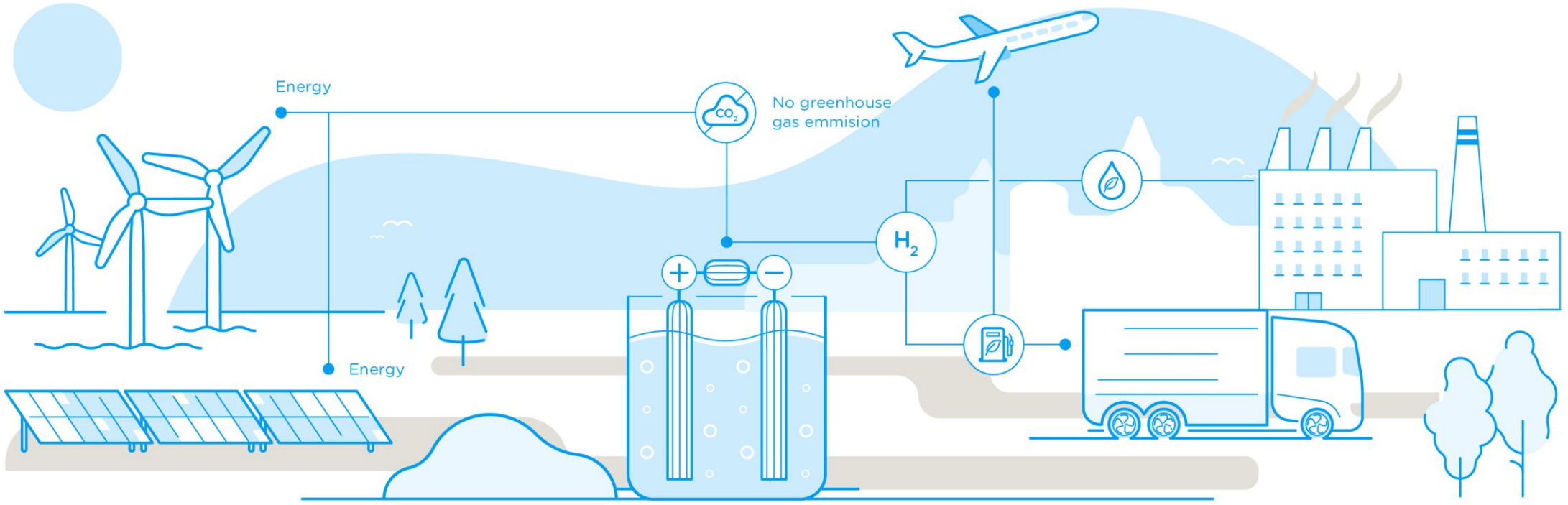


Beyond electrolysers: what else should we look after?

June, 2024

Carlos Bernuy-Lopez, PhD

Senior Consultant

Ramboll in brief

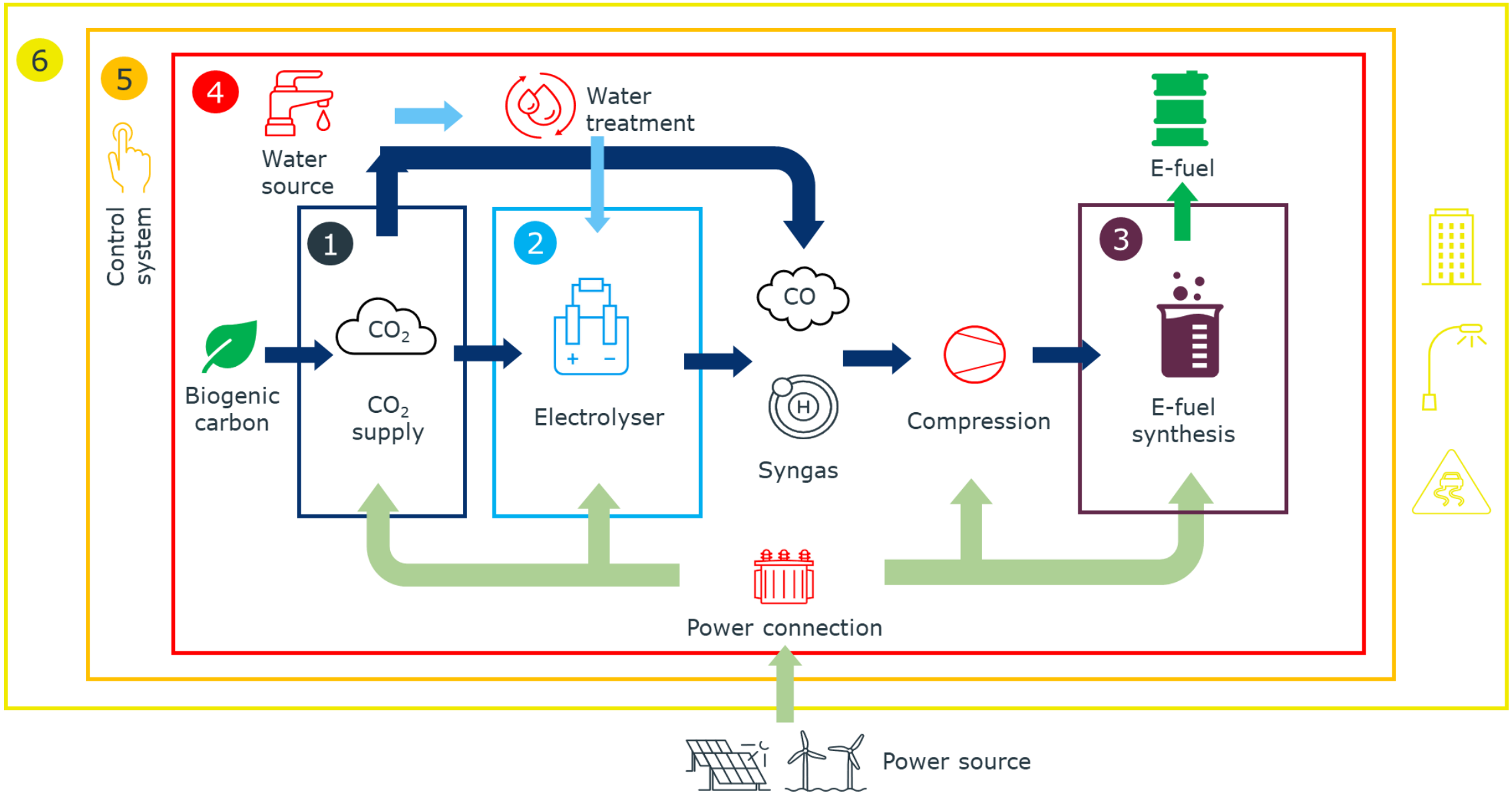
- Independent architecture, engineering and consultancy company
- Founded 1945 in Denmark
- 17,500 experts
- Present in 35 countries
- Particularly strong presence in the Nordics, the UK, North America, Continental Europe, and Asia Pacific
- EUR 1.8 billion revenue
- Owned by Rambøll Fonden – The Ramboll Foundation

We are a multidisciplinary society consultant

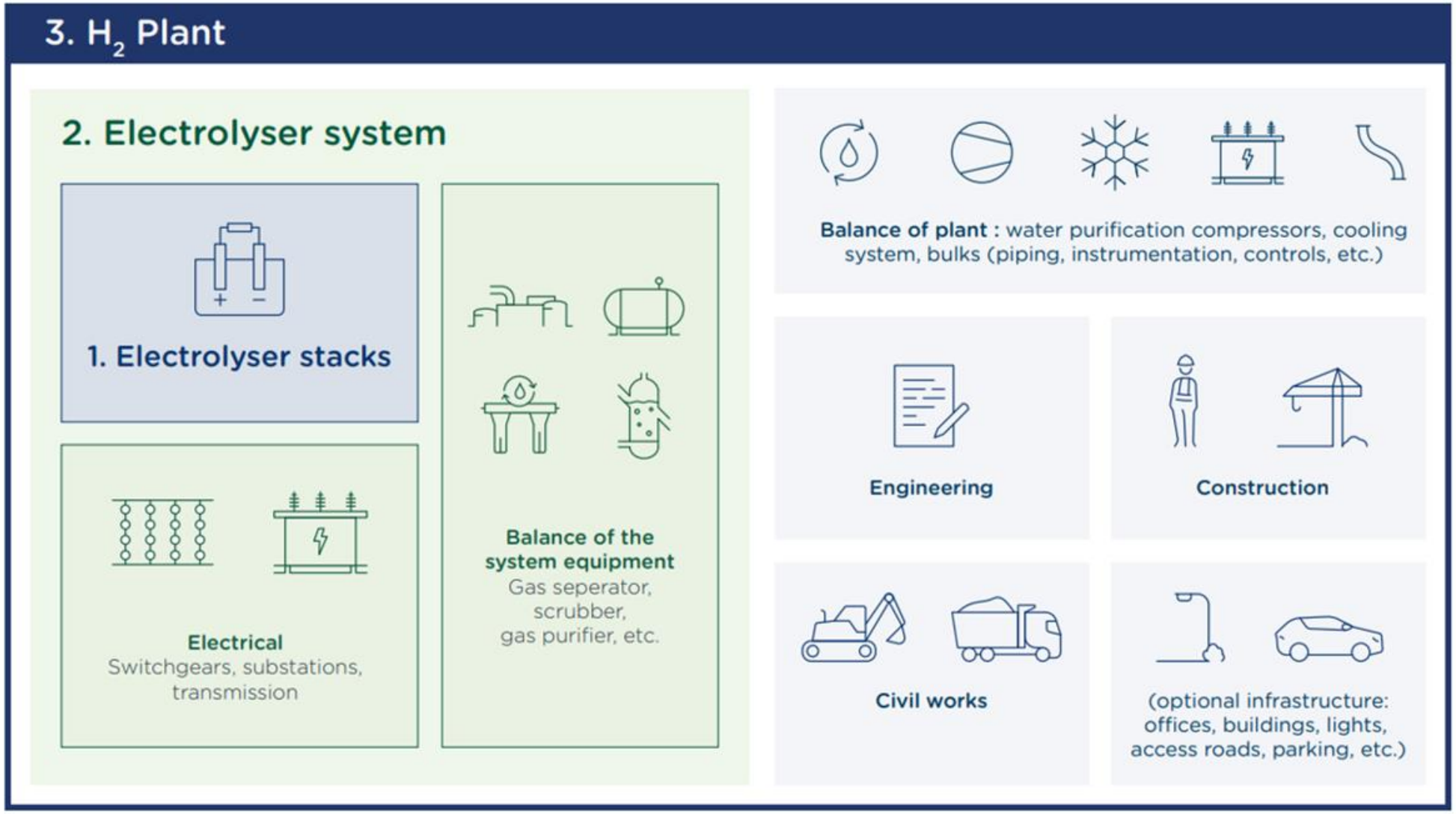
Explore with confidence

- World-class technical expertise on Hydrogen and Power-to-X
- 200 successful hydrogen projects since 2020
- Holistic and multi-disciplinary approach
- Excel in integration of complex systems
- Co-create the best solutions with and for our partners
- Top 100 Innovators in Hydrogen 2023

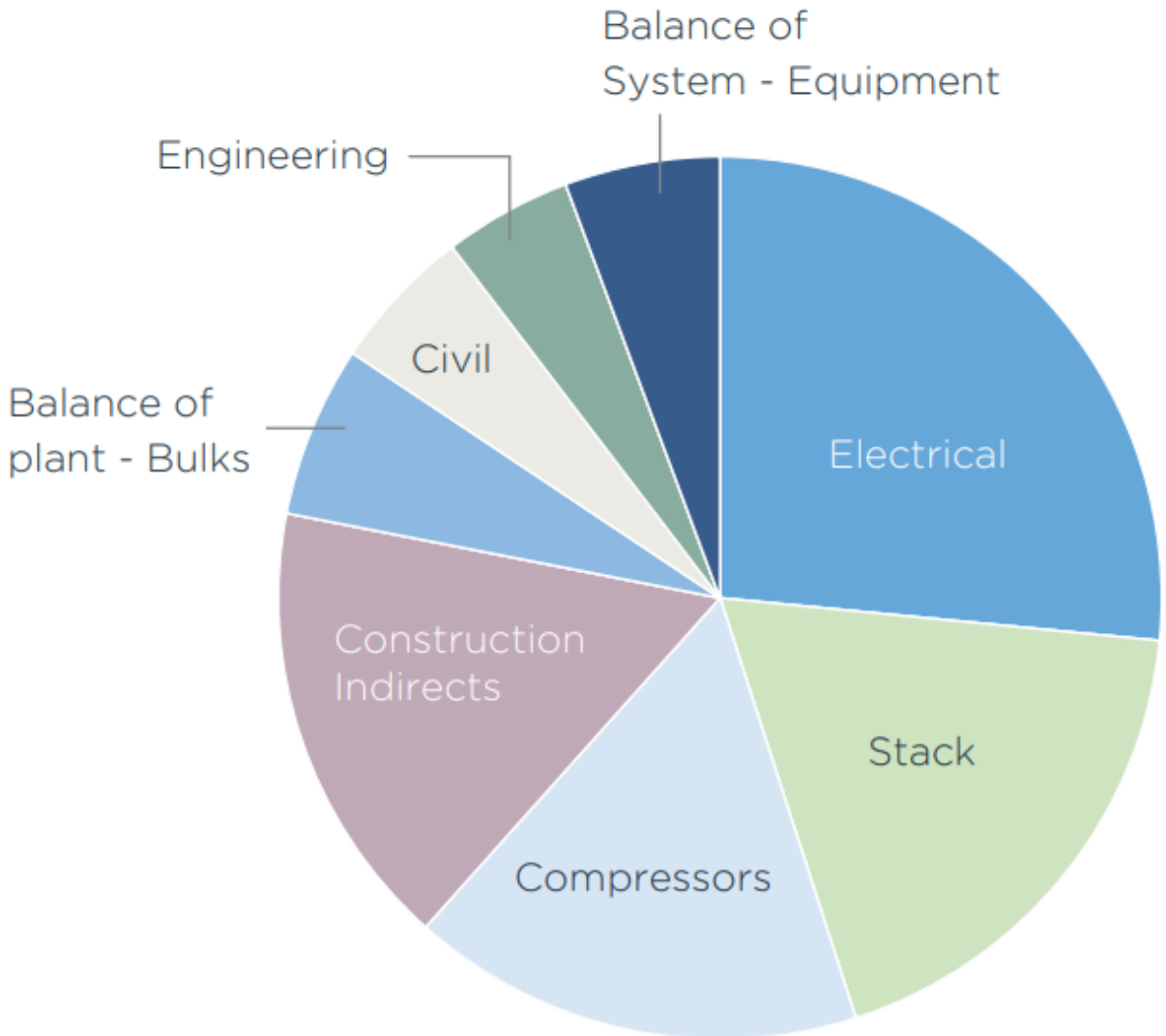
A H_2 plant inside of an e-fuel production plant

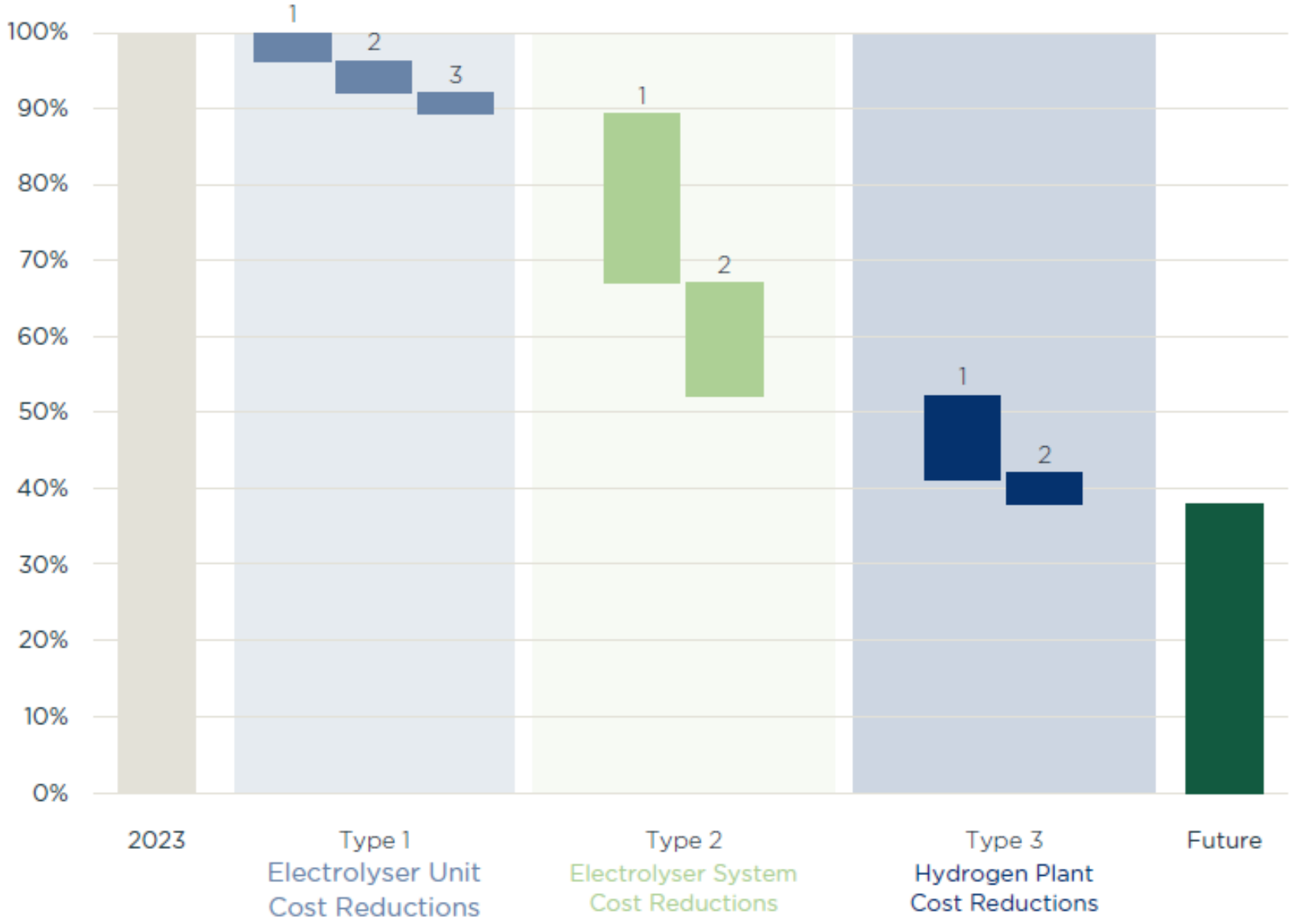


The complexity of a H_2 plant



CAPEX relative cost by category, illustrative based on system in 10 MW - 1 GW scales designed by Ramboll in 2023





Type 1
Electrolyser Unit Cost Reductions ~11%

1. Stack raw materials cost reductions
2. Manufacturing process automation
3. Competitions for market share

Type 2
Electrolyser System Cost Reductions ~37%

1. Electrical system cost reduction
2. Redundancy and resiliency cost reductions

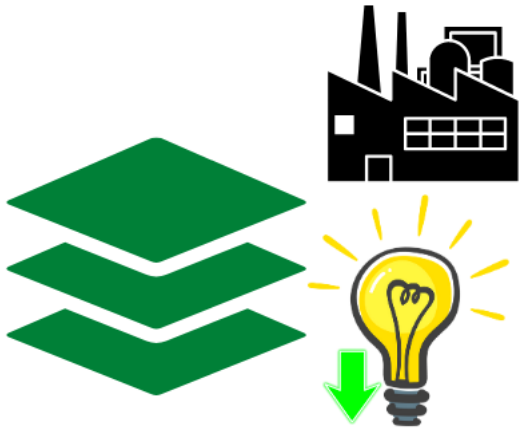
Type 3
Hydrogen Plant Cost Reductions ~15%

1. Plant footprint reductions
2. Compressor technology improvements

Hydrogen Tech World

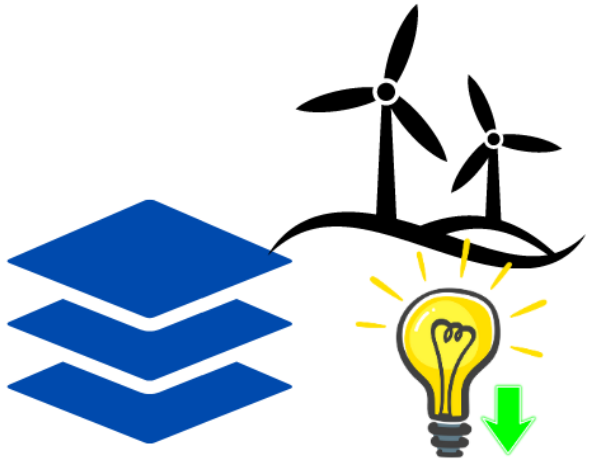
Figure 18: Ramboll analysis of potential hydrogen production plant CAPEX cost reductions from overcoming technology challenges.

Power-to-X and Electrolysis Technologies by 2025



Alkaline

Large footprint available and low electricity price



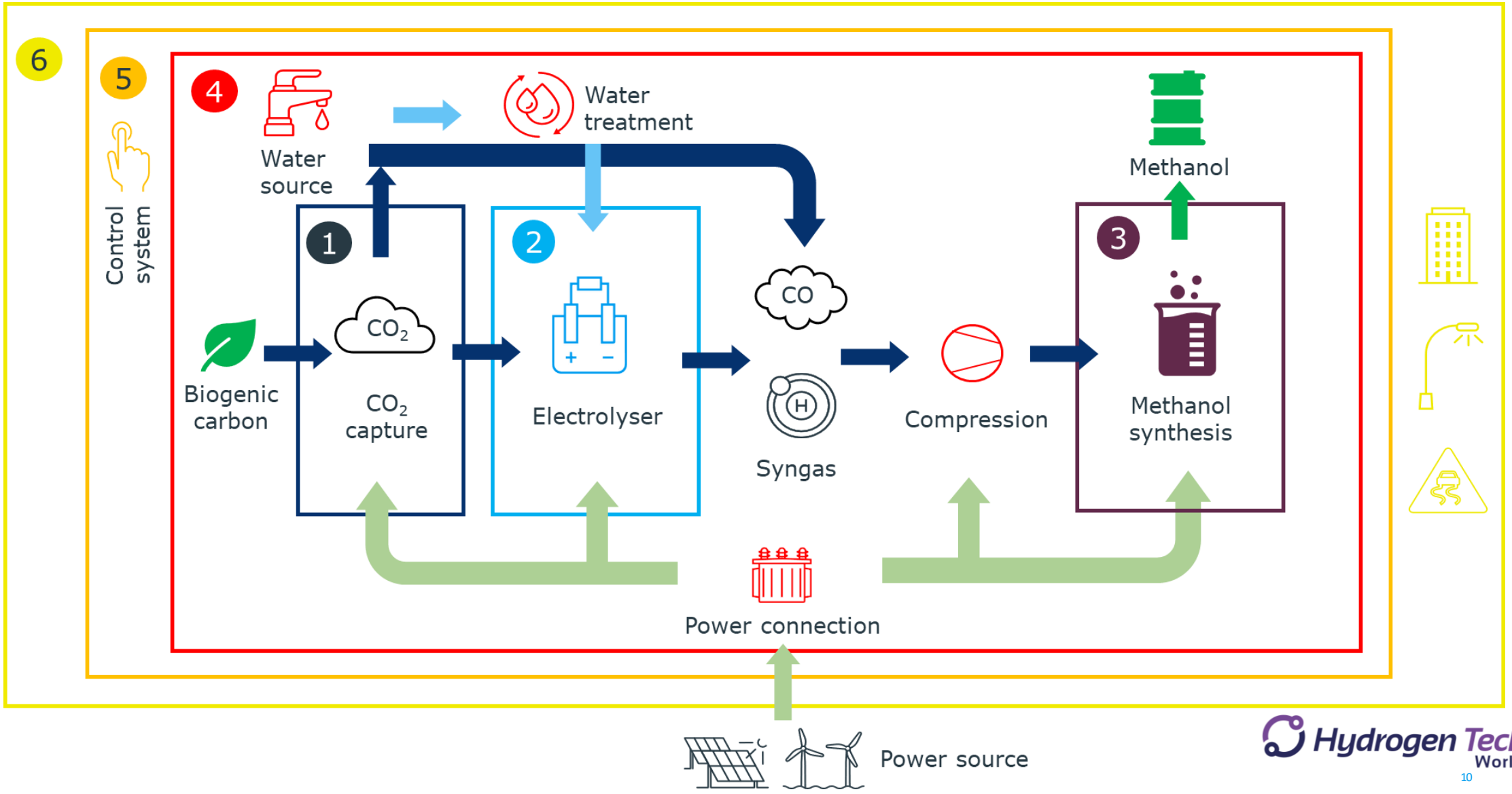
PEM

Small footprint and low electricity price

SOEC

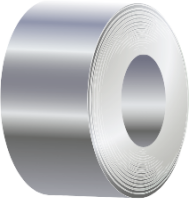
Excess heat and high electricity price

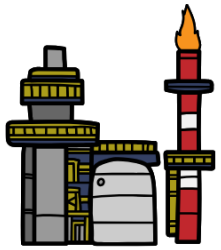
H_2 Plant: a very complex infrastructure



The Power-to-X piramid: Who does What?

Off-taker





Who owns it?

Funding

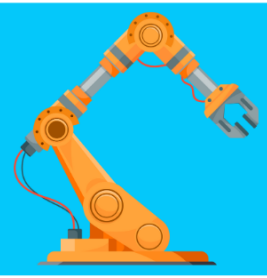
EPCMs
Management

Who coordinates all?

EPCs
Engineering Procurement Construction

Who builds it?

OEMs
Original Equipment Manufacturer



Who provides the equipment?

Author: Carlos Bernuy-Lopez

Water Considerations for a Green Hydrogen Project

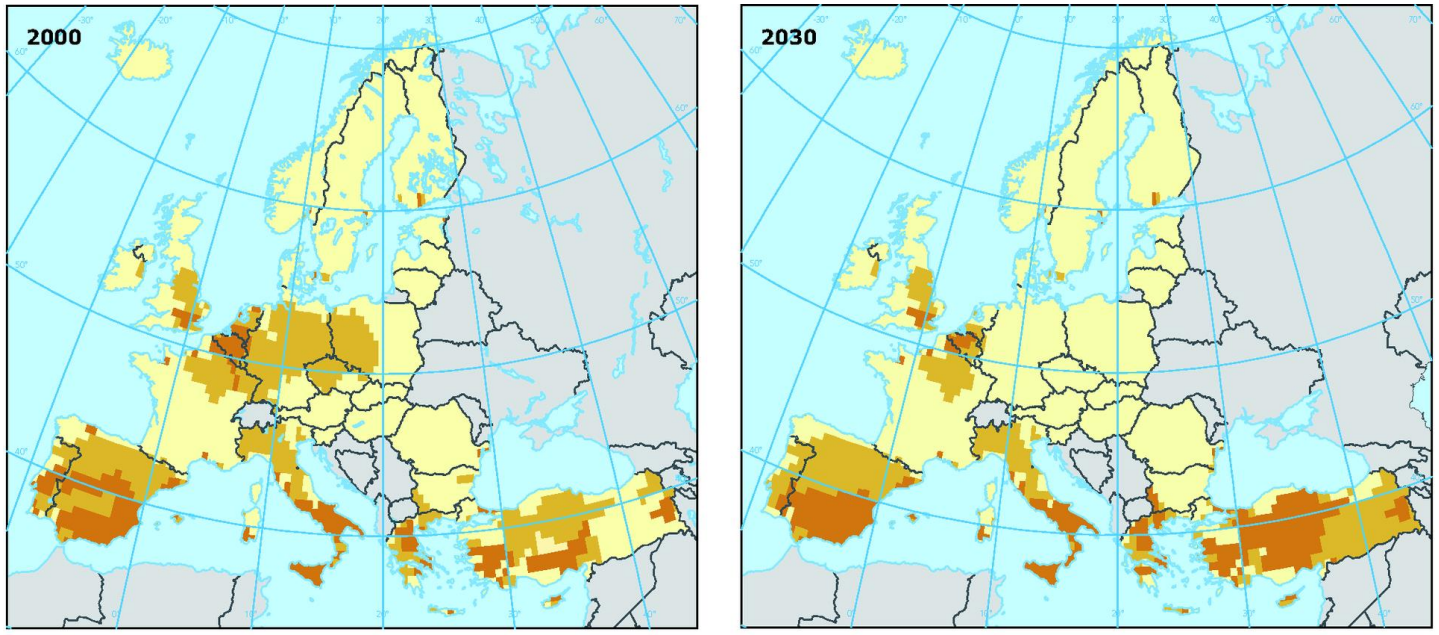
Water Consumption
Quantify the water needed for electrolysis, cooling, and ancillary systems.

Water Resources
Identify and assess the availability and quality of the potential water resources and assess if any impact.

Water infrastructure
Identify the water extraction, treatment and discharge infrastructure (pump and pipelines).

Sustainability Opportunities
Assess the opportunities for circular economy approach to by-products and waste.

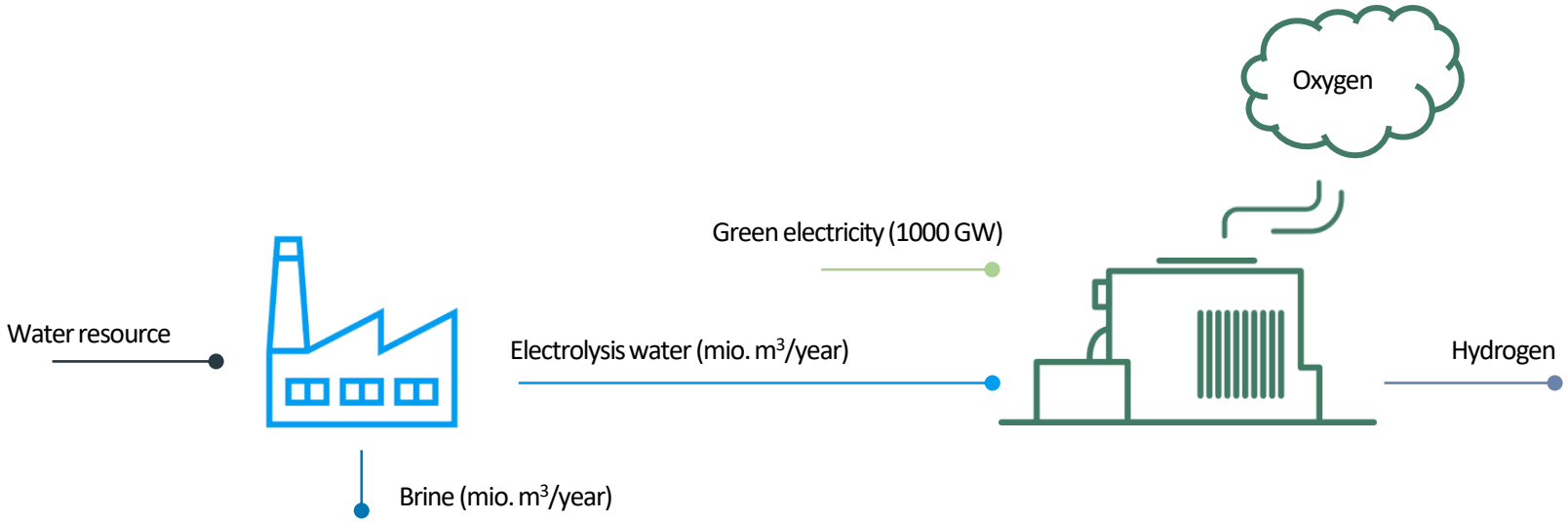
Water scarcity in Europe



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

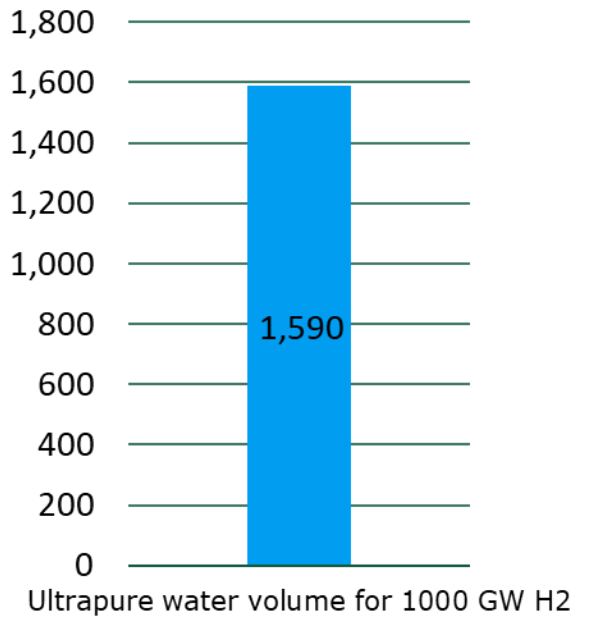
Water exploitation index (%):
- 0–20 (low water stress)
- 20–40 (medium water stress)
- > 40 (severe water stress)
- Outside data coverage

Water needs for 1000 GW hydrogen and wastewater

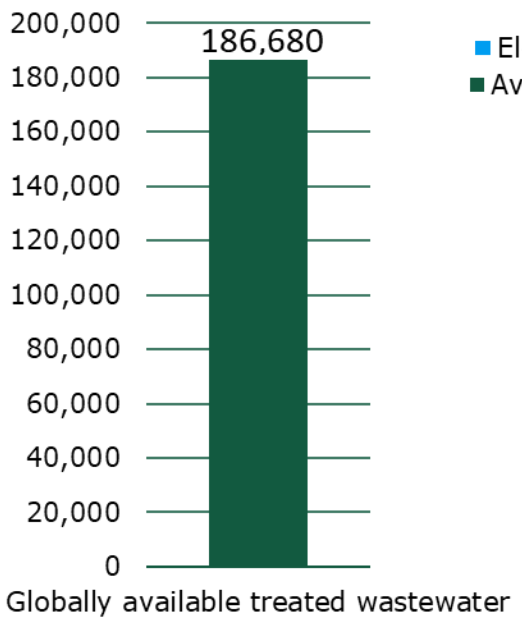


Excluding cooling water needs

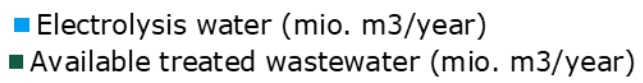
which largely depend on local conditions



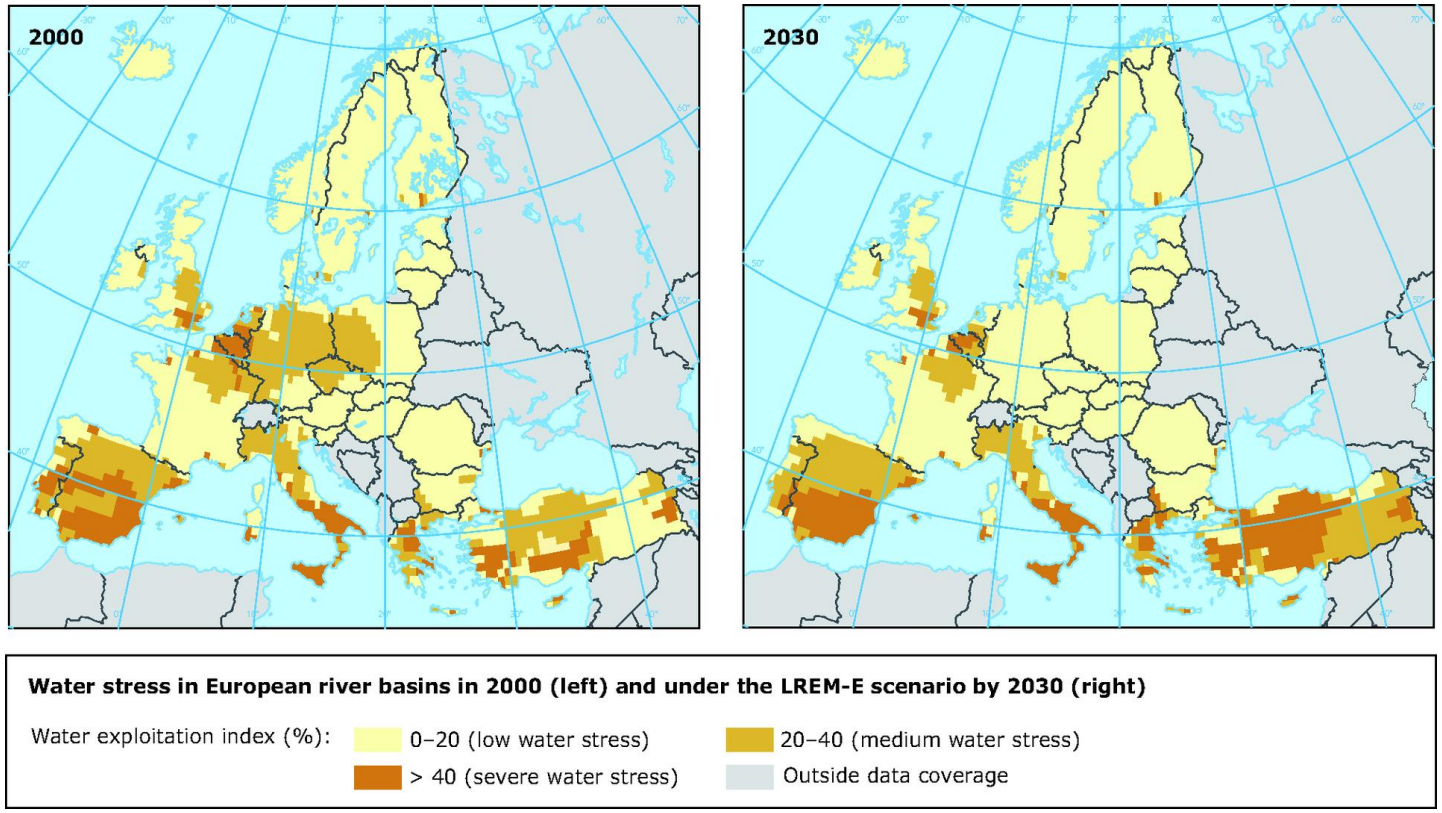
Ultrapure water volume for 1000 GW H2



Globally available treated wastewater



Water scarcity in Europe



With all yearly wastewater of the city of Barcelona we can produce **4 million tonnes of H_2**

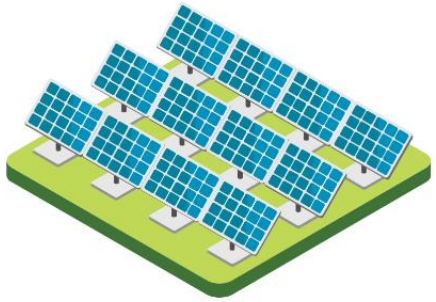
EU target for 2030 → 10 Mt int
+ 10 Mt impor

Opportunities beyond the actual project: a new supply value chain

Manufacturing opportunities around renewables

Solar

Wafer and cells



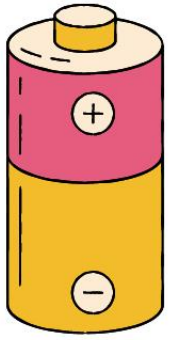
Modules

Wind

Turbines

Blades and towers

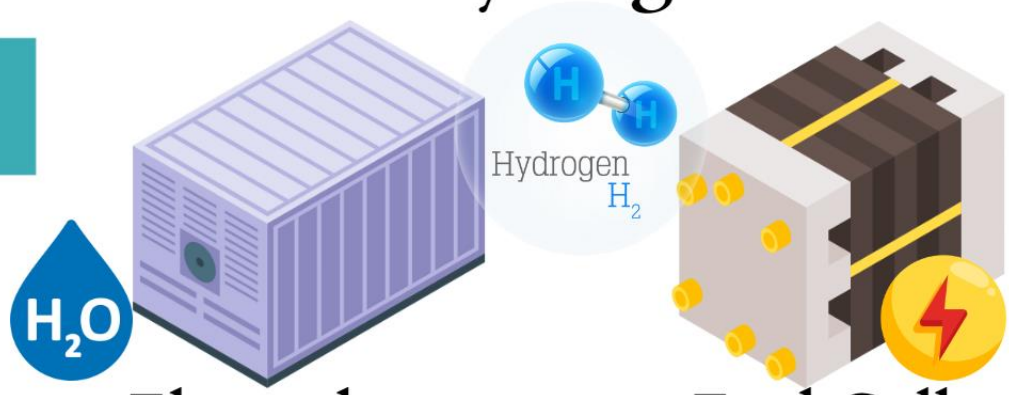
Batteries



Cells

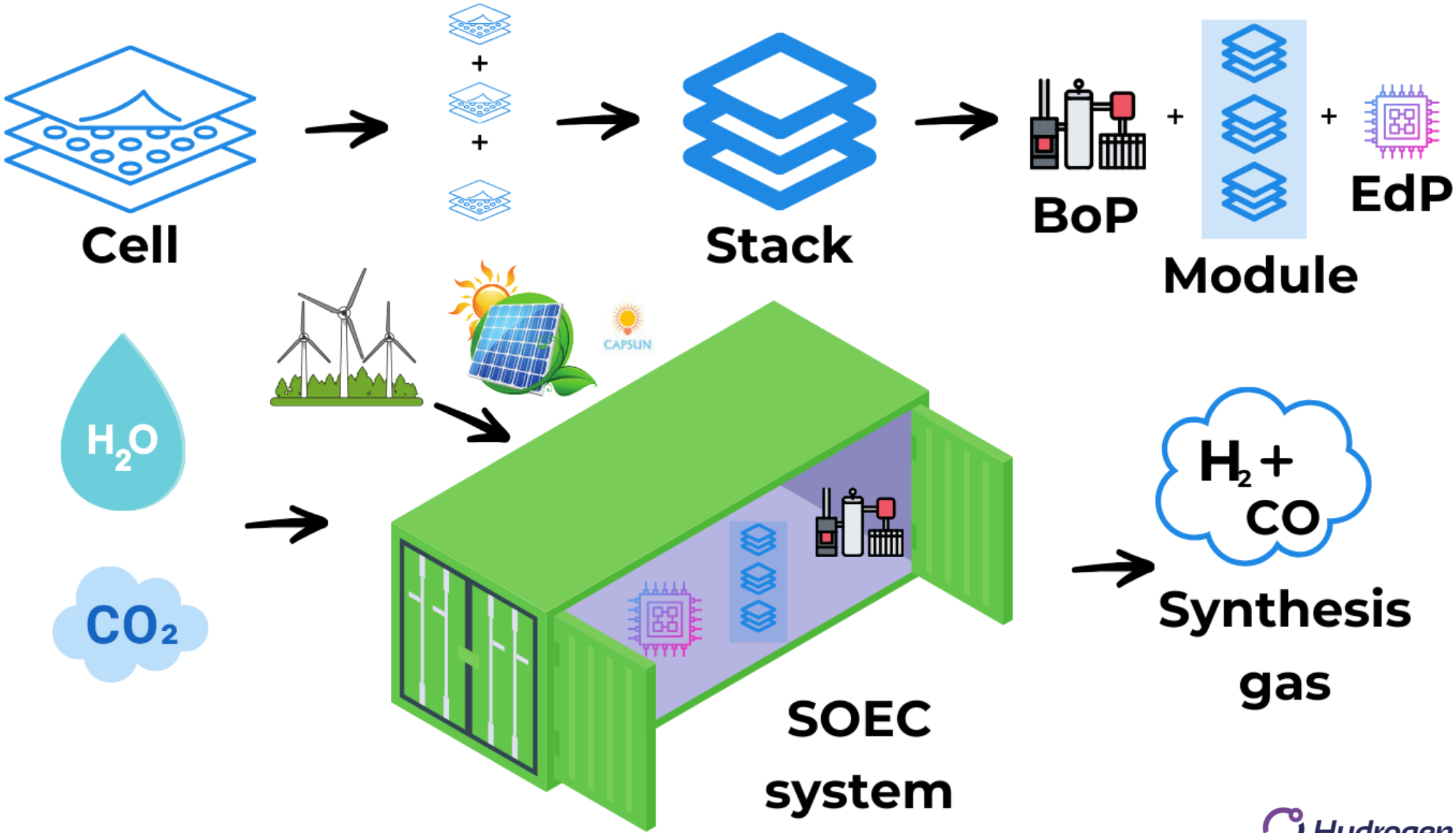
Packs

Hydrogen



Electrolysers

Fuel Cells


Cell
Stack
BoP
EdP
Module
H_2O
CO_2
CAPSUN
SOEC
system
H_2 + CO
Synthesis
gas

Manufacturing opportunities around Water Electrolysis

1
H
Hydrogen
1.008

System

Stack

Component

Material

PEM Alkaline

AEM SOEC

Power Electronics

Water treatment

Gas separators/purifiers

Sealings Connectors

Modules End plates

Porous Transport Layers

Bipolar plates

MEAs/Cells

Coating technologies

Catalyst Polymers

Nanostructures

- Target = 100 Mt Hydrogen
- 100 Mt Green H_2 = 1 000 GW = 1 TW electrolysers
- Market size = 350 B€
- 2023 Electrolysers = 5 GW
- 2023 Manufacturing capacity* = 25 GW/year
- 2030 Electrolysers* = 250 GW

Hydrogen Tech World

Future CAPEX Average electrolyser = 350 €/kW
Electrolyzer installed in 2030 and manufacturing capacity in 2023 = https://about.bnef.com/blog/a-breakneck-growth-pivot-nears-for-green-hydrogen/

Take home messages and perspectives

- Power-to-X : Ramboll capabilities → From Initiation to execution
- H_2 plant: More than electrolysers
- Water challenge could be overcome using waste water resources
- Enormous opportunities around manufacturing of electrolysers

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Sustainable
change.

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