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LIFE Project Number

LIFE18 ENV/SE/000265

Final report – Technical part (PUBLIC VERSION)

Covering the project activities from 01/07/2019[1] to 31/12/2022

Reporting Date[2]

31/03/2023

LIFE PROJECT NAME or Acronym

LIFE RE-Fertilize

Data Project

Project location:	Sweden, Denmark
Project start date:	01/07/2019
Project end date:	30/06/2022 **Extension date:** 31/12/2022
Total budget:	€ 3,625,439
EU contribution:	€ 1,860,565
(%) of eligible costs:	55.00%

Data Beneficiary

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[1] Project start date

[2] Include the reporting date as foreseen in part C2 of Annex II of the Grant Agreement

1 Table of contents

2 List of keywords and abbreviations

Keywords:
wastewater treatment, energy saving, reuse of materials, greenhouse gas, industrial wastewater, fertiliser, urban wastewater

Abbreviations:
HVAC – Heating, Ventilation and Air Conditioning
P&ID – Piping and Instrumentation Diagram
SHE – Safety, health and environment
WWTP – Wastewater treatment plants
EPC – Engineering, Procurement and Construction
EoW – End of Waste
RevoPure AS – RevoPure Ammonium Sulphate (RevoPure is the trademark EasyMining use for the products produced in their processes, if the specific product does not have a specific, own trademark)
FPR – Fertiliser Product Regulation
UWWTD – Urban Wastewater Treatment Directive

3 Executive Summary

The main objective of the LIFE RE-Fertilize project was to demonstrate EasyMining's innovative process for nitrogen removal and recovery. Demonstration runs have been conducted at two application areas, Biofos' wastewater treatment plant (WWTP) Lynetten in Copenhagen (Denmark) and Ragn-Sells landfill Högbytorp outside Stockholm (Sweden). With the runs the process is demonstrated in operational environment at wastewater treatment plant. At the landfill application the process did not prove continuous removal rate required (less than 16 mg/l outgoing flow) even if the required level was reached.
The recovered ammonium sulphate has been tested in cooperation with Lantmännen for the suitability to be used in fertilizers. The pot trial showed similar agronomic effects for the recycled ammonium sulphate as conventional ammonium sulphate.

The project has:

- designed and built a demonstration plant for the process containing both the catchment step and the conversion step,
- conducted demonstration runs at two application areas,
- evaluated the process and the recovered ammonium sulphate
- established business model, market plan etc and the process is now ready for commercialisation
- updated the LCA for the process, and written reports such as After LIFE-report and Layman's report

During the demonstration runs at the wastewater treatment application the process has validated continuous removal and recovery of 95% of nitrogen from the sludge liquor. In the project it is also proven that the energy consumption for the removal and recovery is lower than for removal of nitrogen with today's (biological) methods and production of nitrogen with the Haber Bosch technology. The process should be competitive seen to economy and it significantly lowers the greenhouse gas emissions for nitrogen removal and production.

The original end date for the project was 2022-06-30 but the project has been delayed due to 1) covid-19 (resulting severe delays in equipment for testing during the early basic engineering phase) and 2) the steering group deciding to include a significant process improvement that emerged in the late phase of the process optimization and adjustment phase. An amendment request to extend the project duration was sent in in April 2022, which was approved by CINEA.

The project has been running overall well. The process adjustment, basic engineering, detail engineering and construction have been successful. During the demonstration run at the landfill application we encountered problems with clogging etc due to not optimal piping design. This implied that we were not able to validate a continuous requested removal rate at the landfill application, even if we did reach the requested level at specific times. The demonstration run at Högbytorp (the leachate application) was the most challenging part of the project. However, we still managed to validate the majority of the goals for the demonstration at Högbytorp anyway. After moving the demonstration plant to Lynetten (the sludge liquor application) some reconstruction regarding especially piping was made, and the demonstration runs at Lynetten went therefore much smoother than at Högbytorp. The Lynetten demonstration runs were successful, and the process is demonstrated in operational environment for the sludge liquor application.

The product produced from the process has been evaluated, both to secure fulfilment of legislation, End of Waste and REACH as well as agronomic properties. The agronomic properties have been proven in pot trials. The product from the sludge liquor application fulfils the EU Fertiliser Product Regulation and the pot trials showed agronomic efficiency similar to conventional products.

New studies of releases of greenhouse gas emissions for wastewater treatment plants have showed that these probably are larger than previous known (when writing the EU LIFE-application) which strengthens the need for the solution. Also, the some of the suggested new requirements in the UWWTD strengthens the case for this solution as well; the requirement to recover 15% of the nitrogen, start measuring nitrous oxide and becoming energy neutral by 2040. The last requirement is supported by the Aqua2N-process since this enables more biogas production.

The communication regarding the EU LIFE-project and the process as such has not been able to conduct as first planned, due to covid-19 have e.g. conferences and events been postponed. However, we have lifted the project in as many forums as possible and we are receiving great feedback and a large interest for the solution, which also strengthens the case that a solution like this is needed and sought after. In 2022, the Aqua2N-process and the LIFE RE-Fertilize-project has been presented on several conferences and fairs, both as speaker or in booths, such as IWA WWC 2022, ESPC 4 and IFAT Munich. During the project, the hindrances in legislation for recycled products have been highlighted both at conferences, in referrals and in meetings with policymakers both nationally and on European level in Brussels. Even if the dissemination did not work as planned, at least during the covid-19-pandemic, the dissemination by the project is considered to have been very successful. Going into the commercialisation phase now, after the RE-Fertilize project has finished, EasyMining has not yet started with proactive selling – so far, a lot of potential customers are contacting EasyMining and want to have the process and the conceptual design presented.

Since the RE-Fertilize project was finished, further optimisation of the process has been done with important improvements such as significantly lower the NaOH-consumption. This has a great impact on the OPEX as well as the LCA for the process. These improvements are not included in the report following. EasyMining will continue to optimise this technology after the RE-Fertilize project.

4 Introduction

4.1 Environmental problem targeted

Nitrogen is essential to life and is among the nutrients consumed in the largest quantities by all agricultural crops. However, today's linear flow of nutrients (nitrogen, phosphorus and potassium) from fertilizer manufacturing to wastewater treatment plant via food production and human consumption is not sustainable. Humans and animals excrete a significant fraction of the nutrients contained in the food they ingest. Alongside other agricultural sources, these nutrients find their way back into the environment primarily as municipal wastewater effluents.

Anthropogenic loading of nutrients is the main cause for eutrophication of receiving waterbodies. Therefore, WWTPs are needed for treating these nutrient rich effluents. Both the manufacturing of mineral nitrogen fertilizers and the biological methods for wastewater treatment consume large amounts of energy and chemicals. It also leads to the emission into the air of greenhouse gases (e.g. the strong nitrous oxide) and ammonia, which causes acidification and eutrophication.

Ammonia is the basic compound for the production of nitrogen fertilizers, which is by far the largest reason of carbon footprint in cereal production. The ammonia production industry for manufacturing of mineral fertilizers relies heavily on natural gas as a non-renewable precursor for hydrogen and energy. Ammonia synthesis in Haber-Bosch process is considered to be responsible for about 5% of the world’s natural gas consumption. It is estimated that global ammonia production accounts for 1.3% of the world’s fossil fuel-derived energy use, contributing to considerable greenhouse gas emissions.

The nitrogen treatment process in WWTPs requires massive aeration to oxidize all ammonium to nitrate. In order to obtain an efficient conversion of nitrate to nitrogen gas by de-nitrification an expensive source of carbon such as methanol is usually needed. Also, up to 7% of incoming nitrogen to a WWTP can be emitted into the air as nitrous oxides. Today, only a small proportion of nutrients, nitrogen, phosphorus and potassium, is returned from wastewater treatment plants to food production through application of sewage sludge to arable land.

Stricter water emissions requirements for WWTPs are under way and higher gas emissions and costs are expected in order to meet these stricter requirements. A forecast shows an almost doubling climate effect and up to a 60% increase in costs for WWTPs. A logical conclusion is that nitrogen-containing effluents should be viewed as a nitrogen resource instead of a waste and nitrogen-containing effluents should be exploited through the recovery of nitrogen in forms that efficiently could be used in agriculture or other industries. This positive development is what this project aims to demonstrate.

4.2 Project objectives

The overall goal of the project was to demonstrate a new, innovative removal and recovery process for ammonium nitrogen, which can be used for a number of different ammonia products (e.g. fertilizers).

4.3 Technical /Methodological solution

The project was performed by EasyMining in close cooperation with Ragn-Sells, Biofos and Lantmännen. The set-up of the LIFE project is based on feasibility studies conducted during 2017 and 2018. The project was designed to cover all activities needed to prepare for a full-scale market launch of the process by 2022, this has been delayed to 2023 since the project

time was extended. Project implementation included process adjustment and optimization, designing and building the demonstration plant, demonstration runs at Ragn-Sells' landfill Högbytorp (3 months) and thereafter at Biofos' WWTP Lynetten (6 months), process and product monitoring and evaluation as well as preparation for full scale market launch. The project also included dissemination and reporting such as LCA, Layman's report etc.

5 Technical part

All actions, except final reporting and auditing, were finished by 2022-12-31. A short description of each Deliverable is included in Annex 2.

5.1 Technical progress Action A1 (Planning and Preparations)

Foreseen start date: July 2019 Actual start date: July 2019
Foreseen end date: August 2020 Actual end date: June 2021

Activities undertaken and outputs achieved

The action included, process optimization (sub-action A1.1), basic engineering (sub-action A1.4), detailed engineering (sub-action A1.5) as well as deciding on location for the demonstration plant (sub-action A1.2) at each site, Högbytorp landfill and Lynetten WWTP, permit application for each site (sub-action A1.3), sub-contracts (sub-action A1.6) as well as establishing test schemes for the process and product to be used in the demonstration runs (sub-action A1.7).

- Sub-action A1.1 – Process adjustments & optimisation see below
- Sub-action A1.2 - Deciding on location and permit application have been conducted in close cooperation between EasyMining and Ragn-Sells respectively Biofos. Location at each site was decided in the fall 2019 and these locations were then re-evaluated in the detail engineering (since the demonstration plant has become heavier than planned).
- Sub-action A1.3 - Permit application have also been conducted in close cooperation between EasyMining and Ragn-Sells respectively Biofos. At both sites it was concluded that no permit was needed to apply for in the beginning. This was however re-evaluated during 2021 for Högbytorp and building permit for Högbytorp was applied for and received.
- Sub-action A1.4 – Basic engineering see below
- Sub-action A1.5 – Detail engineering see below
- Sub-action A1.6 – Purchases have been made during the whole project but this sub-action (Sub-contacts etc) relates to the procurement made for the demonstration plant. The procurement for the demonstration plant was divided into different purchase packages and was conducted either as multiple bids or open tender. This action was conducted by Ragn-Sells and EasyMining.
- Sub-action A1.7 - Test scheme for the process was established by EasyMining, and then agreed in the steering group. Test scheme for the product was established by EasyMining in cooperation with Lantmännen. Demonstration set-up (e.g. resources needed) was planned by EasyMining.

Sub-action A1.1 Process adjustments & optimisation

During the project period, mainly during autumn 2019, the process was simplified. In the conversion process, a replacement for solvent extraction of phosphoric acid and a succeeding step for precipitation of a magnesium compound has been introduced where the phosphorous and magnesium is precipitated together. This reduces the complexity of the process as well as the footprint, as the space consuming solvent extraction equipment is not needed.
Compared to the initial new conversion process without solvent extraction, the chemical consumption has been reduced. An alternative with 76 % lower consumption of sulphuric acid and 82 % lower consumption of ammonia has been developed. The new process, with lower consumption of sulphuric acid and ammonia is the process that has been validated during the

Lynetten demo runs, so it works. However, we have during the demonstration runs used more chemicals than expected due to buffering capacity in the media. This has been taken into account in the conceptual design and EasyMining will continue to work after the finalization of the project to optimise (reduce) chemical consumption.

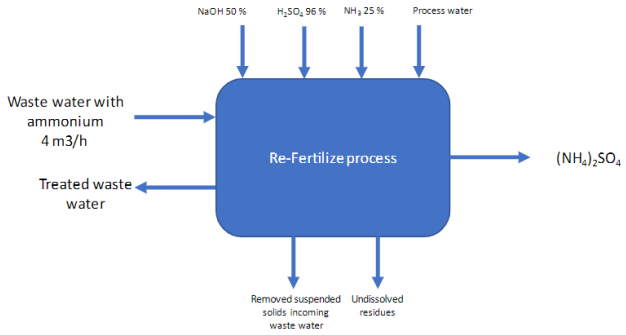

Figure 1. Input and output diagram for the process

Overall, all the process steps was optimized to work in a fully continuous process. All the liquids and solids handled in the process was characterized for physico-chemical parameters needed for the engineering work. Equipment tests was performed, and decanter centrifuges was chosen as the main equipment for solid-liquid separation in the process. In the project application, filters were inserted as separation equipment. Due to the space limitations for the demonstration plant (max width of plant of 3,5 m since it was to stand in a road at Lynetten, where trucks were to be able to pass) we had to change to separation equipment requiring less space. Decanter centrifuges were considered to be most appropriate, and these were tested and validated to work in the process. For the conceptual design work (in the end of the project, see Action D2, filters were reconsidered when we did not have space limitations and in the conceptual design a belt filter has replaced two decanter centrifuges.

During spring 2020 the process had been optimized enough to start involving process engineers for the engineering work. However, optimisation of the process continued during the basic engineering and detail engineering as well.

Sub-action A1.4 Basic engineering

A basic engineering package was developed which included the disciplines process, mechanical & piping, civil & building, electrical & instrumentation, HVAC and SHE. P&IDs were developed to a high detail level and 2D and 3D-layout was prepared with the main equipment. Design basis for each discipline was produced to be used during the detail engineering and construction phase. Equipment to be used for solid-liquid separation in the process has been tested. This includes vibration sieves, decanter centrifuges, bag filters, disc filters, candle filters and a screw conveyor. The majority of the basic engineering was conducted by personnel from EasyMining, some external assistance in disciplines not available in EasyMining was used.

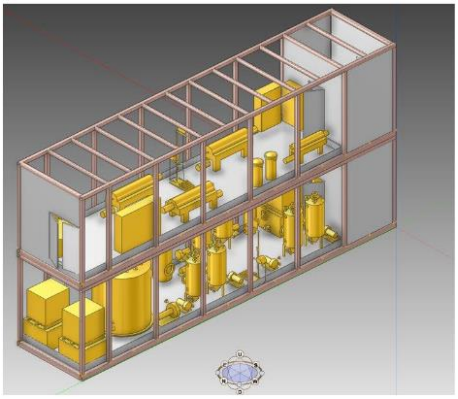

Figure 2. ISO overview when finalized basic engineering

Sub-action A1.5 Detail engineering

During the detail engineering the documents for the basic engineering was taken to Issue-for construction status, and documents not established in the basic engineer phase was developed to the same status.

The majority of the detail engineering was done by an external supplier, COWI, which contracted after an open-tender-procurement. The EasyMining engineering team did some of the work as well, especially in the disciplines Process, Mechanical and Process Control.

5.2 Technical progress, Action B1 (Construction and Installation)

Foreseen start date: Sept 2020 Actual start date: Jan 2021
Foreseen end date: April 2021 Anticipated end date: April 2022

Activities undertaken and outputs achieved

Much of the purchasing planned for in B1.1 has been conducted in sub-action A1.6 since the purchasing of equipment needed to be done before the detail engineering can proceed. Open tenders have been held for decanter centrifuges, detailed engineering, fabrication and installation and control system. For the rest of the purchasing packages multiple bids was used as procurement process.
The construction, installation (assembly), transport to Högbytorp and installation at Högbytorp as well as disassembly at Högbytorp, transportation to Copenhagen and installation at Lynetten were conducted by Enerco, and subcontractors to Enerco.

Construction

In order to save time construction of the steel frame was initiated before the detailed engineering was finalized. Construction (fabrication) began in the spring of 2021. The demonstration plant was constructed at Enerco's workshop in Horndal.

Figure 3. Steel frame (bottom module) with main equipment at the workshop in Horndal

Transportation of demonstration plant to site

In November the modules were transported to Högbytorp. The bottom module was placed on prepared foundations. The top module was then stacked on the bottom one. The transportation and installation were done by Enerco, same company as construction the modules.

Figure 4. Bottom module arriving at Högbytorp 2021

The foundation at Högbytorp was prepared by Ragn-Sells' contracted supplier, PEAB. Ragn-Sells' also contracted external assistance to prepare for electricity and in- and outgoing connections for leachate water and treated water.
During November and December pipes between the modules were connected and pipe supports were constructed.

The transportation of the modules from Högbytorp to Lynetten was procured in one package and the demontage at Högbytorp and the installation at Lynetten as one package. The demontage and installation was awarded to Enerco, since a lot of synergies were gained since they both have built it and installed it. The transport was done by the company Jinert, but the quotation was given by Enerco with Jinert as subcontracter. In this way there was a smooth project management for the whole move.

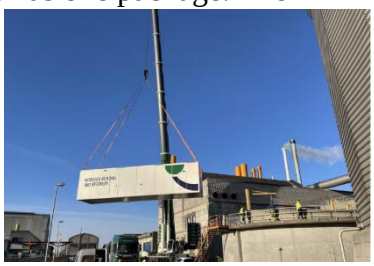

Figure 5. Top module being lifted in place at Lynetten in spring 2022

The foundation at Högbytorp was prepared by Ragn-Sells' contracted supplier, PEAB. Ragn-Sells' also contracted external assistance to prepare for electricity and in- and outgoing connections for leachate water and treated water.
The foundation and in- and outgoing connections at Lynetten were prepared by BIOFOS and external assistance contracted by BIOFOS.

5.3 Technical progress, Action B2 (Demonstrations)

Foreseen start date: May 2021 Actual start date: December 2021
Foreseen end date: May 2022 Actual end date: December 2022

Activities undertaken and outputs achieved

In this action the demonstration plant was run at both Högbytorp (landfill application) for 3 months and Lynetten (sludge liquor application) for 6 months. Included in this action is also the work done together with Lantmännen to define and evaluate the ammonium sulphate produced. The demonstration runs were mainly performed by EasyMining, the evaluation of the product was done jointly by EasyMining and Lantmännen.

The output from the demonstration runs differ from the different application areas.
At Högbytorp the project encountered problems with the flows in the demonstration plant, much due to not optimal piping design. Therefore, not all goals set for the demonstration runs were achieved, see Figure 7 as well as Annex 3 (Report on Demonstration Högbytorp leachate application). Green is fulfilled goal, yellow is partly fulfilled and red not fulfilled.

However, we still managed to ten out of 14 goals, and especially satisfying was that the conversion step worked as planned.

Goal	Comment
Sampling according to sampling scheme	
Stable outgoing concentration of NH4-N, goal <16 mg/l	A steady state of the ammonium was never reached in the treated leachate, values fluctuated. Lowest value obtained during 72 h run verified by external analysis 30 mg/l
Stable outgoing concentration of ammonium sulphate	
Stable consumption of input chemicals and consumption determined for mass balance	Since dosing of input chemicals were based on flow ratios the dosing was varying with the flows in the process. Good mean values of the flows were however obtained.
Amount of gypsum from filters 42F04/05 determined	
Determine if and what levels of Ca that accumulates in 41T02	
Verified chemical composition that newberyite precipitates in 43R01	
Verified chemical composition that struvite precipitates in 44R01	
Composition of solids and concentration of dissolved species in all tanks and reactors determined	
Process data for run longer than 8 h (About 48-72 h if determined possible)	
Losses and required make-up determined	More data is needed on chemical losses of the ammonium catchment chemical. A better understanding is needed for losses related to process equipment is also needed. Further optimization is needed for decanter centrifuge centrate quality.
Electricity consumption determined for the plant	
1 IBC with ammonium sulphate should be collected to be used for product evaluation	
Two more residence times in 41R01 and the effect on NH4-N in treated water	Due to that steady state outgoing ammonium concentration was never reached, more residence times were never tested.

Figure 6. Goals set (and fulfilled/not fulfilled) for the demonstration run at Högbytorp

Before starting up the demonstration runs at Lynetten (sludge liquor application) some rebuilding in the demonstration plant was done, especially seen to piping and outlet from reactors. Thanks to the rebuilding, there was a significant difference in the running of the plant at Lynetten compared to running at Högbytorp even if we could not change all that was needed. Running a Lynetten had significantly less clogging and stops due to our plant. Due to much smoother running, the demonstration runs fulfilled to a greater extent at Lynetten, see Figure 8. The WWTP do not have a requirement to reach 16 mg/l NH4-N in the outgoing flow, 40-50 mg/l is sufficient. But since this was not revised until after the demonstration runs, the goal for the outgoing flow was still 16 mg/l in the goal table. The project did not have time to work with different retention time during the demonstration runs, this will however be elaborated with after the finalisation of the LIFE RE-Fertilize project, in connection to minimizing the sodium hydroxide consumption.

Stable outgoing concentration of NH4-N, goal <16 mg/l	The goal was set based on what was acceptable to release to the recipient at the Högbytorp site. An average of 24 mg/l was achieved in week 38. For the reject water this was a good result.
Stable outgoing concentration of ammonium sulphate	
Stable consumption of input chemicals and consumption determined for mass balance	
Amount of gypsum from filters 42F04/05 determined	
Determine if and what levels of Ca that accumulates in 41T02	
Verified chemical composition that newberyite precipitates in 43R01	
Verified chemical composition that struvite precipitates in 44R01	
Composition of solids and concentration of dissolved species in all tanks and reactors determined	
Process data for run longer than 8 h (About 48-72 h if determined possible)	
Losses and required make-up determined	
Electricity consumption determined for the plant	
1 IBC with ammonium sulphate should be collected to be used for product evaluation	
Two more residence times in 41R01 and the effect on NH4-N in treated water	Instead of testing more residence times, it was evaluated how little solids was needed in order to have good treatment efficiency with a fixed residence time.

Figure 7. Goals set (and fulfilled/not fulfilled for demonstration run at Lynetten

Outcome from the demonstration runs is that as long as the proper process parameters are maintained (ex. pH, temperatures, retention time, sufficient amount of precipitant) the process is robust and can achieve high nitrogen treatment efficiencies. Up to 97 % on average was achieved with a concentration of about 20 mg/l ammonium in the treated reject water could be demonstrated at Lynetten (sludge liqour application). A product with a solution of ammonium sulphate with a concentration of 8-11 wt% was achieved.

With the data gathered for the mass and energy balance, the learnings of process equipment functionality, process control, behaviour of the process media the input needed to make a conceptual design for a full-scale commercial plant has been obtained.

As the process is still new and different types of process equipment can be used in the process, work related to optimizing the process further with respect to chemical and energy consumption, concentration of the product and testing of equipment will be continued with.

In the action, the produced ammonium sulphate was evaluated as well. The product was analysed in regards of different potential contaminations to ensure fulfilment of legislation and also other requests of composition such as pH and free acid. The produced ammonium sulphate that was sent to farmers was verified by the farmer that it was possible to spread by spraying, without clogging the nozzles.
The product has also been presented at various conferences and meetings, in order to increase awareness and interest of recycled products.

Figure 8. Product being delivered to farmer outside Copenhagen

5.4 Technical progress, Action C1 (Monitoring and Evaluation)

Foreseen start date: June 2021 Actual start date: Jan 2022
Foreseen end date: May 2022 Actual end date: Dec 2022

Activities undertaken and outputs achieved

The monitoring and the evaluation of the process and the product has been conducted continuously during the demonstration runs. Monitoring and evaluation of the process have followed the established test/sample scheme to ensure that the goals for the validation of the process was fulfilled, see Figure 7 and Figure 8. For Högbytorp, a majority of the set goals was reached, however we still not managed to get down to a continuous level of <16 mg NH4-N/l in the treated water, why the process is not fully validated for that application area. For the reject water application, the process is validate and the process is considered to have reached TRL 7 (demonstrated in operational environment).

Figure 9. Pot trials conducted at SLU fall 2022

The product has been evaluated according to the set analysis scheme, both for the product produced at the leachate application and at the reject application. Pot trials, see Figure 10, for validating the agronomic effects was conducted in the autumn 2022 and was successful. The first results showed a slightly lower nitrogen efficiency for the unfiltered (non-carbon filtered) ammonium sulphate produced in the demonstration plants. But after the report was finalised, analysis of the nitrogen content in the samples used was made, since it was strange that there was a slight difference. The samples showed an error in the first nitrogen analysis, and the result was recalculated given the correct nitrogen content instead, showing that the agronomic effect is equal to the conventional ammonium sulphate, also for the unfiltered sample.

The LCA, LCC and Socio-economic impact study was performed in late 2022 and showed the impact that the process. Regarding the LCA the largest contributors to the impact of the process are sodium hydroxide and sulphuric acid, chemicals that we will continue to try to reduce consumption of, see Figure 10. The LCA also showed that the recycled product has a lower impact than virgin produced ammonium sulphate in all categories assessed. The LCA was conducted only on the process itself, it did not take into account any reduction of nitrous oxide emissions, lower nitrogen levels from the WWTP plant nor the possibility to reduce addition of carbon source or energy for nitrogen removal. This are factors that give a great impact on an LCA if you look at the whole system. However, the system boundaries this time was set to the process itself.

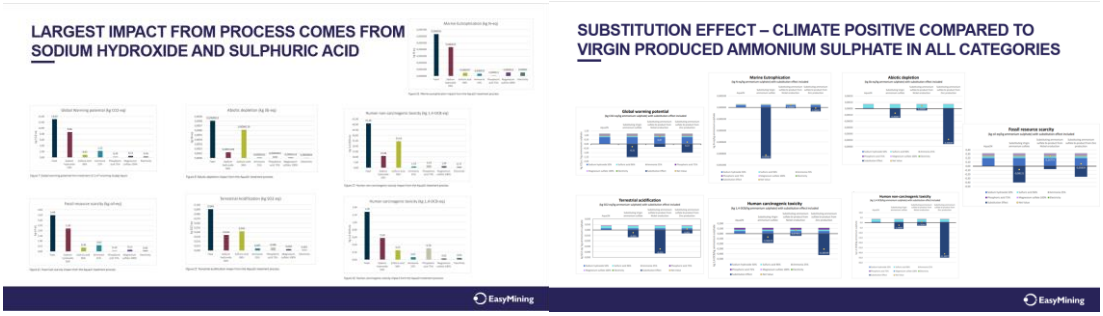

Figure 10. Results from the LCA study conducted

The socio-economic report verified the impacts highlighted in the application:

- Reduction of >15-30% of nitrous oxide emissions
- 30 new jobs in engineering, sales, purchasing within EasyMining only (with the planned roll out pace)

But also added that there is a societal interest in better water quality, which increases the importance and probably willingness to pay for nitrogen removal and recovery.

The results from the product evaluation, the pot trial and the LCA together validate that the recycled ammonia product equals the agronomic effeciency of a conventional fertiliser, it has a better environmental performance and it fulfils the FPR. If the product was the only income for this process, it would however be more expensive than ammonia products produced by the Haber Bosch technology. However, since the process adds a great value in the removal step this part bears much of the cost, and in the business case for the conceptual design the same price as for ammonia products produced by the Haber Bosch technology is calculated with (not taking into account any add on values given the fact that it is more environmental friendly, given results in the LCA, and also that it is recycled).

5.5 Technical progress, Action D1 (Dissemination)

Foreseen start date: August 2019 Actual start date: August 2019
Foreseen end date: June 2022 Actual end date: January 2023

Activities undertaken and outputs achieved

We have experienced great interest in the project both from potential customers, politicians, potential partners and other stakeholders. We also highlight the EU LIFE-funding and find it as a great quality stamp for the project. Some examples of activities done in this action are:

- Obligatory dissemination means; project website was launched (LIFE RE-Fertilize (easymining.se)) and notice boards are still up at beneficiaries.

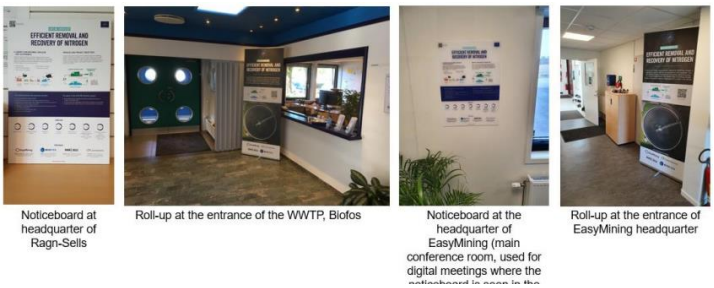

Figure 11. Notice board and roll up about the project at beneficaries

- Statistics for the website has been measured since June 2020. The number of visits to the project website June 2020-Dec 2022 was 9273, a large number of visits should however be at the start of the project and in connection to articles and notification, total number of visitors is expected to be at least 10 000.
- General dissemination means; press releases and articles about the project, social media updates, news at Swedish Vetenskapsradion ("Science radio") when getting the funding, presentation at webinars, seminars, broadcasts, EU-parliamentarians (in order to lobby for change in fertilizer legislation) and potential customers and partners, result webinar for the entire project held in January 2023

Figure 12. Notice board and EU LIFE flag and stickers at the demoplant (here at Lynetten)

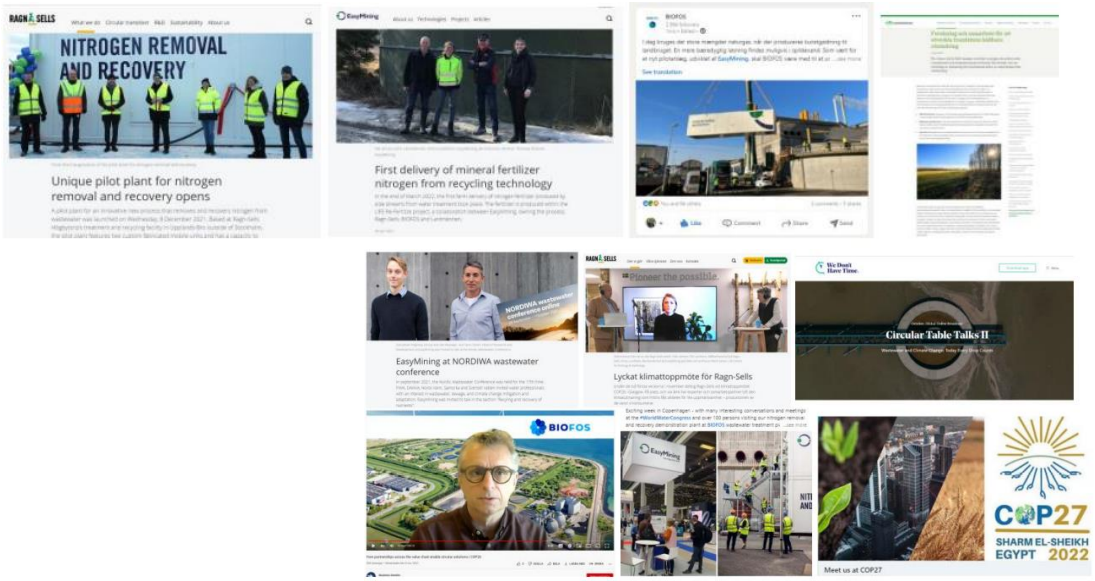

Figure 13. Some examples of dissemination done during the project

- Conferences and exhibitions, some examples: NORDIWA, WeDontHaveTime table talks, COP26&27, IWA WWC 2022, IFAT 2022 and ESPC4
- Study visits to the demonstration plant, with 300+ stakeholders visiting the demoplant at Högbytorp and Lynetten

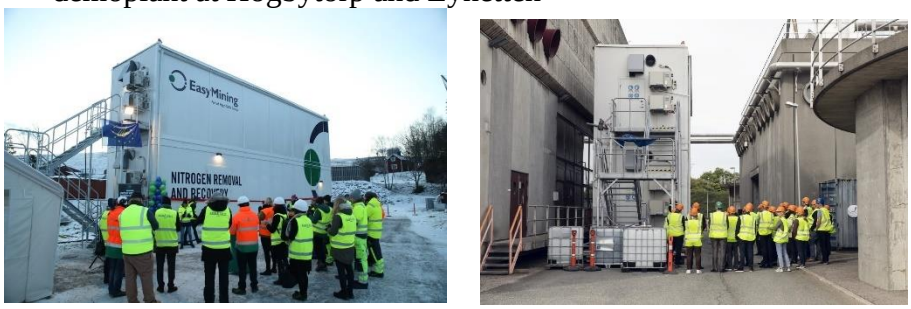

Figure 14. Inauguration at Högbytorp in 2021 and Lynetten in 2022

- Other EU LIFE projects networked with are LIFE Sunalgae, NutriBiomass4LIFE, LIFE CONQUER, H2020 WalNUT, LIFE ENRICH, LIFE LIWE. A specific site for collaboration was set up on the project website.
    - LIFE Sunalgae: Project presentations and discussions about similarities. Even though it was two very different project, except the focus on circular economy, we concluded that the RE-FERTILIZE product were about to be tested in LIFE Sunalgae's algae culture. A sample of ammonium was sent during autumn 2022 and is to be evaluated as an algae fertilizer by Swedish algae factory. However, the LIFE Sunalgae project got delayed and therefor the product is not tested within the end of LIFE RE-FERTILIZE. EasyMining will keep the contact with Swedish Algae factory for follow up on the product and to further evaluate interesting cooperations between the business solutions.

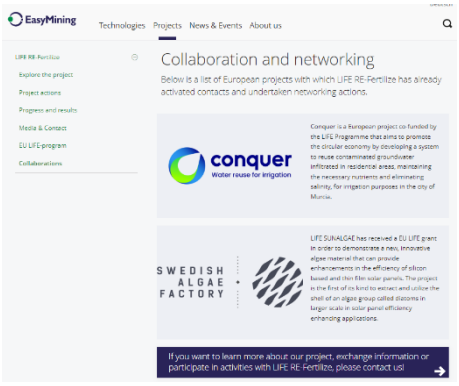

Figure 15. Collaboration site on project website (https://www.easymining.se/projects/re-fertilize/collaborations/)

    - NutriBiomass4LIFE: Both projects got presented and similarities was discussed. Even though both projects are focusing on circular solutions for nutrient recycling and are producing fertilizers in some way, we agreed not to continue the co-operation since the NutriBiomass4LIFE fertilizer did not go through end of waste like RE-FERTILIZE product, making a big difference in the handling and productization process.
    - LIFE CONQUER, H2020 WalNUT and LIFE ENRICH: During the meeting on June 28th all the projects got presented and discussed, with a lot of similarities discovered even if the projects where in different stages (LIFE ENRICH finished), with a big interest regarding LIFE RE-FERTILIZE coming LCA and impact on product value after upgrading it. A new meeting was booked for updating each other later in 2022, and information between the projects were exchanged to publish co-operations and networking on the websites.
    - LIFE LIWE The project was contacted since it seemed to be a good cooperation partner also working for closing nutrient cycles in Sweden. However, no meetings were preformed because responds did not appear.
- An After-LIFE plan has been established. It is very much the same activities as in EasyMining business plan for Aqua2N, see **Fel! Hittar inte referenskälla.**. The conclusions are that:
    - The societal challenges driving the development of the Aqua2N-process and the reason to setting up the project and applying for EU LIFE funding are still valid.
    - Given the suggested changes to the Urban Wastewater Treatment Directive (UWWTD) with suggested required recovery of at least 15% of the nitrogen, the need for nitrogen removal and recovery technologies have even increased.
    - The successful demonstration of the Aqua2N-process and validation the produced ammonium sulphate within the LIFE RE-Fertilize project is a very

good starting point for commercializing the Aqua2N-process – and reaching the long-term goals set up for the process.

- The focus at start of the commercialization will be on the WWTPs, due to limitations to use the product produced from leachate and also the higher complexity of the leachate water.
- The Conceptual design conducted in the LIFE RE-Fertilize is key in the commercialisation phase, it gives the potential customer a very good view of the range of OPEX, CAPEX, site dimensions etc. required by the process and makes it easier to fast evaluate if it is interesting to conduct a feasibility study for that specific site.
- Also, the continued cooperation with Lantmännen regarding the produced ammonium sulphate is important for realising the roll-out for the Aqua2N-process, offset of the ammonium sulphate is key when selling the process.

5.6 Technical progress, Action D2 (Replication and Transferability)

Foreseen start date: Jan 2021 Actual start date: August 2020
Foreseen end date: June 2022 Actual end date: December 2022

Activities undertaken and outputs achieved

In the autumn 2020 a first workshop with an extended steering group meeting was held to start the work with the business model. Thereafter the work with the business plan, strategy for roll-out etc has been worked with continuously. The work has mainly been done by EasyMining but also in discussion with Ragn-Sells, since a cooperation for the roll-out in Sweden and other Ragn-Sells countries is wanted. Meetings has been held with C2M Expert team to discuss business related support needed in LIFE RE-Fertilize. The business plan has been presented and discussed with the board of EasyMining.

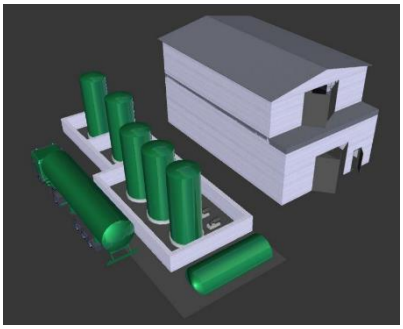

Figure 16. 3D-layout for a 10 m3/h plant, established in the Conceptual design

A conceptual design for a plant of 10 m3/h capacity has been set up. This is what now is presented and discussed with potential customers and is a crucial part of selling a plant. First step is to get a contract for a feasibility study. The conceptual design gives the potential customer a good indication of what the CAPEX, OPEX and resources needed for a plant of that capacity are, making it possible for them to decide if it is of interest to conduct a feasibility study. For all documents that has been established within the Conceptual design see Figure 20. This action has been conducted by EasyMining.

Deliverable	File name
Mass Balance	P113-01-3120 Mass- and energy balance
Energy Balance	P113-01-3120 Mass- and energy balance
Process Flow Diagram	P113-01-3150 Process Flow Diagram
Design Basis, Process	P113-01-1000 Basis of design
Design Basis, E&I	P113-05-1000-Electrical System Design Basis P113-6-1000_Process Control Design Basis
Specification of all incoming and outgoing flows	Included in P113-01-1000 Basis of design
Proof of concept	Included in P113-01-1000 Basis of design
Proven design from pilot runs	Included in P113-01-1000 Basis of design
Cost estimate -30%/+50%	A113-0-1200_Aqua2N_Cost estimation summary incl OPEX
Plot plan general	P113-2-4010
Equipment List	P113-2-3010

Figure 17. Files established within the Conceptual design

The product produced, the ammonium sulphate, has been finalized from the demonstration plant. A product data sheet has been established, see Figure 18, and End of Waste and REACH has been evaluated and prepared. This action has been conducted mainly by EasyMining but in cooperation with Lantmännen.

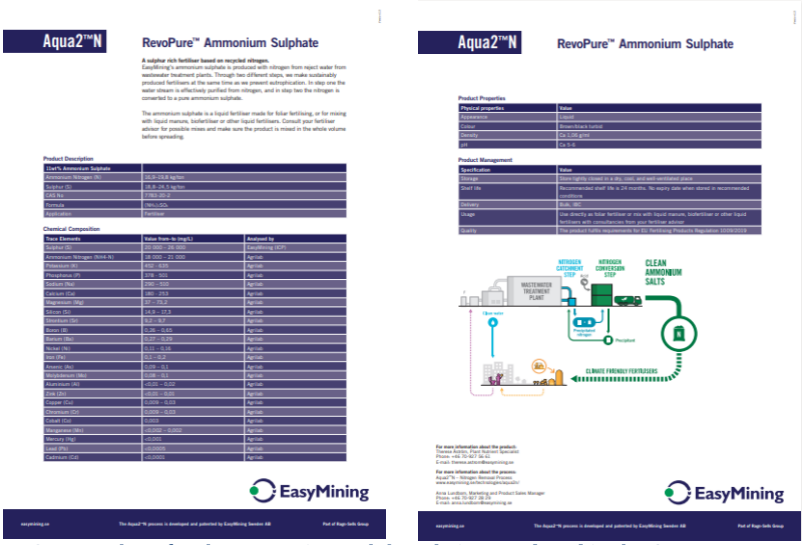

Figure 18. Data sheet for the ammonium sulphate being produced in the Aqua2N-process

Within the End of Waste document produced (appendix 3 in Report on market validation of recycled product) the information needed to prove End of Waste and REACH compliance is explained.

- The product fulfils end of waste criteria:
  - Be commonly used for *specific purposes*
  - Have a market and a *demand that exists*
  - Fulfil the *technical requirements* and *meet relevant legislation/product standards*
  - Not *cause any overall adverse environmental or health impacts*
- The product complies with relevant legislation:
  - Fertiliser Products Regulation 2019/1009
- The product fulfils criteria in Article 2(7)(d) in REACH 1907/2008:
  - The recovered substance is the same as the already registered substance (ammonium sulphate)
  - The required information on the registered substance is available (see SIP-file in appendix 3).

When the investment decision for the first plant is made and the time for construction is set, a notifying authority of the Member State in which the first plant will be established (required within Fertiliser Products Regulation 2019/1009, chapter IV) should be contacted – at least a year before product sales is intended to start. This will be executed by the process buyer for all planned plants, with help of EasyMining and the preparatory work already made.

The End of Waste compilation made by EasyMining will be used as a foundation for all plants that needs a permit or needs to get notified to the municipally, as well as EasyMining being available for further information/document if it is required to get approval to build.

When the product is approved by the notifying authority and registered to the Member States chemical register, the product can be CE marked and sold on the European open market.

The End of Waste document produced within Life RE-FERTILIZE is based on the carbon filtered product. However, the unfiltered product also fulfils all criteria's with only two analyses left waiting for results, but there is nothing to indicate that these results will not be within the limit value.

The demonstration plant will be at Lynetten site until December 2023, 12 months after finalised RE-Fertilize project. The demonstration plant will be used as showcase for potential customers and also for testing of equipment if needed. After December 2023, the demo plant will either be moved to Högbytorp or disassembled. The demonstration plant is really a pilot plant, we have been able to fulfil the aim – demonstration the process – but we have also learned a lot regarding plant design and optimisation of the process.

Replication and transferability of the process is still considered to be very positive to achieve. There is a huge target group for the process, WWTPs with digestion of sludge, as well as other interesting application areas to evaluate. There is about 2800 biogas plants with sewage sludge as feedstock, see Figure 22. Number of biogas plants (total and by feedstock type) per 1 Mio capita in European 2018 statistics some will be too small but the market is still big enough to be highly promising to roll out the process. Also, the new suggested requirements in the UWWTD are positive for the process.

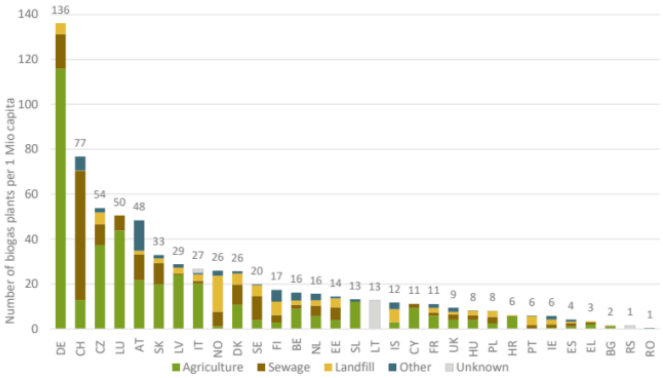

Figure 19. Number of biogas plants (total and by feedstock type) per 1 Mio capita in European 2018 statistics

During 2023, EasyMining will start two project to evaluate; 1. Biogas from manure and 2. Fish sludge from aquaculture as possible application areas. The project regarding biogas from manure is together with RISE (Research institute in Sweden) and has gained funding from JTI (Jordbrukstekniska institutet). The project regarding fish sludge from aquaculture is a project together with Ragn-Sells Havsbruk in Norway. Ragn-Sells Havsbruk is currently applying for funding from Nordic Innovation for this project.