ZERO BRINE

D10.3 Policy Brief and Reports – Advancing the ZERO BRINE process and demo projects

November 2021

Final

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[1] **R**=Document, report; **DEM**=Demonstrator, pilot, prototype; **DEC**=website, patent fillings, videos, etc.; **OTHER**=other

[2] **PU**=Public, **CO**=Confidential, only for members of the consortium (including the Commission Services), **CI**=Classified

Executive Summary

Policy briefs and factsheets are one of the most effective ways to reach policy and decision-makers. For this reason, ZERO BRINE developed four policy briefs and four media kits – key communication tools to communicate and disseminate ZERO BRINE results and recommendations. The policy briefs are targeted to policymakers on European and local level (countries of the demo projects). As a key communication tool, they are central for presenting the results to all stakeholder groups specifically to industry, associations, environmental agencies, authorities, SPIRE network and media.

This document outlines the strategy and implementation of the ZERO BRINE policy briefs that are developed in a collaborative approach by REVOLVE and Water Europe with inputs from pilot plants WP2, WP3, WP4 as well as the Life Cycle Analysis in WP7, business modelling in WP8 and policy review in WP9. The dissemination and outreach are a key component of the strategy.

This deliverable was submitted in M24 as a draft; due to the interconnectedness of this deliverable with results from other work packages, it was decided with the Project Officer and Executive Project Coordinator to update the draft deliverable in increments of every six months. In order to ensure outreach to respective target groups at an early stage, this deliverable was continuously updated with the latest results and project conclusions, with the final deliverable submitted in M54. To have the most impact, the respective policy briefs and media kits (Annex) have been disseminated in a timely manner to contribute to EU legislation.

1. Contents

1. Overview

The policy briefs highlight and outline the learnings and recommendations of the project. They were designed in a P4P (Project for Policy) approach that uses R&I project results to shape policy, ensuring that the ZERO BRINE technology has the best conditions to be implemented to the market.

This way, project results are an excellent tool for policymakers to:

- Provide evidence and data for policy development and design
- Highlight gaps or barriers in current policy frameworks or approaches
- Help develop new opportunities and innovative activities for areas of policymaking across Europe and globally.

Four ZERO BRINE policy briefs highlight the project results and recommendations linked to the European policy context with regards to industry (focusing on the industry of ZERO BRINE's pilot plants), circular economy, and energy and climate action.

The **core policy brief** contextualises the impact of the ZERO BRINE technology, highlighting the key project results and conclusions of the technology, its economic and environmental benefits and the key directives that influence the implementation of the technology (enablers and barriers) with recommendations for a more green and resilient European industry.

The three specialised policy briefs outline the key recommendations of the ZERO BRINE technology to support policy makers to amend legislation in a way that supports the market implementation of the technology and similar green technologies, contextualising the various benefits. These specialised briefs include:

- **Policy brief focusing on the Zero Pollution strategy**
- **Policy brief focusing on the Industrial Emissions Directive**
- **Policy brief in the context of the Urban Wastewater Treatment Directive**

For a comprehensive illustration of the ZERO BRINE technology, results and business opportunities, four media kits including factsheets, videos and photos (one for each demonstration site) were developed.

2. Development of the policy briefs

The policy briefs were developed between M12 and M54 in line with the availability of the results of the pilot plants (WP2, WP3, WP4), life cycle analysis (WP7), business models (WP8) and policy review (WP9) (see Figure 1). D10.3 was updated every six months in M30, M36, M41, M48, and the final deliverable submitted in M54.

The specialised policy briefs are cross-linked with the core policy brief.

Task 10.3 is led by REVOLVE, with co-lead Water Europe, in cooperation with all partners. Inputs and the close collaboration with the following ZERO BRINE tasks and partners were essential to communicate and disseminate ZERO BRINE results effectively via policy briefs:

- WP9: D. 9.1 Environmental impacts of brine and D9.2 Report on policy review and assessment / suggestions for BREF update: NTUA
- WP7: Life Cycle Analysis: TU Delft
- WP2: (Re-designing the supply chain of water and minerals in the Botlek area): TU Delft, Evides
- WP3: (Minimizing energy consumption and increase resource recovery yields through advanced treatment methods in the coal mine and textile industries): SUT, TUBITAK
- WP4: (Promoting circular economy in the chemical sector): Eurecat
- WP8: Business plan/market exploitation and replication / IP: SEALEAU, TU DELFT, Eurecat

i. Core policy brief

The ZERO BRINE core policy brief presents the ZERO BRINE results and recommendations linked to the current policy context on European level with a focus on climate action, circular economy, energy, industry, economy and environment. This policy brief consists of the following structure:

1. Context
2. ZERO BRINE: Closing the loop for industrial wastewater
3. Impact of the ZERO BRINE approach
4. Pilot Projects and outcomes
5. The path of the green technology
6. Policy recommendations for a green and resilient European industry

The first designed draft of the ZERO BRINE policy brief has been delivered in M36. It was updated with latest results and key conclusions in M41, (see Annex) integrating the feedback from the external

review. It was updated in M48 and M54 to integrate key results of the pilot plants, policy review, life cycle analysis and business modelling.

ii. Policy Brief: Zero Pollution strategy

ZERO BRINE developed a policy brief focusing on the Benefits of the ZERO BRINE technology for a successful Zero Pollution strategy (see Annex).

The policy brief has the following structure:

1. Key recommendations
2. Context
3. Circular brine management for turning brine into a resource to prevent pollution
4. Benefits for the Circular Economy Action Plan
5. Benefits for the Chemical strategy
6. Benefits for the Industrial Emissions Directive
7. Benefits for the Water Framework Directive
8. Benefits for the Biodiversity strategy

iii. Policy Brief: Focus on the Industrial Emissions Directive

ZERO BRINE developed a policy brief focusing on the Industrial Emissions directive (IED) (see Annex) to demonstrate the contribution of the ZERO BRINE technology to achieve the requirements of the IED and a more resilient European industry.

The policy brief has the following structure:

1. Key recommendations regarding IED revision
2. Context
3. ZERO BRINE: A technology supporting the effective implementation of the IED
4. ZERO BRINE: An available technology for a more resilient European industry

This ZERO BRINE policy brief has been delivered in M41 and was shared with policymakers to during the public consultation on behalf of Water Europe in M46. It was updated by M54 to integrate final results and conclusions of the pilot plants, policy review, life cycle analysis and business modelling.

i. Policy Brief: Focus on the Urban Wastewater Treatment Directive

ZERO BRINE developed a policy brief focusing on the revision Urban Wastewater Treatment Directive (see Annex) offering recommendations based on policy options suggested by the European Commission in the directive's policy areas.

The policy brief has the following structure:

1. Key recommendations
2. Context
3. Recommendations and explanations per identified areas

This policy brief was delivered in M50 to contribute to the public consultation on the revision to the UWWTD, by Water Europe.

3. Dissemination and communication strategy for policy makers

The policy briefs will be disseminated to EU institutions to targeted departments such as energy, climate action, environment, economy, regional affairs, local government, environmental agencies, SPIRE network and media with full tracking and outreach reporting of the ZERO BRINE project. The policy briefs will be distributed both in print and digitally via the ZERO BRINE website, news alerts and social media. Depending on the timely completion of the final briefs, they will be distributed at key EU and international policy events such as: the EU Green Week, the Water Innovation Forum, the International Water Summit, the World Water Week, Global Water Summit, European Sustainable Energy Week as well as the yearly Water Innovation Europe events organised by Water Europe in Brussels.

The outreach strategy for the dissemination of ZERO BRINE policy briefs is based on three key goals:

1. Outreach to policymakers to impact European legislation
2. Outreach to platforms to disseminate the information on the new technology and increase the visibility and importance of this technology
3. Outreach to local authorities and potential end users of the new technology

a. Outreach to policy makers to impact European legislation

With regards to the first goal to contact policymakers and impact the legislation, the first step is to connect with the three key institutions of the European Union, the Council, the European Commission and the European Parliament. The topic of the ZERO BRINE policy briefs is linked to the Industrial Emissions Directive, the Zero Pollution Action Plan as well as the Urban Wastewater Treatment Directive. Water Europe has prepared a contact database with around 165 contacts to target this stakeholder group and proceeded with three main actions in their dissemination:

1. Target MEPs related to the countries of the ZERO BRINE pilots: Dutch MEPs (29), Polish MEPs (52), Spanish MEPs (59)
2. Target the Perm Reps related to the countries of the ZERO BRINE partners: Embassy of UK, Embassy of Turkey, Perm reps Belgium, Germany, Greece, Italy, Poland, Spain, Netherlands
3. Target key units of the European Commission related to the topics resource recovery and circular economy B.3 DG ENVI, C.1. DG RTD, D.3 DG RTD, B.5 DG RTD, C4 DG ENVI

A policy session dedicated to the topic circular economy and resource recovery for industrial wastewater was organised at Water innovation Europe June 2021 by Water Europe.

Water Europe also replied on behalf of the project to the public consultations on the Industrial Emissions Directive (March 2021), the Zero Pollution Action Plan (May 2021) and the Urban Wastewater Treatment Directive (July 2021).

b. Outreach to platforms

As the ZERO BRINE technology is a cross-sectoral technology, the EU platforms are the right way to disseminate the information to other sectors at the EU level. This way, we will contribute to breaking the siloed approach in term of innovative solutions for resource recovery from several sectors. The policy briefs will be disseminated to CEFIC (chemicals industry), CEMBUREAU (silica industry), EURACOAL (coal industry), EURATEX (textile industry), EUROSIL (silica industry), IMA Europe (industrial minerals association), ITKIB (Turkish association of textile exporters). ZERO BRINE is also a SPIRE project and therefore the SPIRE members are one of the target groups to disseminate this information in addition to a broader communication campaign.

Lastly, ZERO BRINE has joined the AFTERLIFE Horizon Results Booster, and may contribute its work on the policy briefs to a joint-project policy brief that is likely to be finalised after the completion of the ZERO BRINE project and therefore outside the reporting period of M54. In the case this occurs, relevant links to this joint policy brief will be included as a resource on the ZERO BRINE website.

c. Outreach to local authorities and potential end users

The potential uptake of the new ZERO BRINE technologies and the whole process of bringing these technologies to the market can be facilitated through the Water Europe's Water Market Europe event in March 2021 dedicated to promoting new technologies and innovations in Europe and beyond. Water Europe aims to approach local authorities' representatives at the EU level to disseminate the information (Committee of regions & MEPs). ZERO BRINE partners running the pilot plants will support the outreach the national and local actors to (including regional water agencies).

Water Europe has established relations with all the above-mentioned contacts through direct emailing. In addition to this, Water Europe will consider organising a tailored, specialised policy session at one of its annual events (e.g., Water Innovation Europe 2022) to bring together the most relevant contacts for the achievement of the three key goals of the policy outreach plan.

ZERO BRINE has good potential to contribute to Water Europe's working groups such as "Water and Desalination", "Resource Recovery", "Industrial Water Efficiency and Reuse practices". Several ZERO BRINE consortium partners are members of existing Water Europe Working Groups that can function as vehicles for the integration and dissemination of ZERO BRINE learnings and technologies to EU stakeholders and contribute to the white papers' development with the outcomes from ZERO BRINE. The members of the consortium will also be the relay to the local level to share with policymakers the outcomes of the projects.

4. Development of ZERO BRINE media kits

ZERO BRINE developed four media kits including factsheets, infographics, interviews, photos and videos for each demonstration site. The media kits are available here: https://zerobrine.eu/media-kit/

d. Case study I: Demineralised Water Plant in the Netherlands

The Demineralised Water Plant pilot factsheet was developed in M24 by REVOLVE with the guidance of TU Delft and Evides, to disseminate to the attendees (see Annex). This factsheet is included in the online media kit and was promoted in the press release on the pilot and visit. The final factsheet was updated in M54 to include the pilot results and were also included in the technology video developed in M54.

e. Case study II: Coal mine in Poland

The Coal Mine Pilot factsheet (developed in M28) was given to participants in English and Polish on the key aims of the pilot, its context and business opportunities (see Annex). This factsheet is also included in the online media kit. The pilot will be operational until M35; after the data is analysed, thefactsheet was updated with the final results in M54 (see Annex).

Footage from the pilot visit and additional interviews were held with consortium partners and industry experts for use in the technology videos and additional communication outputs. The pilot's technology video was completed to communicate the final results in M50.

f. Case study III: Textile factory in Turkey

The factsheet for the demonstration site of the textile factory in Turkey was developed in M40 and updated with results in M54. The technology video was be developed by M54.

Photos are available on the project website (see here). A digital journey was designed in lieu of a physical visit on 26 May 2021, due to COVID-19 restrictions. See D10.4 for more information.

g. Case study IV: Silica factory in Spain

The silica factory pilot factsheet was developed in M35 and updated with the final results in M54. REVOLVE produced the pilot technology video recapping the results in M54. The technology video was be developed by M54.

By M54, the IQE textile pilot video had 341 views on YouTube and 444 impressions on the ZERO BRINE LinkedIn page.

REFERENCES

NA

CONCLUSION

Despite the project delays and having to await the results of the pilot demonstrations, ZERO BRINE was able to make a timely contribution to several pieces of legislation through the work of Water Europe. Furthermore, because of the findings of ZERO BRINE, a special meeting with project representatives was set up with the Joint Research Center (JRC). Moreover, Water Europe is also member of the Expert group of the European Commissions on the IED and will be able to work closelywith the JRC to continue to promote the outcomes of ZEROBRINE.

At this stage, the impacts of ZERO BRINE's contribution to the Industrial Emissions Directive and Urban Wastewater Treatment Directives remain unclear as the legislative proposals have not yet been released. Nonetheless, the overarching policy contributions is offered in ZERO BRINE's Core Policy Brief.

ANNEX

Core policy brief PDF

Zero Pollution Policy brief PDF

Industrial Emissions Directive Policy Brief PDF

Urban Wastewater Treatment Directive Policy Brief PDF

Demineralised Water Plant Pilot Factsheet (NL) PDF

Coal Mine Pilot Factsheet (PL) PDF

Silica Factory Pilot Factsheet (ES) PDF

Textile Factory Pilot Factsheet (TR) PDF

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.

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. 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.

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.

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.

• 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.

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

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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.

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.

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• 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.

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

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

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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

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 BRINE

• 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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ZERO BRINE

• 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.

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.

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ZERO BRINE

THE CIRCULAR ECONOMY APPROACH FOR INDUSTRIAL WASTEWATER

BENEFITS OF THE ZERO BRINE TECHNOLOGY FOR A SUCCESSFUL ZERO POLLUTION STRATEGY

KEY RECOMMENDATIONS

- Support risk approach in brine management
- Address the white spots of brine management in the Zero Pollution Action Plan
- Encourage a BREF on brine in the updated Industrial Emission Directive or a BREF on water efficiency including brine management and consider brine management in each sectoral BREF that ZERO BRINE addresses
- Update list of the Annex X of the Water Framework Directive in line with the outcomes of the ZERO BRINE project
- Harmonise the definition of brine at EU-level

Disclaimer: Due to the confidentiality of the data, the project cannot disclose information that confirms the below recommendations. The project consortium can be contacted via media@zerobrine.eu to get this information in the respect of this confidentiality framework.

• Context

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 in the white spots in EU legislation, improve the monitoring processes and also contribute to smarter legislation.

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 mineral salts containing sodium, magnesium, calcium, sulphates, bicarbonates, and fresh water. ZERO BRINE demonstrates the use of a combination of existing and new technologies for the recovery and reuse of both the material constituents as well as energy such as waste heat.

Within this policy brief, ZERO BRINE highlights several benefits[1] for a successful Zero Pollution Strategy with impacts that demonstrate the importance of addressing the white spot that brine management be included in this European action plan.

• Circular brine management for turning brine into a resource to prevent pollution

The ZERO BRINE technology tackles a key challenge by managing brines. The discharging of this type of wastewater can have negative impacts for flora and fauna due to its toxicity and even the corrosion of infrastructure. Its release in our environment also impacts the quality of the soil and threatens food security by creating diffuse pollution. Within the EU Green Deal, the 4 ZERO BRINE pilot demonstrations pave the way to several objectives of the European Commission by recovering energy, water and raw materials (See Table 1 on Impacts of the ZERO BRINE technology on water, emissions, energy, and resource recovery in industry).

1 The data provided in this policy brief remain provisional as the results of the project are still under development.

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ZERO BRINE

• Benefits for the Circular Economy Action Plan

Annual waste generation is projected to increase by 70% by 2050; the uptake of the ZERO BRINE technology aims to challenge this projection. A sustainable product policy framework needs to be based on resource recovery but also on the feasibility of new industrial processes that ZERO BRINE demonstrates. The project impacts the whole value chain in several sectors by recovering key products for European industry, considering the value of water for less waste, less energy and water consumption and more circularity.

• Benefits for the Chemical strategy

Nearly 84% of Europeans are worried about the impact of chemicals present in everyday products on their health, and 90% are worried about their impact on the environment.[2] Paired with the Industrial Emission aims, ZERO BRINE also contributes to the chemical strategy objectives of the European Union (EU) by demonstrating that the legislation can be strengthened for better protection within a circular economy. Despite the absence of a common definition of brine at EU-level and the composition diversity of brine, the technology can recover several chemicals which can meet market specifications. It creates safe and sustainable business opportunities and contributes to the reduction of diffuse pollution.

In line with latest conclusions on REACH, ZERO BRINE confirms the importance of the REACH legislation and encourages the EU to maintain and reinforce this tool. The project did not need to register substances and therefore cannot clearly express opinions on the potential administrative burden of this registration procedure.

• Benefits for the Industrial Emissions Directive

ZERO BRINE is evaluating the opportunities of its technology for a smarter Industrial Emissions Directive. ZERO BRINE can be key to improving energy and water efficiency. Consequently, this technology, as a Best Available Technology, can contribute to the sustainable competitiveness of several industrial sectors in Europe (cf. table 2) while preventing damaging impacts to our ecosystems.

The confidentiality and the ongoing research cannot allow us to release data. However, the benefits of the combination of existing and new or innovative technologies for recovery and reuse of both the material constituents as well as energy such as waste heat can contribute to the revision of the BREFs on:

- BREF Large Volume inorganic chemicals – solids and others industry (LVIC-S)
- BREF Textile Industry (TXT)
- BREF Waste Treatment (WT)

The project is also working on recommendations for a BREF on silica/brine management. This option can also reinforce the necessity to have a horizontal BREF on water efficiency.

2 Eurostat, Eurobarometer, 2020.

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ZERO BRINE

Table 1 - Impacts of the ZERO BRINE technology on water, emissions, energy, and resource recovery in industry

	Expected reduction in:			
	Water	**Emissions**	**Energy**	**Recovered resources**
Demineralised Water Plant	• 15-20% reduction in water withdrawal at Evides DWP	• >98% reduction of brine discharged to the environment (>2.5 million m^3/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	• 92% water recovery for internal use (demi water) • 6.2% IEX regeneration solution recovery for internal use (>3.1% purity) • 94.7% Calcium recovery ($Ca(OH)_2$) for external valorisation (>95.6% purity) • 87.8% Magnesium recovery ($Mg(OH)_2$) for external valorisation (>88.9% purity) • 93% Sulphate recovery (Na_2SO_4) for external valorisation (unwashed: 94.6% purity)
Coal mine	NA	• 92.8% reduction of sodium chloride (NaCl) discharged to freshwater resources • 347 kg CO_2 /ton NaCl or 32.5% CO_2 reduction	• 33% energy reduction	• 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/m^3 gypsum for external valorisation
Textile factory	• 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	NA	• 70-80% water recovery from brine treatment system for onsite use • 600-700 tons salt/year for onsite dyeing of textiles
Silica factory	• 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 6,000 tons/year CO_2 reduction or 5 kg CO_2/m^3 of wastewater	• 72% reduction by waste heat (EFC technology compared to direct evaporation)	• 75-90% water recovery suitable for internal use • 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

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• Benefits for the Water Framework Directive

With the ambition to prevent pollution of water, the Water Framework Directive plays a key role. The conclusions of the EC on the non-effective implementation of this legislation by the Member States demonstrates the necessity to embrace the challenges. Despite this absence of revision, the European Commission has decided to update the list of priority substances to monitor in surface water.

The WFD covers surface water pollutants in two ways – by identifying and regulating those of greatest concern across the EU (Annex X to the WFD) and by requiring Member States to identify substances of national or local concern (river basin specific pollutants – included by Member States in their River Basin Management Plans). ZERO BRINE can contribute to a better implementation of the WFD through these two ways:

- ZERO BRINE shall support the inclusion of one substance in the ANNEX X to identify the risk of diffuse pollution by releasing brine into nature.
- ZERO BRINE technology must be mainstreamed by the local and national authorities as contributors to the effective basin management plan tool to reduce local pollution. By extracting raw materials, reusing energy and water, the pilot demonstrations stress the opportunities by reducing pollution and therefore pressure on the pollution and water consumption permits.

This project also demonstrates the necessity to harmonise the definition of brine in Europe. The different national definitions create barriers to allow duplication of technology and higher environmental standards.

• Benefits for the Biodiversity strategy

With only 40% of European water bodies deemed to have a 'good' status, ZERO BRINE is a technology that can be implemented during this critical time for biodiversity to protect and restore nature in Europe. Giving space to nature and investing in nature protection and restoration cannot be achieved without considering the industrial activities through a holistic approach. A Water-Smart society must consider the interconnections between sectors, users and uses. The upstream approach of ZERO BRINE indirectly contributes to prevent pollution and therefore supports the following objectives:

- Protect and restore nature in Europe, particularly, addressing restoration soil ecosystems, offering win-win solutions for energy generations, restoring freshwater ecosystems and reducing pollution;
- Enable transformative changes through stepping up implementation enforcement of EU environmental legislation, building a business model with a whole-of-society approach.

As the EU aims to focus on risk management, the prevention of pollution should also consider the place where brines are released. The negative impact of brine can be neutralised in some areas after pre-treatment in natural saline environments such as the sea. The balance between treatment and natural protection is smartly managed by controlling this risk.

For more information, see our Core Policy Brief

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THE CIRCULAR ECONOMY APPROACH FOR INDUSTRIAL WASTEWATER

BENEFITS OF THE ZERO BRINE TECHNOLOGY FOR THE EFFECTIVE IMPLEMENTATION OF THE INDUSTRIAL EMISSIONS DIRECTIVE

KEY RECOMMENDATIONS

ZERO BRINE proposes a shift from the model of raw minerals extraction to recovery of resources through closing the loop on industry brines.

ZERO BRINE also highlights the necessity to have a holistic approach by:

- Including sectors outside of the existing IED scope that generate brine
- Increasing the emphasis on reducing emissions to water resources
- Strengthening contributions to the circular economy
- Considering the additional benefits of the technology in terms of competitiveness, and reducing pollution in air, water and soil.

ZERO BRINE supports the creation of a horizontal BREF on water efficiency or brine management, or the mandatory inclusion of brine management in each relevant industry process.

• Context

The Industrial Emissions Directive (IED) is key legislation preventing and reducing polluting emissions to air, water, and land, and for minimising waste generation in the context of health and environmental impacts by identifying Best Available Techniques (BATs) within the BREF review process. While important progress has been achieved, the IED needs to be reviewed, not only to fully align with the new climate objectives of the European Union in terms of energy efficiency and circular economy, but also to update the BAT reference documents.

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 mineral salts, containing sodium, magnesium, calcium, sulphates, bicarbonates, and fresh water. ZERO BRINE demonstrates the use of a combination of existing and innovative technologies for recovery and reuse of both the material constituents as well as energy such as waste heat.

The ZERO BRINE approach can support a better implementation of the IED, to offer new standards within an updated IED while going beyond the siloed approach, in particular for chemicals.

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ZERO BRINE

• ZERO BRINE: A technology supporting the effective implementation of the IED

32% of Best available Techniques (BATs) on circular economy focus on energy[1]. But the circular economy also includes resource recovery and water reuse; however, only 20 BATs out of 850 promote water use reductions[2].

Therefore, there is also a necessity to focus on resource recovery and water efficiency to close the loop entirely. The ZERO BRINE technology offers a new technology to fulfil these objectives which is already aligned with the requirements of the existing IED.

Table 1 How Zero Brine contributes to key objectives of the existing IED

	IED REQUIREMENT (EXISTING)	ZERO BRINE'S CONTRIBUTION
1	An integrated approach to prevent and control pollution	Recovery and reuse of salts takes them out of the waste cycle.
2	Prevent or reduce emissions to water, land, and air	Significant reduction (>90%) in the volumes of brine disposal and constituent pollutants to the environment, impacting land and water. The newly proposed technologies of ZERO BRINE also reduce the emissions to air by using fewer polluting solvents and other consumables in the treatment process.
3	Prevent or reduce the generation of waste	Recovery of Sodium chloride, Sodium bicarbonate, calcium hydroxide, Magnesium hydroxide, Calcium, gypsum
4	Reduce impacts on the environment	Reduce discharge of saline water, constituent minerals and of greenhouse gas emissions (GHGs) through efficient energy use and reduced transport impacts.
5	Apply the best available techniques (BATs)	The ZERO BRINE pilots demonstrate a range of best techniques, in some cases developing new ones.
6	To prioritise generated waste in line with the order of priority of the Waste Framework Directive: re-use, recycle and recover, with responsible disposal as a last resort	While the potential for direct reuse of brine is limited, there is significant recycling following the recovery of salts/minerals and fresh water. Waste generation is minimised.
7	With energy efficiency	See ZERO BRINE Core Policy Brief specific data for each pilot.

The proposed technologies for the treatment of brine effluents will reduce adverse impacts to the environment, through the elimination of the need for brine disposal that today causes significant environmental degradation to land and aquatic environments. The United Nations Environment Program (UNEP-MAP) has stated that "one of the two major, urgent threats to the Mediterranean Sea environment is the pollution caused by the increased number of desalination plants and the releases and the effects of brine to the Mediterranean Sea."

The technology will also have a positive impact on soil health by reducing salination resulting from the discharging of industrial brine. This project constitutes an example for the foreseen Soil Health Law in 2023, particularly in the context of a shift from the model of raw minerals extraction to recovery of resources by closing the loop on industry brines.

ZERO BRINE also contributes to the reduction of energy consumption. To **produce one tonne of salt,** by applying the most energy-saving technologies established today (Mechanical Vapour Recompression – MVR) approximately 150 kWh (electricity) is required, which **results in approximately 75-150 kg of CO_2-eq emissions.** For the case of the demineralised water plant in The Netherlands, **34,000 tonnes of industry water** are produced per day, which requires approx. 2,000 tonnes of NaCl per year, which is an equivalent of 300,000 kWh or **300 tonnes of CO_2 emissions per year.** Even though in terms of mass, the quantity of salt used compared to the quantity of industry water produced is less

1 Report on IED Contribution to the Circular Economy, 2019

2 Report on IED contribution to Water Policy, 2018

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than 0.01%, in terms of energy consumed, it represents approximately 6% of the energy required to produce this quality of industry water. On top of this, energy consumed for transportation and relevant costs and CO_2 emissions should also be considered.

ZERO BRINE proposes a shift from the model of raw minerals extraction to recovery of resources by closing the loop on industry brines.

In the table below, key numbers for reduction are presented, related to the ZERO BRINE project, representing the chemical, demineralized water, coal mining and textile industries.

Table 2 - Impacts of the ZERO BRINE technology on water, emissions, energy, and resource recovery in industry

	Expected reduction in:			
	Water	**Emissions**	**Energy**	**Recovered resources**
Demineralised Water Plant	• 15-20% reduction in water withdrawal at Evides DWP	• >98% reduction of brine discharged to the environment (>2.5 million m^3/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	• 92% water recovery for internal use (demi water) • 6.2% IEX regeneration solution recovery for internal use (>3.1% purity) • 94.7% Calcium recovery ($Ca(OH)_2$) for external valorisation (>95.6% purity) • 87.8% Magnesium recovery ($Mg(OH)_2$) for external valorisation (>88.9% purity) • 93% Sulphate recovery (Na_2SO_4) for external valorisation (unwashed: 94.6% purity)
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	Expected reduction in:			
	Water	Emissions	Energy	Recovered resources
Silica factory	• 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 6,000 tons/year CO_2 reduction or 5 kg CO_2/ m^3 of wastewater	• 72% reduction by waste heat (EFC technology compared to direct evaporation)	• 75-90% water recovery suitable for internal use • 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

Further benefits will also be demonstrated through the Water-mining project (https://watermining.eu/) which aims to work on the next generation water smart management systems with large scale-demonstrations for a circular economy and society.

• ZERO BRINE: An available technology for a more resilient European industry

Several points of attention in the IED have been stressed by the European Commission that make the revision a priority. ZERO BRINE partners welcome the revision of the IED to update the directive in line with the EU Green Deal and the Zero Pollution Strategy.

Particularly, the ZERO BRINE technology demonstrates the opportunity for industries to contribute to GHG reduction and energy efficiency meeting requirements in terms of brine management:

- **GHG reductions and energy efficiency through the promotion of heat reuse in recovery processes. (see Table 2)**
- **GHG indirect reductions and energy efficiency by reduced transportation impacts** from the import of raw minerals, often from outside the EU. The reuse of water will also reduce the energy needs for pumping ground water.

However, the revision of the Industrial Emission Directive should also consider in the development and update of BREFs the dilemma between energy consumption and resource recovery. In line with the Zero Pollution Strategy, the IED can contribute to prevent diffuse pollution in our environment (see ZERO BRINE Policy Brief on the Zero Pollution Strategy).

Furthermore, the benefits of the ZERO BRINE technology support competitiveness through the implementation of river basin management plans with the permits provided by the national authorities. The production might increase without requesting additional rights to pollute.

The IED BREFs focus principally on individual industry sectors; however, the ZERO BRINE approach applies to a wide range of sectors that produce brine. At least it can contribute to improving the BREFS of the 4 industrial sectors selected for this project. Therefore, the consortium also welcomes the revision of Best Available techniques Reference documents (BREFs) such as the ones for Textiles Industry (BREF TXT) and the large volume inorganic chemicals – solids and other industry (BREF LVIC-S).

But its impact can be maximised by its opportunity to break the siloed approach and develop industrial symbiosis by the interconnection of sectors by, for example, recovering minerals or water volumes that are of value to others.

ZERO BRINE focuses on the manufacturing sector. According to Eurostat, this sector includes a vast array of economic activities performed by 2.1 million enterprises in Europe. It therefore contributes to:

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- **Highlighting the environmental benefits of reduced demand for raw materials and resource efficiency and recovery.** The impacts that will be reduced include less mining (both inside and outside Europe) and all its associated impacts, and reduced transportation with its associated energy and GHG emissions.
- **Identifying and highlighting the positive opportunities and benefits of compliance.** For the operator, they can include: a reduced need to purchase raw materials, and reduced spending on energy and water supplies. Some operators will also gain an economic benefit from the selling of recovered minerals to others.

Consequently, the ZERO BRINE technology can support the revision of the BREF process and the update of the BATs by either creating a horizontal and mandatory BREF on water-efficiency or including the need for circular brine management in several key industrial processes.

ZERO BRINE also encourages the necessity to have a holistic approach by:

- Including sectors outside of the existing IED scope that generate brine
- Increasing the emphasis on reducing emissions to water
- Strengthening contributions to the circular economy
- Considering the side benefits of the technology in terms of strategic autonomy, competitiveness, and diffuse pollution in air, water, and soil. (see ZERO BRINE Core Policy Brief)

For more information, see our Core Policy Brief

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CIRCULAR ECONOMY APPROACH TO INDUSTRIAL WASTEWATER

CONTRIBUTION TO THE REVISION OF THE URBAN WASTEWATER TREATMENT DIRECTIVE

ZERO BRINE demonstrates the technical feasibility, 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 EU Green Deal, and the Industrial Emissions Directive.

The below recommendations are based on the political options suggested by the European Commission on the revision of the Urban Wastewater Treatment Directive.

KEY RECOMMENDATIONS

- Set up integrated management plans for large agglomerations (prevention and optimal management of the collection/storage network + treatment).
- Reduction of use: obligation to connect when there is a centralised system.
- Impose track and tracing of pollution at source (prevention and optimal management of the collection network + treatment)
- Disconnect all industrial wastewater releasing industrial pollutants not treated in the public treatment facilities from urban wastewater (to ensure that the sludge is not polluted with industrial pollutants.)
- When the disconnection is not possible, the exploitation of the value of water must consider the Circular Economy of minerals in the brine flows, more than just the agricultural flows of phosphorous.
- No action is needed in the case of ZERO BRINE pilot plant - industrial discharges are handled within the industrial permits.
- UWWTPs and their network need to carry out energy efficiency audits. Cover all or only large agglomerations.
- Set EU fixed energy use reduction targets.
- Establish a baseline of methane emissions for large facilities and reduction targets.
- Set emission limits for greenhouse gases for large UWWTPs.
- Include monitoring and reporting requirements for greenhouse gas emissions.
- Impose prevention at source strategies that would ensure that the sludge is not polluted for all agglomerations or only large ones or only those using sludge in agriculture.
- Increase transparency obligations in directive to better inform the public.
- On top of minimum standards in the UWWTD, develop an approach similar to Best Available Techniques Reference Documents (BREFs) (as under the Industrial Emissions Directive).

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• CONTEXT

The Urban Waste-Water Treatment Directive (UWWTD) has set an international reference case in the global effort in wastewater management, exemplified in the UN Sustainable Development Goal indicator 6.3.1. Today, 95% of the EU's urban wastewater is collected and over 85% is treated according to the Directive' requirements[1, 2].

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 mineral salts, containing sodium, magnesium, calcium, sulphates, bicarbonates, and fresh water. ZERO BRINE demonstrates the use of a combination of existing and innovative technologies for recovery and reuse of both the material constituents as well as energy such as waste heat.

Within the context to better coordinate the revision of the Industrial Emissions Directive, and the Urban Wastewater Treatment Directive (UWWTD), the ZERO BRINE approach demonstrates options towards a greener, more circular, and resilient UWWTD in relation with the industrial activities, embracing industrial symbiosis. This policy brief is a complement to the previous briefs on the Zero Pollution Action Plan and the Industrial Emissions Directive. It is also paired with the Deliverable 9.2 Report on Policy Review and Assessment Suggestions for BREF Updates.

• Recommendations and explanations per identified areas.

In the context of the public consultation opened by the European Commission on the revision of the Urban wastewater treatment directive, ZERO BRINE expresses below some recommendations in line with the political options suggested by the European administration.

Storm waterflow and urban runoff

ZERO BRINE considers that it should be mandatory to set up integrated management plans for large agglomerations (prevention and optimal management of the collection/storage network + treatment), particularly in the connection of industrial activities which can have high potential impact on biodiversity through pollution. In line with the Zero pollution action plan of the European Union, we consider that pollution prevent is key to achieve a Water-Smart Society.

The concept of industrial symbiosis and circular economy that are key to the ZERO BRINE project are related to this. In ZERO BRINE we will demonstrate what the environmental, social, and economic benefits are of these integrated plans.

Individual or other appropriate systems (IAS)

ZERO BRINE pilot plants are in relatively high densified regions. Therefore, paired with the explanation for storm waterflow and urban runoff, the implementation of industrial symbiosis system can require centralised systems. However, it depends not only on the capacity and the possibility to work with mixed flows of several types of industrial productions and also the geographical location of the industry.

Industrial discharges

In addition to the recommendations in the policy brief on the Industrial Emissions Directive, ZERO BRINE supports a smart management of industrial discharges. Being based in highly industrialised areas, the pilot plants enjoy specific conditions such as the good implementation of industrial

1 https://ec.europa.eu/environment/water/water-urbanwaste/pdf/UWWTD%20Evaluation%20SWD%20448-701%20web.pdf

2 https://ec.europa.eu/environment/water/water-urbanwaste/implementation/pdf/COM_2020_492-final.pdf

The ZERO BRINE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730390.

permits and generally a separate network for industrial wastewater collection. In this context, ZERO BRINE can illustrate how the duplication of wastewater collection from industries can be done through environmental technology verification.

Moreover, our Deliverable 9.2 Report on Policy Review and Assessment Suggestions for BREF Updates also raises in its preliminary conclusions the importance to encourage not only urban wastewater reuse but also industrial wastewater reuse, thus contributing to greenhouse gas emissions reduction and reduced energy use.

ZERO BRINE also considers that it is not needed to have additional actions regarding industrial discharge management and supports the imposition of track and tracing of pollution at source. This is key to the integrated sustainability impact assessment of ZERO BRINE.

Energy consumption of the wastewater collection system and UWWTP and renewable energy production

ZERO BRINE is based on eco-design principles that are monitored and assessed with an integrated sustainability assessment scheme, this also includes the energy consumption and carbon footprint. ZERO BRINE shows how this can be done in four locations throughout the EU as an example to other locations. Therefore, the consortium supports the necessity for UWWTPs and their networks to carry out energy efficiency audits and the need to set European fixed energy use reduction targets.

Methane emissions

In our view, eco-design principles also include energy consumption and methane emissions. Paired with sludge management, ZERO BRINE supports the creation of a baseline of methane emissions for large facilities and reduction targets. However, ZERO BRINE does not support the imposition of only one technology, such as anaerobic digestion.

Moreover, greenhouse gas emissions must be strictly controlled by setting emissions limits for large UWWTPs and by requiring monitoring and reporting processes of these emissions. These political options can contribute to the objectives of the Green Deal and particularly the Zero Pollution Action Plan targets.

Circular economy – sludge reuse

Linked to the principle of tackling pollution at source, ZERO BRINE supports prevention at source strategies that would ensure that the sludge is not polluted for all agglomerations, or only large agglomerations or those using sludge in agriculture. ZERO BRINE is expecting results in September 2021 within the framework of its research activities and technologies in line with the concepts of industrial symbiosis and circular economy.

Information to the public

Improving transparency helps citizens to better understand the infrastructure, the challenges, and solutions. It improves the social acceptance of the solutions implemented and their costs. ZERO BRINE has organised workshops at local levels to match brine producers and mineral users, visits of pilot plants, and online trainings (see here). We therefore support the inclusion of additional provision in the UWWTD for transparency to the public.

Innovation/ adaptation to technological progress

ZERO BRINE validates the BREFs approach and its extension to the UWWTD. Moreover, in its previous policy briefs, the consortium has already provided advice to improve the BREFs.

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ZERO BRINE

ZERO BRINE PILOT DEMONSTRATION

DEMINERALIZED WATER PLANT IN BOTLEK, ROTTERDAM, THE NETHERLANDS

1. Context

At the Botlek industrial district of the Port of Rotterdam, demineralized water is an essential commodity required for the many production processes of surrounding enterprises. To produce demineralized water, reverse osmosis (RO) has become one of the main demineralization processes; however, RO alone is not sufficient to produce water of the required purity from the available water resources (fresh surface water), requiring several pre- and post-treatment processes to reach the desired purity for industrial use.

At the Evides demineralized water plant (DWP), one of the largest demineralized water production facilities in Europe, surface water is treated by RO combined with ion-exchange softening (IEX) and other technologies that results in the generation of brine as spent regenerant of IEX and RO concentrate (see Fig. 2).

2. Impact

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.

The demonstration plant comprised two sites combining residual heat (mimicked by low-pressure steam) and wastewater streams with the aim to eliminate the brine effluent at DWP (zero brine discharge). At Site 1, the aim was to treat the spent regenerant of the IEX unit and to recover valuable minerals and salts as well as water from the brine stream. This was done by nanofiltration, crystallization, and evaporation of IEX brine (see Fig. 3). Site 2 was an innovative design that aimed to treat the reverse osmosis concentrate of DWP by electro-oxidation followed by activated carbon adsorption, nanofiltration, reverse osmosis filtration, crystallization, and evaporation to remove the organic matter and to recover salts as well as water from the brine stream (see Fig. 4).

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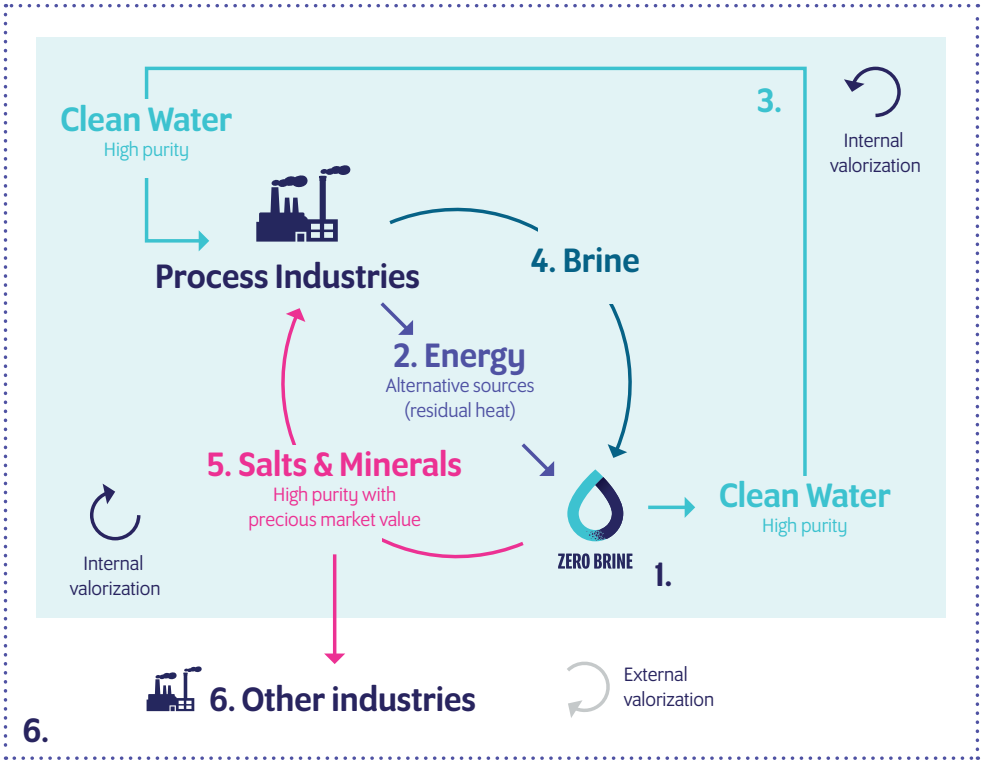
Fig. 1 – Circularity concept of Zero Brine



1. ZERO BRINE technology
- High CAPEX / Low OPEX
- Required lower energy compared to current treatment practices

2. Energy
- Alternative and cheaper energy source to reduce CAPEX

3. Clean Water
- Lower water consumption by reusing the recovered water

4. Brine
- No water required for dilution
- No brine discharge
- No environmental levies

5. Salts & Minerals
- Internal use of salts and minerals
- Trading salts and minerals as a new source of revenues

6. Other Industries
- New supply chain of water and minerals lead to lower water pollution and potentially would lead to lower carbon emission on global scale

Within the demonstrations, materials with commercial values were recovered on the two sites for potential internal and external valorisation.

3. Business opportunities

The concept of circularity proposed by the ZERO BRINE technology presents potential circular benefits for the companies at the Botlek industrial area. This is shown with the possible internal valorisation of salt and minerals that can be reused in the production of demi water at the Evides DWP, by recovering an NaCl rich solution that can be reused in the regeneration of IEX resins, as well as pure water that can be used internally in mixed bed polishing at Evides to produce ultra-pure water.

Additionally, the external valorisation of salts and minerals is also possible. The recovered resources from Site 1, magnesium hydroxide crystals ($Mg(OH)_2$) can be used in the pharmaceutical industry, food industry (added directly to human food and wastewater treatments (neutralized acidic wastewater). Calcium hydroxide crystals ($Ca(OH)_2$) can be used in industrial settings, such as sewage treatment, paper production, construction, and food processing, as well as medical and dental uses.

Recovered resources from Site 2, sulphate salts (Na_2SO_4), can be used in the manufacturing of kraft paper, paperboard, glass, and detergents and as a raw material for the production of various chemicals, while the ice recovered by EFC can be used for cooling and cleaning purposes.

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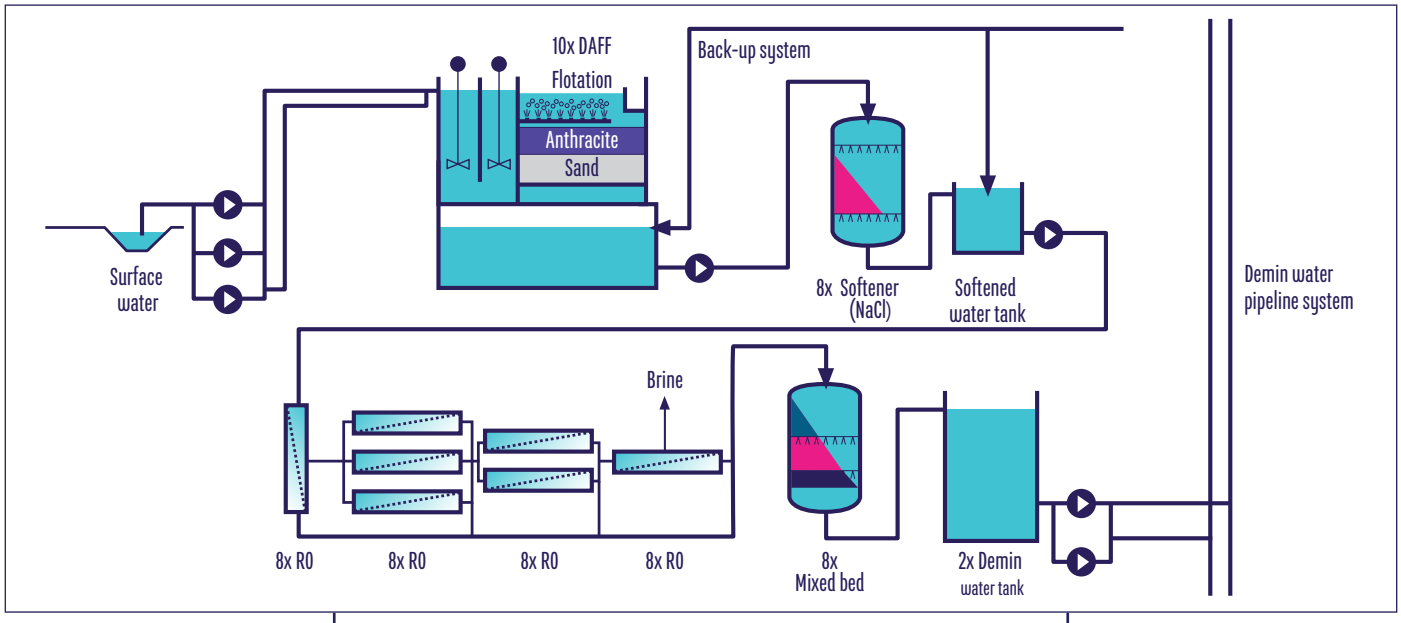
4. Key results

	Reductions in:			
	Water	**Emissions**	**Energy**	**Recovered resources**
Water plant	• 15%-20% reduction in water withdrawal at Evides DWP	• >98% brine discharge into the environment eliminated (>2.5 million m^3/year) • Reduction in CO_2 emissions by 1,012 tons/year or 14% 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	• 92% water recovery for intenal use (demi water) • 6.2% IEX regeneration solution recovery for internal use (purity > 3.1%) • 94.7% Calcium recovery ($Ca(OH)_2$) for external valorization (purity > 95.6%) • 87.8% Magnesium recovery ($Mg(OH)_2$) for external valorization (purity > 88.9%) • 93% Sulfate recovery (Na_2SO_4) for external valorization (unwashed: 94.6% purity)

For more information, see D2.6 Report on the operation and optimization process of the pilot plants at Botlek

Fig. 2 – Schematic view of the current processes at the DWP plant at Botlek



1 Site 1: Technologies

Nanofiltration (NF) – Multi Feed-Plug Flow Reactor Crystallizer (MF-PFR) – Multi Effect Distillation Evaporation (MED) for the treatment of Ion Exchange (IEX) spent regenerates

2 Site 2: Technologies

Electro-Oxidation Reactor (EOR) coupled with Granular Activated Carbon (GAC) commercially called NYEX – Nanofiltration (NF) – Reverse Osmosis (RO) – Multi Effect Distillation Evaporation (MED) – Eutectic Freeze Crystallizer (EFC) for the treatment of RO Concentrates

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Fig. 3 – Site 1 Technology scheme

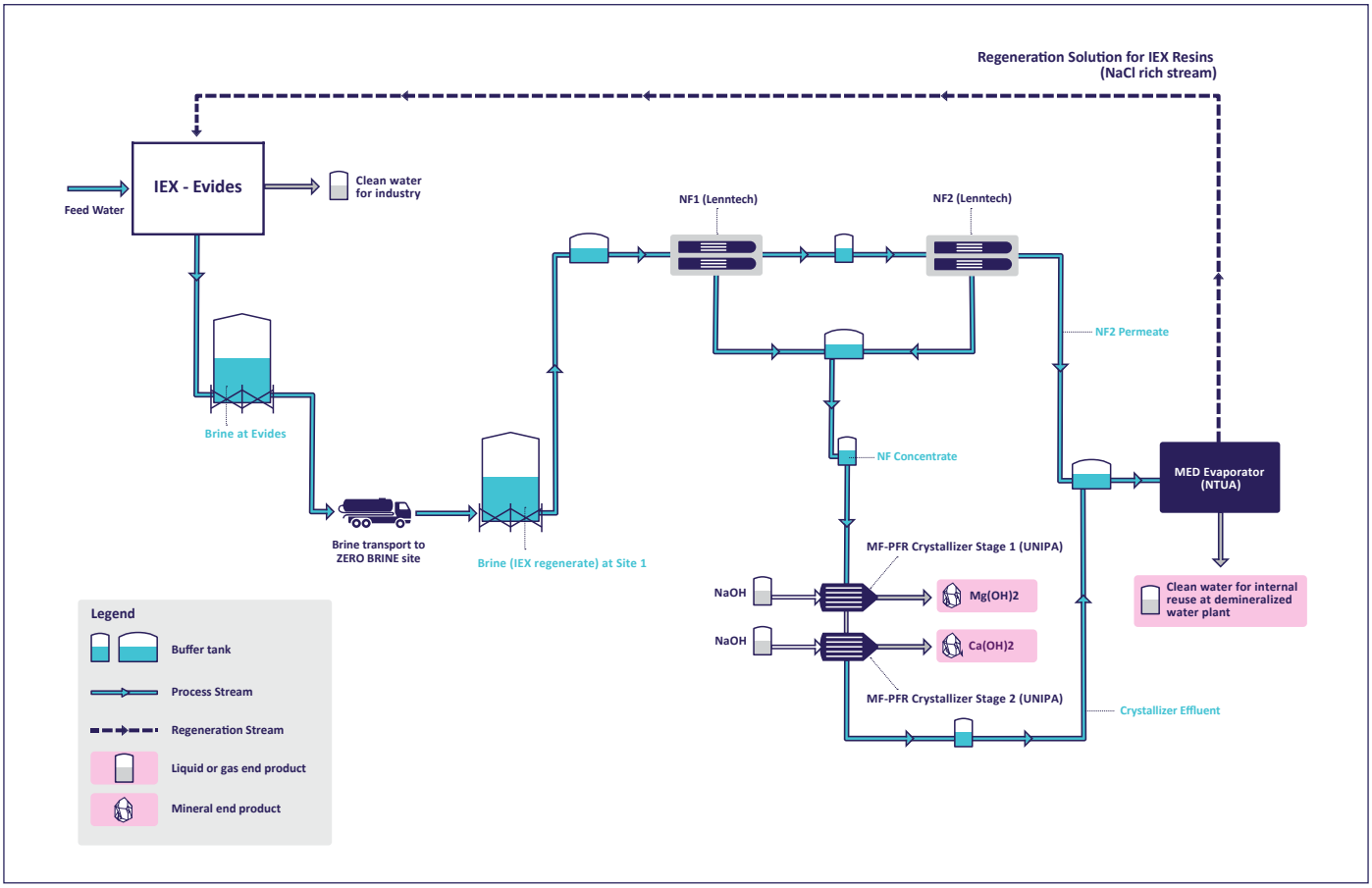
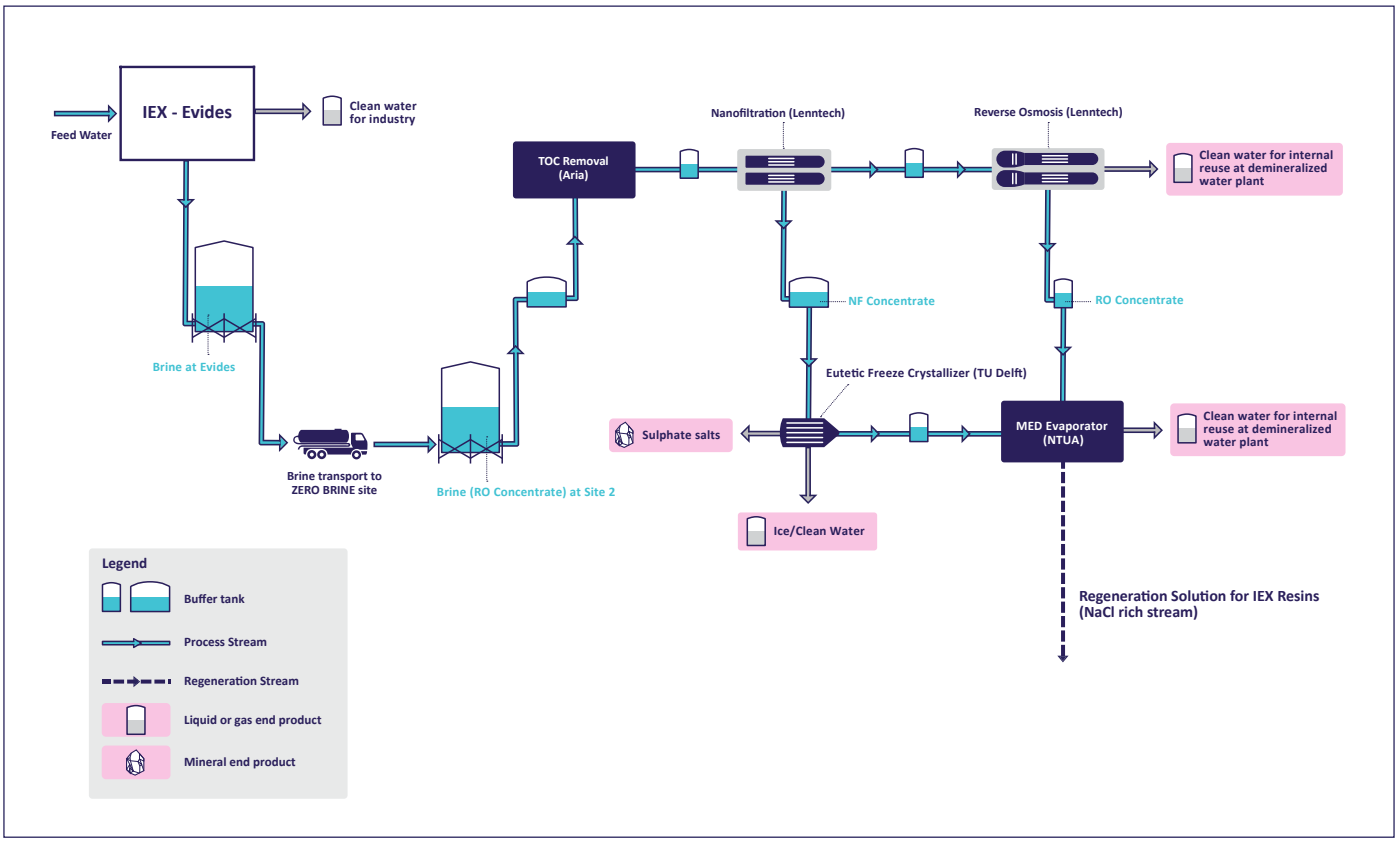


Fig. 4 – Site 2 Technology scheme



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ZERO BRINE

ZERO BRINE PILOT DEMONSTRATION
BOLESŁAW ŚMIAŁY COAL MINE IN ŁAZISKA GÓRNE, SILESIA, POLAND

Context

Saline wastewaters are a concern of many industries. The coal mining industry is particularly affected: every year Poland discharges around 4 million tonnes of sodium chloride (salt) into rivers, coming mainly from coal mines. This causes environmental damage and economic strains due to pollution fees. ZERO BRINE is turning this problematic issue into a source of income by recovering valuable resources such as water, salts, and minerals for reuse in other industries, creating potential jobs and societal improvements. The pilot plant is operated and overseen by the Silesian University of Technology (SUT) that is located nearby in the small city of Gliwice.

Coal mines are an important sector in the EU. Overall, coal is produced in 11 EU countries, having a major contribution to the energy security in nearly half of the Member States. In addition, coking coal is identified by the European Commission (EC) as one of the 27 critical raw materials since its supply risk is high. Coking coal also has a high economic importance due to its use in the metallurgy sector. As such, coal production will remain a very important sector in the future.

The coal mining industry is deeply affected by the environmental and economic problems with saline wastewater disposal. Every year, the mining sector discharges around 4 million tonnes of salt into the rivers in Poland. Poland's two longest rivers (Vistula and Odra) are under significant pressures from mining activities. For many years, excessive salt concentration has been found in the Vistula River, with 94% of the chlorides originating from hard coal mining activity. The Vistula River contains about 55% of the total fresh water resources in Poland and covers about 60% of the water needs in the country (including the river basin). The rising salination of the Vistula River is the cause of losses in industry, agriculture and water transport, which are estimated to be $100-250 million per year.

One possible solution is to use coal mining wastewater as the source of raw materials, thus turning the problem into a business opportunity. Poland only has one industrial-scale desalination plant in Czerwionka-Leszczyny, owned by PGWiR, which produces around 70,000 t/year of salt from coal mine water. The plant operates on coal mine water originating from operational "Budryk" mine and from an inactive mine, "Dębieńsko". The plant does not use chemical treatment. The low salinity coal mine water is pre-concentrated by reverse osmosis (RO). Then, after mixing with more saline coal mine water, it is subjected to further concentration by vapour compression (VC), and salt is obtained in a VC crystallizer. Unfortunately, this technology exhibits high energy consumption as well as limited salt recovery due to the presence of bivalent contaminants such as magnesium and calcium, which are not removed from the feed stream. The existing technology also does not allow the recovery of valuable raw materials, such as magnesium hydroxide.

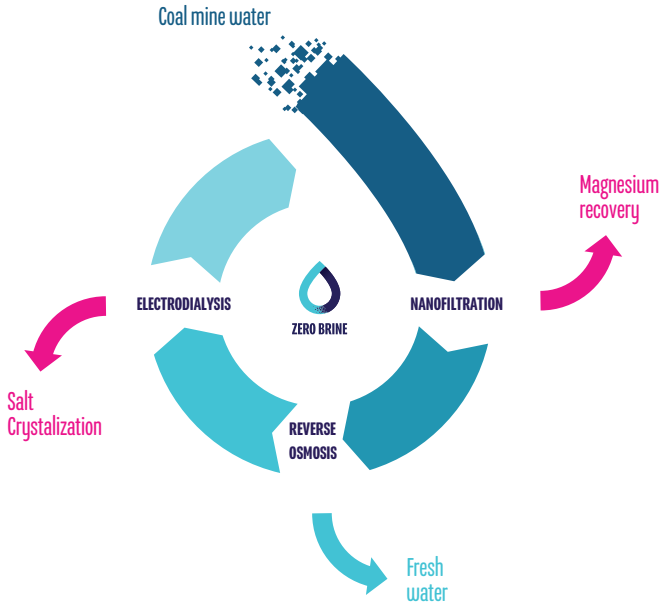
Decrease energy consumption by **33%**

Faster processing time than existing technologies

Recover materials such as **salt or concentrated brine, magnesium hydroxide**

Impact

ZERO BRINE aims at providing a technological solution of the saline wastewater problem for the coal mining industry. The ZERO BRINE technology is expected to decrease the energy consumption in the production of concentrated brine by 50% (target: 22 kWh/m3 of brine treated), compared to the vapour compression technology already used in Czerwionka-Leszczyny. The technology will also allow the recovery of raw materials: evaporated salt or concentrated brine, which both have multiple applications in the chemical industry, as well as magnesium hydroxide, which is a valuable commodity in the refractory materials industry. The ZERO BRINE team has already confirmed the interest of Poland's refractory materials manufacturer in new sources of high-purity magnesium hydroxide. Moreover, the same technology can be applied to other branches of industry which generate saline discharges.



Business opportunities

The problem of saline wastewaters is not unique to only one mine or one company – it has been a systemic issue throughout the whole industry for years. At the moment, 18 hard coal mines are still operational in Poland, provided below by coal mine industry: Jastrzębska Spółka Węglowa JSW Group (4 coal mines), Polska Grupa Górnicza (8 coal mines), Tauron Wydobycie (3 coal mines), Przedsiębiorstwo Górnicze Silesia (1 coal mine), Węglokoks (1 coal mine), Lubelski Węgiel Bogdanka S.A. (1 coal mine). All of those companies might be interested in turning their big environmental problem into a potential source of income.

An important business opportunity is the production of salt. The average production in Poland is around 4.3Mt/y, with salt-in-brine accounting for around two-thirds of production. Some 63% of salt-in-brine produced domestically is consumed in two synthetic soda ash plants (operated by Soda Polska Ciech). Around 21% of salt-in-brine is used in the production of evaporated salt and 16% in chlor-alkali production (by Anwil Nitrogen Plant, PCC Rokita and Organika-Zachem Chemical Works).

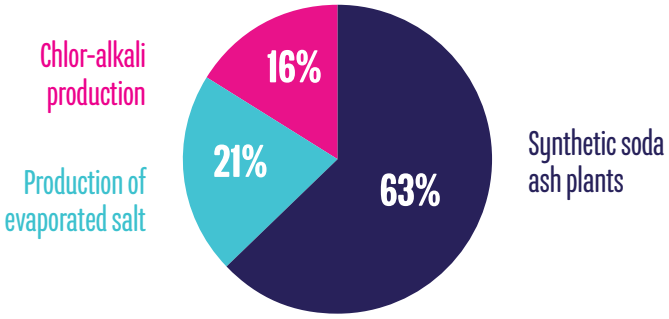
The magnesium hydroxide is of interest for the refractory materials industry. In 2006, the production of refractories in Poland reached nearly 300,000 tonnes, around 28% of which were unshaped materials. The main manufacturers in Poland include ZM Ropczyce S.A., PMO Komex (part of Alcerol-Mittal), PCO Z˙arów S.A., Vesuvius Skawina.

The business opportunities of ZERO BRINE are not limited to Poland. Because of how similar in composition the coal mine waters are to the sea water, the proposed technology could also be applied in the desalination industry – a sector which will become increasingly important due to the increasing water stress.

Turning waste into a potential source of income for operational coal mines

Salt production: **4.3 MT/y**

Usage of salt-in-brine:



Magnesium hydroxide is used in refractory materials industry - which reached **300,000 tonnes** in 2006

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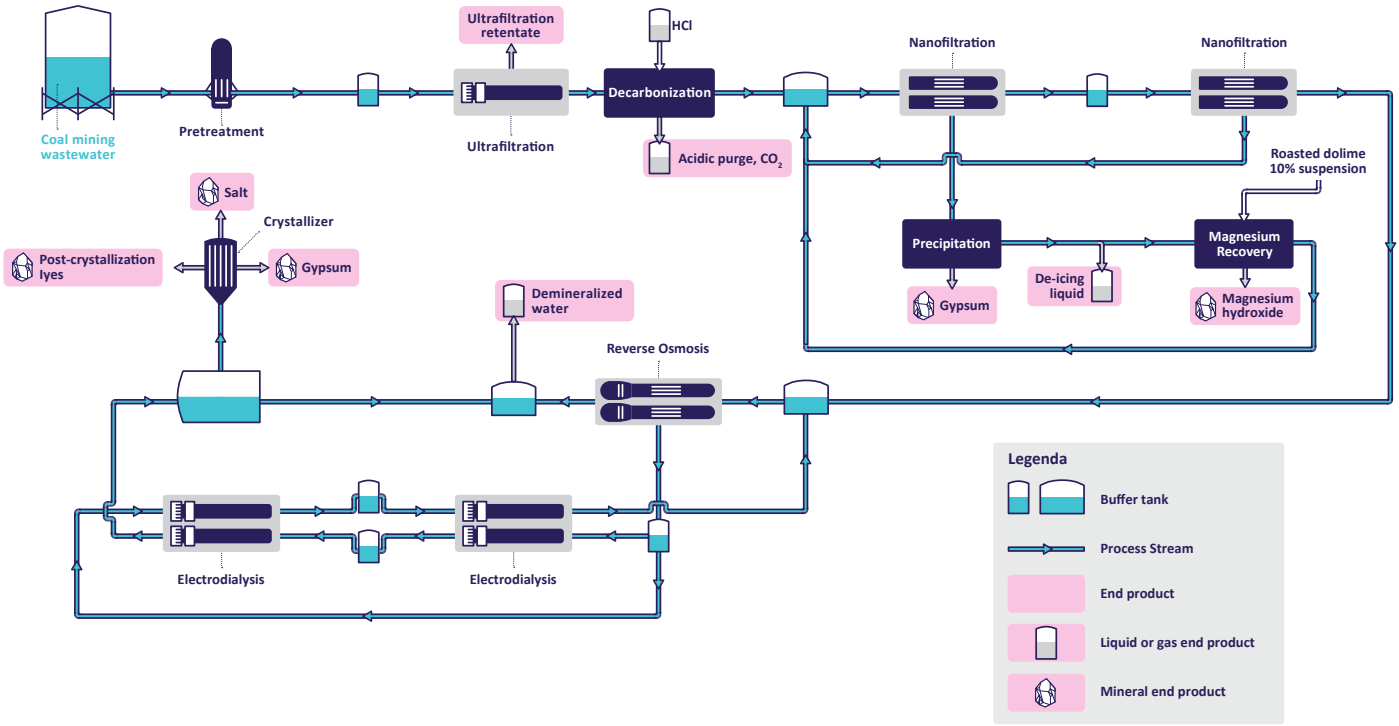
Technology

The feed – coal mine water – after being pre-treated with decarbonization and ultrafiltration, is subjected to a two-pass nanofiltration. Nanofiltration is a membrane method, which allows separation of univalent ions – such as sodium and chlorides – from bivalent ions – calcium, magnesium, sulphates. The nanofiltration unit thus splits the coal mine water into two streams: salt-rich permeate and calcium and magnesium-rich retentate. The retentate can be used n the recovery of magnesium hydroxide. Magnesium is a critical raw material officially listed by the European Commission as having high commercial value. (Currently, Europe imports over 95% of its magnesium from China.) The remaining calcium-rich solution could be used as a de-icing liquid. The nanofiltration permeate is concentrated in a hybrid reverse osmosis-electrodialysis system, which produces demineralized water of quality close to distilled water, highly saline concentrate, and the diluate, an essential commodity that can be used at the site. The highly saline concentrate could then be sold directly or used as a source for salt crystallization.

The pilot plant operating in the "Bolesław Śmiały" coal mine tests the nanofiltration-reverse osmosis-electrodialysis part of the proposed technology.

General scheme of the proposed technology



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Key results and conclusions

The pilot plant aimed at testing the proposed technology has been constructed in the "Bolesław S´miały" coal mine in Łaziska Górne, Poland. The pilot plant consists of pretreatment system, ultrafiltration, decarbonization, two-pass nanofiltration, r everse o smosis and electrodialysis, and is capable of treating 400 L/h of coal mine wastewater. The desalination experiments have been run in the pi-lot plant since July 2019 and it was confirmed that nanofiltration can split the coal mine wastewater into sodium-chloride rich stream suitable for further concentration and the magnesium-rich stream suitable for magnesium hydroxide recovery.

	Expected reduction in:			
	Water	**Emissions**	**Energy**	**Recovered resources**
Coal mine	NA	• 92.8% reduction of sodium chloride (NaCl) discharged to freshwater resources • 347 kg CO_2 /ton NaCl or 32.5% CO_2 reduction	• 33% energy reduction	• 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/m^3 gypsum for external valorisation

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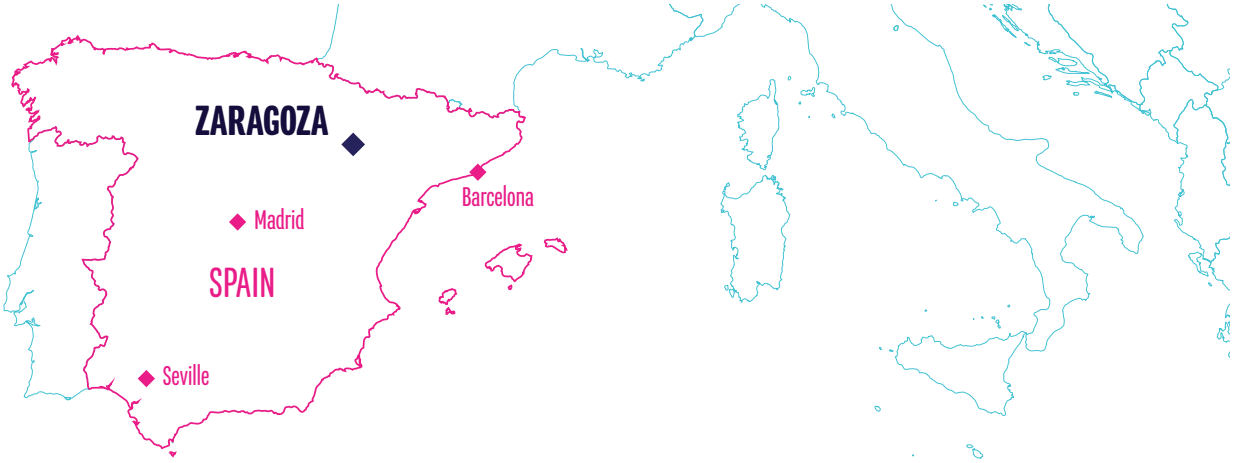
ZERO BRINE

ZERO BRINE PILOT DEMONSTRATION

INDUSTRIAS QUIMICAS DEL EBRO (IQE) IN ZARAGOZA, SPAIN



1. Industry context

Synthetic amorphous silica are used in a wide range of industrial applications. Due to their physico-chemical properties, they are used in synthetic resins, plastics, rubbers, cosmetics, nutritional products and drugs, for example, as fillers or anti-caking agents. Synthetic amorphous silica are produced either by a wet process – precipitation of a water glass solution with acids (precipitated silicas, silica gels, silicates) – or by high temperature hydrolysis of chlorosilanes (pyrogenic silicas).

In the production of silica by a wet process, high amounts of water (≈40m^3 per each tonne of silica) are consumed, as well as sulfuric acid (H_2SO_4) and sand. As a result, around 35m^3 of wastewater containing a high concentration (20 g/L) of sodium sulphate (Na_2SO_4) are produced. This wastewater is normally discharged to natural water sources such as rivers and seawater after passing through wastewater treatment plants.

It is estimated that 620,000 tonnes of precipitated silica is produced per year in the EU and 21,700,000 m^3 of wastewater is discharged.

Industrias Quimicas del Ebro (IQE) is seeking novel methods to recover resources (water and sodium sulphate) and minimize the wastewater generated, while reducing the cost of water supply and wastewater treatment. Even so, as it is stated in the BREF for the inorganic chemical industry sector, the concentration of sodium sulphate in wastewaters from the production of precipitated silica is too low for its recovery to be economically viable through available methods (spray drying, precipitation of gypsum or membrane dialysis, etc.).

2. Impact of the ZERO BRINE technology

ZERO BRINE aims at providing a technological solution for the saline wastewater problem for the silica industry. The technology applied in the ZERO BRINE project would enable IQE to recover up to 80% of wastewater generated, producing water suitable for its reuse in the same company, thus reducing freshwater consumption. In addition, the technology allows the recovery of raw materials: sodium sulphate, which is a valuable product for various industrial sectors, like the powered detergent or the glass industry.

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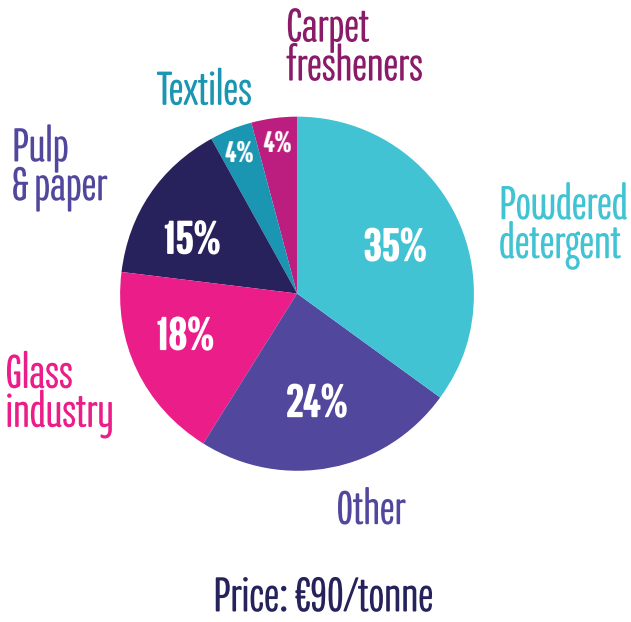
3. Business opportunities

The ZERO BRINE solution can be applied not only to the silica industry, but also to other industries which generate saline discharges containing high concentrations of sodium sulphate. This is the case for the pulp and paper industry, where sodium sulphate is one of the main reagents and also by-products of the pulping processes, especially the kraft process.

Na_2SO_4 – Uses & Market Shares



Price: €90/tonne

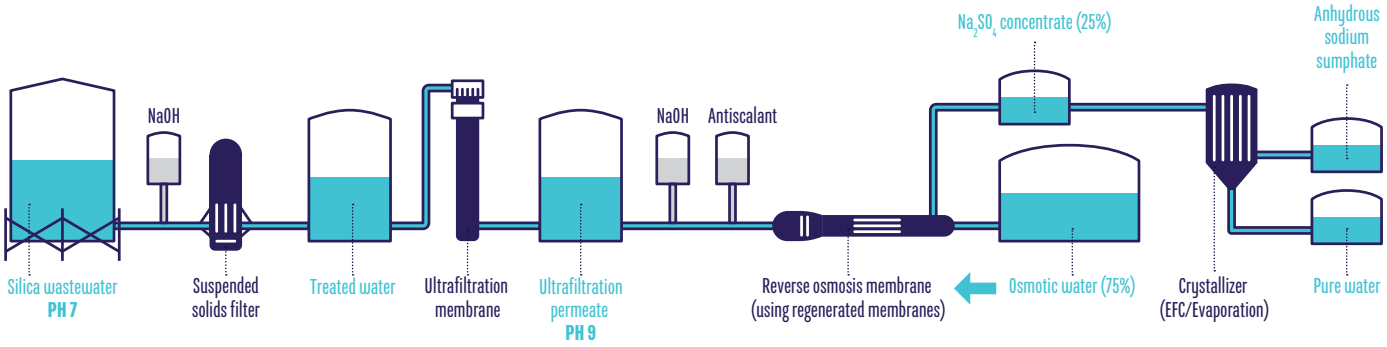
An important business opportunity is the production of sodium sulphate that is a valued product for various industrial sectors, like the powdered detergent or the glass industry.Business opportunities of ZERO BRINE are not limited to saline wastewater containing sodium sulphate. The technology developed and tested in ZERO BRINE can also be applied to recover valuable inorganic compounds other than sodium sulphate. The potential users are all industries with a high concentration of inorganic compounds in their effluents that could be recovered instead of discharged into the environment, such as desalination plants, salt mining, and chemical industries.

4. Technology + proposed scheme

The ZERO BRINE process is based on: a) a first membrane-based process using tailor-made membranes produced by regenerating end-of-life reverse osmosis (RO) elements from desalination plants otherwise destined for a landfill; b) treatment of the concentrate stream produced in the first stage by crystallization to achieve Zero Liquid Discharge. In order to avoid scaling problems during treatment with membranes, a pre-treatment to remove aluminium and iron is applied.

Regenerated membranes are able to achieve a suitable quality of water, equivalent to the current quality in the industry that could also be reused in the production process. In addition, a high saline concentrate is obtained to be treated by crystallization, either Eutectic Freeze Crystallization (EFC) or Evaporation. The concentration of wastewater using membranes reduces the energy consumption of the crystallization stage.

The ZERO BRINE process has been demonstrated at IQE at pilot plant scale.



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5. Key results and conclusions

The technology applied in the ZERO BRINE project would enable IQE to recover 20,000 tonnes per year of sodium sulfate and 80% of the wastewater generated (1,000,000 m^3 per year).

The concentration of saline wastewater using regenerated membranes before the crystallization process allows the reduction of treatment costs up to 70% when compared with the direct evaporation of wastewater.

The preliminary business plan elaborated for the development of the ZERO BRINE proposal foresees savings in the cost of water supply and wastewater treatment of around €460,000 per year and turnover of €1,800,000 per year from the sodium sulphate recovered.

Table 1 - Impacts of the ZERO BRINE technology on water, emissions, energy, and resource recovery in industry

	Expected reduction in:			
	Water	**Emissions**	**Energy**	**Recovered resources**
Silica factory	• 30% reduction in overall annual water consumption at IQE	• 100% reduction of brine discharged to the environment • 60% reduction of sodium sulphate (Na2SO4) releases into the Ebro River 6,000 tons/year CO2 reduction or 5 kg CO2/ m^3 of wastewater	• 72% reduction by waste heat (EFC technology compared to direct evaporation)	• 75-90% water recovery suitable for internal use • 90% recovery of sodium sulphate (Na2SO4) or 20,000 tons/year for external valorisation (>99% purity) • Sodium hydroxide (NaOH) (94% purity) and sulphuric acid (H2SO4) (72% purity) for external valorisation

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ZERO BRINE

ZERO BRINE PILOT DEMONSTRATION
ZORLU TEXTILE FACTORY IN LÜLEBURGAZ, TURKEY

1. Context

The management of industrial wastewater to comply with Zero Liquid Discharge (ZLD) has been receiving significant attention. The textile industry is one of the largest sectors in Turkey and makes up 10% of the country's GDP and employs around 750,000 people. However, the industry is also responsible for numerous environmental effects due to wastewater discharges which contain various chemicals, dyes, salts and other auxilary materials from unit processes. The industry covers 1-3% GNP of the countries worldwide. Turkey ranks 5th and 6th in production of woolen and cotton products worldwide which makes up close to 40% of total export income and 10% of the industrial work force. Therefore, the implementation of a well-designed solution to prevent pollution along with the ZLD concept is highly favorable for both environmental concerns and economically.

The textile industry is a highly water intensive sector. Water consumption ranges between 60 to 120 L/kg for cotton products and 110-650 L/kg for wool. Water is utilized at various steps of the unit processes such as pre-treatment, dyeing or finishing. Processes require extensive water use for dyeing, rinsing, conditioning and finishing operations. The crucial parameters of discharges from textile enterprises include mainly organic constituents, dissolved solids, inorganic salts, color, sulfate and pH.

Salt usage is also significant in the textile industry. Salt is consumed for dyeing cotton or linen fabrics and acts as a raw and auxiliary material.

Physicochemical and biological treatment techniques are widely employed to treat textile industry wastewater to comply with local discharge criteria. Moreover, membrane processes such as Nanofiltration (NF) and Reverse Osmosis (RO) are also utilized following conventional treatment methods as a tertiary treatment step to obtain a reusable stream. Membrane treatment for reuse is a very effective method for removal of ions and other pollutants. Reusable, high quality water is obtained using RO membrane processes.

RO on the other hand, results in the formation of highly polluted concentrate (brine) along with the high-quality, treated water stream. The impurities and pollutants in brine have serious adverse impacts on the environment. Principally, the brine discharges may cause environmental and ecological impacts on especially inland receiving water bodies such as lakes and rivers and may cause salinization of the soil which is one of the most severe environmental problems in agriculture.

The concept of circular economy and ZLD options are investigated for Zorlu Textile's integrated polyester yarn and cotton home textile manufacturing industry within the context of ZERO BRINE project. In this manner, treatment and recovery of the concentrated salt solution (brine) which can be reused in the dyeing baths of the textile plant and/or utilized as feed for salt production is targeted.

The demo project is primarily focused on the management of brine generated from the RO unit and developing an innovative brine treatment and recovery system. Brine from the RO treatment unit presents an important environmental concern due to the high concentration of impurities including various chemicals, salts, colors, hardness, alkalinity and nutrients. The primary difficulty to be overcome by this approach is the separation of hardness and color from brine while concentrating the salt solution which can, in turn, be used in textile dyeing processes. The recovered salt solution should also comply the criteria for textile dyeing process requirements.

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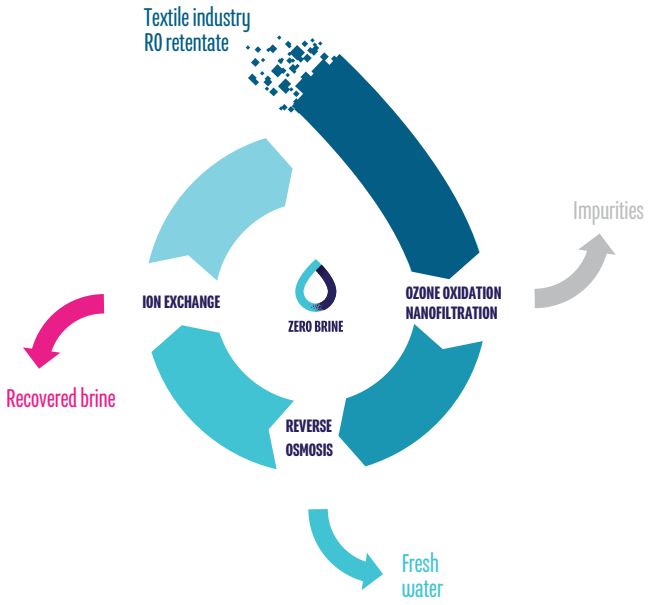
2. Impacts

The ZERO BRINE project intends to reduce saline wastewater streams generated by industry by recovering and reusing minerals, water and metals from wastewater. ZERO BRINE aims at the development of innovative technological solutions of the highly saline wastewater problem for several industrial sectors including the textile sector. In this context, concentrate (brine) recovery of approximately 400 tons/year as NaCl is targeted for Zorlu Textile. Depending on the brine impurity, recovered concentrate is utilized for in-plant processes. The conditions for recovery is appraised, and off-site use may also be made possible. Moreover, production 80 Km^3/year high quality water is also among the goals.

The results would have great impacts on the textile industry in achieving resource efficiency and improving sustainability due to the reduced consumption of process inputs, as well as the mitigation of greenhouse gasses accordingly. In this way, it is estimated that the reduction of 200 tons of CO_2 on an annual basis could be achieved.

Moreover, the similar technology and approach can be applied to other sectors of industry which generate saline discharges.

Fig. 1 – Conceptual scheme for textile pilot



3. Business opportunities

Brine is a valuable resource for the recovery of salt and water. In this way, the purpose is to close the loop between the saline wastewater generated by process industries and to contribute the circular economy. The goal is achieved by means of innovative existing and new technologies to recover and reuse high quality end-products. By taking into account the demo system results, other various enterprises actively operating in the textile sectors will likely be encouraged. The solutions developed may sustain;

I. compliance with the relevant regulations likely to be in force in the near future,

II. economic benefits for the enterprise implemented ZLD approach due to the reduction in consumption of salt and water,

III. improvements in visibility of the enterprise due to the increased concerns for environmental issues, and also relevant growth in export potential with good market value,

IV. business opportunities foreseen for the companies involved wastewater treatment and reuse/recovery options,

V. creation of new job alternatives for technical personnel in both textile or other relevant enterprises for various sectors including environmental fields (wastewater treatment and reuse companies).

4. Technology

Zorlu Textile industry wastewater is treated with physicochemical, biological methods and advanced treatment processes (activated carbon adsorption, ultrafiltration and RO) to obtain a reusable stream which is utilized for an energy company's cooling systems located near the Zorlu Textile. RO treatment consequently results in the generation of a highly polluted concentrate retantate (brine).

The proposed configuration of the brine treatment and recovery pilot system was developed based on the comprehensive characterization in bench scale tests, as well as the relevant assessments.

In this perspective, ozone oxidation and (NF) membrane processes are applied as the pre-treatment phase essentially to remove or mitigate impurities such as color, hardness, organic constituents and sulfate. NF provides 50-60% rejection of impurities whilst allowing 10-20% salt passage. Whereas, after NF membrane systems, RO is utilized as the concentration step for the NF permeate stream. At this stage, the concentrate stream of the RO unit is the recovered salt solution while the permeate of the RO unit is the reusable water – close to demineralized water quality – that can be reused for textile processing purposes.

The ion exchange softening process is also applied as the final step to acquire extra hardness removal of the recovered salt solution prior to the dyeing applications. This step would provide additional assurance as hardness is considered to be the critical parameter for textile dyeing processes. An activated carbon adsorption column and an UV oxidation unit are also provided within the pilot system to remove excess ozone remaining in the concentrate stream to provide protection for the membranes.

The ZERO BRINE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730390.

Fig. 2 – General outline of the proposed system at Zorlu Textile

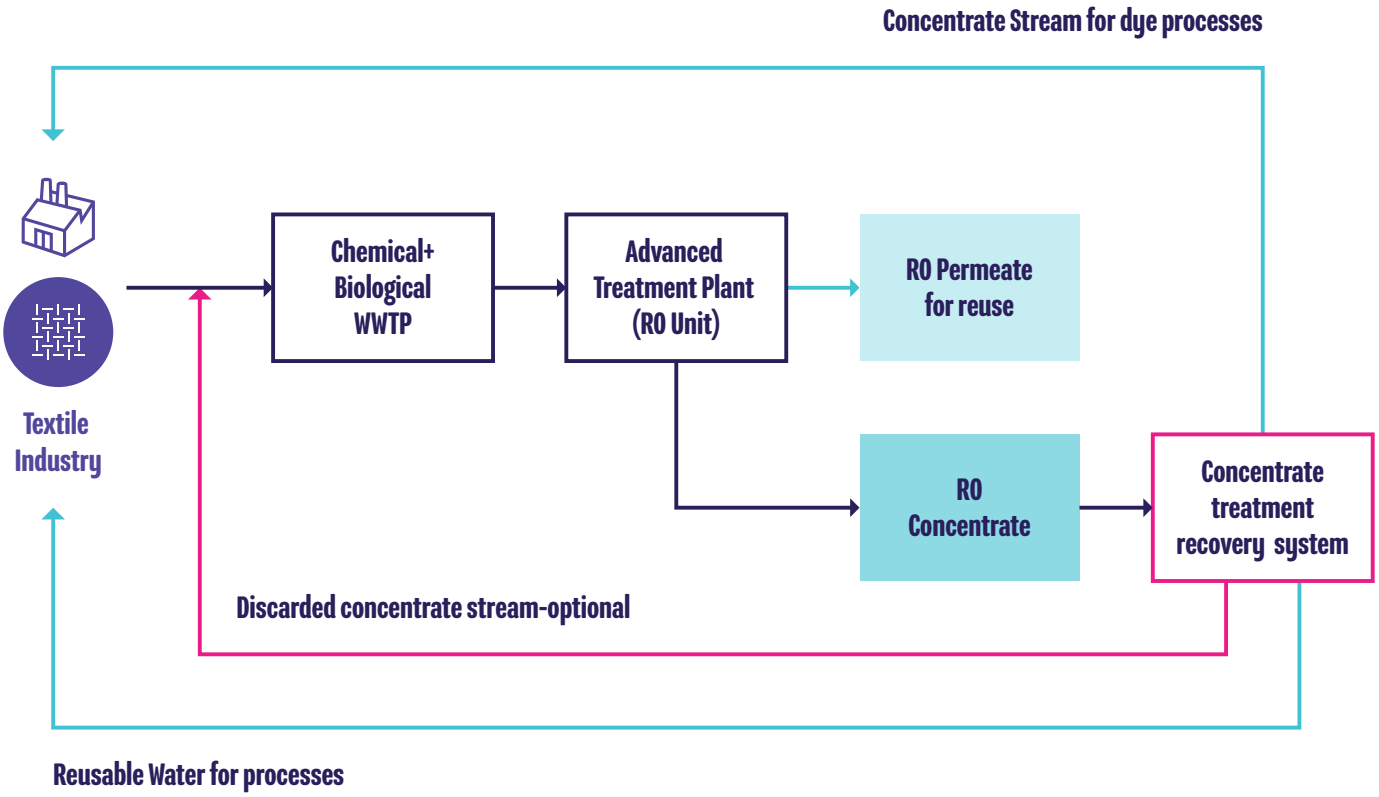
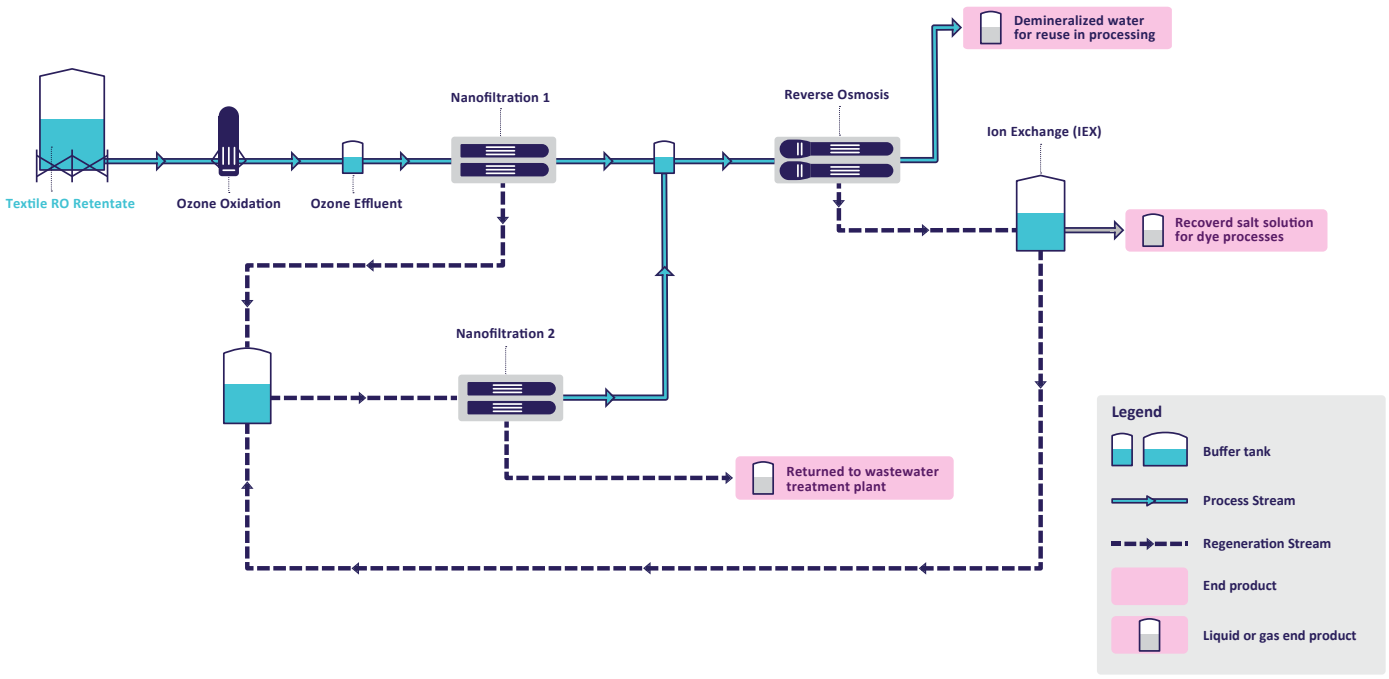


Fig. 3 – Process scheme of the applied technology for the pilot system



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5. Key results and conclusions

The textile brine recovery pilot plant is intended for testing and verifying the proposed technology. It has been constructed and is being operated at the Zorlu Textile premises at Lüleburgaz, Kırklareli.

The pilot system involves a pretreatment stage with ozone oxidation, nanofiltration, concentration stage with reverse osmosis and, as a precaution, a softening unit by an ion exchange column. The pilot plant is capable of treating 300 L/hr of RO retentate discharged from advanced wastewater treatment facilities of Zorlu Textile. The developed process scheme results in 50-60% of recovery of NaCl for the dyeing processes. Whereas, the clean water recovery as permeate of the RO treatment unit would be 70-80%. Alternatively, this stream will be reused within the enterprise for various purposes. The process design system allows the flexibility to be operated at relevant variable flow intervals. Moreover, the arrangement of the proposed treatment units and the piping connections could be varied to a certain extent depending on the operational conditions and the requirements throughout the operation period. Hence, by this approach it is anticipated to accomplish efficient recovery of salt solution for dyeing processes.

	Expected reduction in:			
	Water	**Emissions**	**Energy**	**Recovered resources**
Textile factory	• 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	NA	• 70-80% water recovery from brine treatment system for onsite use • 600-700 tons salt/year for onsite dyeing of textiles

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