ZERO BRINE

THE CIRCULAR ECONOMY APPROACH FOR INDUSTRIAL WASTEWATER

CORE POLICY BRIEF

The Horizon 2020 project ZERO BRINE demonstrates the technical feasibility and economic and environmental benefits of recovering minerals and water from waste industrial brine for reuse, and its compatibility with the principles of a Circular Economy, the EU Green Deal and the Industrial Emissions Directive.

1. INTRODUCTION

The chemical industry alone produces 11.5 million tonnes of brine every year.[1] Brines are highly concentrated solutions of salt water containing many chemicals, minerals, metals, and organics which can be extracted as valuable resources for reuse. The current linear economy approach perpetuates the disposal of brine. This has economic consequences in terms of treatment and disposal costs and environmental impacts such as harmful salinity for land and aquatic ecosystems and the greenhouse gas (GHG) emissions of energy consumption.

ZERO BRINE proposes a circular economy approach to reduce the negative impacts of brine from process industries and to create economic value from the reuse of its constituents such as sodium chloride, magnesium, calcium, sulphates, sodium bicarbonate, heat and fresh water. ZERO BRINE demonstrates the use of a combination of existing and innovative technologies for recovery and reuse. This approach combined with promotion of low carbon energy sources aligns with the EU's Circular Economy Action Plan and Green Deal.

This policy brief first demonstrates the resource recovery, environmental and economic benefits that can be achieved. It then highlights where it aligns with existing policy objectives and includes recommendations on addressing policy gaps and updating BREFS in relation to the Industrial Emissions Directive (IED).

2. ZERO BRINE: CLOSING THE LOOP FOR INDUSTRIAL WASTEWATER

Four industries in diverse geographies implement the ZERO BRINE technology: demineralised water production, coal mining, silica production and textiles. They demonstrate the applicability of this technology for wastewater treatment in a wide range of industrial processes with significant potential for replication. All four pilot studies are monitored intensively by an integrated impact assessment tool based on societal, economic, and environmental aspects. This policy brief presents preliminary results on the potential of ZERO BRINE technology with the final results to be presented - along with the Environmental Technology Verification and an Innovation Deal formulation - at project end (mid 2021).

The outcomes show that ZERO BRINE technology can achieve significant recovery of water, brine and minerals and a reduction in GHG emissions through more efficient process design. They also confirm that reuse of materials can reduce the large-scale value chain demand on fresh and raw materials.

1 Smart Water Grids – A cyber-physical systems approach, 2018, by LLC Francis Group

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3. IMPACT OF THE ZERO BRINE APPROACH

Discover the ZERO BRINE media kits for more information including the pilot factsheets, photos, and videos.

• Resource recovery

Resource recovery is the key outcome, contributing to both environmental and economic benefits. The four pilot projects demonstrated the following results:

- Fresh water recovery between **60% and 91% (average 73%)** of the brine volume.
- Brine recovery as principally NaCl solution of **30% to 40%** of volume.
- **High recovery rates** of a range of minerals (more details in section 4).

• Environmental benefits

Industry accounts for 22% of global water demand.[2] Closing the loop on industrial wastewater helps reduce the demand for fresh water resources and the need to pump water long distances, resulting in fewer GHG emissions. Mineral recovery lessens the demand for mining and processing of raw minerals and the related environmental and transport impacts. The pilot projects achieved the following range of environmental benefits:

- **Reduced abstraction of freshwater resources** due to the volumes recovered.
- **Reduction of GHG emissions through energy efficiency**, waste-heat capture and reduced transport impacts.
- **Reduced volumes of brine** disposal to the environment **of more than 90%.**

• Economic benefits and opportunities

Cost savings.
Circular industry processes are essential to develop a sustainable, low carbon, resource efficient, and competitive economy in the EU. The ZERO BRINE technology addresses the issues of cost and management of brine and the compliance with more stringent, costly environmental regulations for polluting, as is the case in Poland, as well as decreasing costs by reusing water and other resources within the production process.

Resilience & Critical raw materials.
Additional economic benefits include the cost savings from resource efficiency from using less water and resources than required for linear production processes as well as producing critical raw materials such as magnesium. With 99% of magnesium being imported currently, the EU is dependent on imports mainly from China. ZERO BRINE thus contributes to a strong European industrial strategy reducing dependence and transportation impacts of importing resources.

Revenue streams.
Opportunities for companies arise from new possible revenue streams from recovering resources of good market value. What cannot be recirculated into their own production lines can be sold as high quality, second generation minerals at a good market value.

New businesses & jobs.
Additional economic benefits lie in new businesses powered by circular economies, ranging from those companies involved in wastewater treatment and reuse, to the creation of new jobs for technical personnel in process industries and other sectors including environmental fields.

2 https://www.unwater.org/water-facts/quality-and-wastewater/

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4. PILOT PROJECT RESULTS AND OUTCOMES

• Demineralised water plant, The Netherlands

Recovery of minerals and freshwater with waste heat reuse

Demineralised water is an essential commodity required for many industrial processes. The Port of Rotterdam is one of the largest petro-chemical clusters in Europe whose supply of distilled water is sourced from the Brielse Meer. At the Energy Port and Petrochemical cluster of Rotterdam, residual heat from a nearby factory is used to eliminate brine effluent while recovering high purity magnesium, calcium hydroxide, sodium chloride solution and clean water. Impacts on the aquatic environment are reduced due to reduced surface water discharge. Two sites investigate the ZERO BRINE concept: Site I aims to **recover >90% high purity magnesium and calcium treating 20% of total brine,** Site II demonstrates the concept of using waste heat in a multi company site as one of the energy source to eliminate brine discharge and aims to treat 5% of the brine. Preliminary results achieved:

Resources recovery
- Fresh water: Site I **40-90%** & Site II **80-90%** of brine volume
- Brine: **30%** of original volume as NaCl solution
- Magnesium hydroxide, $Mg(OH)_2$: **80%** recovered at **80-95%** purity
- Calcium hydroxide, $Ca(OH)_2$: **>95%** recovered at **92-98%** purity

Environmental benefits.
Extracting and purifying the water requires a lot of energy. Use of waste heat reduces CO_2 emissions. Reduced brine discharge is a benefit to the Brielse Meer which has experienced increasing salinity over recent decades.

- Brine discharge to the environment **reduced by 100%**
- Freshwater abstractions r**educed by 15%**
- CO_2 emissions reduced by **300 tonnes of CO_2**

Economic benefits.
The recovered NaCl solution and sulphate salts are recycled back into the site and reused, advancing resource efficiency.

• Coal mine, Poland

50% less concentrated brine, reduced energy use and value recovery of salts

At the Bolesław Śmiały coal mine in Łaziska Górne, a technological solution for mine wastewater is demonstrated. An innovative combination of nanofiltration, reverse osmosis (RO), electrodialysis and crystallisation was applied to recover sodium chloride, magnesium hydroxide and clean water. As coal mine wastewaters are similar to sea water, the technology could also be applied in the desalination industry – a sector expected to become increasingly important.

Resources recovery
- Fresh water: **91%** of brine volume
- Sodium chloride, NaCl: **90.5%**
- Gypsum, CaSO4.2H2O: **75.5%**
- Magnesium hydroxide, $Mg(OH)_2$: **94.9%** at **97.9%** purity

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Environmental benefits.
Poland's mining sector currently discharges **4 million tonnes of salt** into its rivers annually including to the country's main river, the Vistula, which contains 55% of Poland's freshwater reserves and covers 60% of its water needs. Mineral reuse reduces the transport impacts of raw materials, reducing transport related GHG emissions. Preliminary results achieved:

- CO_2 emissions reduced by about 340 kg CO_2 per ton of NaCl, the **energy reduction is about 33%** by reduced on site energy consumption and reduced minerals transport
- Recovered demineralised water (0.91 m^3/m^3 of treated brine) can be reused for technological purposes, decreasing the freshwater abstraction by the industry
- Avoiding the discharge of 20.64 kg of NaCl/m^3 of treated brine into the freshwater

Economic benefits.
Recovered salts are a valuable product for resale. The average production in Poland is around 4.3MT/year, with salt-in-brine accounting for around two-thirds of production. Increased salinity of the Vistula river **is estimated to cost industry, agriculture, water, and transport combined losses of $100-250 million per year.** The method includes reduced energy consumption of 50%, thus saving on costs.

• Textile industry, Turkey

Recovery and reuse of sodium chloride for textiles dyeing

The textile industry is **highly water intensive** using 60 to 120 L/kg for cotton products and 110-650 L/kg for wool.[3] Salt (as NaCl) is an important agent for fixing dye to the cloth by creating attracting electrical forces in place of negative forces between water and cloth. Thus, the ability to reuse water and salt is highly beneficial.

At the Zorlu Textile factory in Lüleburgaz, innovative treatment and membrane technology were used to recover high concentrations of NaCl and clean water for direct reuse. The project aims to recover **400 tonnes of salt/year,** thus reducing the demand for raw salt. A further benefit is heat reuse and an associated reduction in GHG emissions.

Resource recovery
- Fresh water: **60%** of brine volume for direct reuse due to internal recycling and reuse of salt product and clean water
- Brine: **40%** of brine volume recovered as NaCl solution
- Sodium chloride, NaCl: **60-70%** recovery for direct reuse

Environmental benefits
- Brine discharge to the environment **reduced by 100%**
- Reduced freshwater abstractions by 50,000 tonnes (15-20%) per year.
- CO_2 emissions reduced by **20% and 200-300 TCO_2** [From reduced onsite energy consumption and reduced minerals transport]

Economic benefits.
The expected outcomes will **decrease the salt consumption of the factory by 40% and water consumption by 15%.** The results will greatly help the textile industry achieve resource efficiency and improve sustainability through reduced consumption of process inputs, as well as the mitigation of GHG emissions with an estimated 20% decrease.

- Cost savings from reduced water consumption of 200-250k EUR/year (Water price of 1 EUR/m^3 for Kırklareli is considered.)
- Cost savings from reduced volumes of purchased salt are 15-20k EUR/year, from reduced water intake and service water treatment about 20-30k EUR

3 The Textile Industry and the Environment, UN Sales No: E93-III-D5, UNEP, Paris 1994.

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- **Silica industry, Spain**

Recovery of minerals and recovery and direct reuse of clean water

The EU silica industry produces **620,000 tonnes of silica per year** for use in the manufacture of a range of products as an additive for food, pharmaceuticals and cosmetics. The industry also **generates over 21 Mm^3 of wastewater**. At the chemical supplier IQE in Zaragoza, an innovative combination of eutectic freeze crystallization and forward fed evaporation are applied to silica precipitate production for the removal and recovery of sodium sulphate (Na_2SO_4).

Resource recovery.
- Fresh water: **more than 90%** of brine volume for direct reuse.
- Sodium sulphate, Na_2SO_4: **more than 90%** recovery
- Zero Liquid Discharge achieved

Environmental benefits
- Wastewater and brine discharge to the environment reduced **more than 90%, 1 Mm^3/year**
- Reduced freshwater abstractions of **30%**

Economic benefits
- Cost savings from reduced demand for freshwater: **460,000 EUR per year** and **turnover of 1.8 M EUR.**
- **20,000 tonnes** of sodium sulphate recovered. At a market price 90 EUR/tonne, sodium sulphate is a valuable product for many industrial sectors including powdered detergent, glass, pulp & paper, textiles, and carpet fresheners.

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5. THE PATH OF THE GREEN TECHNOLOGY

Based on the outputs of this project, the following enablers and barriers were identified.

ENABLERS	BARRIERS
• Brine recovered chemicals already fulfil ECHA and REACH criteria. • The techniques proposed within the project framework are considered as Best Available Techniques (BAT) in Reference Documents (BREFs) for substances and water recovery from waste. • Environmental: EU Circular Economy Package enhances water and substances reuse and recycling partly covering brine. • Economic: New and/or innovative business models support resource efficiency in several industry types which can represent significant economic benefits companies applying the ZERO BRINE approach.	• Existing legislation is oriented more to brine discharging than to brine processing and resources recovery. New sections offering more data should be added to BREFs particularly recovering water and substances from brines. • Few financing programmes for new brine management technologies adoption exist, thus reducing the incentive to apply them. • Technologies that manage a wide range of brine contaminants are not supported financially and a less attractive option for industries. • Difficulties on the market application of secondary raw materials due to lack of information/trust. • Existing legislation focuses on pollution prevention with limited mention of the potential environmental and economic benefits of resource recovery.

6. POLICY RECOMMENDATIONS FOR A GREEN AND RESILIENT EUROPEAN INDUSTRY

Within the framework of a post COVID-19 political context, sustainability is a critical component to rebooting our economy. The new paradigm to build a resilient Europe must be in line with the Green Deal objective, including the 'zero pollution' ambition and support the exploitation of the value in water use and water reuse processes, particularly for industry. The ZERO BRINE technology is relevant to different legislation that needs to be adapted or strongly supported by appropriate guidance for improved implementation.

• EU Circular Economy package - Europe as the world leader of the circular economy

The ZERO BRINE approach will strongly support the Circular Economy Action Plan which includes 54 measures to "close the loop" of product lifecycles: from production and consumption to waste management and the market for secondary raw materials. It also aligns with the 2020 amendments which encourage water reuse and the exploitation of the value in water from industrial processes. ZERO BRINE represents innovative solutions to help achieve these objectives.

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• The Industrial Emissions Directive (IED) 2010/75/EU

The IED is one of the main legislative tools for preventing and reducing polluting emissions (to air, water and land) and for minimising waste generation in the context of health and environmental impacts. IED does not refer to specific standards for water emissions but requires that implementation should be based on Best Available Techniques (BATs) as described in Best Available Techniques Reference Documents (BREFs) and taking into account national emissions legislation on which to base operational permission from the responsible authorities.

IED covers all the industry categories that ZERO BRINE addresses. **The project will make recommendations for updating the relevant BREFs for these sectors** for which present the most effective combinations of technologies. Moreover, results for water and minerals recovery rates, treated water quality, mineral purities, and energy consumption will be presented for each process based on pilot project outcomes.

The existing IED focuses on the need to reduce the negative impacts of pollution and waste. What it does not do is identify and highlight the positive opportunities and benefits of its approach. These can be environmental and economic benefits as demonstrated in the ZERO BRINE pilot demonstrations.

ZERO BRINE proposes to the IED to be more oriented to a circular economy approach to the recovery and reuse of water and minerals, and in particular to highlight the potential economic benefits to the businesses in question.

• Best Available Techniques (BAT) reference documents (BREFs)

There are currently 34 BREFS supporting the IED covering a wide range of industry sectors, including chemicals manufacturing, textiles and wastewater – as relevant to the pilot demonstrations. In the absence of BAT guidance, operators should still ensure their installations meet the highest achievable environmental standards. New science and technological standards must be included in BREF periodic updates of which ZERO BRINE is an example. ZERO BRINE will make recommendations regarding **five technology combinations applicable to the four industry sectors.**

• Water Framework Directive, 2008/98/EC & amendment COM (2015) 595 final

Maintaining the good quality and quantity of water bodies is the main focus of the overarching European Water Framework Directive (WFD) 2000/60/EC. ZERO BRINE pilot plants show how water bodies can be better protected by reducing discharges of brine, and reduced freshwater abstraction. Reclaimed water contributes towards the increase of water availability and improved water quality. More specifically, the WFD refers to the promotion of technologies for water efficiency in industries to establish a good environmental status of water bodies. The ZERO BRINE technology supports a better implementation of the WFD by combining water efficiency with brine management technologies in a range of industry sectors.

• Regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH regulation No. 1907/2006)

In the framework of ZERO BRINE, mineral recovery is achieved through the treatment of saline wastewaters. The economic value of recovered minerals is an important consideration and the relevant existing legal and policy framework review was considered as necessary towards this direction. The chemical materials market is subject to legislation to ensure safety in terms of human health and environmental protection related to chemical use and management. All recovered salts within ZERO BRINE are already REACH registered, thus requiring no new registrations. No obstacles are presented for salts commercialisation under the application of this regulation for ZERO BRINE operators.

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• End of waste criteria (Waste Framework Directive, 2008/98/EC)

The End-Of-Waste (EoW) criteria indicate when certain waste ceases to be waste and obtains a status of a product or a secondary raw material providing to EU member states the opportunity to introduce high-quality secondary raw materials and products. The Joint Research Centre (JRC) has outlined a methodology for the development of EoW criteria providing guidelines for analysis principles and parameters against which the criteria should be established and to deliver the necessary impact assessments.

Within these policy contexts that ZERO BRINE proposes the following recommendations:

RECOMMENDATIONS

- Support the development and updating of strong and credible BREF documentation with detailed information on different brine concentrates, mineral concentrations, efficiency of processing techniques and environmental and societal impacts.
- Establish financial instruments for advancing associated business models of new brine management technologies to contribute to the Green Deal's objectives. However, no specific criteria are currently available for brine materials. This situation constitutes a barrier that the EU can shed to open up new sustainable business, improve the competitiveness of the European industry and create green jobs.
- Further implement industrial symbiosis and multi-stakeholder platforms to advance sustainable production and EU industry competitiveness, information exchange and the Resource Efficient Europe flagship initiative.
- Initiatives under the Circular Economy Action plan should strongly support new business models enhancing the collaboration of renewable energy resources and brine management associated economic actors.
- Facilitate communication with National Legislative Helpdesks for brine recovered materials to develop EoW criteria that considers the ZERO BRINE technology, as well as between recovery operators with downstream users of the supply chain for pricing information.
- Promote technologies for water efficiency in industries with supportive national and EU legislation with a particular focus on digital water solutions.
- Expand schemes such as Extended Producer Responsibility and eco-design.

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