TETRAS – PILOT 1

Water reclamation from landbased RAS-plant

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Final TETRAS Event
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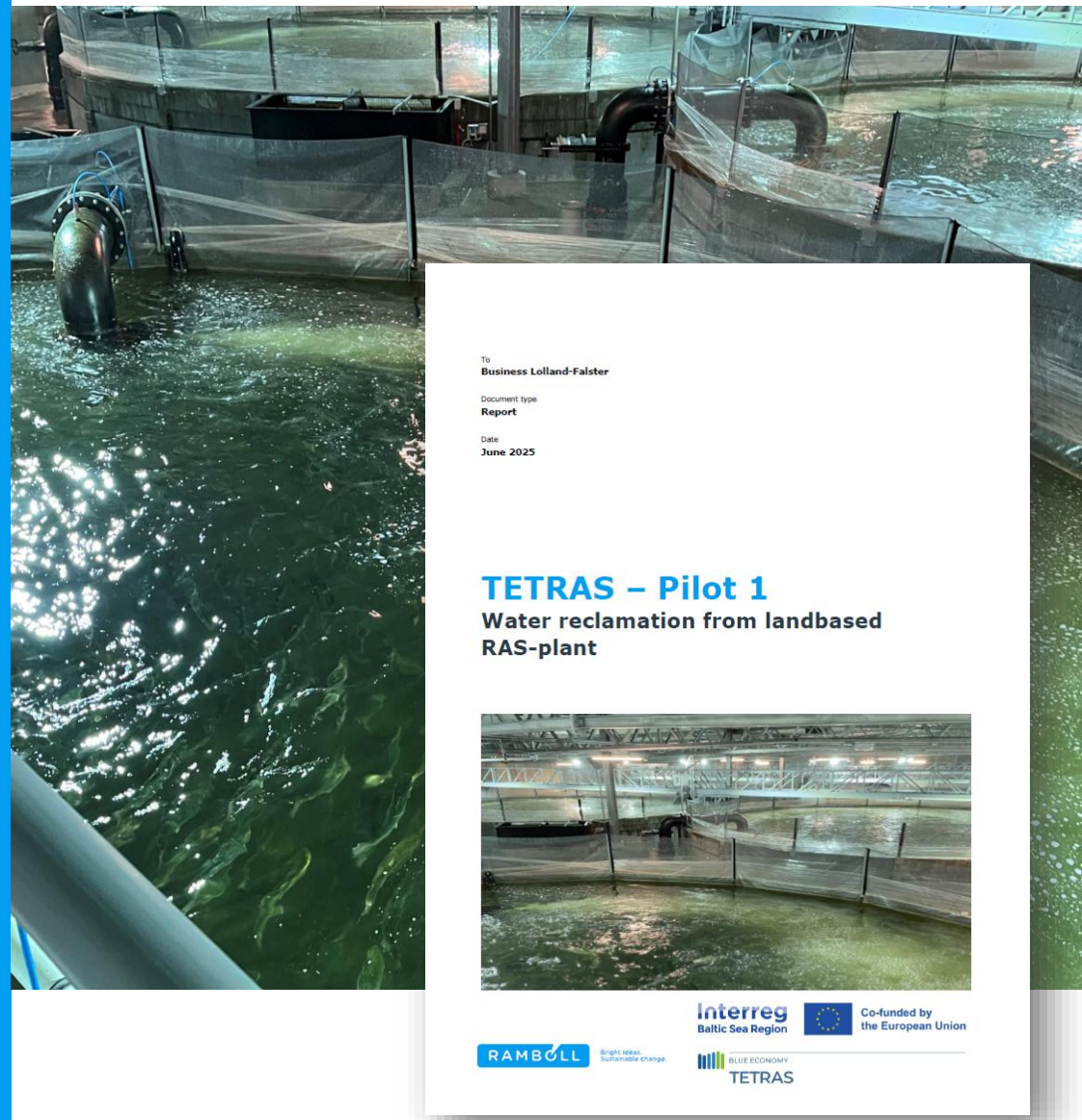
RAMBØLL



Introduction to Tetras Pilot 1

Pilot 1 Objectives

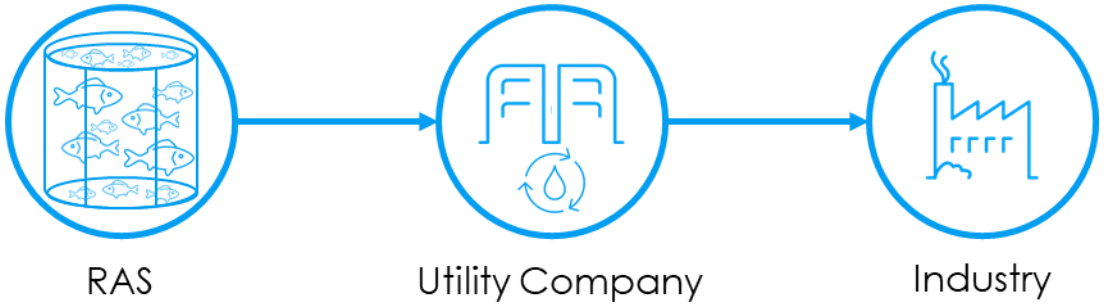
- Demonstrate water reclamation from RAS (Recirculating Aquaculture Systems)
- Use membrane technology for purification
- Evaluate the reuse of RAS wastewater as technical water for other industries
- Examine economic feasibility of a full-scale RAS plant

Key Technologies Tested

- Ceramic Ultrafiltration (CUF)
- Reverse Osmosis (RO)
- Membrane Distillation (MD)

Why This Matters (Business Drivers)

- Stricter discharge regulations and water scarcity increase operational risk.
- Circular water solutions reduce freshwater intake, improve compliance, and strengthen ESG.
- RAS growth demands reliable non-potable technical water for industrial uses.



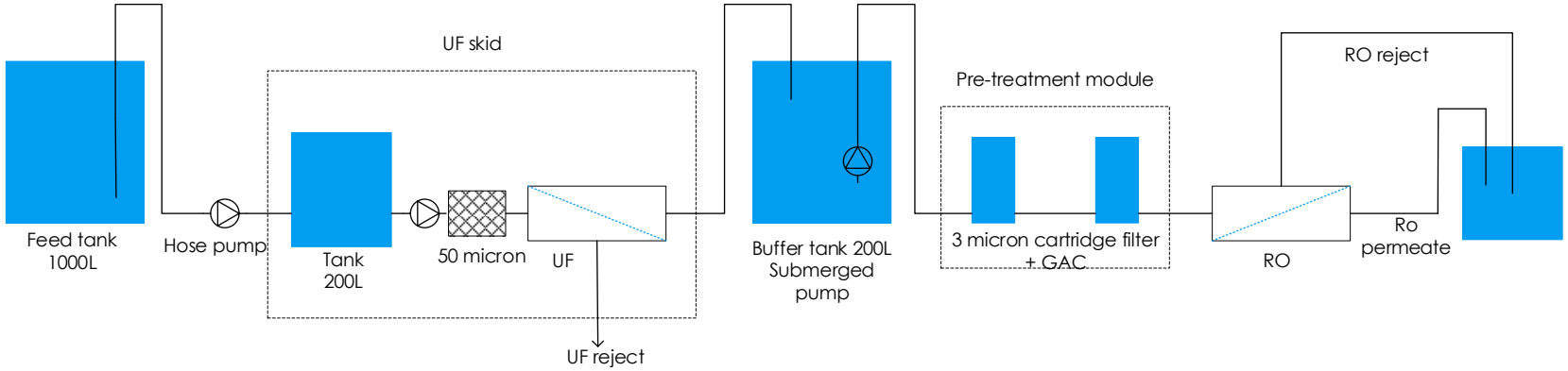
The test set-up

Objective & Scope

Produce technical water of near-drinking quality from RAS wastewater using membranes (CUF, RO, MD)

Pilot Test Setup

- **Step 1: Pretreatment** – Mechanical filtration & activated carbon
- **Step 2: Ultrafiltration (UF)** – Ceramic membranes for suspended solids removal
- **Step 3: Reverse Osmosis (RO)** – High-recovery desalination process
- **Step 4: Membrane Distillation (MD) [Additional Test]** – Evaluating alternative desalination



Test location: Skagen Salmon – RAS Facility

Overview of Skagen Salmon:

- Established in **2020**, state of the art **saltwater-based RAS facility**
- Produces **3,800 tons of salmon per year** (~1 million fish)

Water Management & Treatment:

- Multi-step treatment process:
  - **Mechanical filtration (drum filter, 50 µm)**
  - **Biological filtration (MBBR) & fine polishing**
  - **Deoxygenation & ozonation** for disinfection

External wastewater treatment before discharge to Skagerrak

- Discharges **150 m³ wastewater per hour**
- **90% reduction** in nitrogen & phosphorus discharge through treatment

Results showing satisfying permeate water qualities

Permeate Water Composition & Quality

- **RO Permeate (65% Recovery):**
  - Conductivity reduced from **1700 mS/m to 25 mS/m**
  - Chloride reduced from **14,000 mg/l to 55 mg/l** (below drinking water limit)
  - Ammonia **< 1 mg/l**, requiring further validation

- **Membrane Distillation (MD) Permeate:**
  - **High purity water**, low conductivity (**0.26 mS/m**)
  - Chloride **<1 mg/l**, well within safe limits
  - **Ammonia (2.1 mg/l) exceeds drinking water standards**

High quality water offers plenty of opportunities for reuse

Application Potential for Permeate Waters in Lolland-Falster

1.Industrial Use:

1. **Cooling Systems:** Prevents scaling & corrosion
2. **Cleaning & High-Pressure Cleaning:** Leaves no residues
3. **Concrete Production:** Ensures durability & strength

2.Energy & PtX Technologies:

Hydrogen Production: Need further purification to meet ultra-pure water (UPW) requirements

The reuse water does not fully meet Danish drinking water standards

- Minor adjustments necessary to comply: ammonia stripping and pH adjustment

Reject Water: Risks and Reuse Pathways

Limitations

- **Not suitable for agriculture:** can be used as fertilizer, rich in nutrients (nitrogen), but high salinity and chloride could harm soil health.
- **Not suitable for biogas production**: High salt levels and low biodegradable organic matter hinder anaerobic digestion.
- **Cannot be discharge to sea:** High chloride, nitrogen, and metals require additional treatment for compliance with environmental regulations
- **Require treatment before discharge to local:** High salinity, ammonia, and heavy metals disrupt treatment processes and require advanced technologies for regulatory compliance

Potential Solutions:

- Dilution with fresh water to reduce salinity.
- Use of salt-tolerant crops (halophytes) for specific regions.
- Treatment technologies to remove heavy metals (e.g., filtration, adsorption).
- Ammonia management strategies (e.g., volatilization).

Perspectives to turn the pilot into commercial projects

- Conduct comprehensive technical and economic assessments for full-scale installation.

  Include sensitivity to energy price, recovery rate, and membrane life.

- Determine reject water strategy and manage risk
  - Map regulatory landscape for treatment & discharge in the Baltic Region
  - Finalize realistic pathways for the reject water
  - Quantify reject water treatment costs

- Water quality: validate ammonia removal to meet Danish drinking water limits

What it takes to move on

- Continued coastal RAS **site access** for assessments and test validations.

- **Vendor engagement** for water treatment technology incl. ammonia stripping: partner with several to build integrated offers. Offer turnkey and quick-turn pilots to accelerate adoption.

- **Joint workshops with regulators/utilities about reject water management**: regulatory drivers to go hand in hand with engagements to improve regional water resilience in vulnerable regions with high potential (e.g. Lolland-Falster)

- Detailed design and **local business cases** including reject water