Wastewater as a resource

Bornholm, Denmark

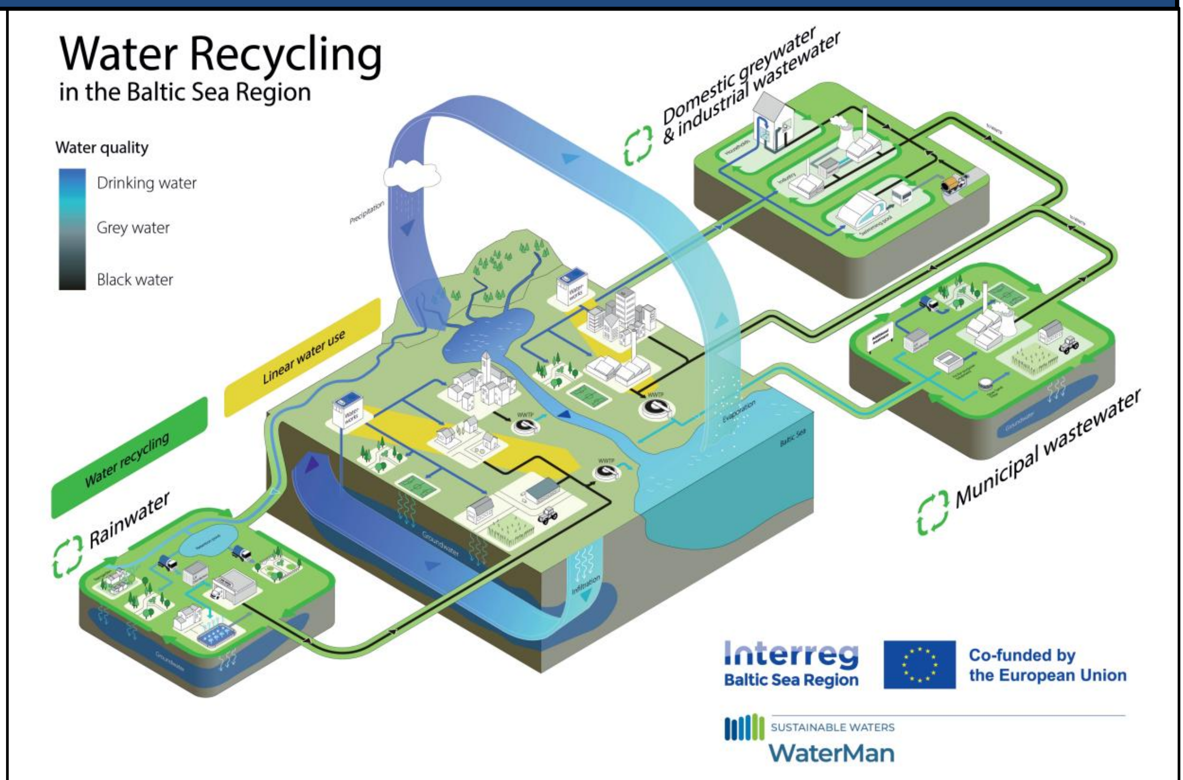
Interreg
Baltic Sea Region

Co-funded by
the European Union

SUSTAINABLE WATERS
WaterMan

2025

WaterMan Local Model Strategy Bornholm



Paulo Silva & Sara Björkqvist
Bornholms Energi og Forsyning
09-12-2025

Content

Summary 3

Introduction - Scope, Outline and Structure 3

- National and European Regulation 3
- BEOF's Strategic Ambition 4
- Local Model Strategy on Bornholm 4
- Stakeholder Involvement 4

Status on Regulations and Future Plans 5

- The New Urban Wastewater Treatment Directive (UWWTD) 5
- New National Regulation on Technical Water 5
- EU Regulation 2020/741 on Minimum Requirements for Water Reuse 5
- BEOF's "Future Wastewater Structure" 5

Outlook for Groundwater Sustainability under Climate Change 6

- Key Findings on Groundwater Resource and Climate Change 6

Proposed Goals and Measures 7

- Increasing the Interest and Possibilities of Wastewater Reuse at WWTPs 7
- Increasing Awareness, Interest, and Acceptance 8
- Engagement with Authorities and Policymakers 8
- Building Networks and Sharing Knowledge 8

Technical Knowledge – Overview of Technologies for Reuse 8

- Treatment Objectives and Processes 8
- Technology Evaluation 10
- Slow Sand Filter Pilot – EnviDan Report Introduction 11
  - Strategic Integration 11
  - Summary of Slow Sand Filtration Feasibility Study 11
- Potential for Scale-Up or Replication of Slow Sand Filtration on Bornholm 13
  - Key Takeaways for Future Implementations 13
  - Technical Feasibility of Scaling Up 14
  - Financial Viability 14
  - Transferability and Adaptability 14
  - Preconditions for Successful Replication 14

Technical Knowledge – Library on Technologies for Reuse 15

- Purpose of the Library 15

Contents of the Library 15
Wastewater Quality – Mapping and Risk of Contaminants 16
Mapping Wastewater Sources 16
Contaminant Risk Assessment 17
Wastewater Quality – Overview of Contaminants Monitored by National Program 17
Purpose of Monitoring 17
Categories of Contaminants 18
Application to Reuse Strategy 18
Wastewater Quality – Overview of Contaminants in Waterbodies / Recipients 19
Purpose of Monitoring Waterbodies 20
Data Sources and Tools 20
Increase Awareness, Interest and Acceptance – Workshop Summary 22
Workshop Participants 22
Activities and Focus 23
Key Takeaways 23
Showcasing Wastewater Reuse – Awareness and Engagement Activities 23
International Exposure 24
Anchor as a Guiding Framework for the Future 24
Dynamic Documentation and Continuous Follow-Up 24
Conclusion 25
Annex 1 - Technologies comparative evaluation 26
Annex 2 – Tech Library 39

Summary

The WaterMan project on Bornholm positions wastewater as a strategic resource in the island's transition toward climate resilience and circular economy. The local model strategy integrates European and national regulatory developments, BEOF's infrastructure planning, and stakeholder engagement to explore and implement wastewater reuse.

Key components of the strategy include:

- Regulatory Alignment: Anchored in the upcoming EU Urban Wastewater Treatment Directive (UWWTD), Denmark's technical water legislation, and reuse standards under EU Regulation 2020/741.
- Infrastructure Planning: Linked to BEOF's decision on centralizing WWTPs.
- Reuse Scenarios: Agricultural irrigation, PtX hydrogen production, industrial use, and municipal applications.
- Technical Foundation: Mapping of treatment technologies, contaminant risks, and water quality data from national monitoring programs.
- Stakeholder Engagement: Workshops, site visits, and knowledge sharing with local and EU-level actors.
- Knowledge Tools: A technology library and wastewater quality data bank to support decision-making and future planning.
- Governance Anchoring: Strategy embedded in active project groups with dynamic documentation and regular follow-up.

Introduction - Scope, Outline and Structure

The local model strategy for Bornholm is developed at the intersection of national regulation, EU policy requirements, and BEOF's long-term vision for wastewater management. The central theme is wastewater as a resource, with the objective of increasing both the interest in and the practical possibilities for water reuse at wastewater treatment plants (WWTPs) in the future.

National and European Regulation

Wastewater reuse is strongly influenced by national regulation and European Union directives. The forthcoming implementation of the new EU Urban Wastewater Treatment Directive (UWWTD) places a stronger emphasis on water reuse, nutrient recovery, and environmental protection. In Denmark, the Ministry of Environment is responsible for the implementation of the directive in the Danish regulations. The Danish Water and Wastewater Association (DANVA) actively works for a feasible implementation of the directive. These evolving regulations provide both requirements and opportunities for local reuse models.

BEOF's Strategic Ambition

Bornholm Energi & Forsyning (BEOF) has articulated the vision of *"Clean waters surrounding Bornholm."* This strategy is a natural extension of that ambition, aligning with the development of a future wastewater structure that integrates advanced treatment and reuse options. Wastewater is no longer treated as a by-product to be disposed of but as a valuable resource that can contribute to water security, agriculture, and energy integration.

Local Model Strategy on Bornholm

The local model strategy seeks to:

- Frame wastewater as a resource within the broader water cycle.
- Demonstrate practical reuse options at WWTPs.
- Provide input to the development of Denmark's wastewater structure and EU-wide discussions.

By focusing on Bornholm as a living laboratory, the internal strategy aims to show how a small island can pioneer approaches that are scalable and transferable to other regions.

Stakeholder Involvement

The strategy is embedded in a multi-stakeholder process. It involves coordination between:

- National authorities (Environmental Ministry).
- Industry associations (DANVA).
- Local utilities (BEOF).
- Working groups tasked with UWWTD implementation.
- Backing groups providing technical, economic, and governance input.

This ensures that the model is aligned with policy, supported by sector stakeholders, and rooted in local practice.

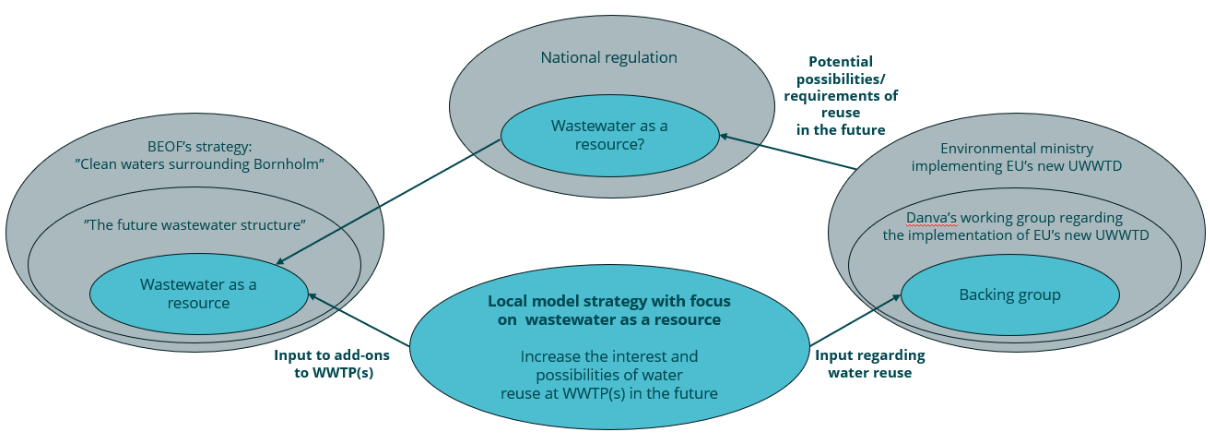


Figure 1 - Multi-stakeholder process

Status on Regulations and Future Plans

The development of a local model strategy for wastewater as a resource must be seen within the context of ongoing regulatory changes at both European and national levels. These frameworks will shape the possibilities and requirements for reuse, as well as the long-term planning of wastewater infrastructure on Bornholm.

The New Urban Wastewater Treatment Directive (UWWTD)

The revised UWWTD represents a significant regulatory milestone. In Denmark, the directive will be fully implemented by 1 July 2027. Importantly, the directive foresees evaluations in 2033 and 2040, during which the European Commission and member states will review the effectiveness of national water reuse plans. This means that the groundwork laid in the coming years will not only influence local implementation but also feed into broader European assessments of progress on water reuse.

New National Regulation on Technical Water

Denmark is introducing new legislation on technical water, which will create the legal framework for establishing dedicated technical water companies. These entities will be authorized to supply water for non-drinking purposes, such as industrial processes, irrigation, and potentially Power-to-X applications. Being Ptx the main driving force behind the regulation. The regulation entered into force in July 2025, providing a clear pathway for utilities like BEOF to expand beyond traditional wastewater treatment roles.

EU Regulation 2020/741 on Minimum Requirements for Water Reuse

Regulation EU 2020/741, which sets minimum requirements for water reuse in agricultural irrigation, is currently on hold in Denmark. While its formal implementation has been delayed, it remains a critical reference point for setting quality standards and operational frameworks. Future decisions will determine whether and how these requirements will be applied in the Danish context.

BEOF's "Future Wastewater Structure"

At the local level, Bornholm Energi & Forsyning (BEOF) is working toward defining the future wastewater structure. A central question is whether Bornholm should move toward centralization of wastewater treatment plants (WWTPs) or maintain a decentralized approach.. During this not yet defined timeline (still in planning phase) an alignment with the EU's evaluation points is expected, creating opportunities to demonstrate Bornholm's role as a model for integrated and resource-oriented wastewater management.

Outlook for Groundwater Sustainability under Climate Change

This section summarizes the key analyses and results from the workshop held by Bornholms Energi og Forsyning (BEOF) and De Nationale Geologiske Undersøgelser for Danmark og Grønland (GEUS) on February 18, 2025, as part of the WaterMan project. The purpose of the workshop was threefold:

- To establish a shared understanding of the limitations and opportunities of the groundwater resource and develop recommendations for future management.
- To gain deeper insight into the development of Bornholm's groundwater resource under future climate conditions, particularly to compare results from the latest water resource assessment (Henriksen et al., 2023) and discuss the selection of water resource indicators in relation to BEOF's operational experience.
- To clarify whether additional model simulations would be necessary to understand the effects of changes in climate and abstraction.

Key Findings on Groundwater Resource and Climate Change

GEUS conducted a study, as part of the WaterMan project, to assess the groundwater availability and outlook in Bornholm. This report can be found in appendix and explains that it is expected that the sustainable groundwater resource will increase under future climate conditions. Current assessments show that the groundwater resource is generally not overexploited. Calculations of the impact on two key indicators—groundwater recharge and streamflow dynamics—were based on ensemble data from HIPdata.dk for the RCP8.5 scenario for the distant future.

GEUS has expressed reservations about the validity of the streamflow dynamics indicator for Bornholm's streams. Overall, climate projections indicate a trend toward wetter conditions for Bornholm, with increased net precipitation, higher groundwater recharge, and greater median streamflow. However, HIPdata for northeastern streams shows lower median minimum flows, suggesting that local streams may respond differently than the general trend toward wetter conditions. Local stream characteristics, which are not captured in the current modelling, remain unaddressed.

Changes in groundwater recharge directly influence the assessment of water resources, while changes in streamflow dynamics support this evaluation. The expected changes in groundwater resources are based on model calculations provided via HIPdata.dk. Both the sustainable water resource assessment and HIPdata.dk calculations use the National Hydrological Model, which for Bornholm is configured in a 100x100 m grid. Although HIPdata.dk does not include scenarios for altered abstraction, the data are considered sufficient to assess trends in sustainable resources, as the current resource is primarily determined by groundwater recharge to aquifers and EQR changes. Both data types point toward an increase in groundwater resources.

Therefore, additional model simulations with abstraction scenarios are not expected to alter this conclusion.

Future sea-level scenarios indicate that Bornholm's coastline will experience a rise of approximately 65 cm under the RCP8.5 scenario in the distant future. A sea-level rise of less than one meter is not expected to cause saltwater intrusion problems for the current abstraction structure, due to the large groundwater gradients toward the coast.

Proposed Goals and Measures

The local model strategy for wastewater as a resource on Bornholm is guided by a set of proposed goals and practical measures. These are designed to increase the feasibility, acceptance, and implementation of water reuse in the coming years, while ensuring that local activities are aligned with both national and European developments.

Increasing the Interest and Possibilities of Wastewater Reuse at WWTPs

A primary goal of the strategy is to enhance both the demand for and the practical capacity of wastewater reuse. This involves several complementary actions:

- Mapping Potential Consumers (Fig. 1): Conduct systematic identification and mapping of potential consumers of reused wastewater, such as farmers, industrial users, and Power-to-X facilities.
- Technical Knowledge: Build an overview and accessible library of treatment technologies for wastewater reuse, covering processes such as filtration, disinfection, reverse osmosis, and advanced oxidation.
- Wastewater Quality: Establish a "data bank" to consolidate existing knowledge and monitoring data on wastewater quality, with particular attention to contaminants of emerging concern (e.g., PFAS, pharmaceuticals, microplastics).
- Regulatory Monitoring: Ensure continuous monitoring of legal and regulatory developments, keeping the strategy aligned with new Danish and EU requirements.

High quality water

Water consumer	Quality	Transportation
Breweries	+++	Pipeline
Dairy company	+++	Pipeline
Fish factories	+++	Pipeline
Laundry	+++	Pipeline
Livestock / farming	+++	Pipeline
Slaughterhouse	+++	Pipeline
Swimming pools	+++	Pipeline
PtX in the future?	+++	Pipeline

Medium quality water

Water consumer	Quality	Transportation
Agricultural irrigation	++	Pipeline
Irrigation parks / trees	++	Tank trailer
Cleaning streets	++	Tank trailer
Irrigation golf clubs	++	Pipeline
Metal industry	++	Pipeline
Concrete factory	++	Pipeline
Car wash	++	Pipeline / tank?
WWTP – internal reuse	++	÷

Low quality water

Water consumer	Quality	Transportation
Sewer inspection and flushing	+	Tank trailer

Figure 2 - Mapping of water consumers and identification of potential consumers of reclaimed water

Increasing Awareness, Interest, and Acceptance

Public and stakeholder awareness is a key enabler of wastewater reuse. To address this, the strategy proposes:

- Workshops and Showcases: Organize events such as *"Wastewater as a Resource"* workshops to highlight local results, and arrange demonstration activities showcasing practical reuse applications.
- Communication Materials: Develop clear, transparent communication explaining the safety, sustainability, and benefits of reuse to different audiences.

Engagement with Authorities and Policymakers

Influencing the regulatory and policy environment requires active engagement:

- Participation in Hearings: Take part in public hearings and consultations on new regulations to ensure that the Bornholm perspective and reuse ambitions are represented.
- Round Table Talks: Invite relevant decision-makers and stakeholders to structured dialogues, such as the *Round Table Talks in Brussels*, to position Bornholm as a frontrunner in wastewater reuse.

Building Networks and Sharing Knowledge

To remain at the forefront, the strategy emphasizes continuous networking and knowledge exchange:

- Networking: Maintain active participation in professional networks at national and European levels to stay updated on innovations and best practices.
- Knowledge Sharing: Disseminate results from the WaterMan project and local Bornholm initiatives to the DANVA backing group that supports the implementation of the new UWWTD. This ensures alignment with national discussions while providing input from practical demonstration projects.

Technical Knowledge – Overview of Technologies for Reuse

A robust technical foundation is essential for advancing wastewater reuse on Bornholm. This section provides an overview of treatment technologies relevant to different reuse objectives, helping stakeholders understand the available options and their applicability.

Treatment Objectives and Processes

Water reuse requires tailored treatment depending on the intended use and quality requirements. The following categories outline the main treatment objectives and associated processes:

1. Removal of Suspended Solids

    - Coagulation
    - Flocculation
    - Sedimentation
    - Media filtration (e.g., sand filters)
    - Microfiltration (MF)
    - Ultrafiltration (UF)

2. Reduction of Dissolved Chemicals

    - Ion exchange
    - Biologically active filtration (BAF)
    - Reverse osmosis (RO)
    - Nanofiltration (NF)
    - Granular activated carbon (GAC)

3. Disinfection

    - Ultraviolet (UV) disinfection
    - Chlorine/chloramines
    - Peracetic acid (PAA)
    - Chlorine dioxide
    - Ozone ((O_3))
    - Nature-based solutions (NbS)

4. Removal of Trace Organic Compounds

    - Ozone
    - Ozone + BAF
    - NF/RO
    - GAC
    - NbS
    - Advanced oxidation processes (AOP)

5. Stabilization

    - Sodium hydroxide
    - Lime stabilization
    - Blending
    - Calcium chloride

6. Aesthetics

- Ozone + BAF
- MF/RO

7. Salinity

- RO
- Ion exchange
- Electrodialysis

These technologies vary in complexity, cost, energy demand, and climate footprint. Selecting the appropriate combination depends on the reuse scenario (e.g., irrigation, PtX, industrial use), local water quality, and regulatory requirements.

Treatment objective	Process	
Removal of suspended solids	• Coagulation • Flocculation • Sedimentation	• Media filtration • Microfiltration (MF) • Ultrafiltration (UF)
Reduce concentrations of dissolved chemicals	• Ion exchange • Biologically active filtration (BAF)	• Reverse osmosis (RO) • Nanofiltration (NF) • Granular activated carbon (GAC)
Disinfection	• Ultraviolet disinfection (UV) • Chlorine/chloramines • Nature based solutions (NbS)	• Peracetic acid (PAA) • Chlorine dioxide • Ozone (O_3)
Removal of trace organic compounds	• O_3 • O_3 + BAF • NF/RO	• GAC • NbS • Advanced oxidation processes (AOP)
Stabilization	• Sodium hydroxide • Lime stabilization	• Calcium chloride • Blending
Aesthetics	• O_3 + BAF	• MF/RO
Salinity	• RO • Ion exchange	• Electrodialysis

Source: US EPA Potable Reuse Compendium, 2017.

Figure 3 - Overview of technologies for reuse (Source: WaterMan – 1st method & tool workshop. Water reuse with focus on risk & life cycle assessment.

Technology Evaluation

A detailed comparative evaluation of these technologies is available in Annex 1, to support decision-making and scenario planning. Focusing on:

1. Energy demand
2. Climate footprint
3. By-products and residuals
4. Operational complexity
5. Cost-effectiveness

Slow Sand Filter Pilot – EnviDan Report Introduction

As part of the WaterMan project, a pilot installation of a slow sand filter was conducted at the Svaneke WWTP to explore low-tech solutions for wastewater polishing. The pilot aimed to assess the feasibility of using treated wastewater for agricultural irrigation, with a focus on reducing nitrogen, phosphorus, and E. coli levels.

An external consultant, EnviDan, has been commissioned to deliver a detailed report on the pilot's performance, findings, and implications. This report will play a key role in shaping the local reuse strategy and informing broader regional and European discussions.

Strategic Integration

The EnviDan report contributes to the strategy in three keyways:

- **Informing Deliverable D2.4 – Local Water Reuse Strategy**
  The pilot's results will be used to validate reuse scenarios, assess treatment effectiveness, and guide future infrastructure planning on Bornholm.

- **Connecting to Deliverable D2.5 – BSR Water Reuse Toolbox**
  Insights from the pilot will be processed into transferable knowledge and practical guidance for other regions in the Baltic Sea area, supporting peer learning and replication.

- **Supporting Scale-Up and Replication**
  The pilot serves as a proof of concept for low-tech reuse solutions. Depending on the findings, similar systems could be deployed at other WWTPs on Bornholm or adapted for use in follower regions.

Summary of Slow Sand Filtration Feasibility Study

(Full report available in Appendix)

As part of the WaterMan project, Bornholm Energi & Forsyning (BEOF) conducted a pilot study to evaluate the use of slow sand filtration (SSF) for polishing effluent from Svaneke Wastewater Treatment Plant (WWTP). The objective was to determine whether SSF could produce water meeting EU Class D reclaimed water standards for agricultural irrigation, particularly microbial requirements.

The pilot system consisted of a 2-meter diameter filter well filled with sand and gravel, operating at a target filtration rate of 0.1 m/h. Despite technical functionality, the filter experienced rapid clogging, requiring frequent cleaning. Wet-harrowing temporarily restored hydraulic capacity, while thorough cleaning (removal of the top layer) was necessary for full recovery. Algae growth and biological activity were observed during warmer months, adding operational complexity.

Microbial removal was generally effective, achieving 90–99.9% reduction in E. coli (1–3 log10), with effluent concentrations below 1,000 cfu/100 ml in most samples. However, performance declined immediately after cleaning, requiring several days for recovery. SSF showed no significant effect on chemical parameters such as COD, phosphorus, ammonium, or nitrate.

Key limitations include:

- Low filtration rates and large land area requirements (approx. 10 m^2 per 1 m^3/h flow).
- Frequent maintenance and cleaning, making full-scale application impractical without influent pre-treatment to reduce TSS to ~1 mg/L.
- Potential operational nuisances such as algae growth and insect breeding.

While SSF can achieve microbial compliance under stable conditions, its economic and operational feasibility for large-scale reuse is doubtful. Future studies should explore pre-treatment options, hydraulic resistance behavior, and alternative polishing technologies such as rapid sand filtration or UV disinfection for consistent microbial control.

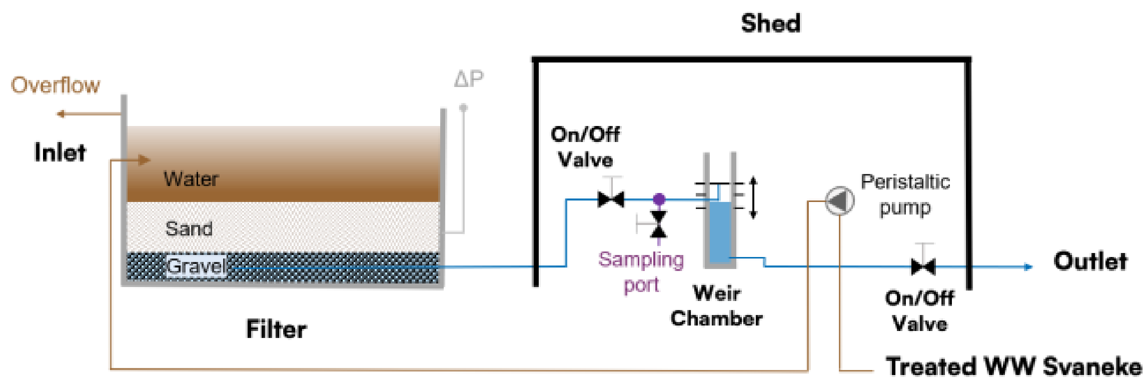


Figure 4 - Process Flow Diagram Slow Sand Filter (SSF)

Figure 5 - Photo of pilot-scale Slow Sand Filter (SSF) installation at Svaneke WWTP.

Potential for Scale-Up or Replication of Slow Sand Filtration on Bornholm

The pilot implementation of slow sand filtration on Bornholm has provided valuable insights into its technical feasibility and operational challenges. While the technology demonstrated strong performance for small-scale applications, its potential for scale-up or replication requires careful consideration of technical, economic, and regulatory factors.

Key Takeaways for Future Implementations

Experience from the pilot indicates that smaller-scale farms can benefit significantly from modular, low-tech filtration systems. Intermittent operation proved preferable to continuous flow, as it helps manage biofilm development and maintain filter efficiency. Thermal insulation emerged as a critical factor for ensuring year-round performance under Bornholm's climate conditions. Furthermore, early involvement of stakeholders—such as farmers' associations—was essential for strengthening policy impact and fostering acceptance. Economic viability must be demonstrated early in the process to support regulatory flexibility and encourage adoption.

If the pilot were to be repeated, influent pre-treatment using a drum filter, real-time monitoring, and automated scraping would be incorporated to improve operational reliability and reduce manual labor. Future pilots aiming for scale-up should also integrate co-measurement of soil moisture and crop yield in collaboration with farmers, with results shared during seasonal workshops to build trust and demonstrate tangible benefits.

Technical Feasibility of Scaling Up

Scaling up slow sand filtration on Bornholm is technically possible but comes with significant limitations. Larger-scale implementation would require extensive land areas and intensive maintenance, which may not be practical for centralized systems. Adaptations for larger-scale operations include increasing filter surface area to handle higher water volumes, introducing automation to reduce manual maintenance, and improving insulation and temperature control for year-round operation. Efficient sludge and Schmutzdecke management systems would also be necessary to maintain performance and minimize downtime.

Financial Viability

Economic analysis suggests that large-scale deployment is not viable under current conditions due to the high volume of water requiring treatment, the substantial land footprint, and increased operational complexity and maintenance costs. Slow sand filtration is better suited for small-scale farms or modular applications with lower water demand, where its simplicity and low energy requirements offer clear advantages.

Transferability and Adaptability

Despite limitations for large-scale use, the technology's modular design allows for flexible adaptation to other regions or systems. It can be applied in rural areas with limited infrastructure, small-scale farms seeking alternative irrigation sources, and municipal or industrial reuse scenarios such as park irrigation, cleaning, or process water. Regions experiencing seasonal water stress, high nutrient runoff, or with an interest in circular water solutions may find slow sand filtration particularly attractive.

Preconditions for Successful Replication

Successful replication requires several preconditions: availability of WWTP effluent with basic treatment, sufficient land for low-flow filtration systems, and strong stakeholder engagement, including farmers, municipalities, and regulators. Monitoring capacity for water quality and system performance is essential, as is regulatory flexibility or pilot-friendly frameworks. Finally, economic feasibility must be demonstrated through clear O&M cost estimates and farmer-friendly operation protocols to ensure long-term adoption.

Technical Knowledge – Library on Technologies for Reuse

To support the development and implementation of wastewater reuse strategies, a curated library of resources has been assembled. This library serves as a reference point for internal use, offering access to relevant treatment technologies and best practices.

Purpose of the Library

The library is designed to:

- Provide clarity on the legal and regulatory frameworks governing water reuse in Denmark and the EU.
- Offer technical guidance on available treatment technologies, including their suitability for different reuse scenarios.
- Support decision-making by consolidating practical examples, feasibility studies, and pilot project outcomes.
- Enable knowledge sharing across regions and sectors, fostering innovation and alignment with EU directives.

Contents of the Library

The library includes:

- Legislation and Policy Documents: EU directives (e.g., UWWTD, 2020/741), Danish national regulations, and technical water legislation.
- Technology Overviews: Descriptions of treatment processes, performance data, and applicability to various reuse cases (e.g., irrigation, PtX, industrial use).
- Case Studies and Pilots: Results from Bornholm's Svaneke pilot and other WaterMan demonstration sites.
- Guidelines and Standards: Quality requirements for reclaimed water, including contaminant thresholds and monitoring protocols.
- Stakeholder Input: Contributions from DANVA, ministries, and working groups involved in shaping reuse policy.

This library is available for internal consultation and will be continuously updated as new data, technologies, and regulations emerge. An overview table is available in Annex 2.

https://www2.mst.dk/Udgiv/publikationer/2021/03/978-87-7038-291-5.pdf Tekniska lösningar för avancerad rening av avloppsvatten Centralized Non-Potable Reuse Resources | US EPA

Figure 6 - Library examples on technological knowledge

Wastewater Quality – Mapping and Risk of Contaminants

Understanding the quality of wastewater and the potential risks associated with contaminants is a critical component of developing a reuse strategy. This section outlines the mapping of wastewater sources and the associated industrial and institutional contributors, as well as the approach to assessing contaminant risks.

Mapping Wastewater Sources

Each wastewater treatment plant (WWTP) on Bornholm receives influent from a variety of sources, including industrial facilities, healthcare institutions, hospitality services, and other specialized operations. A mapping exercise has been conducted to identify the types of contributors for each WWTP, which helps assess the potential contaminant load and treatment needs.

WWTP	Boderne	Melsted	Nexø	Rønne	Svaneke	Tejn	Vestermarie
Industries / factories / hospitals etc.	• Dentist • Heat plants • Retirement home • Anti corrosion workshop • Car workshop • Machine workshop • Undercarriage handling workshop	• Car workshop • Retirement home • Smoke house	• Car workshop • Fish factory • Retirement home • Smoke house	• Brewery • Car wash • Car workshop • Concrete factory • Cruise ships • Dairy company • Dentist • Heat & power plant • Dry cleaner • Fire drill site • Fish factory • Hospital • Landfill • Laundry • Restaurants and hotels • Retirement homes • Slaughterhouse • Smoke house • Steel industry	• Brewery • Heat plants • Dentist • Car workshop • Fish factory • Restaurants • Smoke house	• Blacksmith • Brewery • Car wash • Fire drill site • Restaurants and hotels	÷
Contaminants	Literature study based on categories above						
Contaminants	Overview of data on contaminants monitored in wastewater and waterbodies by national monitoring program						

Figure 7 - Mapping of wastewater quality and risk of contaminants

This mapping includes facilities such as:

- Dentists, hospitals, and retirement homes (potential pharmaceutical and disinfectant residues)
- Car workshops and dry cleaners (solvents, heavy metals, chelating agents, TCE, fats, oils and grease)
- Fish factories and slaughterhouses (organic load, nitrogen, H_2S, fats, oils and grease)
- Breweries and restaurants (organic matter, cleaning agents, fats, oils and grease)
- Cruise ships and fire drill sites (PFAS, heavy metals and varied chemical inputs)

The diversity of contributors across WWTPs like Rønne, Nexø, and Svaneke highlights the need for tailored treatment approaches and monitoring protocols.

Contaminant Risk Assessment

A literature-based categorization of contaminants has been developed based on the types of facilities mapped. This includes:

- Pharmaceuticals and personal care products (PPCPs)
- Heavy metals
- Organic pollutants (for example solvents, PAHs)
- PFAS and other emerging contaminants
- Fats, oils and grease
- H_2S
- Surfactants

In addition, national monitoring programs provide data on contaminants in wastewater and receiving water bodies. This data will be used to:

The mapping and risk assessment will feed into the development of a centralized "data bank" on wastewater quality, supporting both strategic planning and operational decision-making.

Wastewater Quality – Overview of Contaminants Monitored by National Program

Monitoring the quality of wastewater is essential for ensuring safe and sustainable reuse. In Denmark, a national monitoring program provides systematic data on contaminants found in wastewater and receiving water bodies. This data forms the basis for risk assessments, treatment planning, and regulatory compliance.

Purpose of Monitoring

The national program aims to:

- Track the presence and concentration of key pollutants.
- Identify trends and emerging contaminants.
- Support environmental protection and public health.
- Inform reuse strategies and technology selection.

Categories of Contaminants

The monitoring program typically includes:

- Nutrients: Nitrogen, phosphorus
- Organic matter: COD, BOD
- Microbiological indicators: E. coli, coliforms
- Heavy metals: Lead, mercury, cadmium
- Emerging contaminants: PFAS, pharmaceuticals, microplastics
- Physical parameters: Temperature, turbidity, conductivity

Application to Reuse Strategy

This data is critical for:

- Determining the suitability of wastewater for different reuse applications.
- Designing appropriate treatment trains.
- Ensuring compliance with EU and national reuse standards.
- Communicating safety and quality to stakeholders and the public.

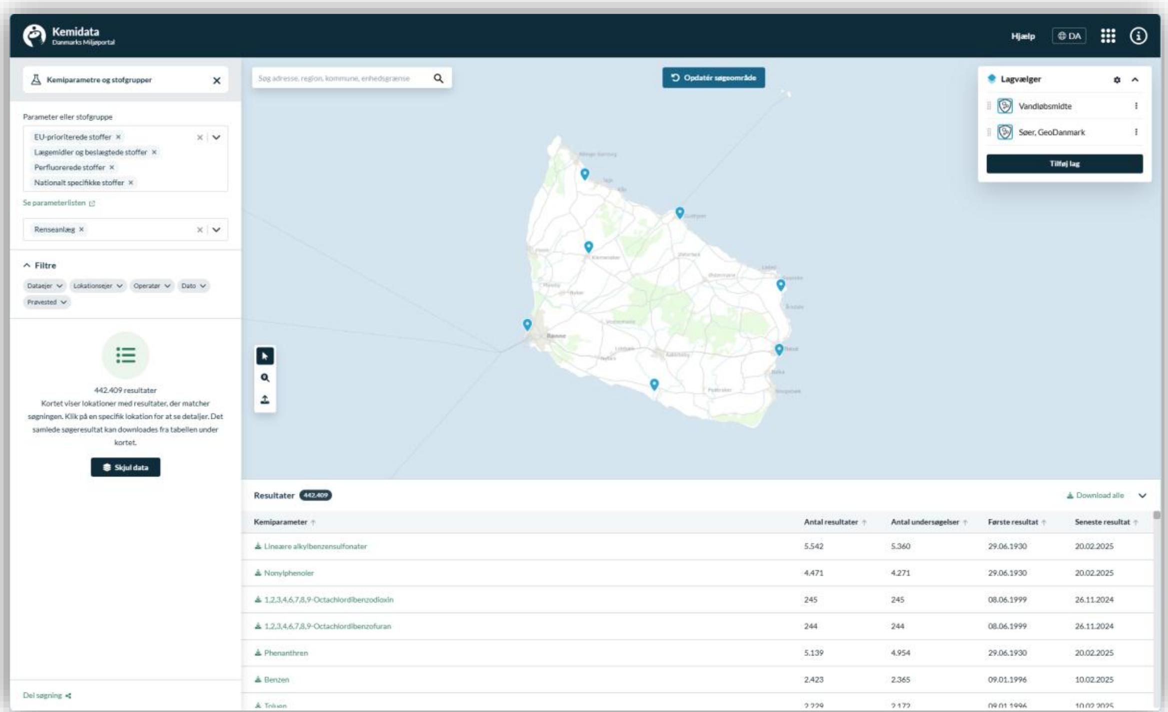


Figure 8 - https://kemidata.miljoeportal.dk/

Figure 9 - Pharmaceuticals @Svaneke WWTP 2011-2016

Wastewater Quality – Overview of Contaminants in Waterbodies / Recipients

An important input for developing a wastewater discharge monitoring program is understanding the quality of the waterbodies that receive treated effluent. This information helps identify which contaminants may be present in the effluent and, consequently, which compounds should be included in the monitoring program. Based on the results of such monitoring for a specific reuse case, reuse strategies can be planned more effectively, including technology selection, risk assessments, and compliance measures.

Purpose of Monitoring Waterbodies

Monitoring contaminants in surrounding waterbodies serves multiple strategic functions. First, it informs the design of monitoring programs by defining scope and frequency based on local conditions. Second, it supports risk assessment by evaluating environmental and health risks associated with water reuse.

Beyond these functions, monitoring is essential to understand whether substances present in surrounding waters could influence wastewater discharge quality. This insight helps utilities identify potential contaminants that may require additional treatment or operational adjustments.

When implementing the "4th treatment step" (*4. rensetrin*), understanding the characteristics of nearby waterbodies becomes critical. These waterbodies may set the performance requirements for advanced treatment processes, which will form the basis for new wastewater treatment plants and underpin future opportunities for water reuse. Although reused water is expected to be discharged primarily on land rather than into waterbodies, the surrounding aquatic environment still plays a key role in defining compliance targets and ensuring sustainable integration of reuse strategies.

Data Sources and Tools

Existing data from national environmental databases, such as the Danish **MiljøGIS** platform (miljoegis.mim.dk), provides spatial and chemical information on water quality across Bornholm. This includes:

- Nutrient levels (N, P)
- Organic pollutants
- Heavy metals
- Microbiological indicators
- Emerging contaminants (e.g., PFAS)

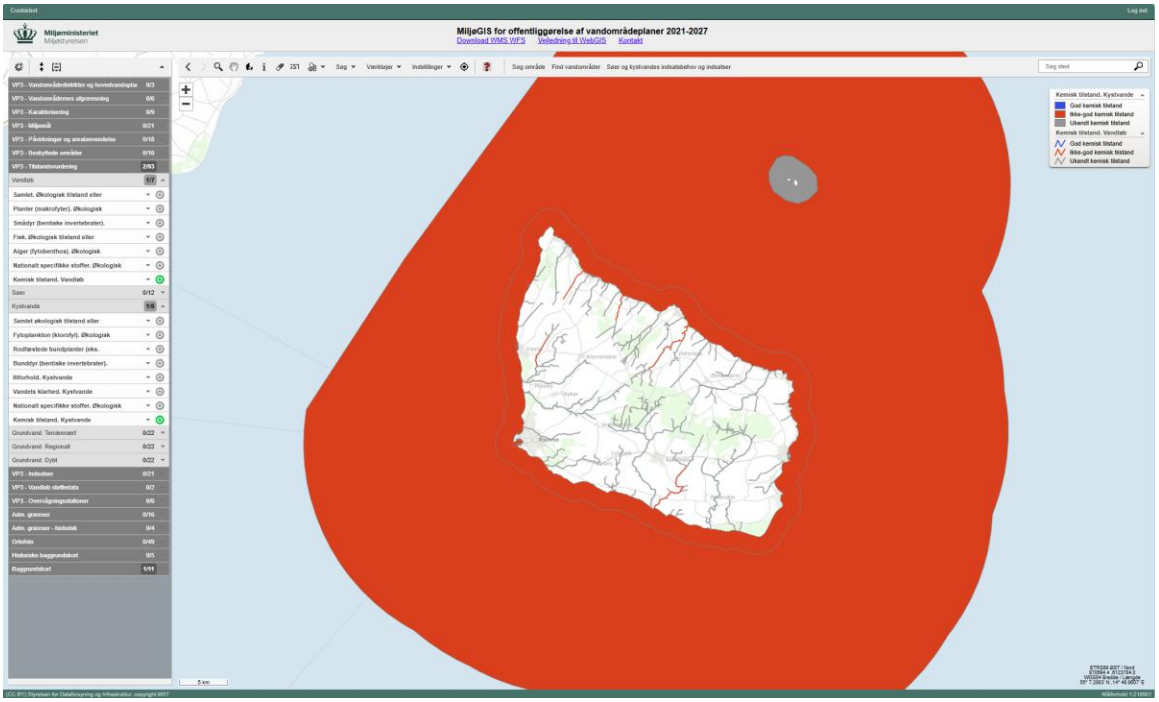


Figure 10 - https://miljoegis.mim.dk/spatialmap?profile=vandrammedirektiv3-2022

These datasets are essential for identifying sensitive areas, setting reuse thresholds, and aligning with EU Water Framework Directive goals.

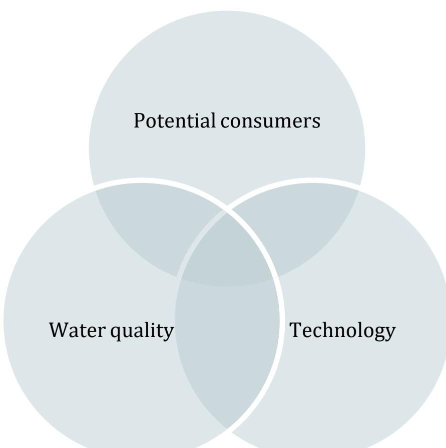


Figure 11 - Framework for Evaluating Water Reuse Opportunities

Increase Awareness, Interest and Acceptance – Workshop Summary

As part of the WaterMan strategy development, a dedicated workshop titled "Wastewater as a Resource" was held on March 20th. The event aimed to foster dialogue, build understanding, and identify practical opportunities for wastewater reuse on Bornholm.

Workshop Participants

The workshop brought together a diverse group of stakeholders, including:

- Local farmers
- Bornholm's Agriculture Association
- Agricultural consultancy firm
- Bornholm's Waste Company
- Bornholm's Municipality
- Danske Bank
- Bornholms Energi & Forsyning (BEOF)

This broad representation ensured that perspectives from agriculture, finance, utilities, and governance were included.

Activities and Focus

Participants visited the Svaneke WWTP and its pilot sand filter installation. The visit served as a live demonstration of low-tech wastewater polishing for potential agricultural reuse.

The workshop focused on:

- Identifying barriers to water reuse
- Envisioning future possibilities
- Highlighting low-hanging fruits
- Outlining necessary first steps

Key Takeaways

- There is genuine interest in using reclaimed water for agricultural irrigation.
- Barriers identified include:
    - Lack of distribution infrastructure
    - Economic concerns (who pays for what)
    - Seasonal limitations (limited use October–March or in wet years)
    - Regulatory hurdles (e.g., use of stormwater/drainage water)
    - Long processing times for environmental permits

These insights will inform the next phases of strategy development, particularly in stakeholder engagement, infrastructure planning, and regulatory alignment.


Showcasing Wastewater Reuse – Awareness and Engagement Activities

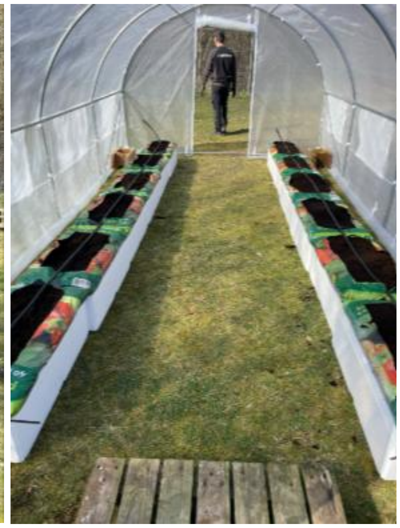
To build public and stakeholder support for wastewater reuse, it is essential to showcase practical applications and create opportunities for direct engagement. One such initiative involves demonstrating reclaimed water use for greenhouse irrigation near the Svaneke WWTP.

International Exposure

On September 24th, the site was visited by participants of the Interreg South Baltic Annual Event. This visit will:

- Showcase Bornholm's pilot to a transnational audience
- Facilitate knowledge exchange with other Baltic Sea Region stakeholders
- Position Bornholm as a model region for circular water solutions

These activities complement the broader WaterMan strategy by turning technical demonstrations into public-facing experiences that foster acceptance and enthusiasm.

Anchor as a Guiding Framework for the Future

To ensure continuity, relevance, and long-term impact, the local model strategy is anchored within two key project groups:

- **"The Future Wastewater Structure"**
- **"Wastewater as a Resource"**

These groups serve as the strategic backbone for the development and implementation of reuse initiatives on Bornholm.

Dynamic Documentation and Continuous Follow-Up

The strategy is supported by dynamic documentation, which is regularly updated to reflect:

- New regulatory developments
- Technological advancements
- Stakeholder feedback
- Pilot project results

This living document ensures that the strategy remains adaptable and responsive to changing conditions.

Regular follow-ups are conducted within the project groups to:

- Review progress and milestones
- Align with broader infrastructure planning
- Integrate new data and feasibility findings
- Coordinate stakeholder engagement and communication efforts

By embedding the strategy in these active project groups, Bornholm ensures that wastewater reuse is not treated as a standalone initiative, but as a **core component** of future water management planning.

Conclusion

Bornholm's local model strategy under WaterMan demonstrates how a small island can lead in sustainable water management. By combining technical innovation, stakeholder collaboration, and regulatory foresight, the strategy transforms wastewater from a liability into a valuable asset.

The approach is scalable, adaptable, and aligned with EU climate and circular economy goals. It provides a blueprint for other regions seeking to integrate water reuse into their infrastructure and policy frameworks.

With continued investment, monitoring, and engagement, Bornholm is well-positioned to become a model region for wastewater reuse — contributing to environmental protection, resource efficiency, and long-term water security.

Annex 1 - Technologies comparative evaluation

Comparative Evaluation Table: Removal of Suspended Solids

Technology	Energy Demand	Climate Footprint	By-products & Residuals	Operational Complexity	Cost-effectiveness
Coagulation	Low	Moderate (due to chemical production)	Sludge with metals and organics	Medium – requires precise dosing and pH control	High – effective and widely used
Flocculation	Low	Low	Sludge similar to coagulation	Medium – requires controlled mixing	High – enhances coagulation efficiency
Sedimentation	Very Low	Low	Settled sludge	Low – passive process	High – simple and cost-effective
Media Filtration	Low	Low	Filter backwash water	Low – mature technology	High – low O&M costs
Microfiltration (MF)	Moderate	Moderate	Membrane fouling, backwash waste	Medium – requires maintenance	Moderate – higher CAPEX
Ultrafiltration (UF)	Moderate to High	Moderate	Similar to MF, with finer particles	High – sensitive to fouling	Moderate – effective but costly
Enzyme-assisted Sand Filtration	Low to Moderate	Low to Moderate (enzyme production footprint)	Organic residues; spent enzymes	Medium – requires enzyme dosing and monitoring	Moderate – improves biofilm control, but adds cost
UV/H_2O_2 (AOP)	High	High (energy-intensive UV lamps + chemical use)	Minimal DBPs[1] if optimized; residual peroxide	High – requires precise control and monitoring	Moderate – excellent for micropollutants but costly

1 - *DBPs stands for Disinfection By-Product.*

Suspended Solids Removal Technologies

Coagulation & Flocculation

These are chemical processes that destabilize and aggregate colloidal particles. They are essential for removing fine particles that sedimentation alone cannot handle.

- **Pros**: Effective for turbidity and organic matter; enhances downstream processes.
- **Cons**: Generates significant sludge; requires chemical dosing and monitoring.

Sedimentation

A gravity-based process that removes heavier particles after coagulation/flocculation.

- **Pros**: Simple, low energy, and cost-effective.
- **Cons**: Limited to particles with sufficient mass; large footprint.

Media Filtration

Uses sand or gravel to remove remaining suspended solids.

- **Pros**: Low energy and operational costs; effective for polishing.
- **Cons**: Requires periodic backwashing; limited for very fine particles.

Microfiltration (MF)

Membrane-based filtration for bacteria and suspended solids.

- **Pros**: High removal efficiency; compact footprint.
- **Cons**: Moderate energy use; membrane fouling; backwash waste.

Ultrafiltration (UF)

Similar to MF but with smaller pore sizes, removing viruses and macromolecules.

- **Pros**: Superior contaminant removal; useful for reuse applications.
- **Cons**: Higher energy demand; sensitive to fouling; costly.

Enzyme-Assisted Sand Filtration

Pros:

- Enhances biological activity and accelerates organic matter breakdown, reducing clogging.

- Extends cleaning intervals compared to conventional slow sand filtration.
- Improves microbial removal efficiency when combined with natural processes.
- Low to moderate energy demand; suitable for decentralized or small-scale applications.

Cons:

- Requires careful enzyme dosing and monitoring to maintain effectiveness.
- Adds chemical and operational complexity compared to traditional sand filters.
- Potential cost increase due to enzyme procurement and handling.
- Limited long-term data on large-scale performance and stability.

UV/H_2O_2 (Advanced Oxidation Process)

Pros:

- Highly effective for removing micropollutants and pathogens, including resistant organisms.
- Provides an additional oxidation barrier, improving overall water safety.
- No formation of persistent harmful by-products when optimized.
- Compact footprint compared to multi-barrier physical systems.

Cons:

- High energy consumption due to UV lamps and chemical dosing.
- Requires precise control of peroxide concentration to avoid residuals.
- Higher operational complexity and need for skilled operators.
- Costly for large-scale applications; better suited for high-value reuse scenarios.

Comparative Evaluation Table: Reduction of Dissolved Chemicals

Technology	Energy Demand	Climate Footprint	By-products & Residuals	Operational Complexity	Cost-effectiveness
Ion Exchange	Low	Low to Moderate (chemical regeneration)	Brine waste from resin regeneration	Medium – requires resin management and regeneration	High for hardness and specific ions; less effective for broad contaminants
BAF	Low	Low (biological process)	Sloughed biofilm and spent media	High – sensitive to temperature, nutrients, and requires monitoring	Moderate – good for organics and DBP precursors but needs capital investment
RO	High (up to 3–6 kWh/m³ for seawater)	Moderate to High (energy-intensive)	Concentrated brine with salts and organics	High – complex pretreatment and fouling control	Moderate – excellent removal but costly CAPEX/OPEX
NF	Moderate (lower than RO)	Moderate	Concentrated brine similar to RO	High – similar fouling issues as RO	Moderate – good for hardness and organics, less for salts
GAC	Low	Low (passive adsorption)	Spent carbon requiring regeneration or disposal	Medium – periodic media replacement	High for organics and taste/odor control

Summary: Dissolved Chemical Removal Technologies

Ion Exchange

- Pros: Highly effective for hardness and specific ions (e.g., nitrate, heavy metals); low energy demand.
- Cons: Generates brine waste; requires frequent regeneration; not effective for organics or pathogens.

Biologically Active Filtration (BAF)

- Pros: Removes organics, DBP precursors, and improves water stability; low energy footprint.
- Cons: Operationally complex; sensitive to seasonal changes; requires skilled operators.

Reverse Osmosis (RO)

- Pros: Broad-spectrum removal (salts, organics, micropollutants); essential for ultrapure water.
- Cons: High energy demand; significant brine disposal challenges; expensive infrastructure.

Nanofiltration (NF)

- Pros: Lower energy than RO; good for hardness and organics; partial salt removal.
- Cons: Still produces brine; fouling risk; less effective for full desalination.

Granular Activated Carbon (GAC)

- Pros: Excellent for taste, odor, and organic removal; low energy and simple operation.
- Cons: Limited for inorganic contaminants; spent carbon disposal/regeneration needed.

Comparative Evaluation Table: Disinfection

Technology	Energy Demand	Climate Footprint	By-products & Residuals	Operational Complexity	Cost-effectiveness
UV	Low to Moderate (lamp power)	Low (chemical-free)	None; no DBPs	Medium – requires lamp cleaning and monitoring	Moderate – higher CAPEX, low OPEX
Chlorine/Chloramines	Low	Moderate (chemical production & DBPs)	THMs, HAAs; residual chlorine	Low – mature technology, but chemical handling required	High – low CAPEX and scalable
Ozone (O_3)	High (electricity for generation)	High (energy-intensive)	Bromate, aldehydes; corrosive water	High – complex equipment and safety protocols	Moderate – effective but costly
Peracetic Acid (PAA)	Low	Low (decomposes to water, oxygen, acetic acid)	Minimal; no persistent chemicals	Medium – dosing control required	Moderate – growing adoption for sustainability
Chlorine Dioxide (ClO_2)	Moderate	Moderate (chemical synthesis)	Chlorite, chlorate by-products	High – on-site generation and monitoring needed	Moderate – effective for taste/odor and pathogens

Summary: Disinfection Technologies

Ultraviolet (UV)

- Pros: Chemical-free; no DBPs; effective against chlorine-resistant pathogens (e.g., Cryptosporidium).
- Cons: No residual protection; requires electricity and lamp maintenance; higher initial cost

Chlorine/Chloramines

- Pros: Residual protection; proven effectiveness; low cost and scalable.
- Cons: DBP formation (THMs, HAAs); taste/odor issues; chemical handling risks.

Ozone (O_3)

- Pros: Strong oxidizer; effective against viruses and bacteria; no residual chlorine.
- Cons: High energy demand; bromate formation; expensive equipment.

Peracetic Acid (PAA)

- Pros: Rapid pathogen inactivation; decomposes into harmless compounds; minimal DBPs.
- Cons: Requires careful dosing; less common in large-scale systems.

Chlorine Dioxide (ClO_2)

- Pros: Effective for taste/odor control; strong disinfectant.
- Cons: Produces chlorite/chlorate; requires on-site generation and monitoring.

Comparative Evaluation Table: Removal of Trace Organic Compounds

Technology	Energy Demand	Climate Footprint	By-products & Residuals	Operational Complexity	Cost-effectiveness
O_3 + BAF	Moderate (ozone generation + pumping)	Moderate (electricity for ozone)	Bromate, NDMA (controlled with process optimization)	High – requires ozone system, biofilter acclimation	Moderate – effective for organics, but higher CAPEX than GAC
GAC	Low	Low (passive adsorption)	Spent carbon requiring regeneration/disposal	Medium – periodic media replacement	High – proven, widely used for organics and DBPs
AOP (UV/H_2O_2 or UV/Cl)	High (UV lamps + chemical dosing)	High (energy-intensive)	Minimal DBPs if optimized; residual peroxide or chlorine	High – requires precise control and monitoring	Moderate – excellent for micropollutants but costly
NF	Moderate (lower than RO)	Moderate	Concentrated brine with organics	High – fouling control and pretreatment needed	Moderate – good for NOM and DBP precursors
RO	High (up to 0.84 kWh/m^3 for municipal reuse)	High (energy-intensive)	Brine with salts and organics; disposal challenges	Very High – complex pretreatment and brine management	Moderate – excellent removal but expensive

Summary: Trace Organic Removal Technologies

Ozone + Biologically Active Filtration (O_3 + BAF)

- **Pros**: Effective for a wide range of organics and emerging contaminants; improves downstream UV/AOP performance; reduces membrane fouling[^turn5search55^].
- **Cons**: Bromate and NDMA formation risk; requires acclimation and skilled operation; moderate energy demand[^turn5search62^].

Granular Activated Carbon (GAC)

- **Pros**: Proven technology; high removal efficiency for organics, taste, odor, and DBP precursors; low energy footprint[^turn5search51^].
- **Cons**: Media replacement/regeneration needed; performance declines with competing contaminants[^turn5search53^].

Advanced Oxidation Processes (AOP)

- **Pros**: Excellent for micropollutants and refractory organics; strong oxidation barrier[^turn5search55^].
- **Cons**: High energy and chemical demand; operational complexity; residual peroxide/chlorine management[^turn5search55^].

Nanofiltration (NF)

- **Pros**: Removes NOM and DBP precursors; lower energy than RO; compact footprint[^turn5search54^].
- **Cons**: Produces brine; fouling risk; less effective for full desalination[^turn5search54^].

Reverse Osmosis (RO)

- **Pros**: Broad-spectrum removal including salts, organics, and micropollutants; essential for ultrapure water[^turn5search50^].
- **Cons**: High energy demand; brine disposal challenges; expensive infrastructure[^turn5search60^].

Comparative Evaluation Table: Stabilization

Technology	Energy Demand	Climate Footprint	By-products & Residuals	Operational Complexity	Cost-effectiveness
Sodium Hydroxide	Low (simple dosing)	Moderate (chemical production impact)	Sludge with precipitated salts; caustic residues	Medium – requires safe handling and corrosion control	High for pH adjustment; widely available
Lime Stabilization	Moderate (lime calcination energy-intensive)	High (CO_2 emissions from calcination)	Carbonate sludge; gypsum if sulfate present	Medium – requires mixing, curing, and dust control	Moderate – effective but higher material cost
Calcium Chloride	Low	Moderate (chloride production footprint)	Chloride-rich residuals; potential soil salinity issues	Medium – dosing control and corrosion risk	Moderate – good for dust control and hardness adjustment
Blending	Very Low (mechanical mixing)	Low (no chemical footprint)	None beyond mixed water streams	Low – simple process	High – cheapest option when compatible sources exist

Summary: Stabilization Technologies

Sodium Hydroxide

- **Pros**: Rapid pH adjustment; effective for corrosion control; widely available.
- **Cons**: Caustic handling risks; generates alkaline sludge; moderate climate footprint due to chemical manufacturing.

Lime Stabilization

- **Pros**: Improves water stability; disinfects sludge; widely used in wastewater treatment.
- **Cons**: High CO_2 emissions from lime production; dust and odor issues; requires curing time.

Calcium Chloride

- **Pros**: Effective for hardness adjustment and dust suppression; low energy demand.
- **Cons**: Adds chloride to water; corrosion risk; environmental concerns for soil and aquatic systems.

Blending

- **Pros**: Extremely low energy and cost; no chemical footprint; simple operation.
- **Cons**: Limited applicability; requires compatible water sources; does not address contaminants.

Comparative Evaluation Table: Aesthetics

Technology	Energy Demand	Climate Footprint	By-products & Residuals	Operational Complexity	Cost-effectiveness
O_3 + BAF	Moderate (ozone generation + pumping)	Moderate (electricity for ozone)	Bromate formation risk; biofilm sloughing	High – requires ozone system and biofilter management	Moderate – effective for taste/odor but higher CAPEX
MF/RO	MF: Moderate; RO: High	MF: Moderate; RO: High (energy-intensive)	Membrane fouling residues; brine for RO	High – pretreatment and maintenance critical	MF: Moderate; RO: Low for aesthetics-only applications

Summary: Aesthetics Technologies

Ozone + BAF

- **Pros**: Excellent for taste and odor control; also removes organics and improves biological stability.
- **Cons**: Bromate formation risk; requires skilled operation and acclimation; moderate energy demand.

MF/RO

- **Pros**: Improves clarity and removes fine particles; RO also removes salts and organics.
- **Cons**: High energy for RO; fouling risk; costly for aesthetics-only purposes.

Comparative Evaluation Table: Salinity

Technology	Energy Demand	Climate Footprint	By-products & Residuals	Operational Complexity	Cost-effectiveness
RO	High (0.84–3.6 kWh/m³ depending on feedwater)	High (energy-intensive)	Concentrated brine with salts and organics	Very High – pretreatment, fouling control, brine disposal	Moderate – effective but costly for large-scale desalination
Ion Exchange	Low	Moderate (chemical regeneration footprint)	Brine waste from resin regeneration	Medium – requires resin management and chemical handling	High for hardness and selective ion removal; not suitable for full desalination
Electrodialysis (ED)	Moderate (lower than RO for brackish water)	Moderate (electricity-driven process)	Concentrated brine similar to RO	High – requires membrane stack maintenance and scaling control	Moderate – competitive for brackish water; less for seawater

Summary: Salinity Technologies

Reverse Osmosis (RO)

- **Pros**: Most effective for desalination; removes salts and organics; widely adopted for potable reuse.
- **Cons**: High energy demand; brine disposal challenges; expensive infrastructure.

Ion Exchange

- **Pros**: Low energy; effective for hardness and selective ions; simple operation for small-scale systems.
- **Cons**: Not suitable for full desalination; generates brine waste; chemical handling required.

Electrodialysis (ED)

- **Pros**: Lower energy than RO for brackish water; modular design; selective ion removal.
- **Cons**: Scaling and fouling risks; brine disposal; less effective for seawater.

Annex 2 – Tech Library

Table 1 - Tech library

Name	Resource (author, type, etc.)	Description
Analytics and plant documentation for targeted micropollutant removal methods	Work report from the DWA Technical Committee KA-8. PDF file.	Recommendations for a systematized comparison of processes in terms of micropollutant removal, by-products and disinfection.
Removing wastewater from domestic sewage: Insights from seven years of testing the cleaning effect	Article (Aqua & GAS n1 2024). PDF file.	The concept for verifying the cleaning effect and the 12 key substances have proven effective in practice. It allows for a certain degree of flexibility in substance selection, which the authorities utilize. The specific substances included in the calculation significantly impact the cleaning effect.
MV - STAGE-STABLE OPERATION HELPFUL OPERATING PARAMETERS	Article (Aqua & GAS n1 2024). PDF file.	The cleaning effect for micropollutants is determined by ARA through periodic measurements of the indicator substances. For daily operation, timely statements regarding cleaning performance can also be made based on UV measurements and the dosed amounts of ozone or activated carbon.
Guideline for advanced API removal - Optimization and control of advanced treatment	CWPharma (12/2020). Report, pdf file.	The overall aim of the “Clear Waters from Pharmaceuticals” (CWPharma) project is to provide guidance on how to reduce the load of active pharmaceutical ingredients (APIs) entering the aquatic environment and especially the Baltic Sea. Even though different methods for reducing the amount of APIs entering the wastewater exist1, 2 , API usage cannot be completely avoided and, thus, “end-of-pipe” measures are also necessary.
Mapping of purification technologies.	Environmental ministry - Miljøministeriet report. PDF file.	For targeted wastewater treatment for metals and environmentally hazardous substances in central treatment plants
Centralized Non-Potable Reuse Resources	EPA. Web page.	Centralized non-potable reuse is when water derived offsite, such as from a community wastewater treatment plant, is appropriately treated and reused for non-potable applications. Applications can include fire protection, commercial

		laundries, vehicle washing, street cleaning, snowmaking, dust control, soil compaction, and other similar uses.
Technical solutions for advanced wastewater treatment	IVL (Svenska Miljoinstitutet). Report, pdf file.	This report, produced by IVL Swedish Environmental Institute, forms the basis for two government assignments for which the Swedish Environmental Protection Agency is responsible: 1) Assignment to investigate the conditions for the use of advanced purification in order to separate pharmaceutical residues from wastewater in order to protect the aquatic environment, including among other things, describing technical solutions and analyzing their advantages and disadvantages. 2) Assignment to identify and propose measures against emissions of microplastics into the sea from major sources in Sweden, including, among other things, reporting on the state of research and best possible purification technology
Innovation partnership strengthens the fight for a clean water environment	Report pdf file. Danish technological institute.	The Innovation Partnership for Environmentally Hazardous Substances has been a gathering point for utilities, authorities, companies and experts who have worked together to strengthen knowledge sharing, technology development and implementation of solutions. Through a series of workshops, the partnership has mapped challenges and opportunities and compiled the industry's experiences in a technology catalogue. The catalogue provides a comprehensive overview of existing and new technologies for handling environmentally hazardous substances and points to where the industry can and should develop in the future.
Advanced wastewater treatment for the removal of pharmaceutical residues and other unwanted substances.	Report pdf file. Naturvårdsverket 2017	Needs, technology and consequences
Working paper Trace substance elimination at municipal wastewater treatment plants in Baden-Württemberg	Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg 2018. Report, pdf file.	The state of Baden-Württemberg intends to advance the expansion of wastewater treatment plants with trace substance removal as a precautionary measure, based on consensus. The following section specifies the technical criteria for prioritizing further expansion,

		defines the requirements for the plants' removal capacity, and provides guidance on legal implementation.
Influence of operational conditions and wastewater properties on the removal of organic micropollutants through ozonation	Research article. Journal of Environmental Management, M. Ekblad et al.. PDF file.	The objective of this study was to evaluate the influence of operational conditions and wastewater properties on the removal of pharmaceuticals, contrast media and antibiotics through ozonation, in order to facilitate the optimization of treatment and its implementation on a full scale. Pilot-scale ozone oxidation trials were performed on treated wastewater, before and after post-precipitation, over a seven-month period, including summer and winter months. Hydraulic retention times as short as 7 min were found to be sufficient for organic micropollutant removal. A short hydraulic retention time reduces both investment costs and land use. Neither the choice of ozone dispersion method, a static mixer or a Venturi injector, nor the wastewater temperature had any significant effect on the removal efficiency of organic micropollutants, however, higher removal was achieved after on-site post-precipitation with aluminum chloride.
Future wastewater treatment	Report Danish Technological Institute 2023 pdf.	
Recycled wastewater for industrial use and irrigation	Svenskt Vatten Utveckling 2019. Report. Pdf.	Does reclaimed water for industrial use need to be specialized or could wastewater utilities provide a water quality that fits many needs? This report shows that the needs in industry are general. Large quantities of water are used for the same applications which require similar water quality. This opens up an opportunity for wastewater treatment plants to provide a basic water quality for industrial use and irrigation.
COST-EFFECTIVE REDUCTION OF MICROPOLLUTANT AT CENTRAL TREATMENT PLANTS	SUEZ, 2023. PPT file.	Theme day micropollutants
A review on sustainable technologies for pharmaceutical elimination in wastewaters — A ubiquitous problem of modern society	Journal of molecular liquids (Sanja Radovic et al, 2023). Article.	The ever-growing consumption of pharmaceuticals (PhCs) and their constant occurrence in wastewater treatment plant (WWTP) effluents requires investigation of efficient, sustainable and economically feasible solutions for their removal.

WORKSHOP about the 4th treatment step	Powerpoint, pdf file. Teknologisk Institut. 2024	Fertile ground for environmental technology development in and across industries through workshops. Specific focus on solutions to reduce release of environmentally hazardous pollutants (MFS) to the environment. Identify targeted interventions for selected aquatic environments.
Sustainable treatment systems for removal of pharmaceutical residues and other priority persistent substances	Paper. National Library of Medicine (C. Baresel et al., 2019)	This paper provides the results from a large 3-year project about the evaluation of sustainable treatment systems for removal of various micropollutants or disruptive effects at Swedish WWTPs and their environmental, economic and future sustainability. The presented results are based on our own pilot tests and related assessment and modelling efforts and provide a holistic view on advanced treatment of wastewater for removal of micropollutants.
Percrystallization: The water purification of the future	WaterTech 2025. Article, online.	Water is an increasingly critical issue. Whether it is about securing the industry of the future, such as water for hydrogen, ammonia or computer chips, or whether it is about removing microplastics, fertilizers or PFAS that pollute Denmark's waterways and groundwater, water plays a central role. It is a key to the society of the future.
Technical water saves drinking water – and just over half a million kroner a year	Ingeniøren, 2024. Online article.	It only requires an exemption from the executive order on sewer work and weekly salt replenishment. Fredericia Wastewater and Energy can then use extra purified wastewater for, among other things, sludge suction and cleaning.
Reuse of purified wastewater	Report 2022. SvensktVatten.	Potential after purification with a membrane bioreactor followed by granular activated carbon.
Guidelines for the safe use of wastewater, excreta and greywater – volume 4	WHO 2013. Report.	Volume 4 of the Guidelines for the safe use of wastewater, excreta and greywater provides information on the assessment and management of risks associated with microbial hazards. It explains requirements to promote the safe use of excreta and greywater in agriculture, including minimum procedures and specific health-based targets, and how those requirements are intended to be used. This volume also describes the approaches used in deriving the guidelines, including health-based targets, and includes a substantive revision of approaches to ensuring

		microbial safety.
Waste Water treatment and reuse in the mediterranean region	The handbook of Environmental chemistry. Springer. Volume 14.	
Water reuse A solution for a more resilient Europe	JRC Water Reuse 2017. Online article. Available for download.	Reclaimed water: a safe source for agricultural irrigation. The JRC is leading the way in reusing treated wastewater for agriculture Water is crucial for agriculture and industry, but with climate change and rising demand, resources are depleting; repurposing treated wastewater for farming is one solution. JRC research shows reusing water could cover 10% of agricultural water needs, reducing overall water consumption. JRC has also established water quality standard for recycled water and is working with businesses and policymakers to ensure a safe and continuous water supply.
Technical guidance - water reuse risk management for agricultural irrigation schemes in Europe	JRC 2022 technical report. Maffettone Roberta; Gawlik Bernd.	This report provides guidance for the establishment of the Risk Management Plan as stated in Article 5 of the Water Reuse Regulation 2020/741. It ensures technical assistance in the implementation of the key elements of risk management set out in Annex II of the regulation. In addition an overview of the current EU progress on water reuse in the European Union, of the Water Reuse Regulations and the principal approaches and guidelines for risk management in water reuse system is shown.
Joint Webinar: Experiences on reusing wastewater for industrial applications	APE co-organised with the European Commission's Joint Research Centre 2024. Online article. Download available.	The workshop provided an opportunity to hear experiences on water reuse for industry from SMAT (Italy), Uisce Éireann (Ireland), Kalundborg Forsyning (Denmark), and Hydria (Belgium). The focus was on innovative approaches to reusing wastewater in industrial processes, with real-world case studies.
Water Europe – Technologies and others catalogue	Water Europe, Web platform.	Search platform.

The „BSR Water Recycling Toolbox" was elaborated as part of the WaterMan project, which is co-financed by the European Union (European Regional Development Fund) and implemented within the Interreg Baltic Sea Region Programme. More information:

eurobalt.org/WaterRecyclingToolbox
interreg-baltic.eu/project/waterman

WaterMan promotes a Baltic Sea Region-specific approach to water recycling, which makes use of the alternation of too much and too little water that has become typical for humid areas in the EU to strengthen the resilience of local water supply. Building on this approach, the project supports municipalities and water companies in adapting their water supply strategies.

The contents of „BSR Water Recycling Toolbox" are the sole responsibility of the authors and can in no way be taken to reflect the views of the European Union, the Managing Authority or the Joint Secretariat of the Interreg Baltic Sea Region Programme.

Interreg Baltic Sea Region

Co-funded by the European Union

SUSTAINABLE WATERS
WaterMan