energy usage. During the IEEA project ammonia, heat and drying were modelled with outline designs for integration developed. ST and CCm have continued to explore demonstrating these elements.

Project Scope review:

During the project, the scope to recover CO_2 from CHP gas engines was changed to focus recovery from higher concentration gas to grid streams. This was deemed as a more replicable approach in terms of future project integration with Severn Trent and the broader water sector. Conceptual designs were completed before June 2021 and future integration is being explored following project closure.

A range of feasibility trials were carried out by the project's EU based ammonia recovery partner, using liquor samples recovered from the site. The outcome of these trials indicated that IEEA approved capital budgets, originally set for the project, would not be sufficient to achieve the full-scale recovery targeted in the originally planned objectives. As such, a scope decision was made to reduce the volume of ammonia recovery demonstrated on site, within the project. Conceptual designs for integration were completed but the project funding ended before on site demonstration took place. Post project closure, project partners continued to explore efficient routes for ammonia recovery integration.

Technical challenges around heat recovery on site, led to a scope review and a new project objective to recover 835MWh/year for use in fertiliser process drying, nitrogen production and ammonia recovery. However, the heat trials were not implemented during the timeline of this project. Project partners continue to explore integration of heat as a priority for future projects.

Severn Trent and CCm Technologies have extended their collaboration agreement beyond the IEEA funding to ensure future the delivery of resource recovery for fertiliser production and improved energy efficiency within water operations can be completed and shared with project stakeholders.

Minworth Sewage Works: The demonstration site

Minworth is one of the UK's largest sewerage treatment works and Severn Trent's biggest facility, serving an equivalent population of 1.75 million from Birmingham. The plant treats sludge from an equivalent population of 1.75 million. The CCm technology was located in a building which previously held sludge thickening belts. This location is close to the newly installed biomethane to grid process which is intended to provide a separated, high concentration stream of CO_2 for capture. Sewage sludge is delivered to the CCm site from the opposite end of the Minworth site, via truck and deposited in storage bunkers, constructed during this funded project. A heat loop covers the Minworth site. It was this heat loop which was initially highlighted to providing heat for the CCm process. This objective was amended during the project scope review.

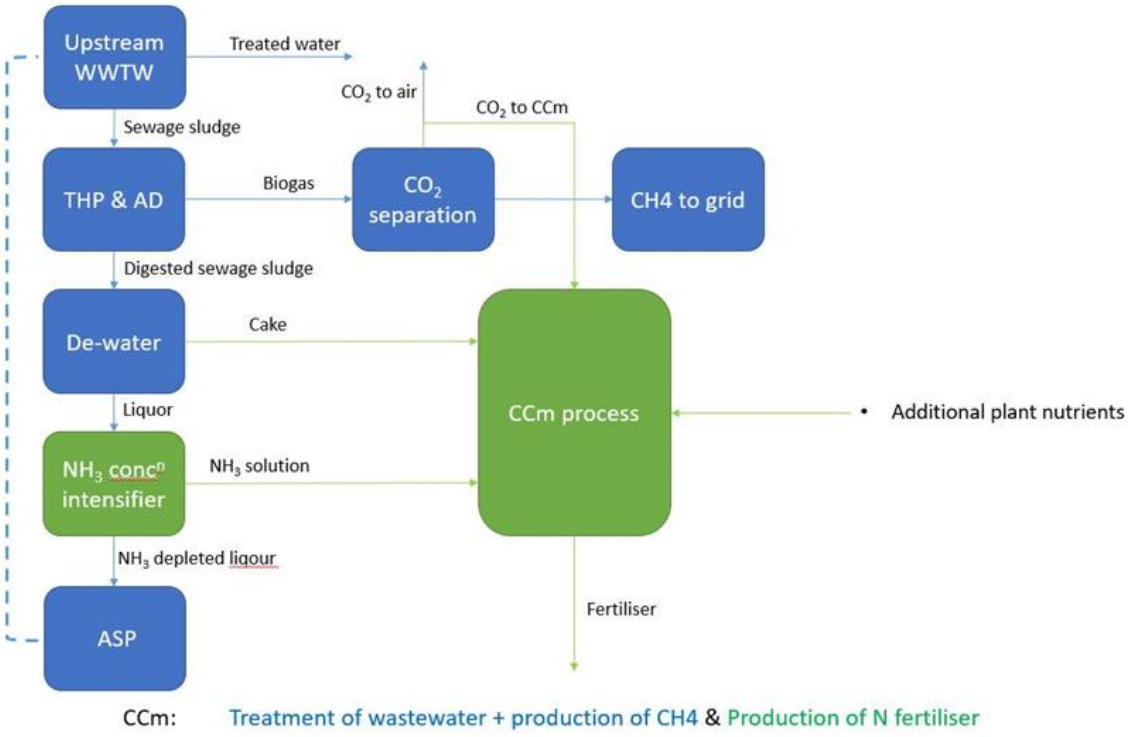

Fig 3. CCm and STW technology future integration

Fig 4. Ammonia Storage tanks

Fig 6. Sludge storage bunker

Fig 5. Pelleting system

Fig 7. Automated control system
Henry Oliphant, CCm's Technical Engineering Manager and Leah Fry, Severn Trent's Head of Bioresources

Monitoring

CCm process equipment has been commissioned for demonstration of sustainable fertiliser production. Work is ongoing on the recovery of CO_2 and ammonia to enhance the sustainability of the process.

Measurement and verification of energy data are planned to be monitored using the CCm control system, including its cloud dashboard, hosted on the Microsoft Azure platform, for full traceability and audit trail of system data and feedstock input. Monitoring systems and models had been developed ready to feed raw data at the point of operational demonstration.

Results

Although operation of the fertiliser plant did not take place before IEEA project closure, Severn Trent Water and CCm Technologies have continued their collaboration post project to explore and assess the impact of the CCm technology to decarbonise wastewater and water treatment systems.

We are currently running trials on several fertiliser formulations to evidence the operability of the plant and the benefits of adapting different fertiliser formulations. These initial trials will be completed in 2022.

We have undertaken additional modelling to support our analysis and to support decisions around future production schedules based upon energy and carbon benefits and the size of the associated markets.

Detailed work has been conducted on resource recovery, with a particular focus on the process flow diagrams for CO_2 recovery, Ammonia and heat recovery, which CCm and ST are continuing to develop as these novel solutions are intended to be further incorporated as part of the continuation of the trials.

Future impact

Following the IEEA demonstration there is potential to roll out further CCm and partner resource recovery plants within the water treatment sector. The CCm technology is also being trialled in the Food and Agricultural biogas and biomethane sectors, providing significant potential for future industry replication.

Innovation lessons

Project partners have achieved a number of learnings both within project management and technical areas; these learnings have provided clarity for improved efficiency on future deployments. A key challenge moving forward is to clarify a pathway through regulation, to ensure the adoption of sustainable fertilisers utilising waste derived feedstocks.

Operating through a global pandemic was a unique challenge in itself, particularly liaising with supply chains across Europe. In the ever-changing environment of this pandemic having clear governance and risk management through this process was key to enabling the continued momentum through the project and making sure this was clearly communicated to all stakeholders involved, particularly at a time when no site or face to face meetings were possible.

Resource recovery development work carried out throughout the project has provided an extensive knowledge of the landscape technologies, specifically in the area of ammonia recovery and CO2 recovery where a number of processes are available to provide a true circular benefit. This knowledge has led CCm and ST to improve our understanding of the current processes and source new technologies suitable for a range of site layouts, particularly as some of these technologies and processes are new and novel solutions.

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From the project lead point of view, this IEEA project has significantly improved knowledge of how to operate on regulated industrial sites. In terms of process development, design, manufacture, installation and commissioning of processes requires a more robust approach. The requirement for ISO 9001 has led CCm to improve all its quality management procedures to ensure improved sustainability across a number of technical stakeholders. CCm successfully achieved ISO 9001 status during this project.

All parties have continued to develop knowledge around agronomic testing best practice, to provide a clear data evidence bank on the produced fertiliser formulations, working closely with the Environment Agency throughout the project to provide clarity and assurance on the outputs of this fertiliser demonstrator and future opportunities.

Contact information

Who to contact for more information

+44 (0) 1865 578 900

alexander.hammond@ccmtechnologies.co.uk

www.ccmtechnologies.co.uk

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