

Utilization of Technical Water for Electrolysis - A Consumer Perspective



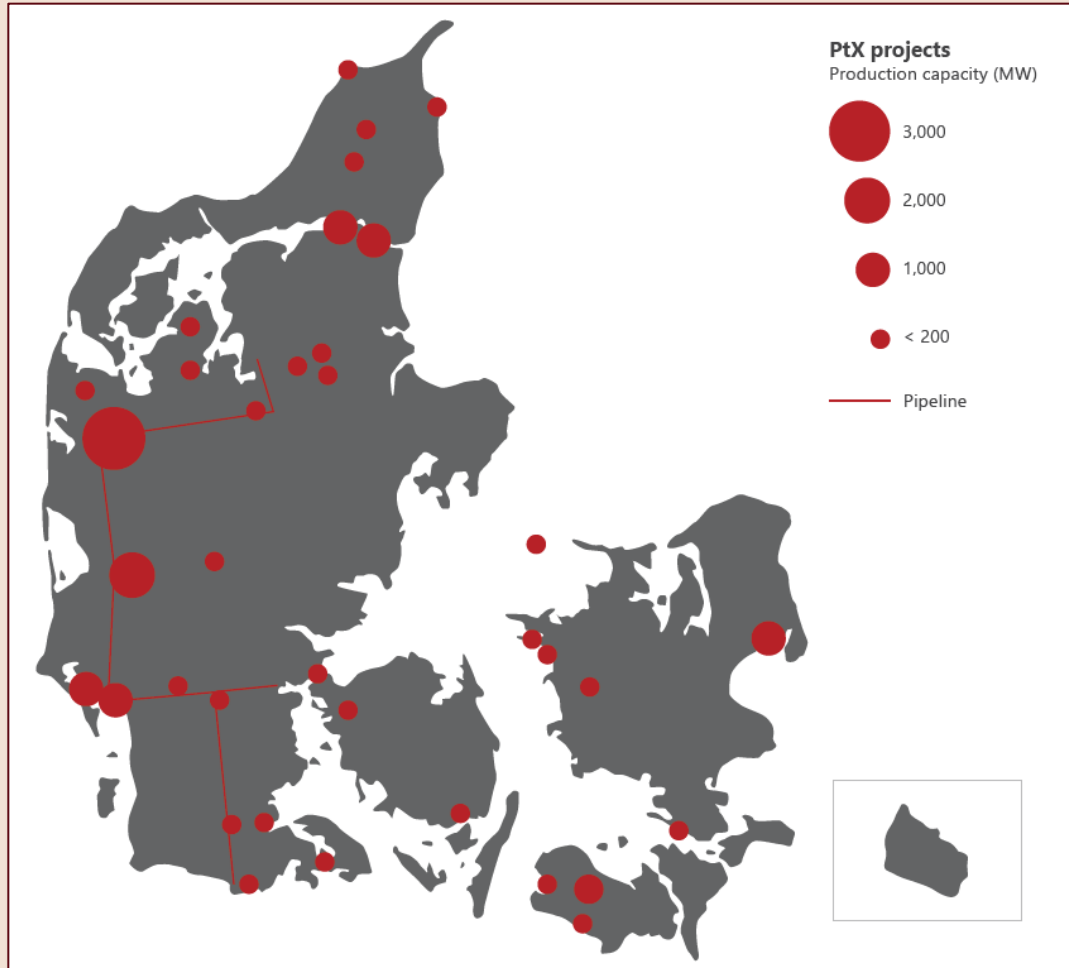
Sebastian Ravn-Andersen

NIRAS

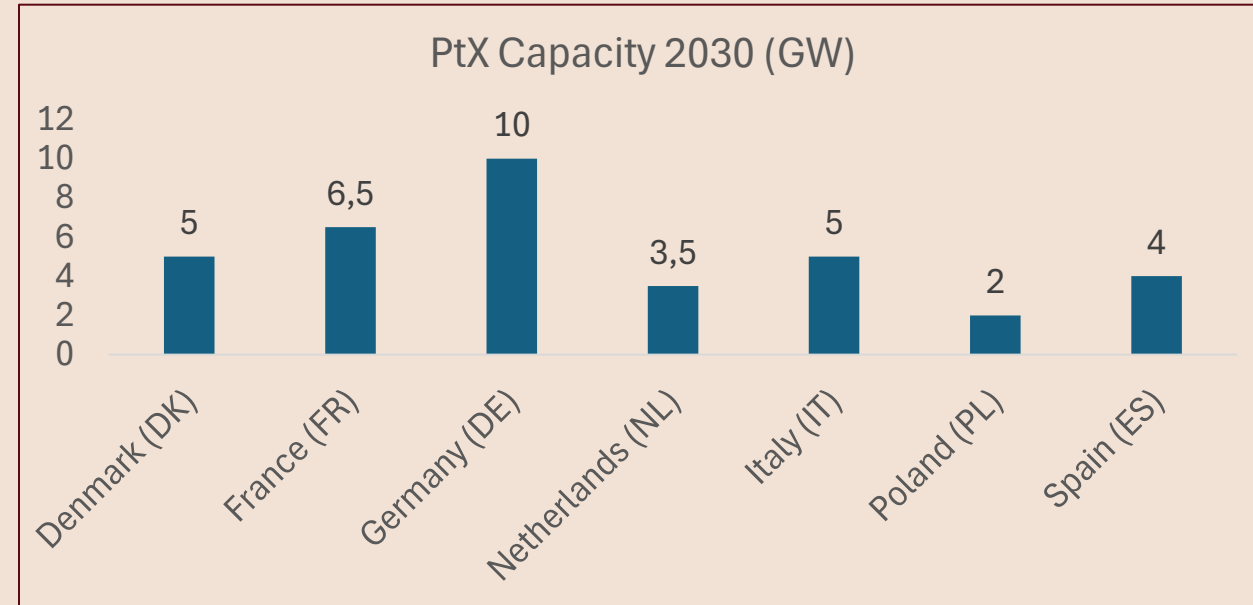
Water Specialist

Realization of current Power-to-X plans require substantial re-thinking of several infra-structural aspects – power congestion is just the first identified

+40 project in DK alone



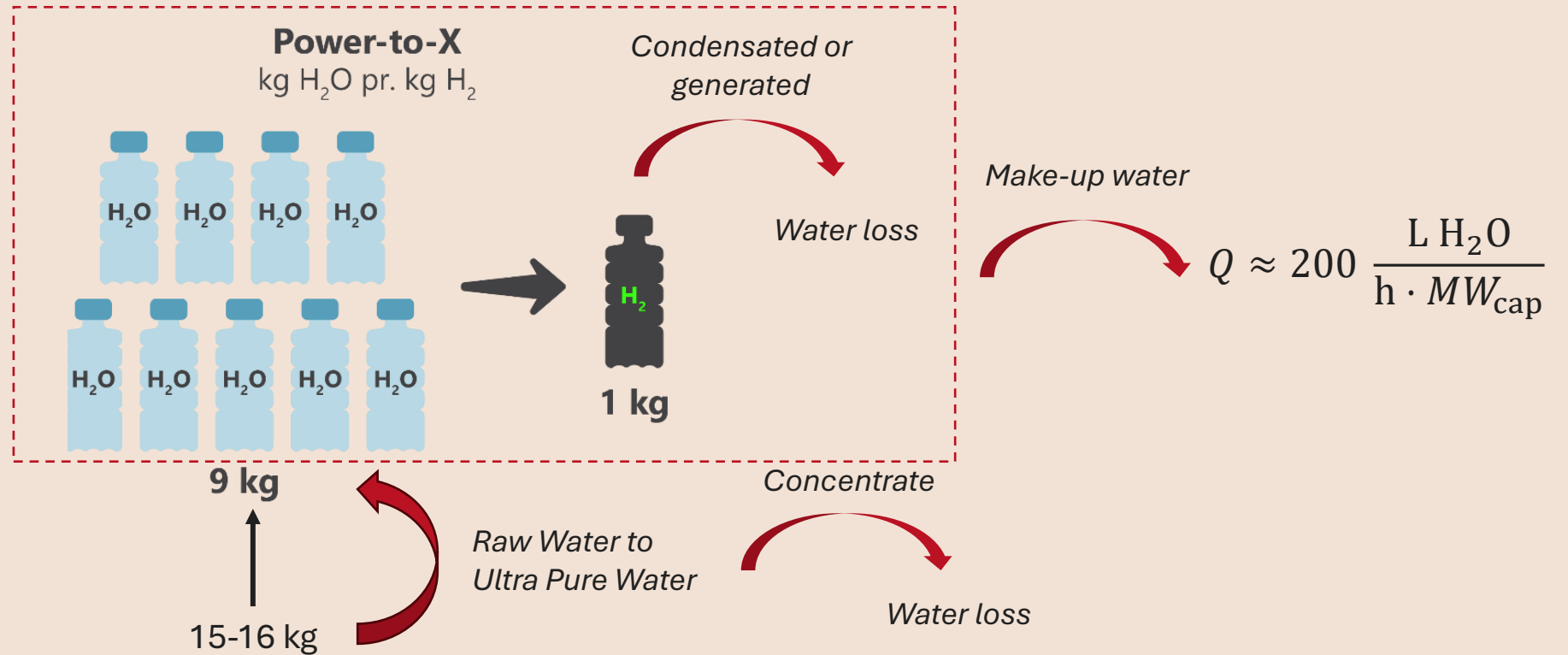
Targets within EU (2030) for producing 40 GW



| | DK | DE | NL | IT |
|---------------------------|----|----|----|----|
| Grid Capacity Now vs 2030 | x8 | x3 | x3 | x6 |

↑
Show-”stopper”?

A lot of Water is Consumed per kg of Hydrogen



Treated Wastewater is The Only Realistic Water Source for Large-Scale Power-to-X

Scale matters – The Esbjerg Case

1. 8 million m³/year drinking water in Esbjerg
2. 24 million m³ wastewater treated annually
3. 4 million m³/year needed for PtX

Polluted Groundwater



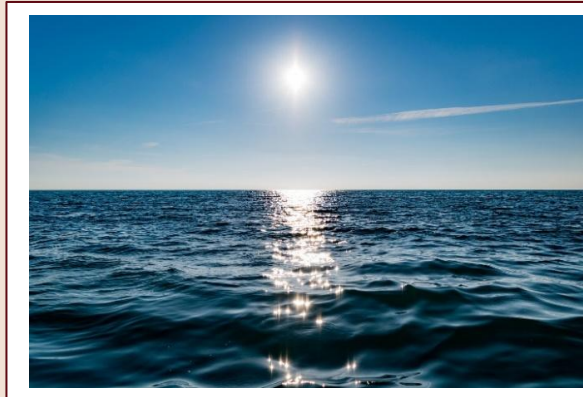
- + Consistent quality
- Intro. of pollutant

Treated Wastewater



- + Abundant & locally anchored
- Changing quality

Sea Water



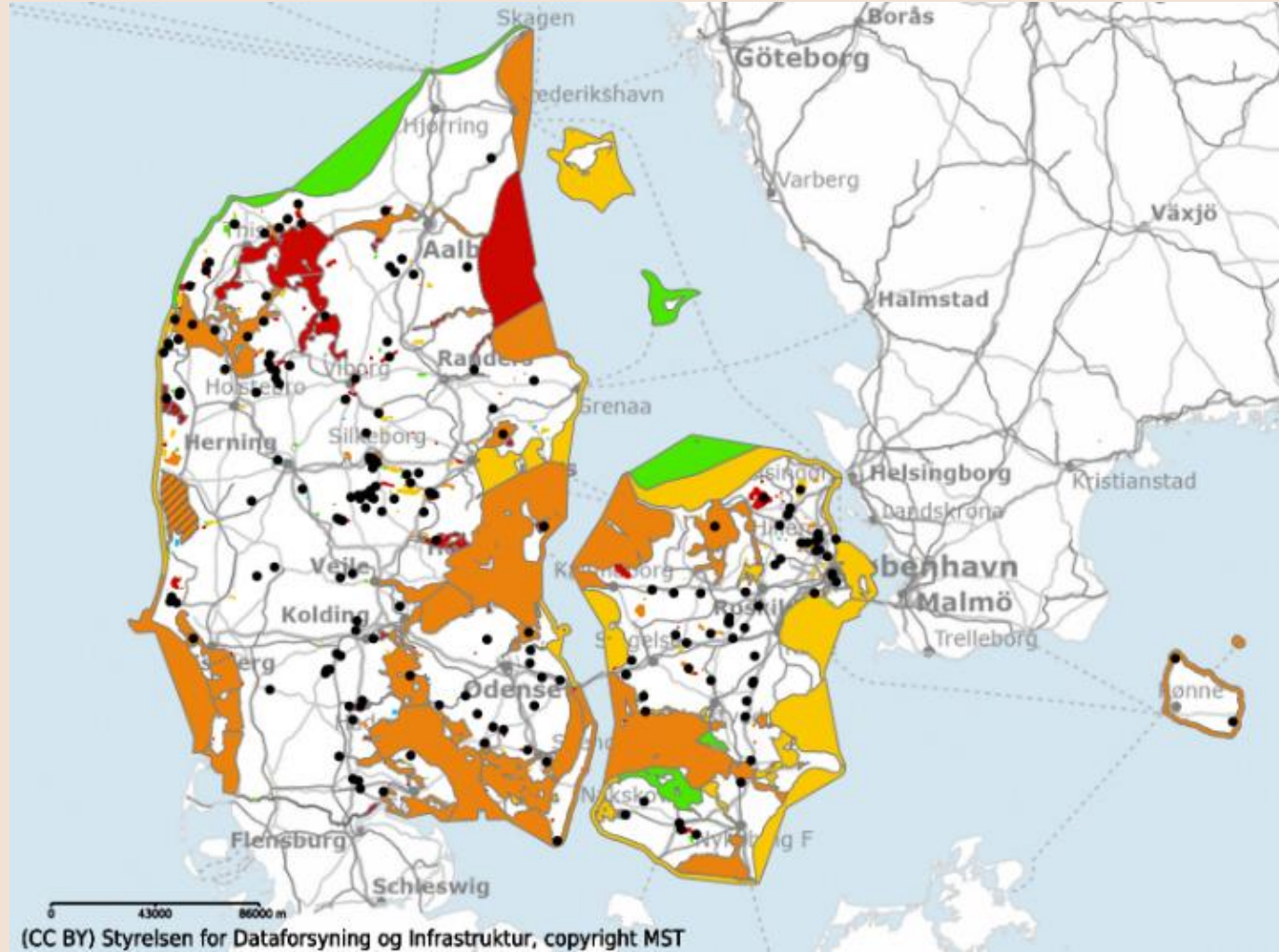
- + Abundant
- Expensive & Regulation

Surface Water

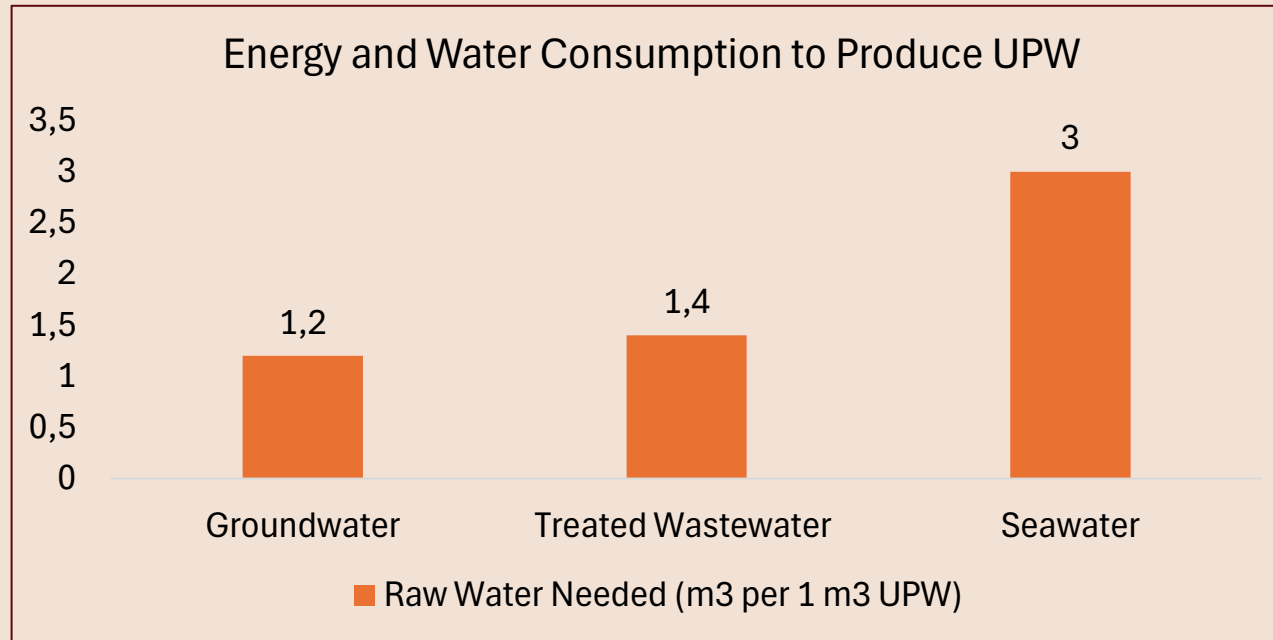


- + Good quality
- Seasonal

Why Use Technical Water for Electrolysis?



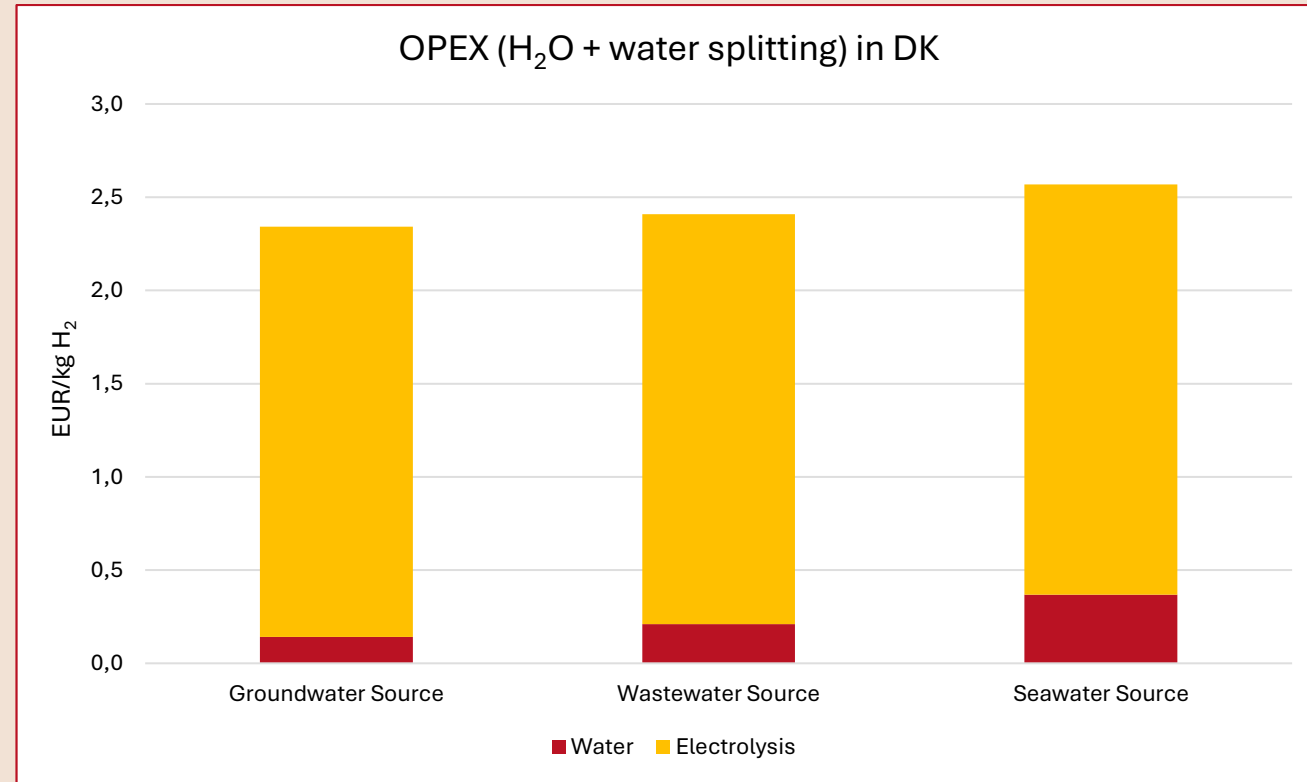
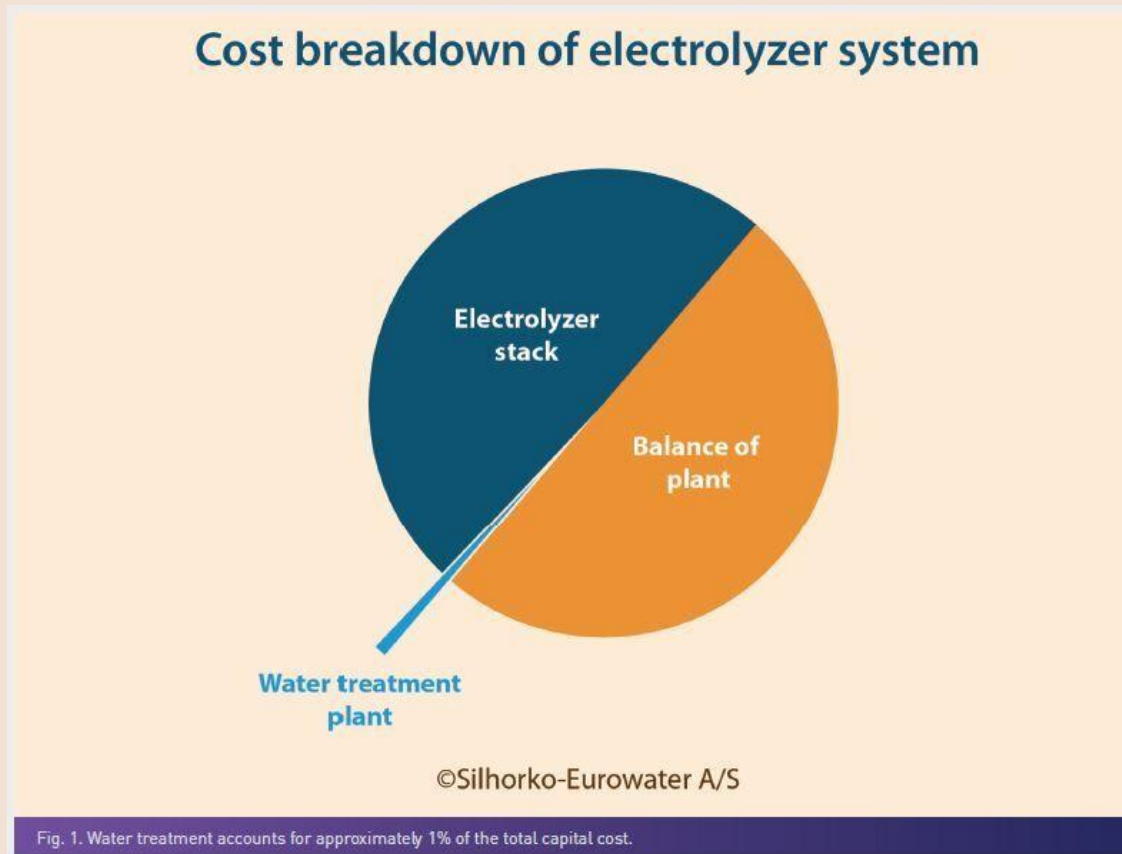
Raw Water Sources Have Different Challenges



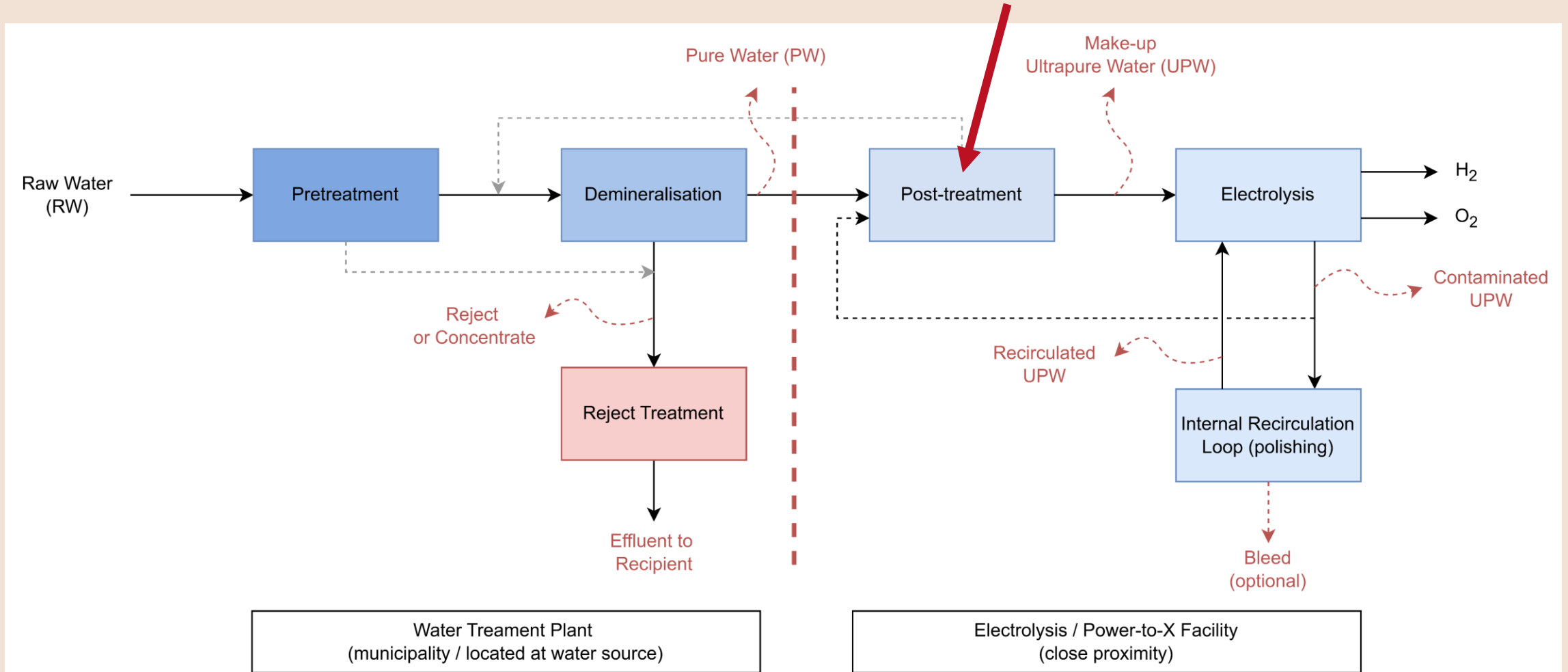
| Raw Water Source | Primary Challenges |
|------------------|-----------------------|
| Groundwater | Fe, Mn, hardness |
| Wastewater | Solids, microbes, TOC |
| Seawater | High salt load |

| Source | Ultrapure Yield % |
|--------------------|-------------------|
| Groundwater | 80-90 |
| Treated Wastewater | 54-86 |
| Seawater | 30-50 |

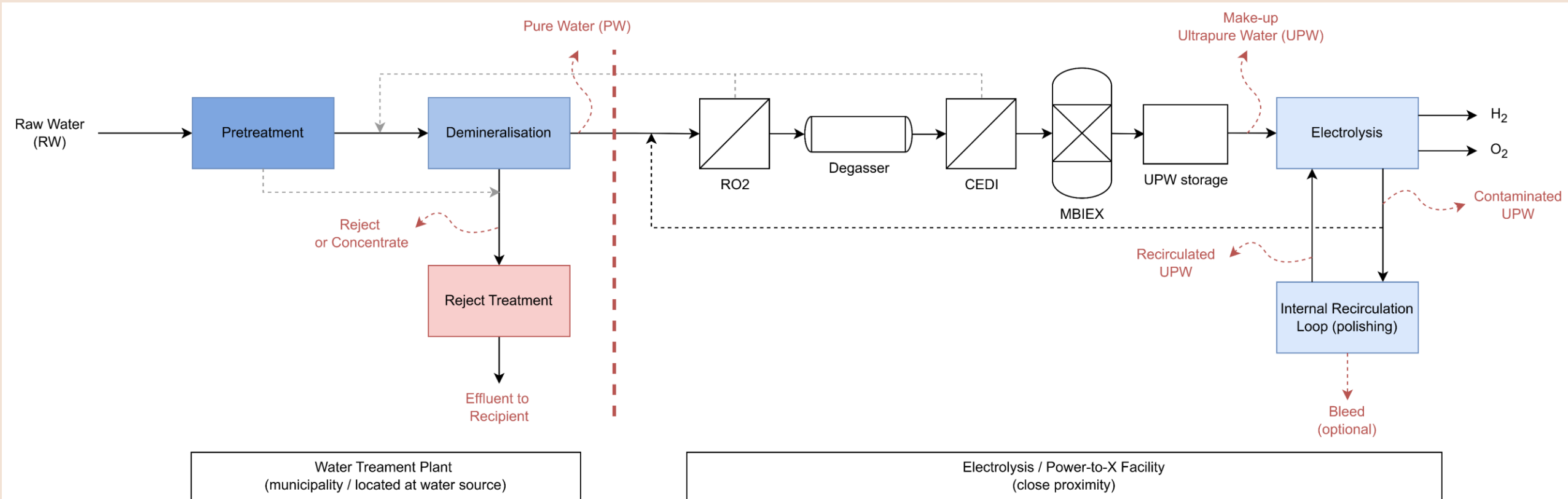
The Main Water Challenge From a PtX Perspective is Neither Economic nor Energetic



Typical/Suggested Purification Scheme



Purification of Technical Water for Electrolysis



Main requirements for Water Purification for Electrolysis

| Electrolyzer Type | Primary Pollutants | Refinement Approach | Treatment Load |
|-------------------|--------------------------|---------------------------------|----------------|
| PEMWE | Dissolved ions, organics | Side-stream polishing with MBIX | 1-10% of loop |
| AWE | Insoluble particles | Full-loop lye filter | 100% of loop |

Specific challenging compounds (type-of-electrolysis):

PEM: Fe, (Ni), Cu, Ca, Mg, Zn, Cd, Pb, (Al), Co, Ti, Cr, Mn, Ce, (Na), (NH₄), Cl, F, SO₄, (NO₃), (CO₂), (MeOH/EtOH), EDTA, Formic acid, HCHO, Chelators, SiO₂, (NH₃)

Alkaline: Cu, Ca, Mg, Zn, Cd, Pb, Al, (Ti), Cl, (SO₄), CO₃, HCO₃, CO₂, MeOH/EtOH), EDTA, chelators, SiO₂

Role of Recirculation Pumps and Piping are Important!

| Parameter | Typical value |
|-------------------------|----------------------------------|
| Recirculation Flow Rate | 50-100 m ³ /h per. MW |
| CAPEX Contribution | Up to 20% of BoP/Stack cost |

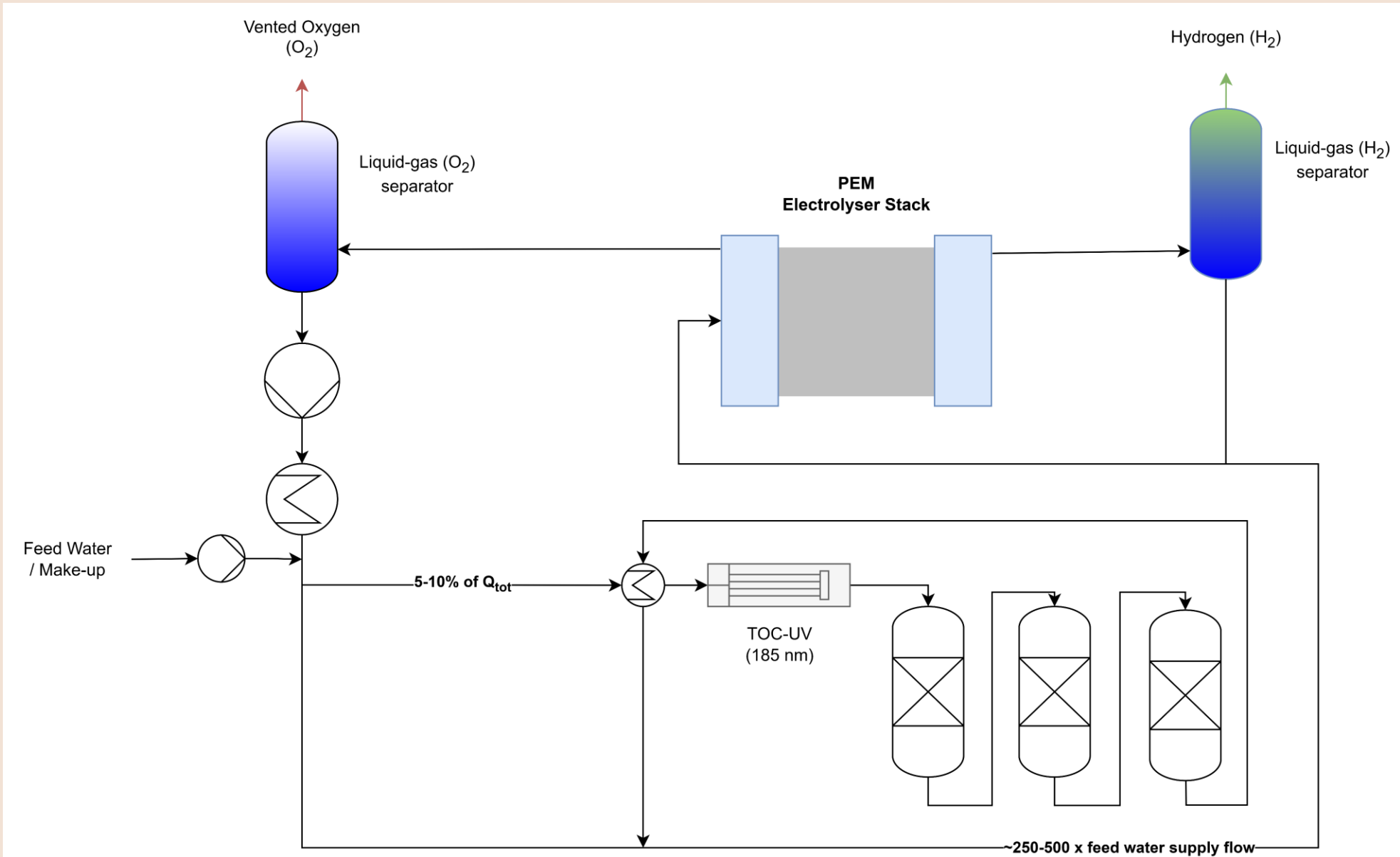
| Pipeline materiale | Recommended | Comments |
|--------------------------------|-------------|--|
| Stainless Steel | - | High resistance to temperature and pressure, but leaching metals |
| Polyvinyl chloride (PVC) | - | High leaching rate |
| Polypropylene (PP) | ✓ | Low leaching rate, suspected leaching silicon |
| Polyvinylidene fluoride (PVDF) | (✓) | Low leaching rate, but leaching flouride |

Water Qualities Specification varies from project to project!

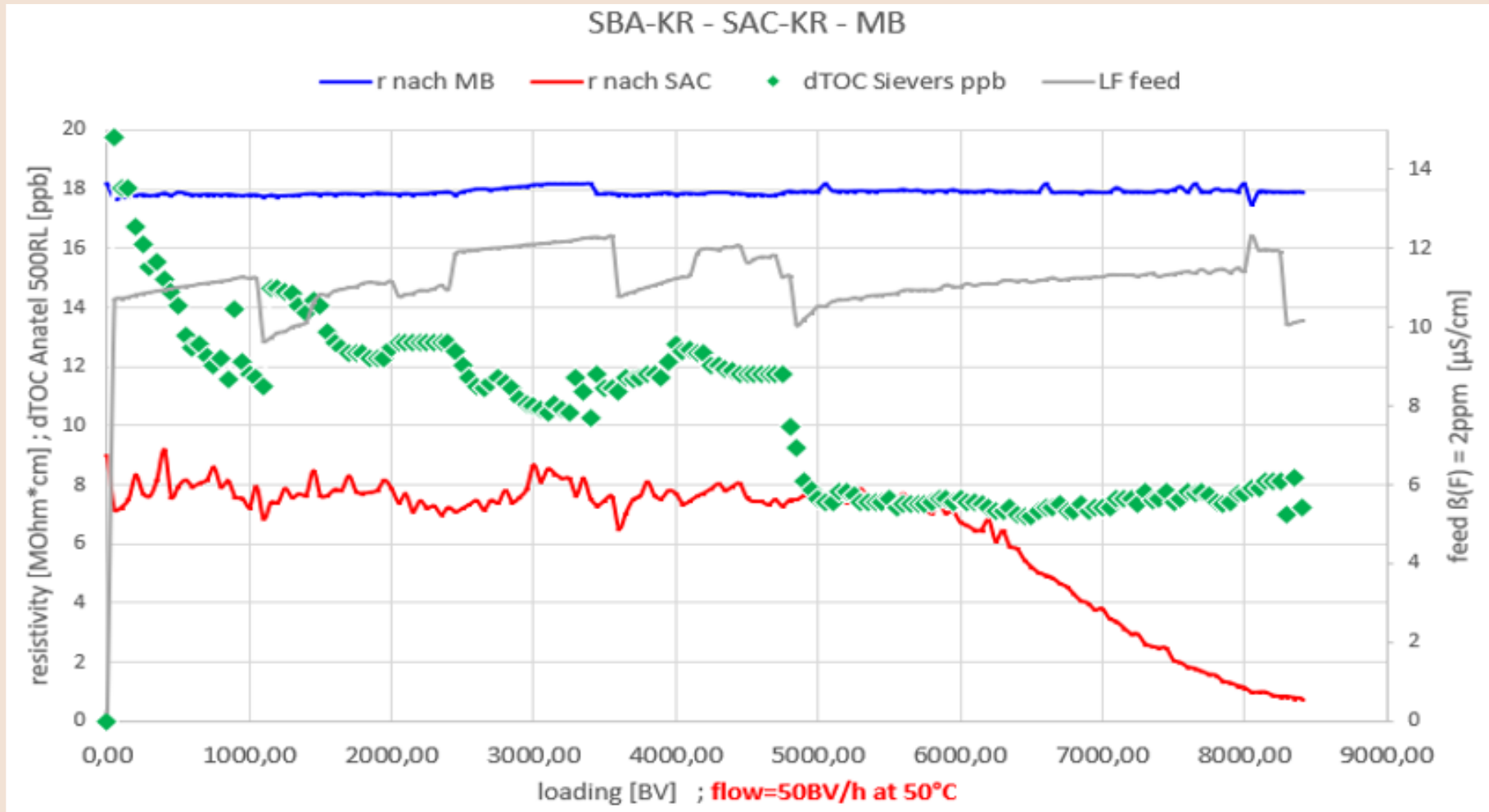
| Parameters | Unit | Ultrapure Water Qualities | | | | |
|--|-------|---------------------------|-----------|------------------------------|------------------|-----------------------------------|
| | | Pure Water ¹ | Demiwater | Ultrapure Water for Hydrogen | ASTM TYPE E1-1.2 | Example. Circulation Loop Quality |
| pH | - | 6.5-7.5 | 7 | 7 | 7 | 5-7 |
| Temperature | °C | <35 | | | | 50-60 |
| Electrical Conductivity (at 25°C) | µS/cm | <70 | <0.2 | <0.06 | <0.056 | <1.5 |
| Total organic carbon (TOC) | mg/l | | <0.2 | <0.01 | <0.05 | <0.25 |
| Chemical Oxygen Demand (COD) | mg/l | <1 | | | | |
| Non-Volatile Organic Carbon (NVOC) | mg/l | <0.3 | | | | |
| Silicate (SiO ₂) | mg/l | <0.5 | <0.2 | <0.005 | <0.003 | |
| Aluminium (Al ³⁺) | mg/l | <0.01 | | | <0.00005 | <0.01 |
| Ammonium (NH ₄ ⁺) | mg/l | | | | <0.0001 | |
| Barium (Ba ²⁺) | mg/l | n.d. | <0.05 | <0.005 | <0.00005 | |
| Boron (B) | mg/l | | | | <0.0003 | |
| Bromide (Br ⁻) | mg/l | | | | <0.0001 | |
| Calcium (Ca ²⁺) | mg/l | <2 | <0.002 | <0.002 | <0.00005 | <0.02 |
| Chloride (Cl ⁻) | mg/l | <5 | <0.2 | <0.02 | <0.0001 | <0.2 |
| Chromium (Cr ³⁺) | mg/l | | <0.002 | <0.002 | <0.00005 | <0.005 |
| Cobalt (Co ²⁺) | mg/l | | <0.003 | <0.0002 | | |
| Cooper (Cu ²⁺) | mg/l | | <0.003 | <0.0002 | <0.00005 | <0.005 |
| Fluoride (F ⁻) | mg/l | <0.01 | <0.005 | <0.0005 | <0.0001 | <0.0005 |
| Iron (Fe ³⁺) | mg/l | n.d. | <0.002 | <0.0002 | <0.00005 | <0.01 |
| Lead (Pb) | mg/l | | | | <0.00005 | |
| Magnesium (Mg ²⁺) | mg/l | <0.1 | | | <0.00005 | <0.005 |
| Manganese (Mn ²⁺) | mg/l | n.d. | <0.002 | <0.002 | <0.00005 | <0.005 |
| Nickel (Ni ²⁺) | mg/l | | | | <0.00005 | <0.005 |
| Nitrate (NO ₃ ⁻) | mg/l | <0.3 | | | <0.0001 | |
| Nitrite (NO ₂ ⁻) | mg/l | | | | <0.0001 | |
| Phosphate (PO ₄ ³⁻) | mg/l | n.d. | | | <0.0001 | |
| Potassium (K ⁺) | mg/l | <1 | | | <0.00005 | <0.02 |
| Sodium (Na ⁺) | mg/l | <20 | | | <0.0001 | <0.02 |
| Strontium (Sr ²⁺) | mg/l | | | | <0.00005 | |
| Sulfate (SO ₄ ²⁻) | mg/l | <0.2 | | | <0.0001 | |
| Sulphur (S ²⁻) | mg/l | | | | | <0.02 |
| Titanium (Ti ²⁺) | mg/l | | | | | <0.005 |
| Zinc (Zn ²⁺) | mg/l | | | | <0.00005 | <0.01 |

(1) Real life example by NIRAS

Typical PEM internal recirculation loop for optimal operations



UPW Mixed Bed Resin Can Significantly Minimize the Recirculation Loop



Source: Lanxess

Conclusion

- Ultrapure feedwater is only the start
- Internal recirculation and cleaning is essential for performance
- Choice of materials and equipment are key to resilience

