ZERO BRINE

ZERO BRINE PROJECT SUMMARY

KEY HIGHLIGHTS AS OF OCTOBER 2020

ZERO BRINE aims to facilitate the implementation of the Circular Economy package and the SPIRE Roadmap in various process industries by developing the necessary concepts, technological solutions and business models to re-design the value and supply chains of minerals (including magnesium) and water, while dealing with present organic compounds in a way that allows the subsequent recovery of the targeted minerals (a.o. Mg, Ca and NaCl). This is achieved by demonstrating new configurations to recover these resources from saline impaired effluents (brines) generated by process industry while eliminating wastewater discharge and minimising environmental impacts of industrial operations through brines.

The project develops and integrates several existing and innovative technologies aiming to recover end-products of high quality and sufficient purity with good market value. It is carried out by large process industries, SMEs with disruptive technologies and a Brine Consortium of technology suppliers across EU. World-class research centres ensure strong scientific capacity and inter-disciplinary coordination to account for social, economic and environmental considerations, including LCA and LCC.

A large-scale demonstration plant has been developed in the Energy Port and Petrochemical cluster of Rotterdam Port. The large-scale demonstration plant is able to treat part of the brine effluents generated by the industry water supplier (Evides), while waste heat is sourced at neighbouring factories. The quality of the recovered end-products is aimed to meet local and European market specifications.

The involvement of representatives covering the whole supply chain provides an excellent opportunity to showcase Circular Economy solutions in Rotterdam Port. In addition, three large-scale pilot plants have been developed in Poland in the coal mining industry, Turkey in the textile industry, and Spain in the silica industry, providing the potential for immediate replication and uptake of the project results after its successful completion.

1. ACHIEVED OBJECTIVES

Eleven specific project objectives have been formulated for which the following results have been achieved in the first 36 months of the project:

1.1. Demonstrate new solutions for materials recovery from brines in 5 large scale demo sites:

- NF, MFPFR, MED at Demineralised Water Plant (Site I) in the Netherlands
- NYEX, NF, RO, MED and EFC at Demineralised Water Plant (Site II) in the Netherlands
- Decarbonisation, NF/RO/EDS, CrIEM and EFC at coal mine in Poland
- O3 OX/NF, RO and IEX at Textile site in Turkey
- NF regenerated membranes and EFC at Silica plant in Spain

1.2. Minimise solid by-products and need for landfilling

- Waste and wastewater reductions on Poland and Spain sites

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1.3. Increase recovery of resources and lost products

Botlek (demi water) case:

- $Mg(OH)_2$: sell to market (food, pharmaceutical, chemical industries, etc.)
- $Ca(OH)_2$: sell to market (food, paper, chemical industries, etc.)
- Clean Water: recovered water MED almost demi water (end product DWP)
- NaCl Solution: can be used for regeneration of IEX resins

Silica case:

- Na2SO4: powered detergent, glass industry, pulp and paper, textiles
- NaOH and H2SO4: internal reuse

1.4. Eliminate organics from brine products

- NYEX at Botlek Site II

1.5. Large scale integrated test and demonstration pilots

- 5 large pilot scale demonstrations: 2 completed and 3 in operation

1.6. Utilisation of waste heat and local exploitation of end-products recovered

- Waste heat used to power the evaporator in Botlek Site 2
- End-products recovered mentioned above

1.7. Establish Brine Excellence Centres and an Online Brine Platform

- 5 BECs established: NL, IT, GR, ES, PO
- OBP operational, NL case registered >200 brine producers and salt users

1.8. Promote uptake and replication activities

- 2 replication studies in preparation
- 3 follow-up projects started

1.9. Develop circular economy schemes in different process industries

- 4 Business Plans in preparation

1.10. Establish a Brine Consortium of technology suppliers

- Framework Agreement signed on 30 April 2020 by 10 partners

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1.11. Assess the possibility of proposing an Innovation Deal for end-of-waste criteria for recovered products

- Ongoing

2. OVERVIEW OF ZERO BRINE ACTIVITIES AND RESULTS

In the first 36 months of the project the following work has been carried out and the following results have been obtained.

For the industrial water brines in the Port of Rotterdam, two demo sites have been developed upon completion of the bench sale tests on the technologies. A location for these sites was selected on the premises of PlantOne Rotterdam test facility where waste heat could be made available. Brine from Evides Industry Water is transported by truck to the facility.

In Site I, the IEX brine form Evides is treated by a technology train of NF (TRL 9), MFPFR (TRL 7->8) and MED(TRL7->8). Re-gaining of high purity $MgOH_2$, $CaSO_4$, NaCl and water has been demonstrated at a brine feed level of 1 m^3/hr. The demonstration has been concluded and the analysis and reporting of the results is in progress.

Site II, in which RO-brines from Evides is treated, has started up in August 2020. Here a technology train has been installed including NF(TRL 9), RO (TRL 9), Nyex (TRL 8->9), EFC (TRL 6->8) and a waste-heat fed MED (TRL 7->8).

At the Bolesław Śmiały coal mine in Gliwice, Poland, the following technologies have been demonstrated: Pretreatment/Ultrafiltration/Decarbonisation (TRL9), an integrated two-pass nanofiltration/reverse osmosis/electrodialysis system (TRL4->TRL6), Magnesium recovery by CrIEM (TRL4), Magnesium recovery by precipitation (TRL4) and Salt recovery by EFC (TRL3->TRL4).

The Turkish pilot at the Zorlu texile factory has started up in spring 2020. Technologies in place are: Ozone oxidation/Nanofiltration pretreatment (TRL4->TRL6), Reverse osmosis concentration (TRL6) and Ion-exchange softening (TRL6).

In the silica mining industry at IQE in Spain, regenerated NF membranes were tested successfully (TRL8->9) in sequence with the EFC (TRL 6->8). The results of the pilot open perspectives for a substantial reduction of wastewater, allowing for further growth of the plant within the existing permits.

On the development of digital tools to foster promotion and use of the ZERO BRINE technologies, two results can be mentioned: (1) For the extrapolation of the pilot results to full-scale, and to form the basis for replication studies and pilots, a set of software tools were developed to simulate integrated technology trains. (2) A match-making tool (the Online Brine Platform) was developed enabling brine producers and salt users to connect. A practical implementation of the OBP has been developed for the case of the Netherlands, where over 200 brine producers have been registered as well as salt users from the 5 large industrial clusters.

The ZERO BRINE systems sustainability performance was analysed using LCA and LCC assessment. Building forward on the preliminary results reported at the end of the first reporting period, data collection on the four demonstration pilots continued. Meanwhile, the Social LCA has been completed and a journal paper published. The Environmental Technology Verification has been started for three technologies: EFC, CrIEM and the FF-MED evaporator. Circular business models for the demonstration pilots have been developed. The analysis of stakeholder needs and objectives in relation to the prospective circular business model has been done through several face-to-face and telephone discussions, interviews and collective consultation events, which took place in the Netherlands, Greece and Spain.

For the replicability of case studies, three business plans have been developed. The business plans will provide an important opportunity both for the end-users involved in the project (Evides, IQE as partners and Zorlu Textile and PGG trough letters of intent) for potential expansion of their current business activities, as well as for the Brine Consortium Task Force to establish new projects. The framework agreement was fully signed in April 2020 between eight technology suppliers of both innovative and enabling technologies, with the aim to form a Brine Consortium Task Force (BCTF).

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A policy review aiming at investigating the regulatory obstacles for the introduction of ZERO BRINE solutions to the market has been started. After completion of data collection from the optimisation of pilot operations, suggestions for the update of the relevant BREFs will be proposed to the responsible committees of the European Commission. The environmental impacts associated with brine discharge have been assessed through field measurements and surveys, combined with the mining of existing data. The first two field surveys took place in September 2019 and January 2020.

3. KEY ZERO BRINE PILOT RESULTS

Impacts of ZERO BRINE can be reported in various fields. In the technology development field, the perspectives for operational use of the different combination of technologies in several industrial sectors had been demonstrated and technology levels have been raised accordingly.

- **Demineralised Water Plant Pilot (NL)**

In Botlek Site I the following products have been recovered from brine:

1. $Mg(OH)_2$ crystals (80-90% of total Mg in MF-PFR feed), to be sold to market
2. $Ca(OH)_2$ crystals (85-90% of total Ca in MF-PFR feed), to be sold to market
3. Clean Water (60-70%v of MED feed)
4. NaCl Solution(30-40%v of MED feed) for regeneration of IEX membranes, recirculated to the demin water producer

Economic Benefits include:

1. With average quality of end products the full scale implementation would have ROI of 5% and IRR of 9% -> improve in quality of end products would have positive impact on annual revenues (3000-8000 K€/year)
2. Avoiding environmental penalties due to brine discharge (>4000 €/year)
3. Internal valorisation of NaCl solution

Environmental Benefits include:

1. Eliminating brine discharge (100-150 m^3/day at full-scale) -> avoid environment impact around the disposal point
2. Demi water recovery (60-100 m^3/day at full scale) -> increase in production capacity of DWP with the same water withdrawal rate
3. NaCl solution recovery would contribute in decreasing the carbon footprint of Rotterdam Port -> currently 2000-3000 ton salt/year is transported from 300 km away

- **Coal Mine Pilot (PL)**

From the Polish pilot the following results and impacts can be mentioned:

1. Energy consumption – 11.2 kWh/m^3 of treated brine: (16.7 kWh/m^3 for reference technology)
2. Salt recovery – 92.8% (81.0% for reference technology)
3. Magnesium hydroxide recovery – 94.9% (0% for reference technology)
4. Water recovery – 90.6% (92.4% for reference technology)

- **Silica Pilot (ES)**

From the Spanish pilot the following results and impacts have been obtained

1. 0,9m^3 of water recovered/m^3 of wastewater treated
2. 20 kg of Na2SO4/m^3 of wastewater
3. Energy reduction by Waste heat recovery (no value available yet)

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4. Economic benefits (no specifications available yet)
5. Environmental benefits (potential water consumption reduction at IQE: >70%, LCA results not available yet)

At the end of the project these technological, economic and environmental results and impacts will be completed when the other pilots (Botlek Site II and Turkey) will be finalised.

4. ZERO BRINE DISSEMINATION AND IMPACTS

Five Brine Excellence Centres have been established, promoting sharing of technologies and fostering replication projects and further technology development.

1. For the replicability of case studies three business plans have been developed. Two replication case studies have been selected, one in the Netherlands and one in Italy. Four follow-up projects have been granted: ResourSEAs, BRINE-MINING, WATER-MINING, and SEArcularMINE.

The Online Brine Platform, implemented for the case-study of The Netherlands, has to date more than 1000 users, brine producers, technology providers and minerals/salt users. The number of users is steadily increasing as is the number of matches.

In order to promote further development and implementation of ZERO BRINE technologies, a Framework agreement has been signed in April 2020 between the following partners: ARVIA, EURECAT, LENNTECH, SUT, TITANSALT. TUDELFT, TYPSA, UNIPA, SEALEAU and ResourSEAs. This group of technology suppliers of both innovative and enabling technologies forms the Brine Consortium Task Force (BCTF).

After completion of data collection from the optimisation of the pilot operations, suggestions for the update of the relevant BREFs will be proposed to the responsible committees of European Commission.

During M1-M36, ZERO BRINE saw representation at over 50 different conferences and event gatherings, reaching all stakeholders. ZERO BRINE press articles tracked by Meltwater analytics estimated an outreach of the project to over 2.2 million readers including industry experts and policy-makers. Field visits to the Netherlands Demi Water pilot-Botlek site I (M24) and the Poland Coal Mine (M29) gathered 45 and 40 industry experts, researchers, and media. The five workshops organised by ISPT gathered over 91 industry experts and potential end-users expressing a clear interest in the idea of online matchmaking of material flows.

The impact to circular economy of ZERO BRINE is based on the collection of technical evidence through practical examples in the industry water, coal mining, silica production and textile industries in four demonstration pilots, showcasing economic and environmental benefits, and developing the digital platforms to share and match this information, and working on stakeholder (industries, policy makers, technology providers) involvement throughout the project.

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