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 industrial brine for reuse, and its compatibility with the principles of a Circular Economy, the Green Deal and the Industrial Emissions Directive.

Within these policy contexts, ZERO BRINE wants to specifically highlight the following recommendations in addition to the ones in each policy brief:

KEY 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.
- Support new business models enhancing brine management associated economic actors by helping them to reach the market, mainstream the available technology and the exchange of best practices in term of industrial symbiosis.
- 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.

1. CONTEXT

The chemical industry alone produces 11.5 million tons 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.

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

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

ZERO BRINE demonstrates the use of a combination of existing and innovative technologies for recovery and reuse. This approach combined with the 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 ON INDUSTRIAL WASTEWATER

Four industries in diverse geographies implement the ZERO BRINE technology: demineralised water production, coal mining, silica production and textile manufacturing. They demonstrate the applicability of this technology for wastewater treatment in a wide range of industrial processes with significant potential for replication. All four pilots are monitored intensively by an integrated impact assessment tool based on societal, economic, and environmental aspects.

With its impact assessment, ZERO BRINE partners embrace a holistic approach by considering the dilemma between energy consumption and resource recovery. The objective is to maximise the benefits of the technology, balancing the economic cost of resource recovery with the energy consumed to achieve sustainable production.

The outcomes show that the ZERO BRINE technology can achieve significant recovery of water, brine and minerals and a reduction in GHG emissions through more efficient process design and energy savings. They also confirm that reuse of materials can reduce the large-scale value chain demand on fresh and raw materials which directly contributes to several European objectives such as the Green Deal.

3. IMPACT OF THE ZERO BRINE APPROACH

• Resource recovery: Turn waste into resource

Resource recovery of fresh water, salts, magnesium and calcium is one of the key outcomes, contributing to both environmental and economic benefits. The four pilot projects demonstrated:

- **Freshwater recovery** from brine for onsite reuse.
- **Brine recovery** as a NaCl solution or salts for onsite reuse in industry processes
- **High recovery of a range of minerals** for additional onsite reuse and possible external valorisation.

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• Environmental benefits: Avoid unnecessary pollution

Industry accounts for 22% of global water demand.[2] Closing the loop on industrial wastewater helps reduce the demand for freshwater 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 of freshwater recovered.
- **Reduced GHG emissions through energy efficiency and potential transport impacts.**
- **Reduced volumes of brine** disposal to the environment **of more than 90%.**

• Economic benefits and opportunities: Strengthen EU industry

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.

Resource savings

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 recovering critical raw materials such as magnesium.

Strengthen the strategic EU autonomy for critical raw materials

With 99% of the magnesium consumed in the EU imported from China, the strategic interest of the EU is threatened. 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. Furthermore, companies that see production restrictions due to brine release limits, which is the case in Spain, could benefit from the brine reductions resulting in the ability to increase production.

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 energy savings

Demineralised water is an essential commodity required for many industrial processes. The Port of Rotterdam is one of the largest petrochemical clusters in Europe whose supply of distilled water is sourced from the Brielse Meer. At the Energy Port and Petrochemical cluster of Rotterdam,two sites aim to demonstrate the circular economy approach to the brine generated from the demi water plant. The first, aims to treat the spent IEX regenerant of the demi water plant and the second treats the plant's RO concentrate stream by mimicking residual heat in order to reach zero brine discharge.

Industrial saline effluents (brines) are an environmental challenge and an economic opportunity. ZERO BRINE demonstrated the circular economy approach to treat brine through redesigning the current scheme of discharging the generated brine – from linear to a circular model – to recover minerals, salts, and demi water from the discharges of the DWP. To achieve this, two large-scale demonstration pilots were tested at Plant One Rotterdam, a test facility focused on sustainable technology and innovation in the Energy Port and Petrochemical cluster of Rotterdam Port.

Resource recovery

- **92%** water recovery for internal valorisation (demi water)
- **6.2%** IEX regeneration solution recovery for internal valorisation (purity > **3.1%**)
- **94.7%** Calcium recovery ($Ca(OH)_2$) for external valorisation (purity > **95.6%**)
- **87.8%** Magnesium recovery ($Mg(OH)_2$) for external valorisation (purity > **88.9%**)
- **93%** Sulfate recovery (Na_2SO_4) for external valorisation (unwashed: **94.6%** purity)

Environmental benefits

The use of waste heat reduces CO_2 emissions.

- **15%-20%** reduction in water withdrawal at Evides DWP
- **>98%** brine discharge into the environment eliminated (**>2.5 million m³/year**)
- **1,012 tons/year** CO_2 emissions or 14% CO_2 reduction by recovering minerals, salts, and clean water
- Thermal energy required for the evaporation process can be supplied by waste heat/residual heat of neighbouring industries
- **44%** less energy used by MED evaporator when compared to conventional methods

Economic benefits

The recovered NaCl solution and demi water can be recycled back into the site for use, advancing resource efficiency and reducing freshwater abstractions. In addition, opportunities for the external valorisation for the recovered high purity calcium hydroxide, magnesium hydroxide, and sulphate remain.

• Coal mine, Poland

Less brine releases, reduced energy and mineral valorisation

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 becoming increasingly important in water scarce regions.

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Resource recovery
- **90.6%** water recovery (demi water)
- **92.8%** salt recovery (**99%** purity)
- **94.9%** magnesium hydroxide recovery ($Mg(OH)_2$) for external valorisation (**97%** purity)
- **0.84 kg/m³** gypsum for external valorisation

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.

- **92.8% r**eduction of sodium chloride (NaCl) discharged to freshwater resources
- **347 kg CO_2/Tn NaCl** or 32.5% CO_2 reduction
- **33%** energy reduction

Economic benefits
Recovered salts are a valuable product for resale. The average production in Poland is around 4.3Mt/yr, 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 €80-200 million per year.** The high purity magnesium hydroxide presents possibilities for new revenue streams, as well as the recovered gypsum.

• 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. Thus, the ability to reuse water and salt is highly beneficial.

In Turkey, the textile sector consumes 176 million m³ of water annually, generating 150 million m³ of wastewater every year. This brine is costly for companies to manage, and is detrimental to ecosystems as it contains dyes, chemicals, salts, and other materials.

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 pilot's recovery of salt reduces demand for raw salt while reusing water on site in the production of textiles. A further benefit is heat reuse and an associated reduction in GHG emissions.

Resource recovery
- **70-80%** water recovery from brine treatment system for onsite use
- **600-700 tons salt/year** for onsite dyeing of textiles

Environmental benefits
- **-7%** reduction in total freshwater consumption of Zorlu Textile or freshwater abstraction by 123,000 tons/year
- **-90-95%** reduction of brine discharged to the environment
- **150-200 tons/year** CO_2 reduction

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

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Economic benefits

Applying the ZERO BRINE technology to Zorlu's current practices would decrease the salt consumption of the factory, greatly helping the textile industry achieve resource efficiency and improved sustainability through reduced consumption of process inputs as well as the mitigation of GHG emissions.

- **Cost savings from reduced water consumption of €120,000/yr** (Water price of €1/m^3 for Kırklareli is considered).
- **Cost savings from reduced volumes of purchased salt are €40-50k/yr, from reduced water intake and service water treatment about €60-70k/yr.**

• 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 million m^3 of wastewater.** At the chemical supplier IQE in Zaragoza, an innovative combination of eutectic freeze crystallization and forward feed evaporation are applied to silica precipitate production for the removal and recovery of sodium sulphate (Na_2SO_4).

Resource recovery

- **75%->90%** water recovery suitable for internal reuse
- **90%** recovery of sodium sulphate (Na_2SO_4) or **20,000 tons/year** for external valorisation (**>99%** purity)
- Sodium hydroxide (NaOH) (**94%** purity) and sulphuric acid ($H2SO_4$) (**72%** purity) for external valorisation

Environmental benefits

- **30%** reduction in overall annual water consumption at IQE
- **100%** reduction of brine discharged to the environment
- **60%** reduction of sodium sulphate (Na_2SO_4) releases into the Ebro River
- **72%** reduction by waste heat (EFC technology compared to direct evaporation)

Economic benefits

The cost savings from the reduction in fresh water consumption are €460,000 per year. Recovering 20,000 tons of sodium sulphate, **a valuable product for many industrial sectors including powdered detergent, glass, pulp & paper, textiles, and carpet fresheners**, offers a possible turnover of **€1.8 M. A major benefit for the pilot site is the ability for the company to expand operations due to compliance with regulations that limit the production capacity due to brine discharge limitations.**

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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 (BATs) 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 for companies applying the ZERO BRINE approach.	• Existing legislation is oriented more to brine discharging than to brine processing and resource 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 objectives, including the Zero Pollution Ambition, the EU's chemical strategy and the Circular Economy Action Plan. EU industry must master the importance of the value of water by reclaiming water and the value in wastewater, such as brine, to recover energy and substances. The ZERO BRINE technology is relevant to different legislation that needs to be adapted or strongly supported by appropriate guidance for improved implementation. As more intensively developed in the project's policy briefs, ZERO BRINE sums up its contributions below:

• 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.

However, there are some gaps in the national legislation on the use of recovered water in the industrial sector to fully exploit the benefits of this type of technology and deploy a circular economy.

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• Zero Pollution Strategy

The Zero Pollution Ambition for a toxic-free environment is a new European strategy which aims to prevent and reduce pollution in water, air and soil and also facilitate remediation. Paired with the objectives to address industrial pollution, the specific action plan wants to fill white spots in the EU legislation, improve the monitoring processes and also contribute to smarter legislation. ZERO BRINE provides several benefits by mobilising industry for a successful Zero Pollution Strategy with several impacts that demonstrate the importance to consider the white spot that brine management is in this European action plan. Brine management remains a white spot in the EU legislation that should be better considered particularly through the harmonisation of its definition in Europe (see ZERO BRINE policy brief on Zero-Pollution Strategy).

Moreover, the new EU Soils strategy stresses the importance of water smart management to prevent pollution: "Preventing diffuse and point-source soil pollution remains the most effective and cheapest way to ensure clean and healthy soils in the long term. As a priority, contamination should be prevented at the source." In this context ZERO BRINE contributes to cleaner industry.[4]

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

The IED is one of the main legislative tools for preventing and reducing industrial polluting emissions and for minimising waste generation. Based on Best Available Techniques (BATs) including in each BREFs (Best Available Techniques Reference Documents), IED has contributed to reduce pollution in air but additional efforts are needed for emission in water and soil. Only 17% of BATs include measures on water emissions which mostly do not focus on reduction at source and only 20 BATs out of 850 promote water use reductions[5].

The ZERO BRINE technology offers a new technology to fulfil these objectives which is already aligned with the requirements of the existing IED. The project developed a specific policy brief on the importance of the ZERO BRINE technology for the revision of this legislation which particularly recommends a new BREF on water efficiency including brine management or a mandatory circular management of the brine in the relevant BREFs (See ZERO BRINE policy brief on the IED).

ZERO BRINE encourages that the IED should be more oriented to circular economy and reuse water within industrial facilities and also encourage industrial symbiosis and zero pollution ambition in line with the Water Framework Directive.

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

Maintaining a good quality and quantity of water bodies is the main focus of the overarching European Water Framework Directive (WFD) 2000/60/EC. The ZERO BRINE pilot plants show how water bodies can be better protected by reducing brine discharge and 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. The ZERO BRINE consortium also encourages the EU institutions to extract all conclusions that this project offers, specifically in term of monitoring specific substances and its benefits for the river basin management actions (See ZERO BRINE policy brief on Zero Pollution Action Plan).

4 Healthy soils – new EU soil strategy: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12634-Healthy-soils-new-EU-soil-strategy_en

5 Report on IED contribution to water policy, 2018 : https://circabc.europa.eu/sd/a/af2ff560-431b-4b61-b318-4543a9b176ff/Summary%20on%20IED%20contribution%20to%20water%20policy.pdf

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- **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.

- **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.

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