Interreg Baltic Sea Region

Co-funded by the European Union

BORNHOLMS ENERGI & FORSYNING

SUSTAINABLE WATERS WaterMan

The WaterMan project
Feasibility study on reuse of WWTP water for hydrogen electrolysis power plant on Bornholm

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Final concept, 31 Dec 2025

The Challenge

➢ What was the problem / need / opportunity?

Bornholm is preparing for a potential large-scale hydrogen production via PtX, powered by offshore wind. However, PtX electrolysis requires **ultrapure water**, and Bornholm lacks sufficient centralized water resources. The challenge is to identify a **sustainable, cost-effective, and scalable water source** for PtX.

➢ Who / what is affected and in what way?

- **BEOF & Bornholm Municipality**: Need to ensure water supply without compromising drinking water or wastewater services.
- **PtX Developers**: Require reliable, high-quality water for electrolysis.
- **Local Environment**: Risk of brine discharge and nutrient pollution if not properly managed.
- **Regulators**: Must balance innovation with environmental protection and legal compliance.

➢ Underlying causes

- **Systemic**: Danish water sector regulation limits the scope of existing utilities; PtX water supply requires a new company structure.
- **Environmental**: Climate change and seasonal droughts reduce available freshwater; brine disposal poses ecological risks.
- **Technical**: Electrolysis demands ultrapure water; seawater desalination is energy-intensive and costly.

Note: the solution must consider multiple customers beyond PtX to reduce dependency.

Objectives

➢ **What does the feasibility study aim to assess?**

To evaluate the **technical, economic, environmental, and regulatory feasibility** of supplying ultrapure water for hydrogen electrolysis on Bornholm using **treated wastewater** and **brackish Baltic Sea water**.

➢ **Areas of Viability Assessed**

- **Technical Viability**: Water quality requirements for PEM, alkaline, and SOEC electrolysers; treatment technologies; infrastructure needs.
- **Economic Viability**: CAPEX, OPEX, TOTEX, cost per m^3 of ultrapure water, economies of scale.
- **Environmental Impact**: LCA comparing wastewater vs. seawater; brine management; eutrophication risks.
- **Social / Political Acceptability**: Regulatory compliance under Danish Water Sector Act; stakeholder engagement; risk analysis.

➢ **Technologies and Approaches Considered**

- **Water Treatment**:
  - UF, UV, RO, Electrodeionization
  - High-recovery RO
- **Electrolysis Technologies**:
  - PEM, Alkaline, AEM, SOEC
  - Thermal techniques (HTSE, thermochemical cycles)
- **Energy Integration**:
  - Use of excess heat for district heating and industrial processes
- **Regulatory Models**:
  - Establishing a dedicated drinking water company for PtX

Context / Background

➢ Why this location / site?

- **Bornholm** is designated as Denmark's **Energy Island** in the Baltic Sea, with planned offshore wind capacity of **3 GW** and potential overplanting of **0.6–0.8 GW**.
- The island offers proximity to **renewable energy infrastructure**, a **transformer station**, and potential industrial zones for PtX development.
- **Rønne WWTP** is strategically located near the proposed energy park, making it ideal for water reuse.

➢ Policy / Industry Background

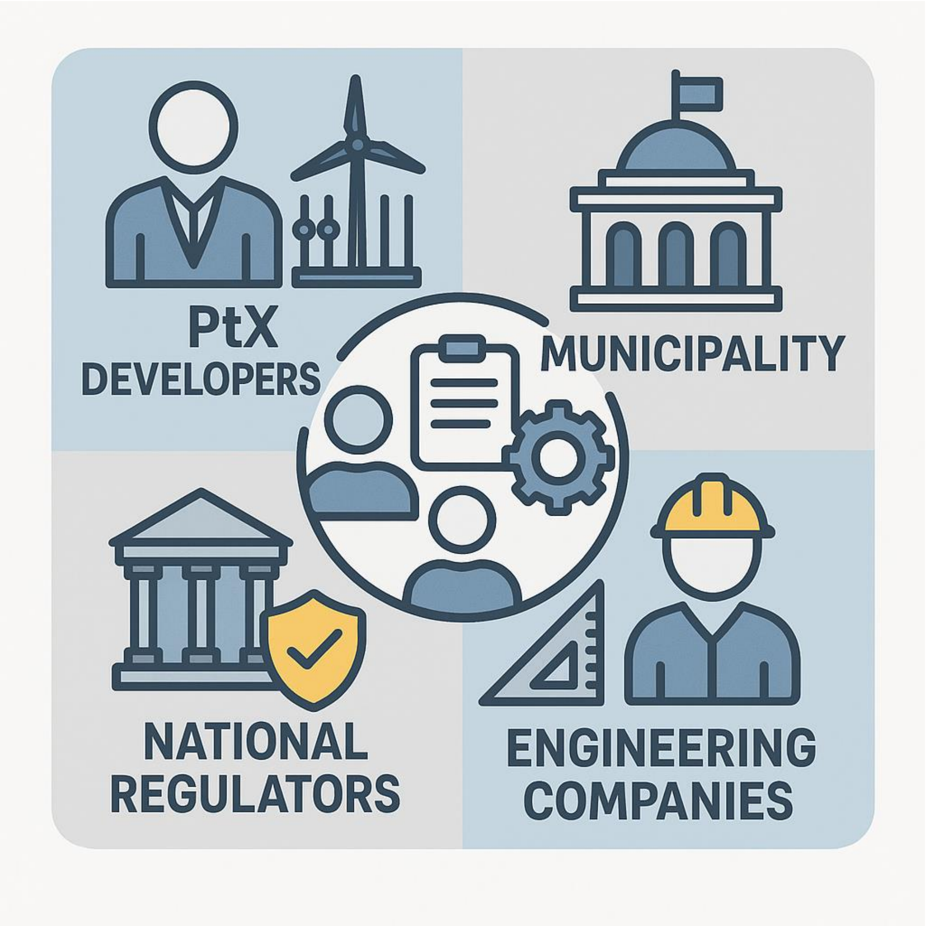
- Denmark's national strategy supports **Power-to-X** as a key pillar in the green transition.
- EU and Danish regulations (VEII, VEIII, Wastewater Directive recast) are evolving to support **renewable energy deployment** and **technical water supply**.
- Industry interest is growing, with many **PtX projects** announced in Denmark.

➢ Conditions

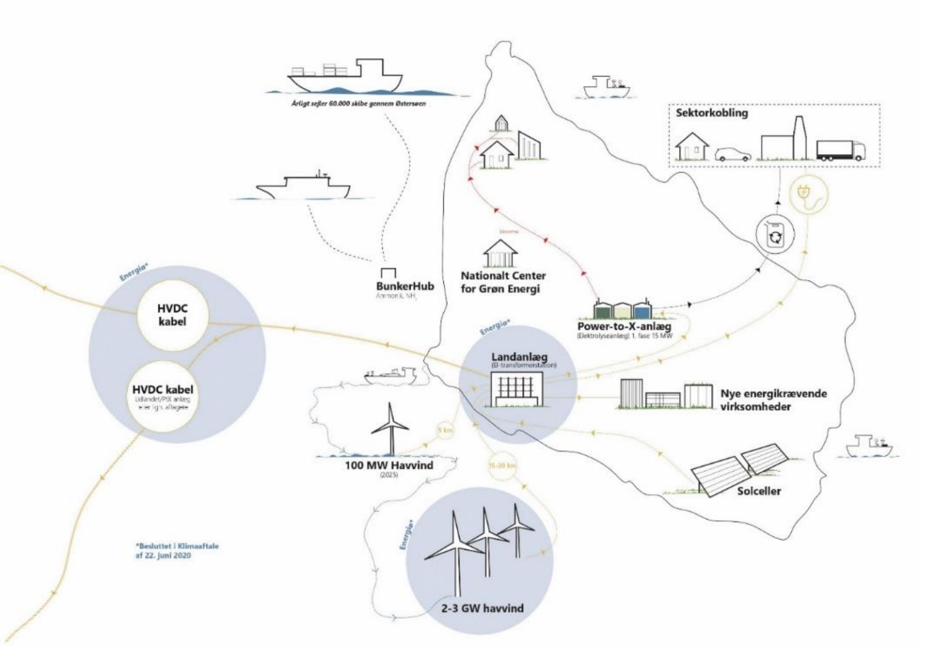
- **Economic**: Rising demand for hydrogen; cost pressures on water supply; need for CAPEX/OPEX optimization.
- **Environmental**: Climate change impacts on water availability; brine discharge risks; nutrient pollution concerns.
- **Institutional**: Danish Water Sector Act requires a **separate drinking water company** for PtX water supply.
- **Socio-Political**: Strong local and national support for green innovation; need for stakeholder alignment and regulatory engagement.

Stakeholders

- **Who was involved in the study or consulted?**
  - **Bornholms Energi og Forsyning (BEOF)** – Lead organization conducting the feasibility study.
  - **EnviDan** – Provided pilot data on slow sand filtration.
  - **NIRAS** – Technical and economic consulting, including CAPEX/OPEX and regulatory analysis.
  - **EUROWATER** – Input on water treatment technologies and brackish water feasibility.
  - **DANVA** – Provided regulatory insights and feedback on technical water supply models.
  - **KWB** – conducted LCA
- **Who would be critical for future implementation if recommended?**
  - **BEOF Subsidiaries** – Bornholms Vand A/S and Bornholms Spildevand A/S for infrastructure integration.
  - **Bornholm Municipality (BRK)** – Local planning, permitting, and stakeholder coordination.
  - **PtX Developers** – Private companies investing in hydrogen production.
  - **Danish Environmental Protection Agency** – Permits for discharge and environmental compliance.
  - **Danish Competition and Consumer Authority** – Oversight of water sector regulation and revenue caps.
- **Institutional Landscape**
  - **Potential Implementers**:
    - BEOF (via a new drinking water company)
    - PtX plant operators
  - **Funders**:
    - National green transition funds
    - Private PtX investors
  - **Regulators**:
    - Danish Energy Agency (Energistyrelsen)
    - Danish Water Sector Secretariat
    - Ministry of Environment



The Concept



➢ What solution / measure was evaluated?

The study evaluated the **reuse of treated wastewater** from Bornholm's WWTPs—primarily Rønne WWTP—as a **source of feed water for hydrogen electrolysis** in a PtX plant. The concept includes:

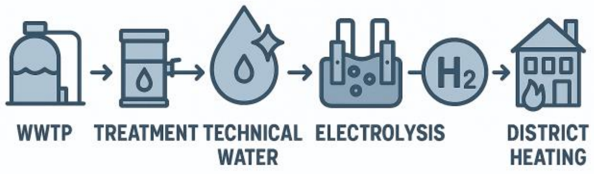
- Treating WWTP effluent to RO water quality.
- Supplying technical water via a **dedicated drinking water company**.
- Integrating the PtX plant with **district heating** and **resource recovery** systems.

➢ Has it been used elsewhere?

Yes, similar concepts are being implemented in:

- **Esbjerg (HØST PtX)**: Uses treated wastewater for ammonia production.
- **Padborg PtX**: Plans to use surface and treated wastewater.
- **Lolland Utility**: Developing a plant to supply drinking-quality water from treated wastewater for PtX.

These cases demonstrate the **technical feasibility and environmental benefits** of wastewater reuse for hydrogen production.



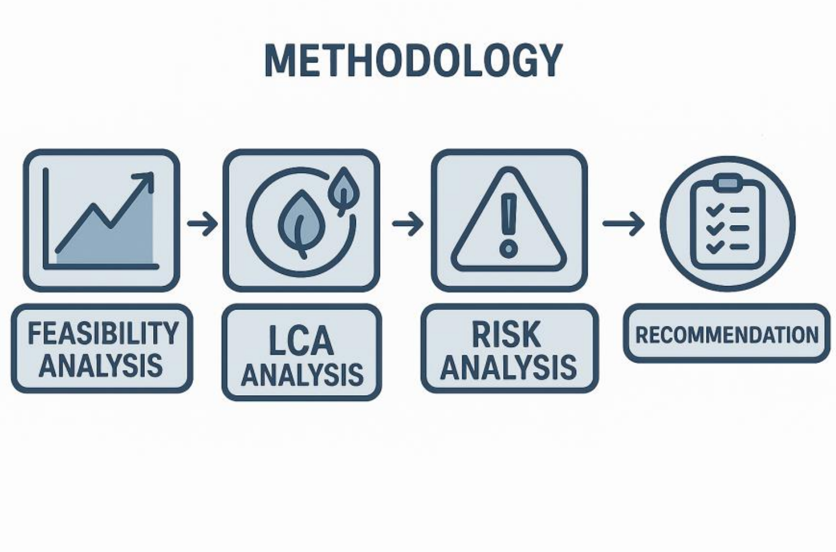
➢ How would it be adapted to this context?

- **Local Integration**: Use Rønne WWTP due to its capacity and proximity to the energy park.
- **Flexible Treatment System**: Design for seasonal flow variations and high recovery RO.
- **Regulatory Alignment**: Establish a separate drinking water company under Danish Water Sector Act.
- **Environmental Safeguards**: Implement advanced brine management and nutrient recovery.
- **Energy Synergies**: Use excess heat from electrolysis for district heating and industrial processes.

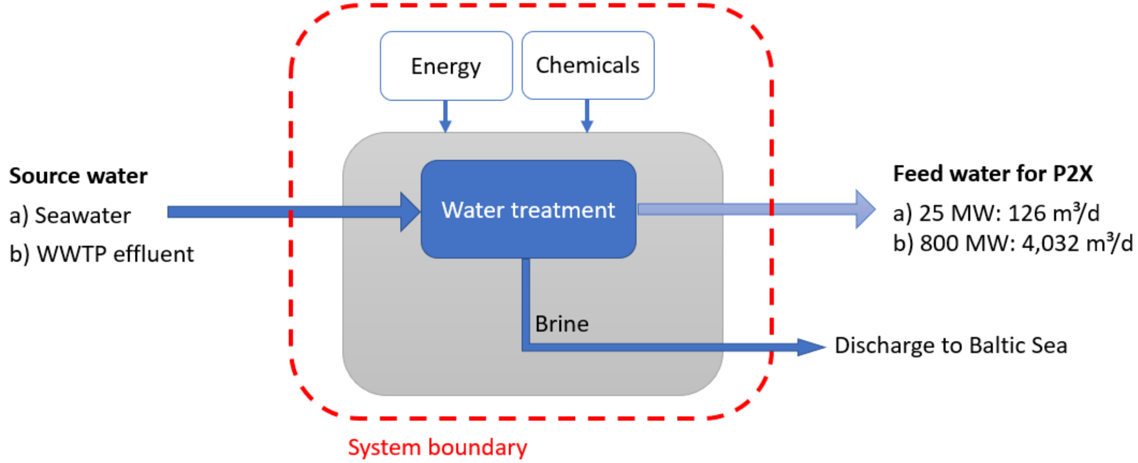
Assessment Approach & Methodology

- **What analytical methods were used?**
  - **Feasibility Analysis**:
    - Technical, economic, environmental, and regulatory dimensions.
    - Comparative assessment of water sources (wastewater, brackish water, seawater).
  - **Life Cycle Assessment (LCA)**:
    - Based on **ISO 14040/44** standards.
    - Functional unit: **per m³ of feed water**.
    - Scenarios: **25 MW** and **800 MW** PtX plant capacities.
  - **Risk Assessment**:
    - Likelihood-impact matrix covering technical, operational, regulatory, financial, environmental, and reputational risks.

- **What tools or frameworks were applied?**
  - **LCA Database**: *Ecoinvent v3.11* for emissions and energy data.
  - **Energy Modeling**: Danish grid mix vs. wind power scenarios.
  - **Regulatory Frameworks**:
    - Danish Water Sector Act
    - EU VEII/VEIII Directives
    - Draft executive orders on nitrogen/phosphorus discharge
  - **Stakeholder Consultations**:
    - Input from BEOF, NIRAS, EUROWATER, DANVA, and regulatory authorities.
  - **Technology Evaluation**:
    - Treatment technologies: UF, UV, RO, EDI
    - Electrolysis technologies: PEM, Alkaline, SOEC, HTSE



System boundaries and scenarios



Key Findings

➢ Summary of Feasibility Dimensions

- **Technical Feasibility**:
  - Treated wastewater meets feed water quality requirements for PtX.
  - Rønne WWTP has sufficient capacity and proximity to the energy park.
  - Advanced treatment technologies (UF, RO, EDI) are available and proven.
- **Economic Feasibility**:
  - Wastewater reuse is significantly more cost-effective than seawater desalination.
  - Economies of scale reduce cost per m^3 from DKK 135 (50 MW) to DKK 35 (1 GW).
  - CAPEX and OPEX estimates validated by NIRAS and EUROWATER.
- **Environmental Feasibility**:
  - LCA shows wastewater reuse has ~44% lower carbon footprint than seawater.
  - Brine management is critical, especially for 800 MW scenario.
  - Eutrophication risks can be mitigated with separate brine treatment.
- **Social / Regulatory Feasibility**:
  - Requires establishment of a separate drinking water company.
  - Regulatory alignment with Danish Water Sector Act and EU directives is essential.
  - Stakeholder engagement and legislative flexibility are key.

➢ Conditions Necessary for Implementation

- Formation of a **dedicated technical water company**.
- **Permits and exemptions** for nutrient discharge and brine management.
- Investment in **high-efficiency RO systems** and flexible treatment infrastructure.
- Collaboration with **regulators and PtX developers**.
- Integration with **district heating and resource recovery systems**.

➢ Major Risks or Limitations

- **Brine disposal** challenges at large scale (800 MW).
- **Regulatory constraints** on nutrient discharge and company structure.
- **Seasonal flow variations** and climate-related water availability.
- **Single-customer** dependency and mitigation through diversified demand.
- **Scaling and fouling risks** in water treatment systems due to concentration factors.

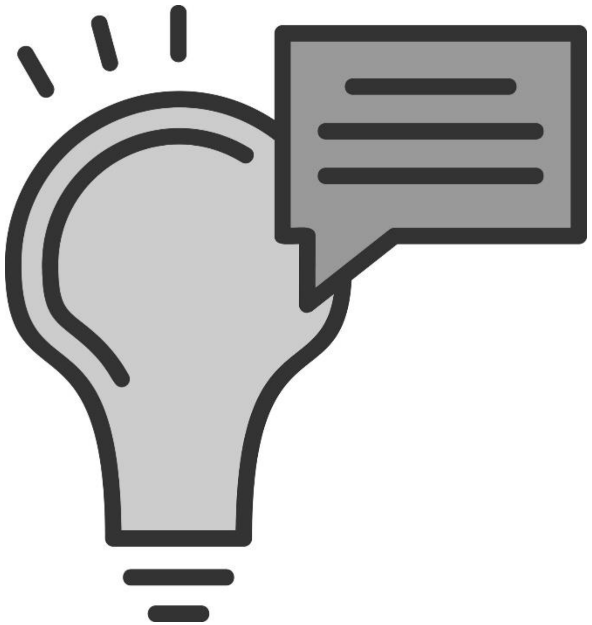
Recommendations & Next Steps

➢ **Should the measure proceed to piloting / implementation?**

✓ **Yes** — the reuse of treated wastewater for PtX water supply on Bornholm is **technically feasible**, **economically viable**, and **environmentally beneficial**, especially at larger scales. A **pilot project** is recommended to validate treatment performance, brine management, and regulatory compliance under real-world conditions. Pilot should include long-term testing of pretreatment and RO systems to validate membrane durability and scaling/fouling control.

➢ **What adjustments or further studies are needed?**

- **Finalize LCA** with full water quality parameters and brine treatment scenarios.
- **Detailed engineering design** for the water treatment plant, including modular RO systems and brine handling.
- **Site-specific risk analysis** for seasonal flow variations and scaling/fouling risks.
- **Materiality Assessment Report** for PFAS, nutrients, and other pollutants.
- **Stakeholder workshops** to align on regulatory pathways and company structure.
- **Explore alternative customers** for technical water (e.g., other water-intensive industries) to ensure long-term viability.



➢ **What enabling conditions should be prioritized?**

- **Policy & Regulatory**:
  - Legislative amendments to allow technical water companies outside current water sector law.
  - Permitting flexibility for nutrient discharge and brine management.
- **Funding**:
  - EU and national green transition funds.
  - Public-private partnerships with PtX developers.
- **Infrastructure**:
  - Investment in high-efficiency RO and flexible treatment systems.
  - Integration with district heating and biogas systems.
  - Planning for centralized WWTP and future water demand fluctuations.
- **Stakeholder engagement**:
  - Organize joint workshops with energy and water utilities to align on shared risks, benefits, and business models.
  - Establish continuous dialogue between water utilities and PtX developers to co-create replicable business models, leveraging lessons from mainland and EU demo sites.

Scalability

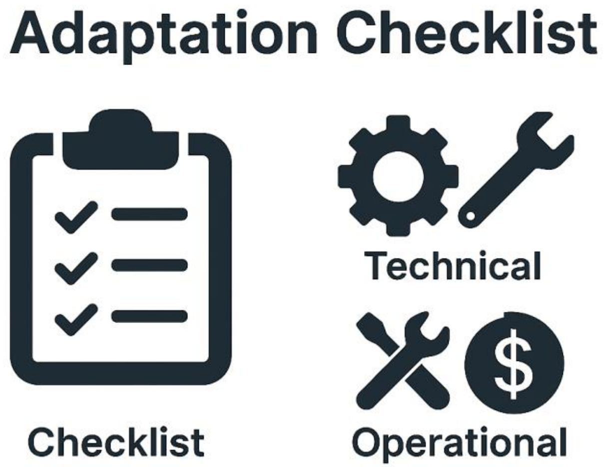
➢ **Can the measure be scaled up within the system / in the region?**

✓ **Yes** — the reuse of treated wastewater for PtX water supply is scalable both:

- **Within Bornholm**: Potential to centralize WWTPs and expand technical water production.
- **Across Denmark and the Baltic Sea Region**: Similar water reuse strategies are already being explored in Esbjerg, Padborg, and Lolland.

➢ **What adaptations are needed for larger scale?**

- **Technical**:
  - High-recovery RO systems with advanced brine management.
  - Modular treatment units to handle seasonal flow variations.
  - Integration with district heating and industrial symbiosis (e.g. biogas, CO_2 reuse).
- **Operational**:
  - Centralized WWTP infrastructure to streamline water collection and treatment.
  - Flexible water treatment systems to handle concentration factor risks.
  - Separate brine treatment or discharge pathways for large-scale PtX plants.



➢ **Is scaling up financially sustainable or viable?**

✓ **Yes**, especially at **GW-scale**:

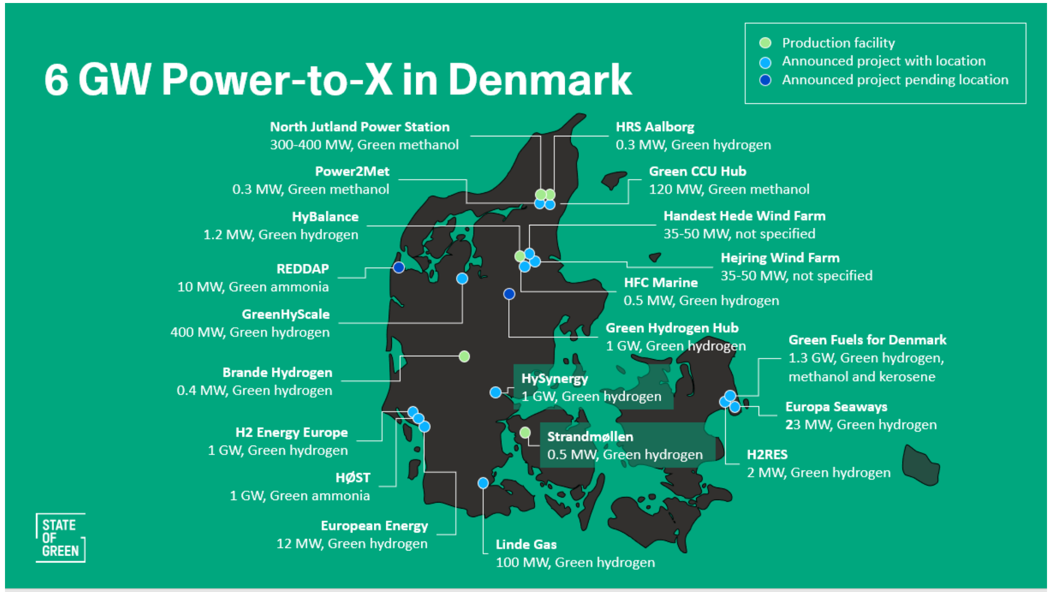
- Cost per m^3 of ultrapure water drops from **DKK 135 (50 MW)** to **DKK 35 (1 GW)**.
- Wastewater reuse is more cost-effective than seawater desalination.
- Potential for **EU and national funding**, public-private partnerships, and integration with existing infrastructure.

Transferability

Knowledge transfer and business model replication as a key precondition.

- **How can these findings be applied to other regions / contexts?**
  - The reuse of treated wastewater for PtX water supply is **highly transferable** to other regions with:
    - **Existing WWTP infrastructure**
    - **Renewable energy potential**
    - **Growing hydrogen ambitions**
  - The approach aligns with **EU sustainability goals**, circular economy principles, and climate resilience strategies.
  - Case studies from **Esbjerg, Padborg, and Lolland** show similar models are already being explored in Denmark.

- **What preconditions would be needed elsewhere for applying it?**
  - **Technical Preconditions**:
    - WWTPs with sufficient effluent volume and quality.
    - Access to advanced water treatment technologies (RO, EDI, etc.).
    - Proximity to PtX infrastructure or planned energy hubs.
  - **Regulatory Preconditions**:
    - Legal frameworks allowing technical water supply from wastewater.
    - Permitting flexibility for nutrient discharge and brine management.
    - Support for establishing dedicated water supply entities.
  - **Institutional & Financial Preconditions**:
    - Stakeholder collaboration between utilities, municipalities, and PtX developers.
    - Funding mechanisms (EU, national, private) for infrastructure upgrades.
    - Risk mitigation strategies for single-customer dependency and environmental compliance.



Final Reflections

➢ **What was the biggest surprise during the elaboration?**

The **complexity of regulatory alignment** — especially the realization that supplying technical water for PtX requires forming a **separate drinking water company** under Danish law. This was unexpected and shaped the entire implementation strategy.

➢ **Was there a moment when you thought: This does not lead anywhere... And what happened next?**

✓ Yes — during the early analysis of **brine concentration factors** and **scaling risks**, it seemed that wastewater reuse might be technically unfeasible at large scale. However, by exploring **advanced RO systems**, **brine management innovations**, and **flexible treatment designs**, the concept was adapted and strengthened.

➢ **What are the most important tips / insights / recommendations that you would give to others?**

- **Engage regulators early** — don't wait until the design phase.
- **Design for flexibility** — seasonal flows, scaling risks, and future regulations will evolve.
- **Think beyond water** — integrate PtX with district heating, biogas, and nutrient recovery.
- **Use LCA early** — it helps validate sustainability and guide technology choices.

➢ **If you could wish for anything related to your pilot measure, what would it be?**

- A **policy framework** that enables the creation of **technical water companies** outside the current water sector law — unlocking innovation and accelerating PtX deployment across Denmark and the Baltic Sea Region.

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Access the „BSR Water Recycling Toolbox” here.
https://www.eurobalt.org/waterrecyclingtoolbox/

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WaterMan

The „BSR Water Recycling Toolbox” was elaborated as part of the project “WaterMan - Promoting water reuse in the Baltic Sea Region through capacity building at local level”, The project 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 region-specific approach to water recycling, which intends to use the alternation of too much and too little water that has become typical in the Baltic Sea Region to make the local water supply more resilient, and supports municipalities & water companies in adapting their strategies.

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