Sustainable Water Supply for P2X

Hydrogen & P2X 2023– June 15th, 2023

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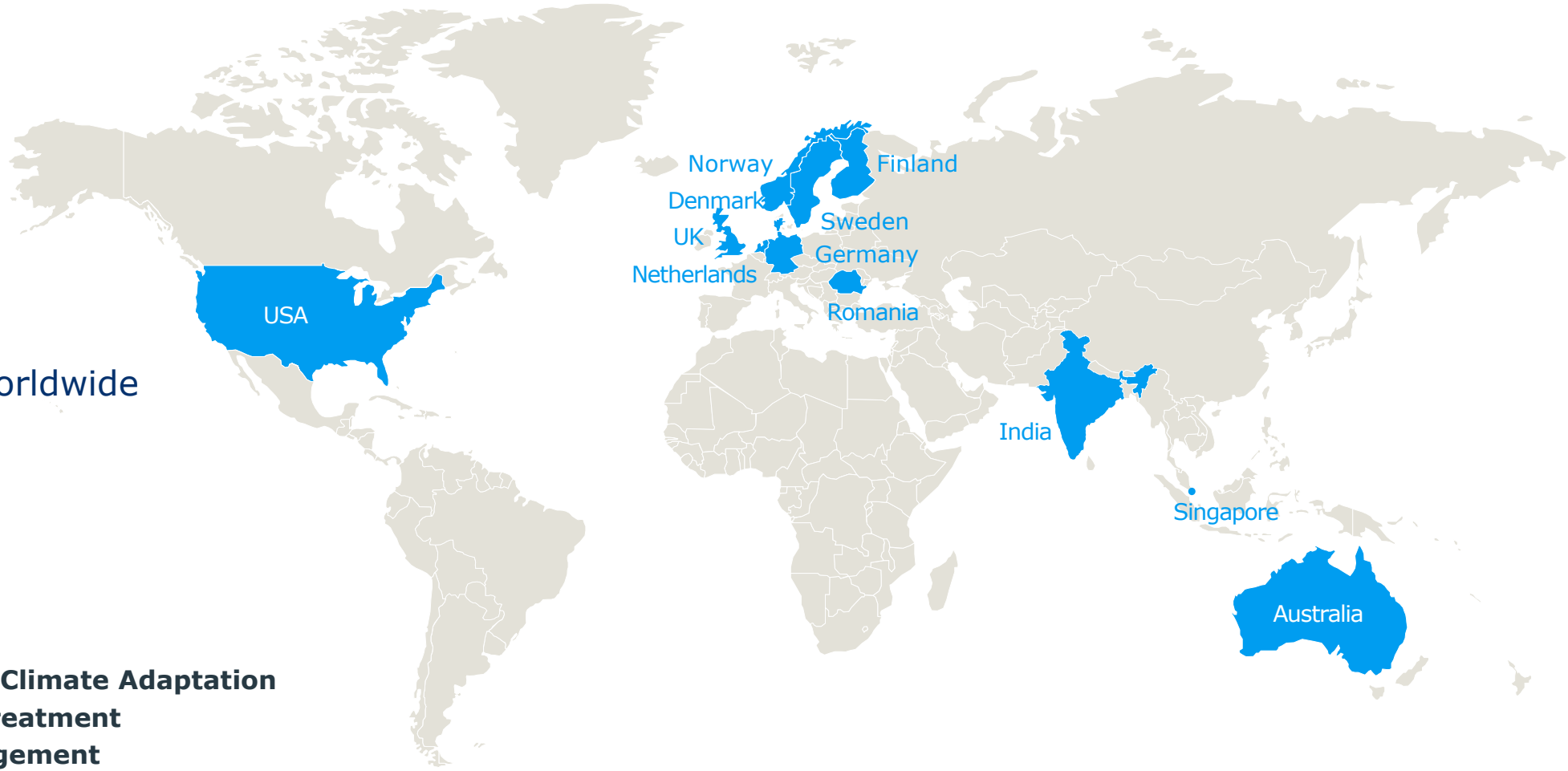

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50+ Offices

12 Countries

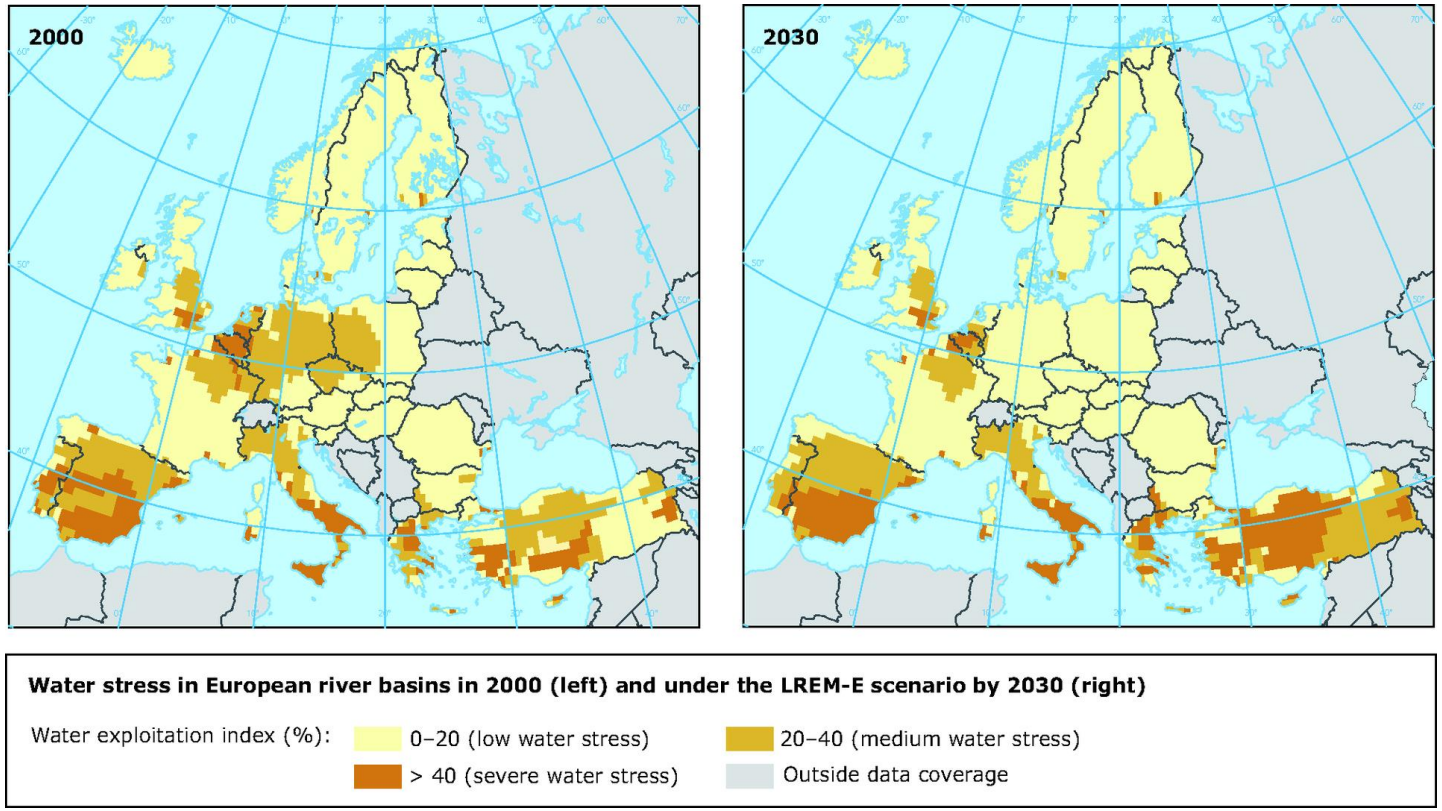
3 Global Divisions

Water Infrastructure & Climate Adaptation
Water & Wastewater Treatment
Water Resources Management

Agenda

- Water treatment needs for P2X
- Water treatment process technology options
- Sustainability and decarbonization of water resources and process technologies
- Case studies
- Resource recovery at P2X plants: co-siting

Water scarcity in Europe calls for sustainable electrolysis water resource management



Water stress in European river basins in 2000 (left) and under the LREM-E scenario by 2030 (right)

Water exploitation index (%): 0–20 (low water stress) 20–40 (medium water stress) > 40 (severe water stress) Outside data coverage

At least 11%

of Europeans directly affected by water scarcity

80%

of Europeans indirectly affected by water scarcity

1 bio. m^3

of treated urban wastewater is reused yearly

6 times more

treated water could be reused than current levels

Megatrends by regulation of the water sector

- Completely new EU regulatory water framework in 2023

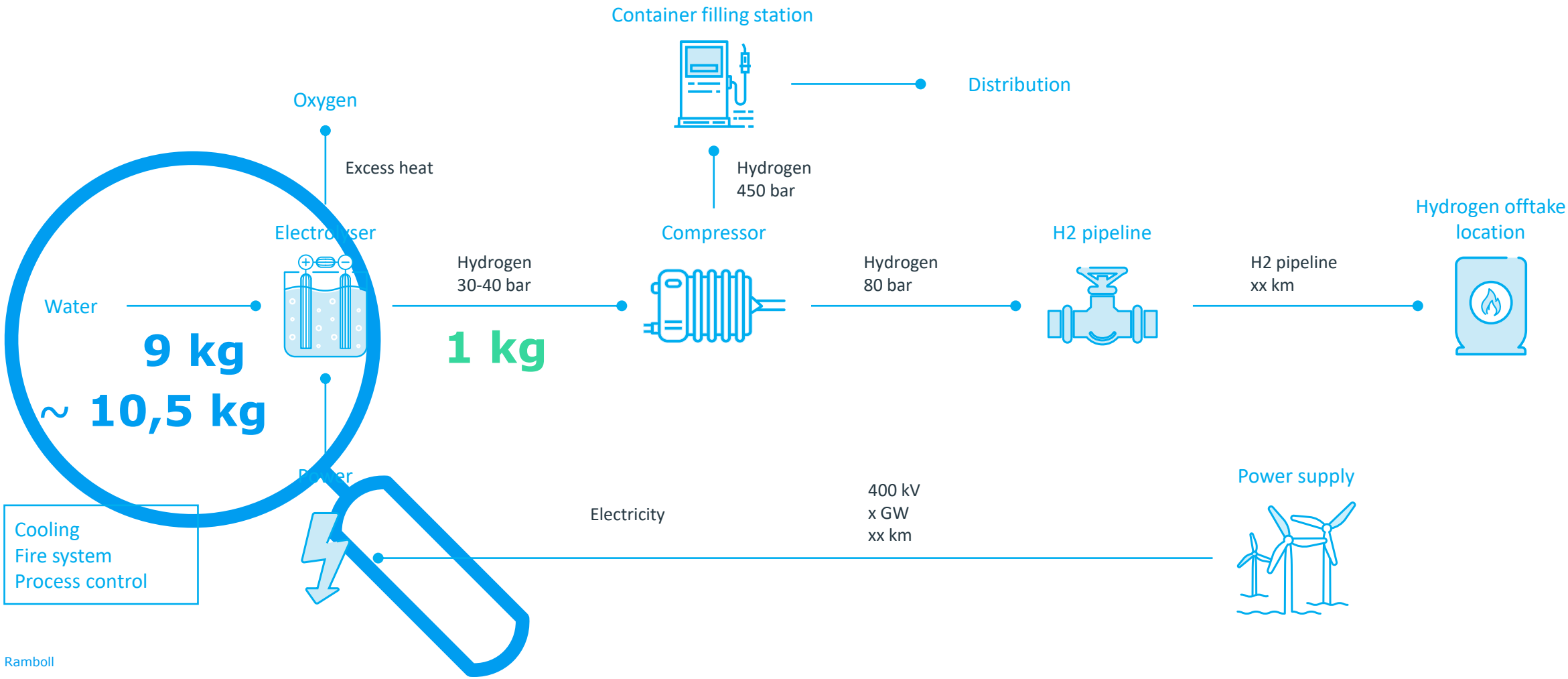
  Revised EU Directives for
  - Drinking water
  - Wastewater
  - Water reuse

  addressing water scarcity, protecting natural waters and making water reuse assessment mandatory for all

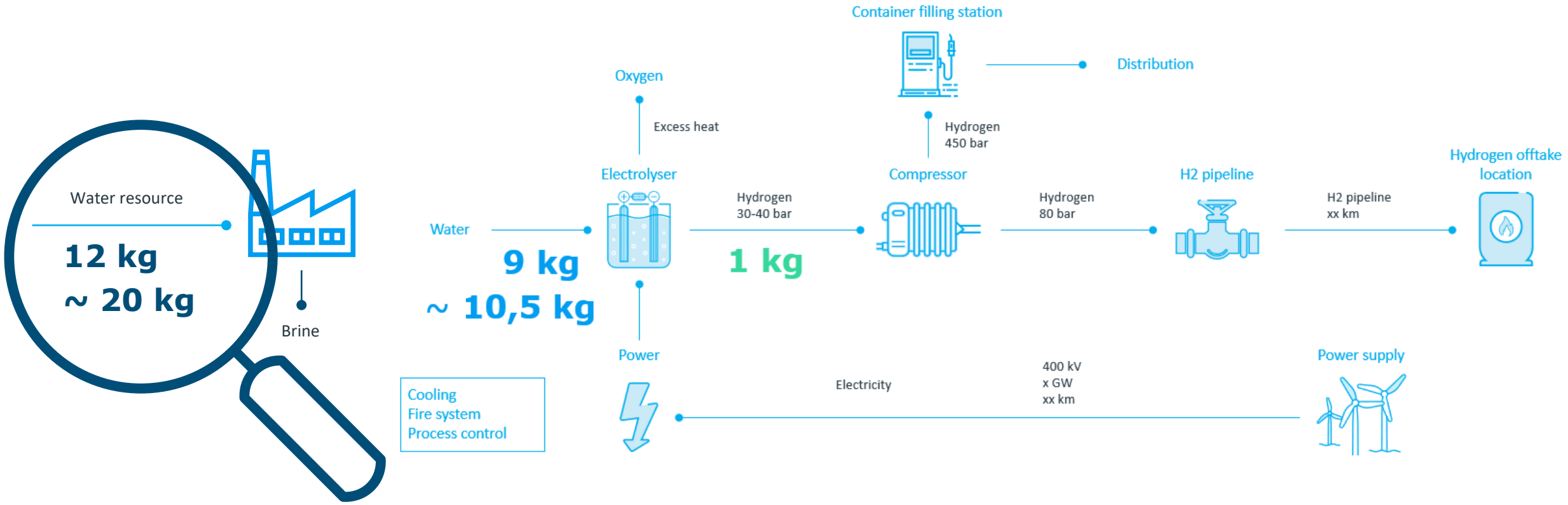
- The EU Taxonomy requiring the water sector to decarbonize and apply sustainable practices where possible

Water treatment needs for P2X

10 kg/kg H_2 electrolysis water in a large-scale H_2 production process



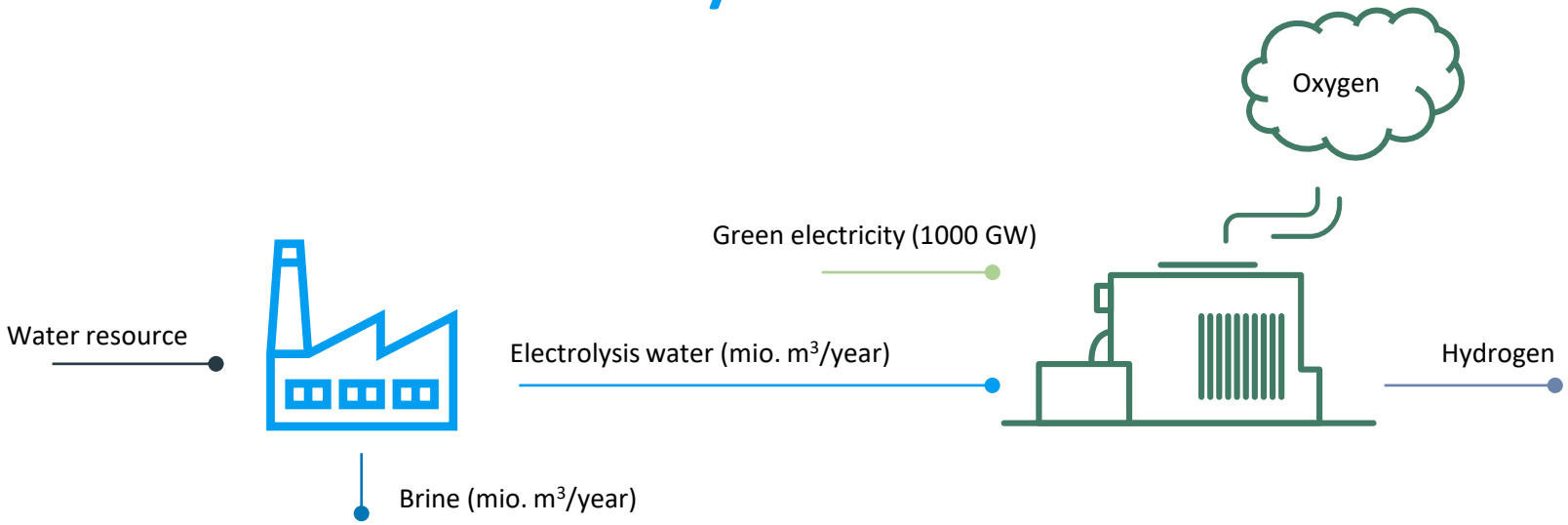
Up to double as much untreated water for large-scale H_2 production

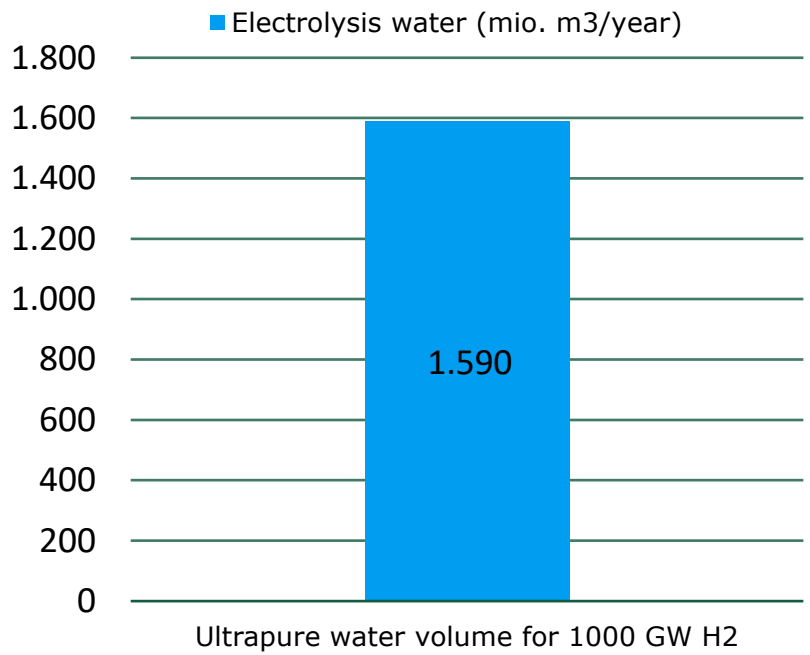


Four potential water resources

Surface water		Availability is local and seasonal
Groundwater		Competition for clean groundwater with drinking water production. Not abundant. Opportunity to utilize and treat contaminated groundwater
Seawater		Abundant in coastal areas
Wastewater effluent		Discharged into water bodies and abundant in urbanized areas

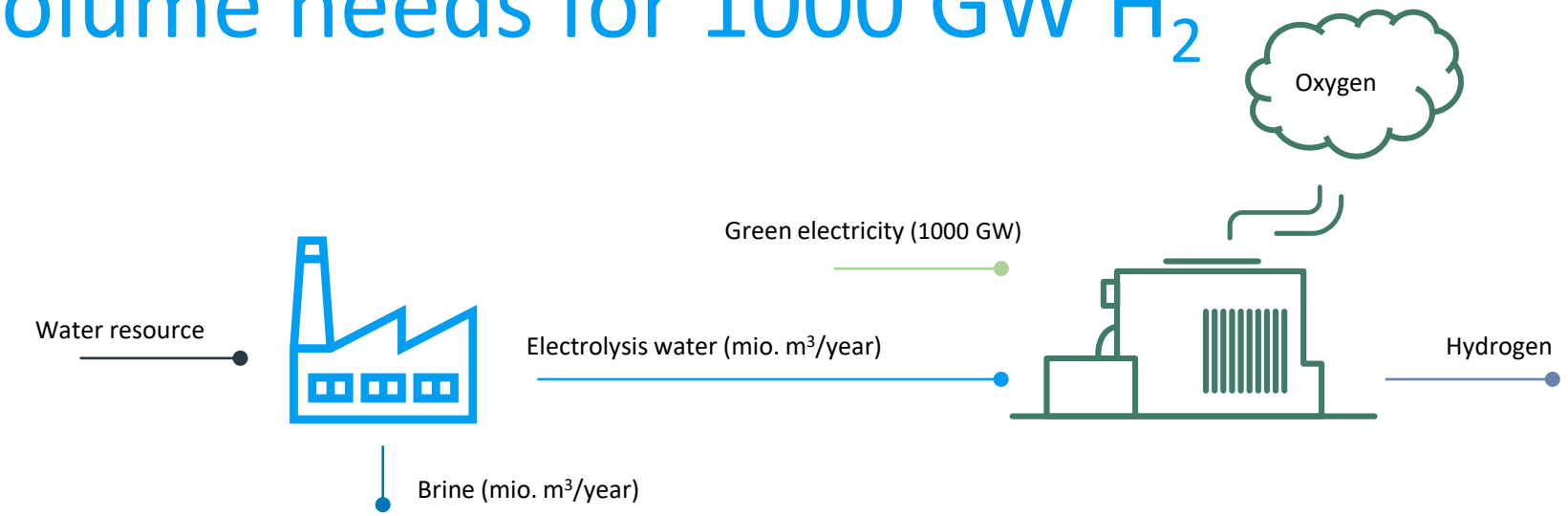
1,6 bio. m^3 electrolysis water for 1000 GW H_2

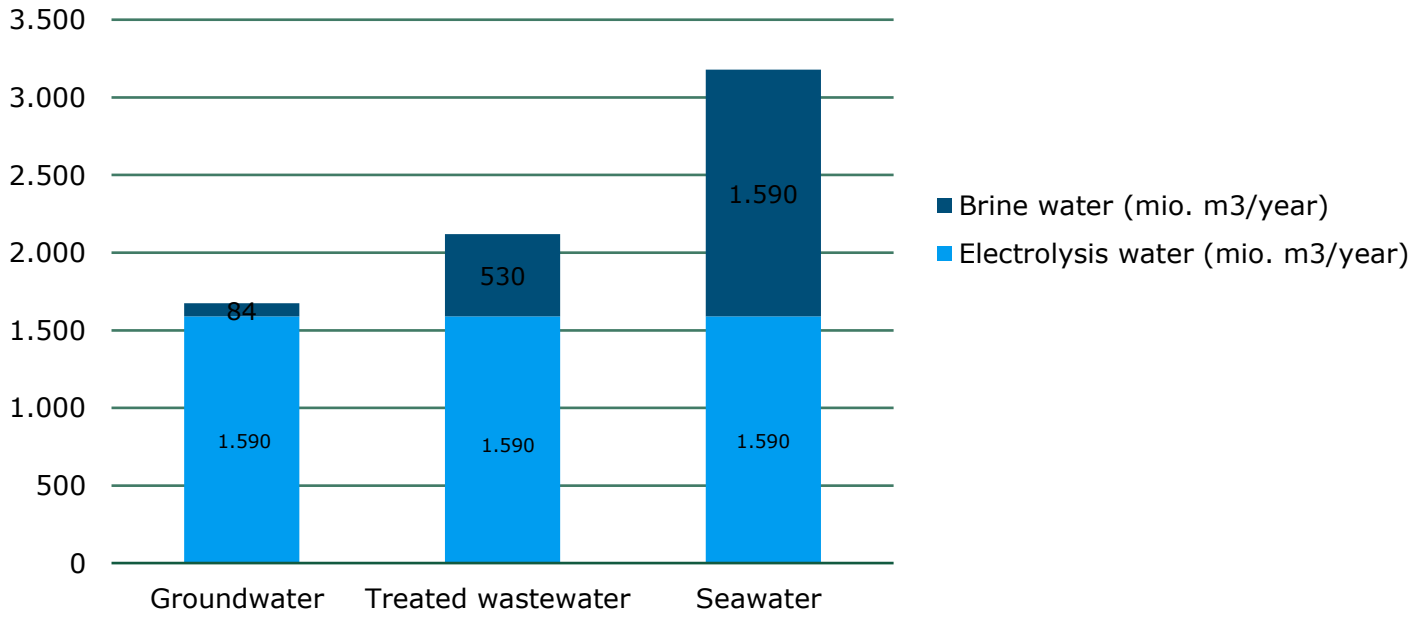




Excluding cooling water needs
which largely depend on local conditions

Water resource type determines untreated water volume needs for 1000 GW H_2





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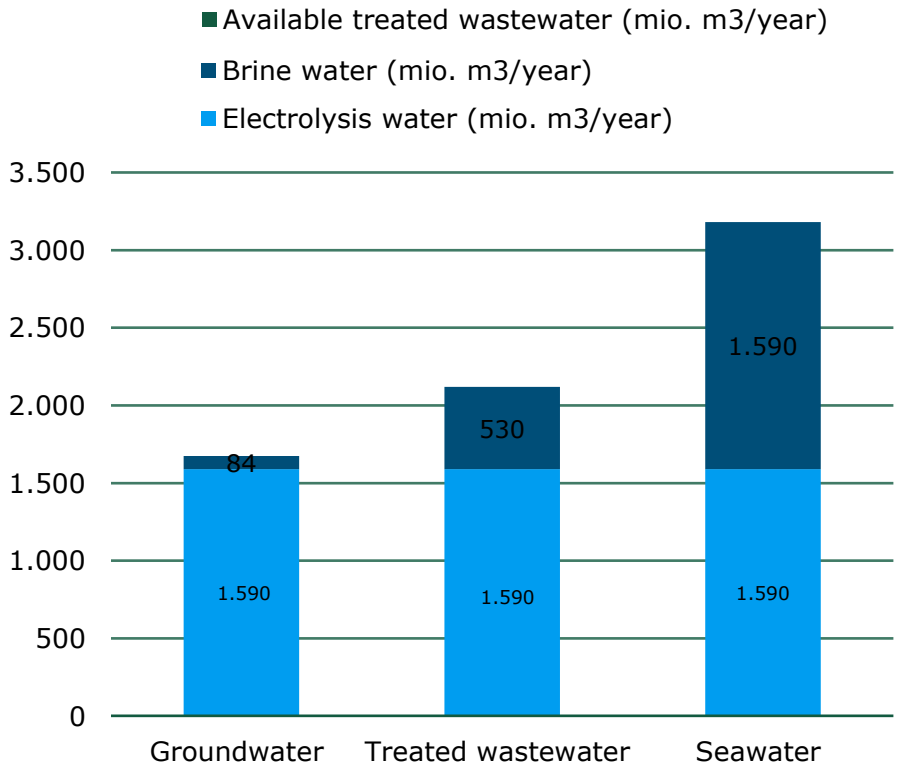
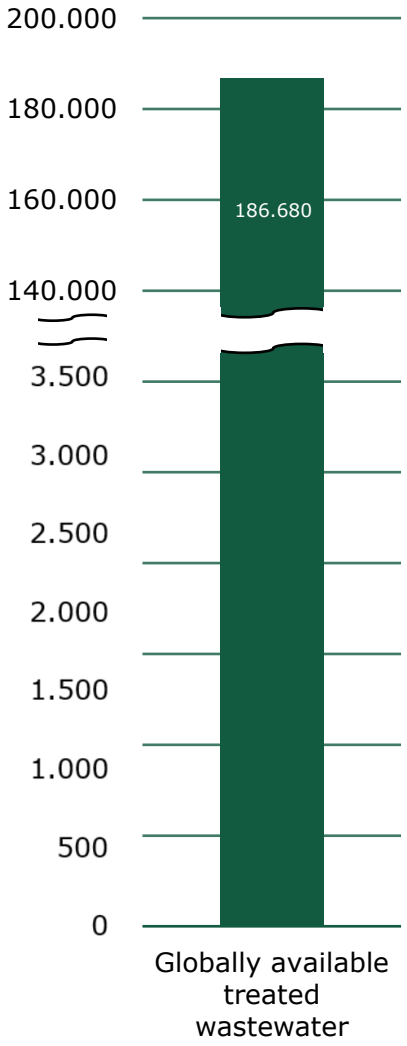
90 times more wastewater effluent than untreated water need for 1000 GW H_2



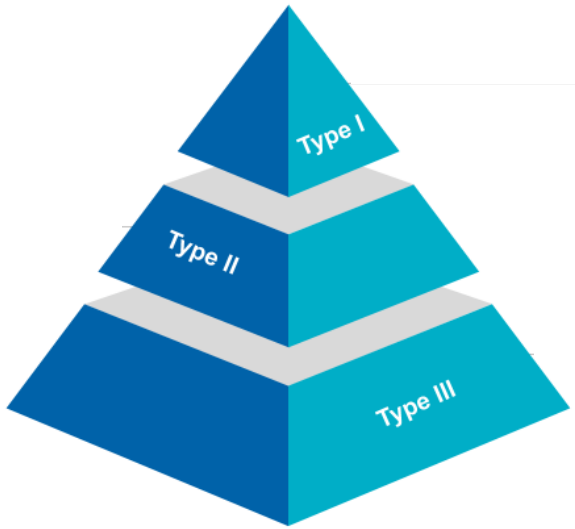


Yearly treated wastewater effluent in Barcelona can generate

4 Mt green H_2

Electrolysis water requires ultrapure water quality

- **Why high water quality?** ensure the lifetime of electrolysis plants against corrosion and maximize electrolyzer performance
- **Quality requirements**:
    1. Ultrapure water, e.g. ASTM type 1-3, known from the pharmaceutical, electronics and semiconductor industries
    2. Different requirements for types of electrolysis plants: PMEC, SOEC, PEM



Parameter (max)	Type I	Type II	Type III	Type IV
Conductivity (µS/cm)	0.056	1.0	0.25	5.0
Resistivity (MΩ-cm)	18.0	1.0	4.0	0.2
pH	–	–	–	5.0–8.0
TOC (µg/l)	50	50	200	No limit
Sodium (µg/l)	1	5	10	50
Silica (µg/l)	3	3	500	No limit
Chloride (µg/l)	1	5	10	50

Water quality standard ASTM types, at 25°C

Water quality needs set the treatment needs

Water Sources	Pollutants and Treatment Parameters	Possible treatment technologies	Remark
Groundwater	Dissolved solids	MMF + RO + active carbon (AC) + EDI	Possibly contains ions like carbonate or metals (e.g. iron, manganese)
Impaired Groundwater	Dissolved solids, heavy metals, pesticides, PFAS, PAH and BTEX	MMF + RO + UV + GAC + EDI	Possibly contains ions like carbonate or metals (e.g. iron, manganese)
Surface Water	TSS, BODs	Fine screening + coagulation/filtration + BWRO + EDI	Seasonal variations in composition
Seawater	Salinity	Screening + MMF/UF + SWRO or Thermal Desalination + EDI	High in sulphate
Treated Industrial Wastewater	Suspended solids, BODs, COD, TN, TP, wide range of industrial contaminants	Coagulation/filtration + MMF/UF + RO/NF or advanced oxidation + active carbon filtration + EDI	Variations in composition and composition depending on industry
Treated Municipal Wastewater	Suspended solids, BODs, COD, TN, TP	MMF/UF + RO/NF or advanced oxidation + active carbon filtration + disinfection + EDI	Mainly nutrient removal
Cooling Water	Dissolved and Suspended Solids, biocides	RO/NF or AO + AC + EDI	Generally reusable in the respective industry
Rainwater	Some dissolved solids, BODs, TSS	Fine screening + MF/UF + RO/NF or AO + EDI	Need of storage bassins

Water treatment process technology options

Water treatment process in several steps/units

1. **Pretreatment, focuses on removal of suspended solids and/or organics:**

- Screening or cartridge filtration
- Coagulation-flocculation followed by separation of ultrafiltration
- Active carbon

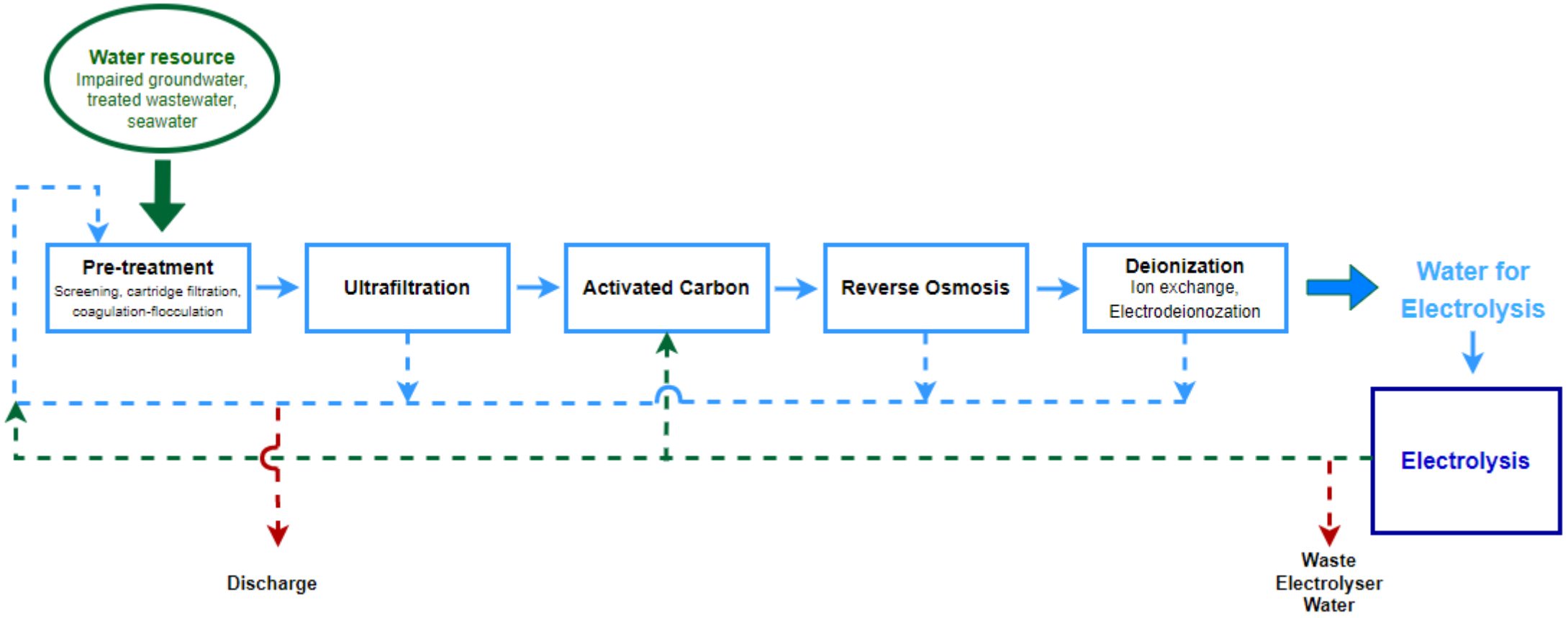
2. **Treatment, focusses on removal of dissolved organic and inorganic contaminants:**

- Membrane technologies
- Advanced oxidation

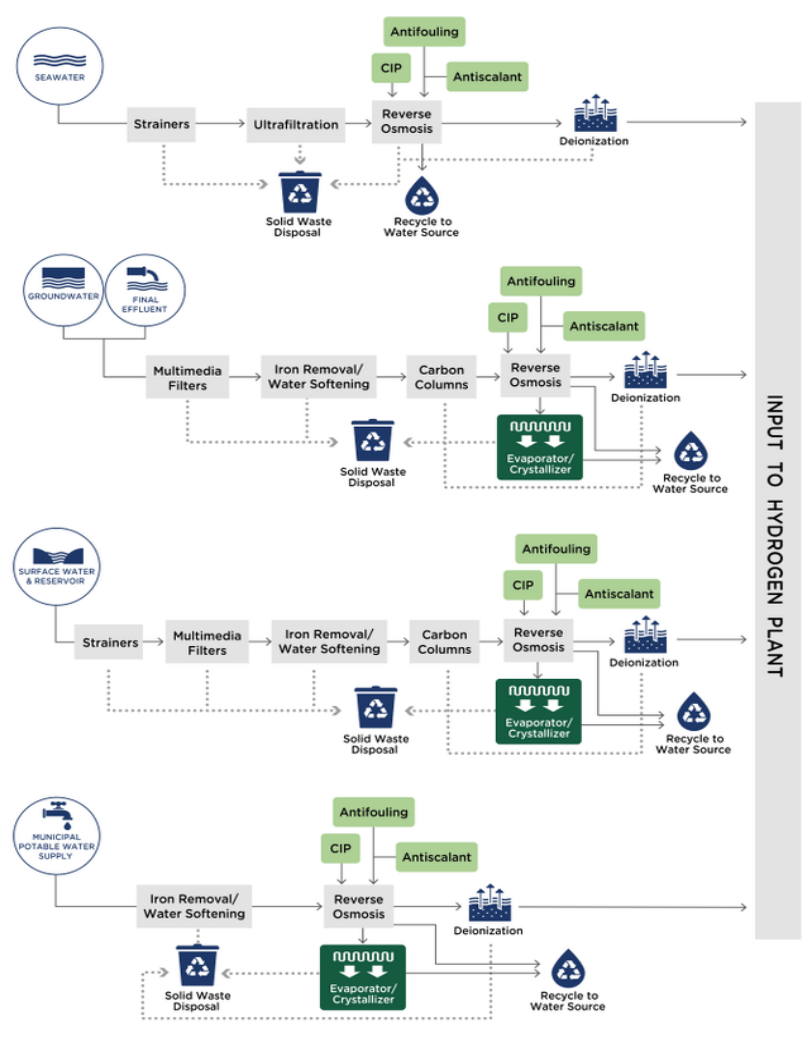
3. **Polishing, focusses on removal of residual concentrations of dissolved contaminants:**

- Active carbon filtration
- Ion exchange
- Electrodeionization
- Degassing

Water treatment process in several steps/units



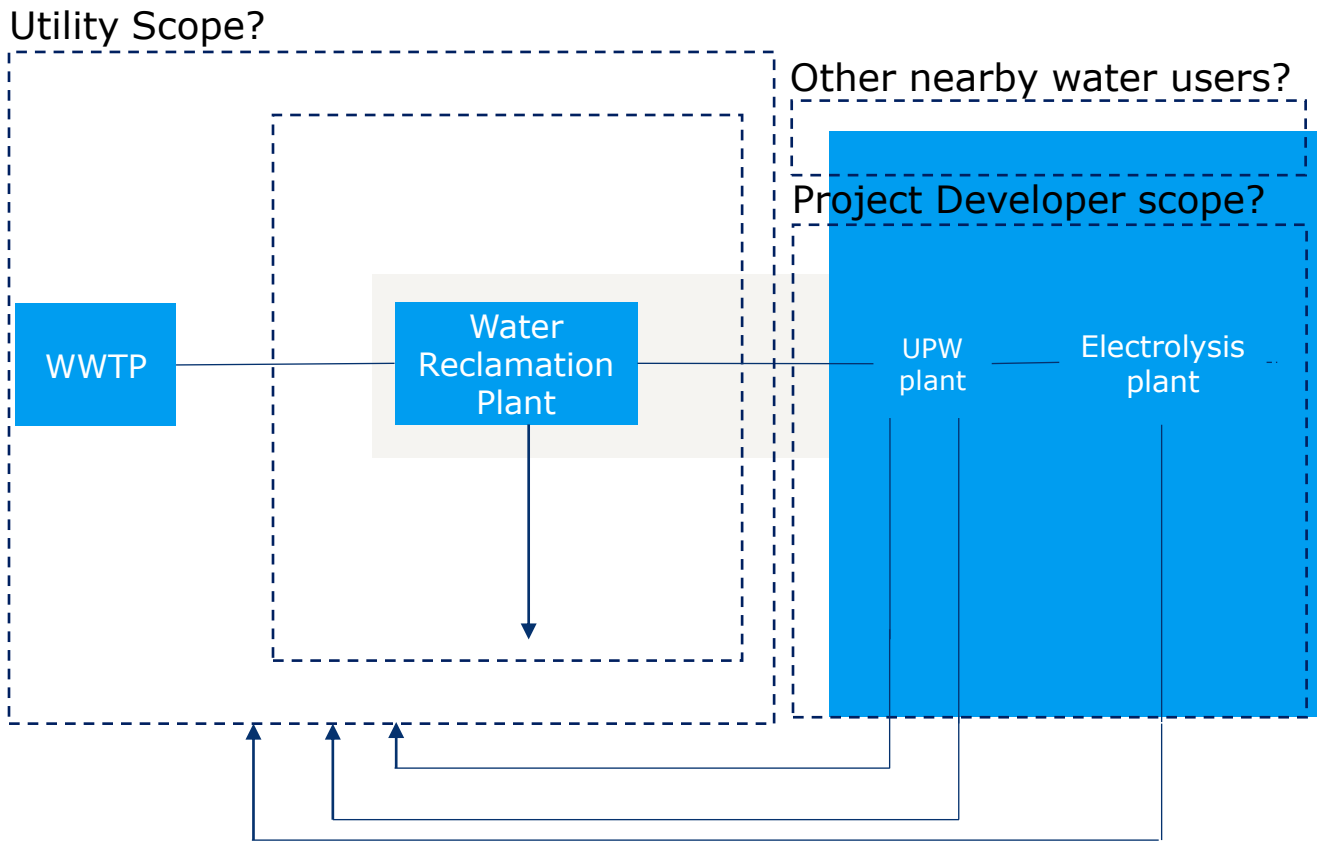
Tailored process design can save a lot of money, energy and chemicals



Water treatment

- Target water quality drives a high level of treatment for all water sources
- Membrane process steps (RO/NF) will generate residuals containing suspended solids or salts for disposal
  - This can be minimized down to 15 by design and process selection (e.g. CCRO)

New types of ownership of water treatment plants for fit-for-purpose effluent water reuse



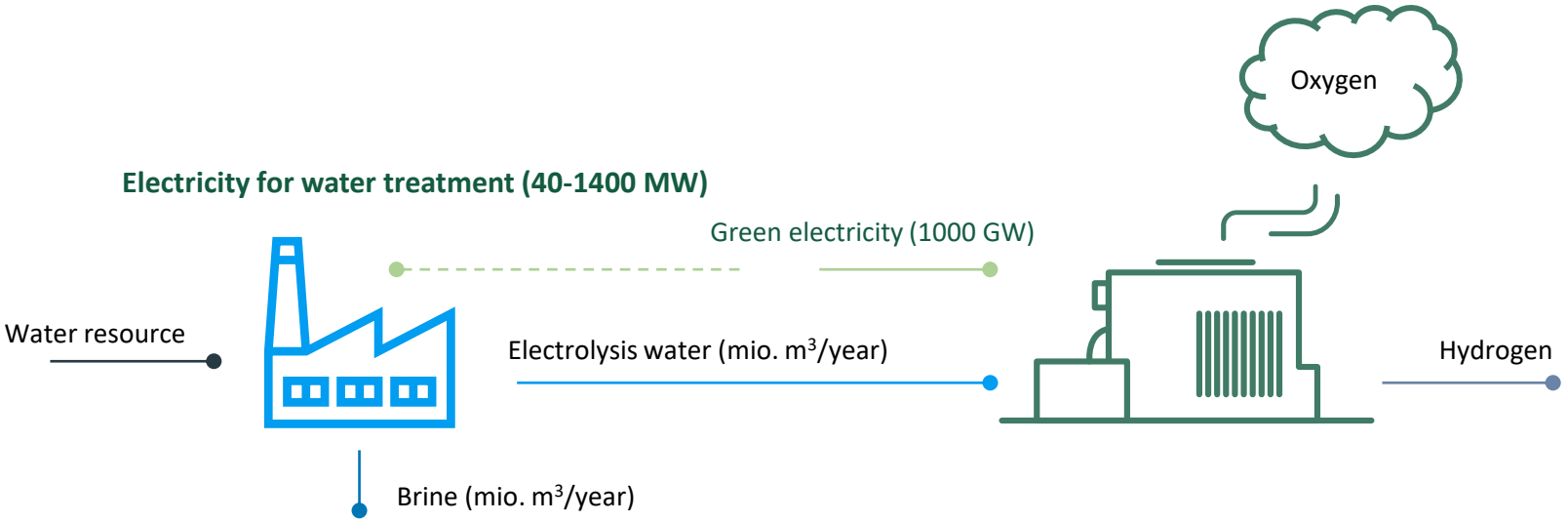
Ownership of water reclamation plant heavily depends on location:

- varying water reuse permitting landscapes
- water needs
- economic needs

Funding of investments is more attractive if the treatment plant is proven sustainable according to EU Water Taxonomy as part of the Corporate Sustainability Reporting Directive (CSRD)

Sustainability and decarbonization of water resources and process technologies

Electrolysis water needs for 1000 GW H_2



Excluding cooling water needs

which largely depend on local conditions

Energy consumption for treatment determined by water resource type

Water resource	Fine screening	Coag./ Floc.	UF	RO	ACF	IEX	EDI	Total
	kWh/m^3	kWh/m^3	kWh/m^3	kWh/m^3	kWh/m^3	kWh/m^3	kWh/m^3	**kWh/m^3**
Impaired Groundwater					0.1	0.1		**0.2**
Treated Wastewater			0.025-0.1	1-2	0.1	0.1	0.5-1.5	**1.6-3.7**
Surface Water	0.5-1.5	<0.05	0.025-0.1	2-4	0.1	0.1	0.5-1.5	**3.2-5.7**
Seawater	0.5-1.5		0.025-0.1	3-6	0.1	0.1	0.5-1.5	**3.6-7.7**

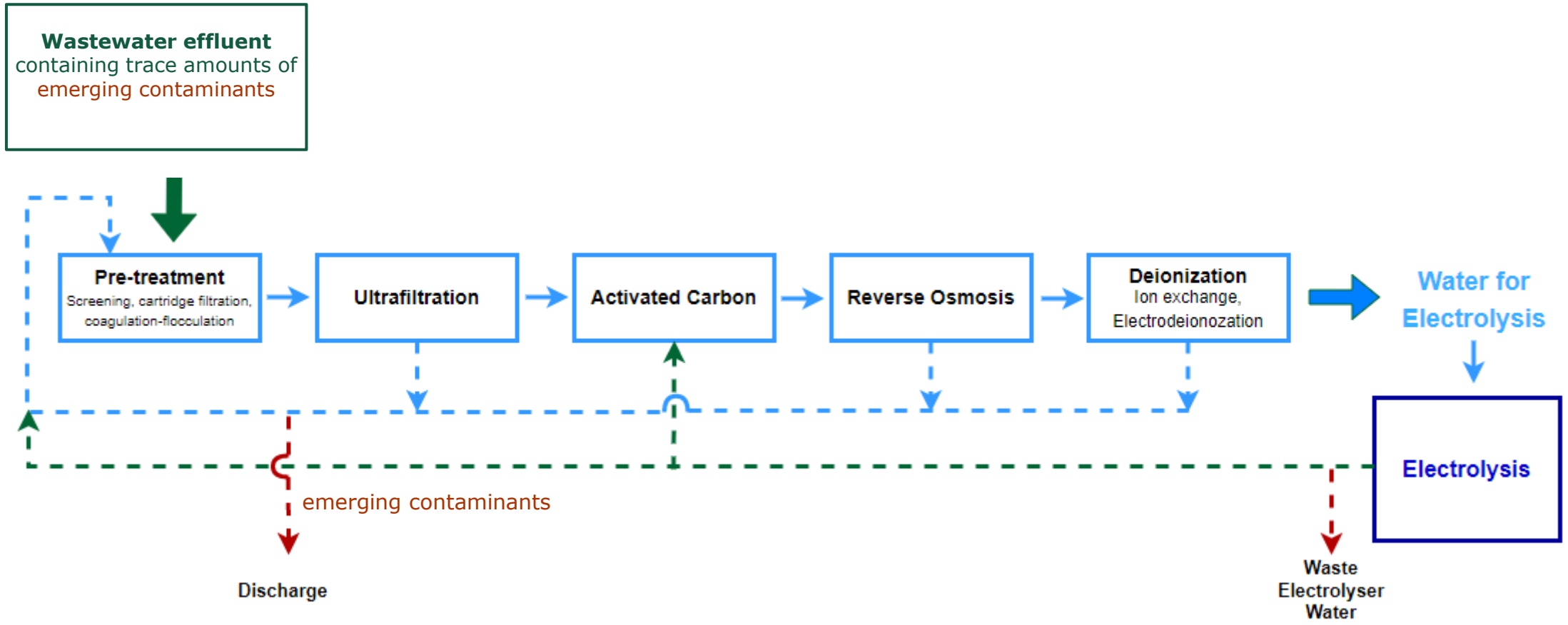
Focus on resilient water resource management

Resilience assessment highly depends on location

Project Location	SURFACE WATER	GROUND -WATER	SEAWATER	EFFLUENT
Location A	5	3	1	2
Location B	3	4	2	1
Location C	4	3	2	1
Location D	4	5	2	1
Location E	NA	NA	1	NA

- Sufficient water resource is available to meet the demand.
- Sufficient water resource is not available to meet the demand.

Wastewater effluent: consider opportunities for treatment of emerging contaminants



Opportunity for water utilities: treat emerging contaminants in concentrated effluent
PFAS, pharmaceuticals, heavy metals,…

Resource recovery at P2X plants: co-siting

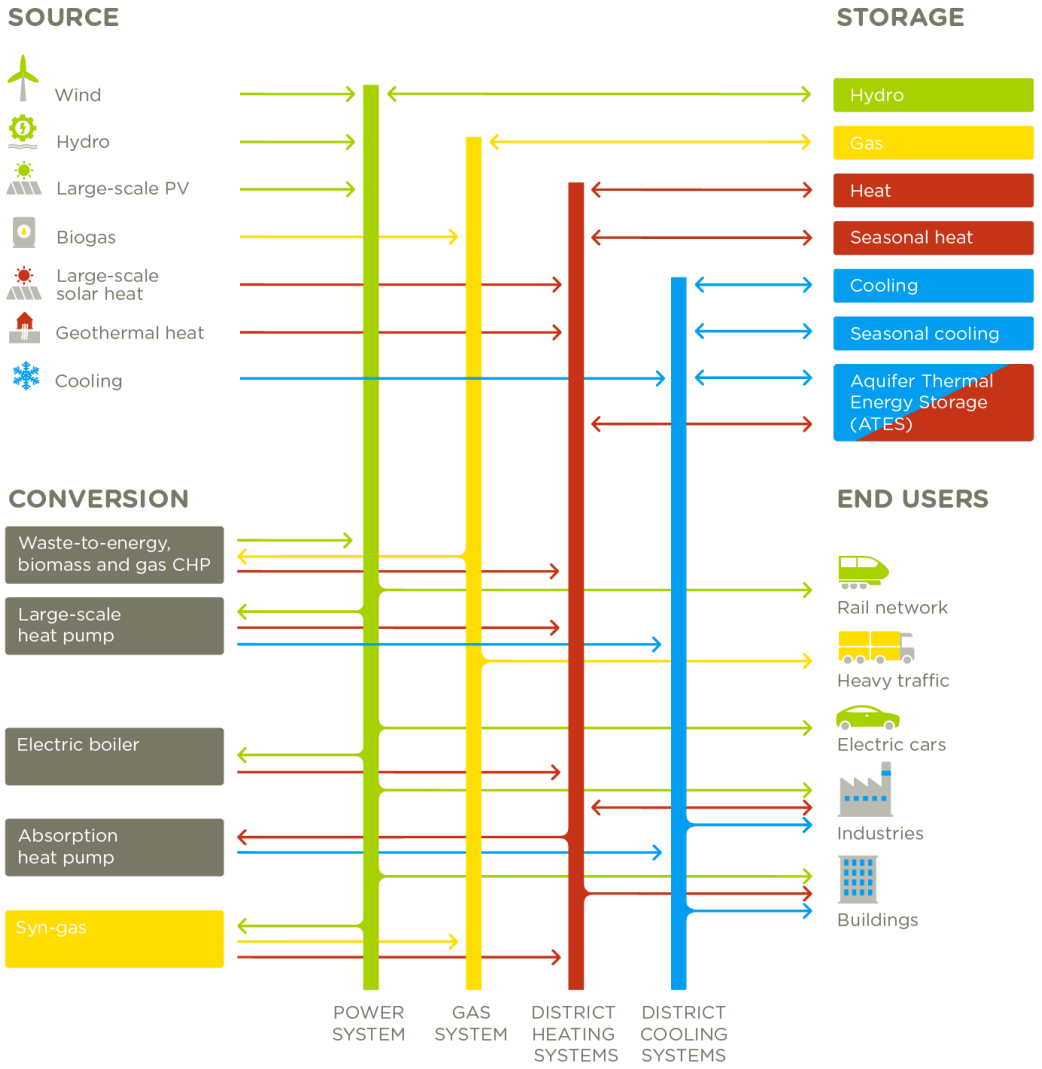
Plenty of opportunities for co-siting at Power-to-X sites

Interconnection of different resources in transport, buildings, water and industry.

1. Symbiotic use of different energy carriers (electricity, gas, district heating/cooling) with conversion between carriers and storage of carriers.

2. Symbiotic use of resources such as water and residual product, O_2

3. Clean, smart and cost-effective way to accelerate low-carbon energy production.



Case studies

Wastewater reuse plant for P2X in Nakskov, Denmark

Hydrogen Generation Water Impact Feasibility Study, Scottish Gas Network, Scotland

Bornholm Energy Island

From wastewater effluent to electrolysis water, Nakskov Denmark

The challenge

Lolland Forsyning A/S wishes an elaboration of a preliminary project which examines the possibility of supplying an annual amount of 500,000 - 700,000 m^3 technical water of drinking water quality, from effluent from Nakskov WWTP

Our approach

- Determination of water quality requirements
- Determination of optimal location of the facility
- Description of the water treatment technologies that are expected to be able to meet the established water quality requirements, as well as obtaining relevant tenders
- Assessment of the necessary installations in relation to dimensions, routes and construction and operating economics
- Preparation of construction and operating economic assessment with 30% uncertainty for a water treatment plant incl. buffer
- tank, water tank, pipeline and possibly building on the basis of a present value consideration
- Clarification of official and regulatory matters
- Screening of the project to identify potentials for sustainability within the environmental, social and economic aspects

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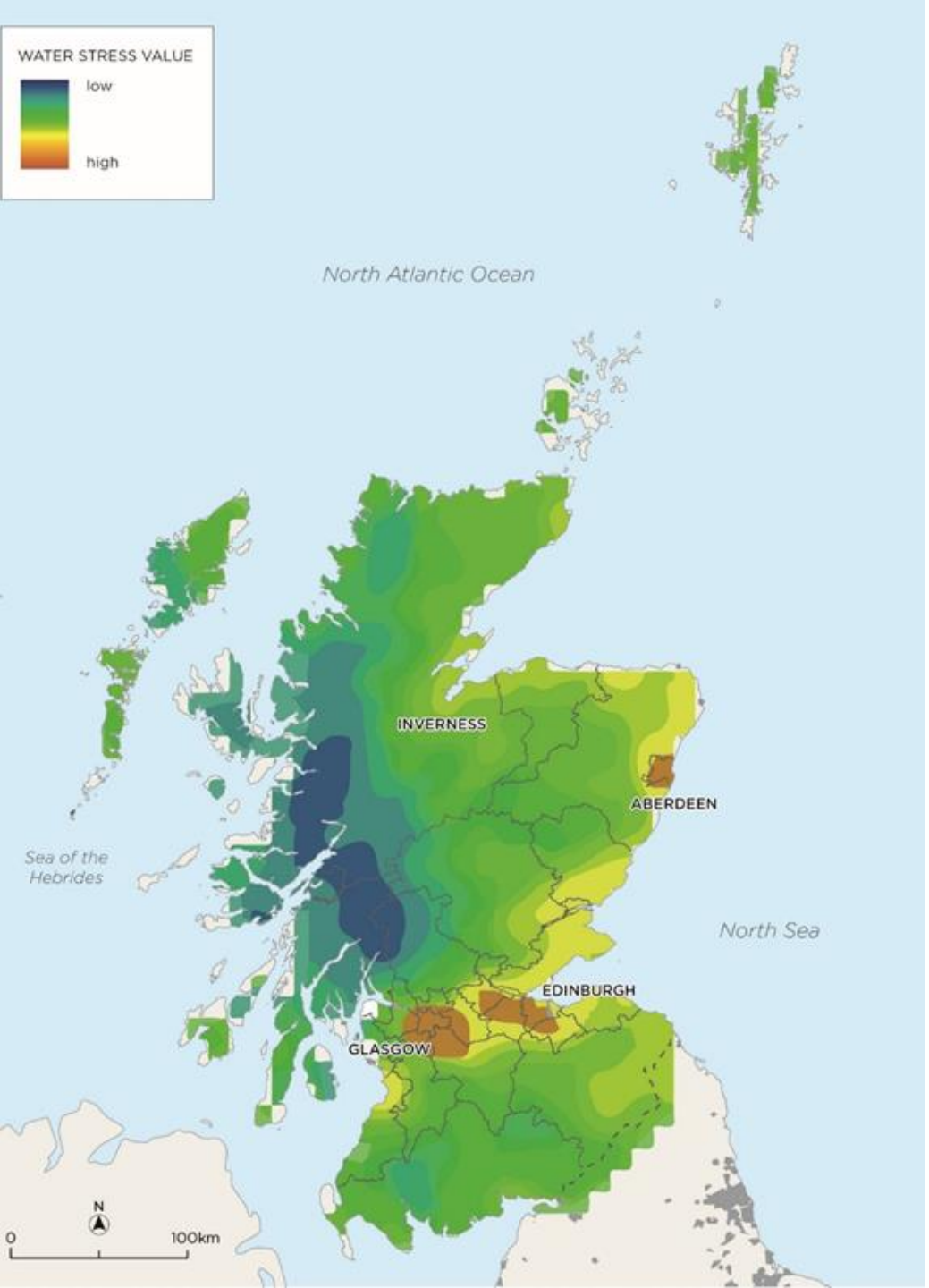


Hydrogen Generation Water Impact Feasibility Study, SGN, Scotland

The challenge

Assessing the impact on water resources and water infrastructure due to hydrogen production in Scotland till year 2045.

Approach

Ramboll identified the regions in Scotland where the significant hydrogen production is likely to take place. Water consumption and water quality requirements for hydrogen production in the different regions were quantified. We then assessed the impact of hydrogen production on 5 different water sources namely surface water, ground water, effluent, portable water and sea water in each of the shortlisted region. We will also identified technical requirements and cost for water treatment systems and overall infrastructure upgrades for using different water sources.

The result

The project made recommendation on preferred water sources in different regions of Scotland. As a part of the project Ramboll generated a tool and nomographs which can be used to carry out similar assessment for different geographies.

Bornholm Energy Island

The challenge

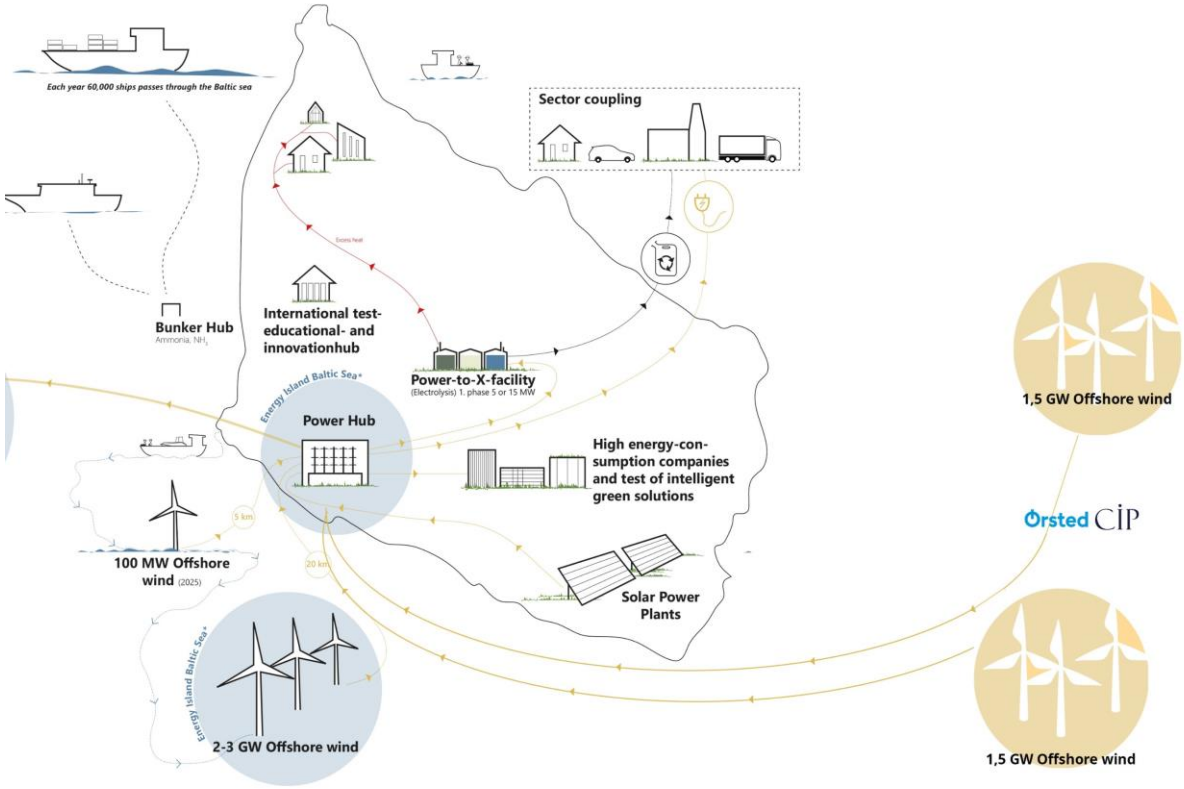
Ramboll is part of a consortium of companies investigating the possibility of establishing power-to-x facilities on the Island of Bornholm in connection with the establishment of the Energy Island Bornholm, which is set to deliver at least 2 GW of offshore power to the island by 2030. An energy island is a hub for large amounts of energy from offshore wind power.

Our approach

Ramboll's role has been to qualify and validate information and assumptions used in the techno-economic model developed by the consortium parties, which will be used to model the most optimal development of a Power-to-X facility.

The result

By August 2023, the project will result in a business case for Power-to-X production at Bornholm, enabling partners to decide whether to continue to pursue the local production of PtX. The project will also develop two simulation tools for Power-to-X developers, potentially accelerating development of new PtX projects nationalwide.



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Take homes

- Water scarcity is a global concern and can impact the feasibility of H_2 projects almost everywhere
- Treated wastewater is next to fresh surface water an attractive source, but with new regulations coming into play, treated wastewater will quickly become more attractive to especially industry and agriculture
- Seawater is available in coastal areas/offshore, but takes a significantly higher investment, energy and chemicals consumption
- Tailor-made design of the water treatment process is key for the overall performance of the electrolyzer process, and contributes to the sustainability footprint overall

Questions?

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