# Technical Challenges and Opportunities in Scaling Up Alkaline Water Electrolysis

**Thijs de Groot**
**9 December 2020**

# Nouryon at a glance

Your partner in essential chemistry for a sustainable future

**10,000 employees**

**€5 billion** in annual revenues

Operating in over **80 countries**

Almost **400 years** of experience

**Top-quartile** safety performer

## Essential chemistry for:

Buildings & Infrastructure

Agriculture

Cleaning goods

Personal care

Packaging

and much more…

# Sustainability is a key business driver

**Top-quartile**
safety performer

**29%** reduction in product carbon emissions
(Per ton of product, 2009-2019)

**€1.9 billion** revenue from Eco-Premium Solutions in 2019*

**60 key suppliers**
assessed in 2019

**24%** reduction in waste per ton of product since 2009


**2019 sustainability report** published on Nouryon.com →

* Eco-Premium Solutions are products that have a significant sustainability benefit over the most common alternative in the market in at least one criteria (toxicity, energy use, use of natural resources/raw materials, emissions and waste, land use, risks, health and well-being), while providing the same or better functionality.

# Leading the way in electrochemistry

Nouryon operates over 1000 MW of electrolysis capacity

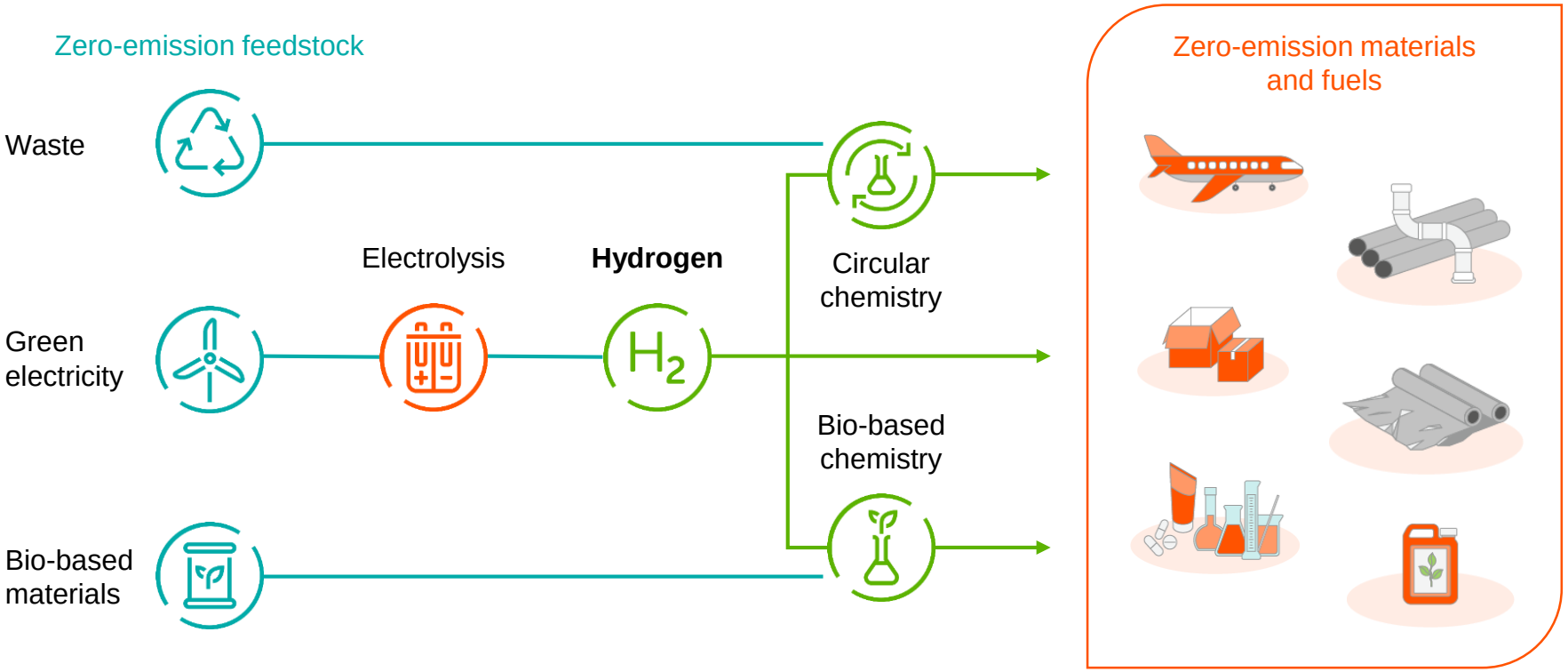
In electro-chemistry since 1899

1000 MW electrolysis capacity

50% renewable energy worldwide

| Chlor-alkali | Sodium chlorate | Water electrolysis |
|---|---|---|
|  |  |  |
| **Installed capacity: 380 MW**<br>**$H_2$ production: 38 kta** | **Installed capacity: 620 MW**<br>**$H_2$ production: 62 kta** | **Installed capacity: 8 MW**<br>**$H_2$ production: 1.2 kta** |

# It’s all about the chemical industry



# Building the circular economy

Scale-up and development of green hydrogen

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| 2 MW Carbon2Chem<br>Duisburg | 20 MW \| 3kt H2<br>Delfzijl | 40 MW \| 6kt H2<br>Delfzijl | 100 MW \| 15kt H2<br>IJmuiden | 250 MW \| 45kt H2<br>Rotterdam |
|---|---|---|---|---|
| thyssenkrupp<br>Nouryon | Nouryon<br>gasunie<br>BioMCN | Nouryon<br>gasunie<br>SkyNRG | Nouryon<br>TATA STEEL<br>Port of Amsterdam | Nouryon<br>bp<br>Port of Rotterdam |

Research & enablers

| Bus pilot Delfzijl | Certification of green hydrogen | GW electrolysis | HydroHub test center |
|---|---|---|---|
| Qbuzz<br>ov bureau<br>provincie groningen<br>GRONINGEN SEAPORTS<br>Nouryon | CertifHy<br>Nouryon | Ørsted<br>gasunie<br>YARA<br>DOW<br>Nouryon<br>OCI | Nouryon<br>gasunie<br>YARA |

# First step has been announced

Delfzijl, Netherlands

**1**

**20 MW | 3 kton $H_2$**
Mainly bio-fuels
FID in 2021

Nouryon
gasunie
BioMCN

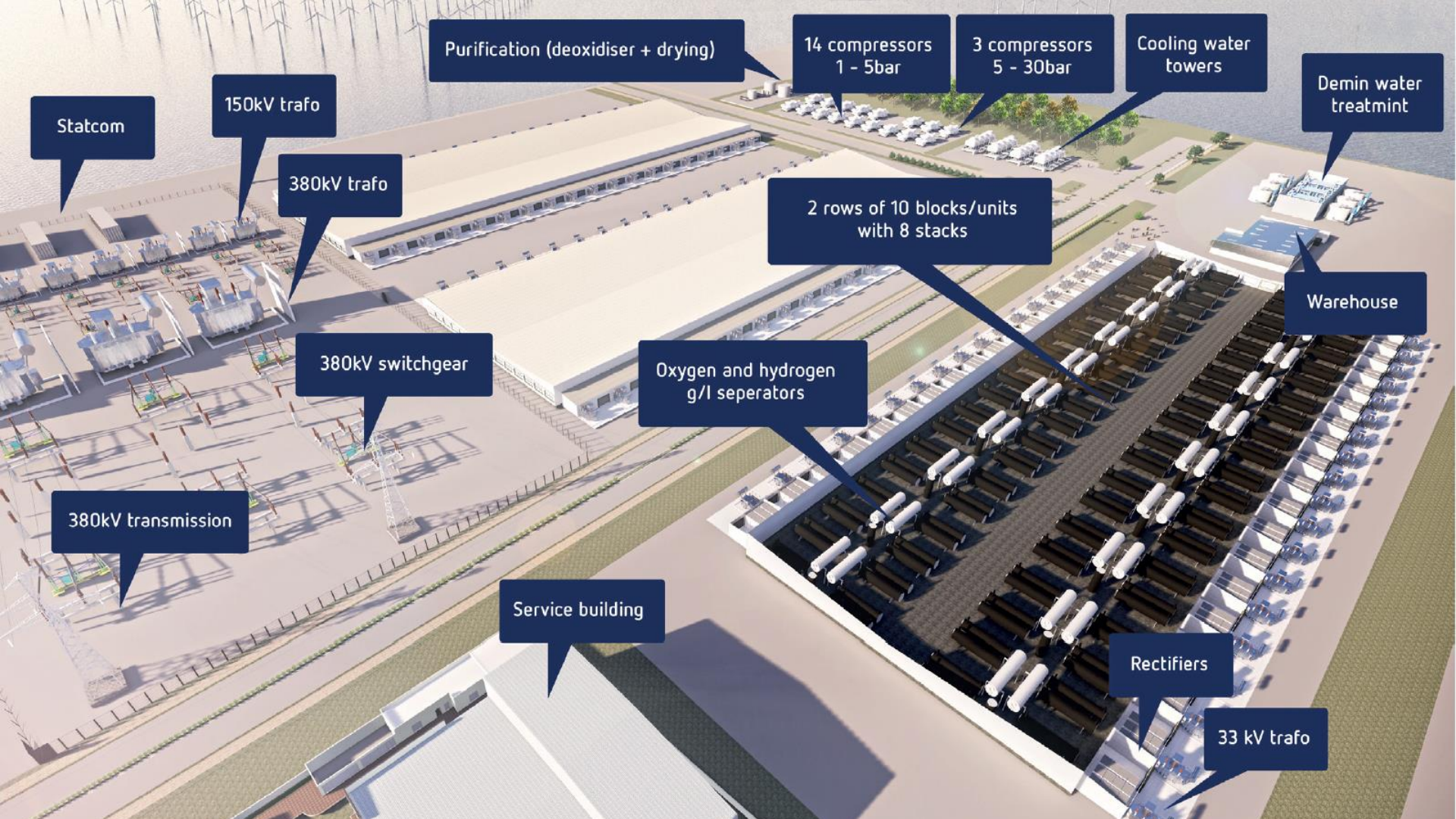
**2**

**40 MW | 6 kton $H_2$**
Bio jet fuel for KLM
FID in 2021

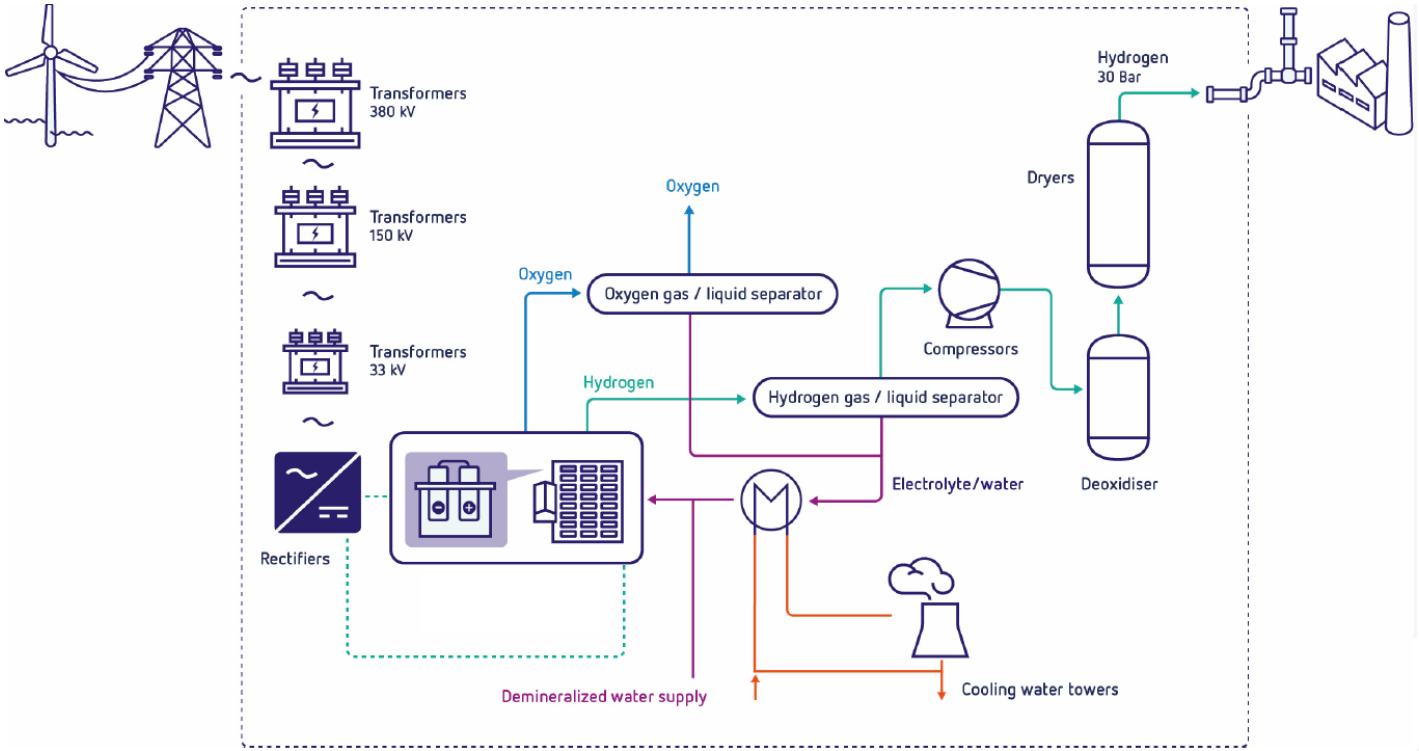
Nouryon
gasunie
SkyNRG

# Can we achieve GW scale in 2030?


Source: https://ispt.eu/gigawattscale/


Purification (deoxidiser + drying)
14 compressors 1 - 5bar
3 compressors 5 - 30bar
Cooling water towers
Demin water treatmint
Statcom
150kV trafo
380kV trafo
2 rows of 10 blocks/units with 8 stacks
Warehouse
380kV switchgear
Oxygen and hydrogen g/l seperators
380kV transmission
Service building
Rectifiers
33 kV trafo

# Plant layout



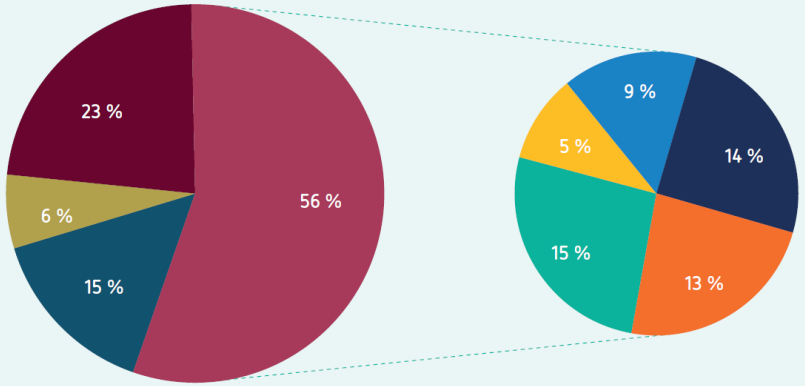

Source: Gigawatt green hydrogen plant, ISPT Oct 2020

# Total plant costs

## Capex cost breakdown Alkaline technology

Total Installed Costs 1400 Euro/kW

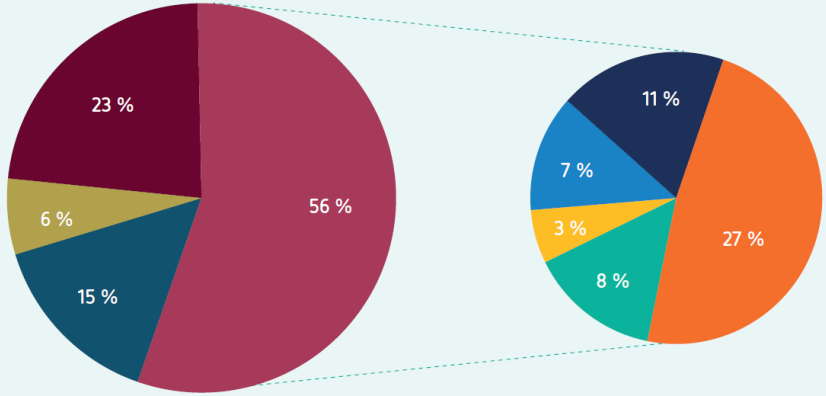
Directs Costs 800 Euro/kW




## Capex cost breakdown PEM technology

Total Installed Costs 1800 Euro/kW

Directs Costs 1000 Euro/kW




- Indirect costs
- Owners costs
- Contingency
- Direct Costs

- Balance of plants
- Civil, Structural &Architect.
- Utilities and Process Automation
- Power supply and electronics
- Stacks

Source: Gigawatt green hydrogen plant, ISPT Oct 2020

# Key electrolysis technologies

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| | Alkaline | PEM | Solid oxide | AEM |
|---|---|---|---|---|
| |  |  |  |   |
| Stack size (MW) | 1 – 6 | 0.5 – 1.5 | ? | 0.0025 |
| Largest installed plant (MW) | 165 / 30<br>Aswan / Xinjiang | 10<br>Cologne | 0.72<br>Salzgitter | 0.02<br>Rozenburg |
| Number of suppliers | 7 | 5 | 2 | 1 |
| Stack price (€/kW) | 100 - 400 | 300 - 600 | ~2500 | ? |
| Stack efficiency (% of HHV) | ~80% | ~75% | ~100% | ~80% |

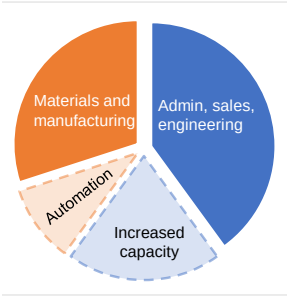
# How to reduce the capital costs of plants?

## Economies of scale

- **Large chemical plants** are relatively cheaper than small chemical plants due to economies of scale

## Stack production scale-up (Economies of numbers)

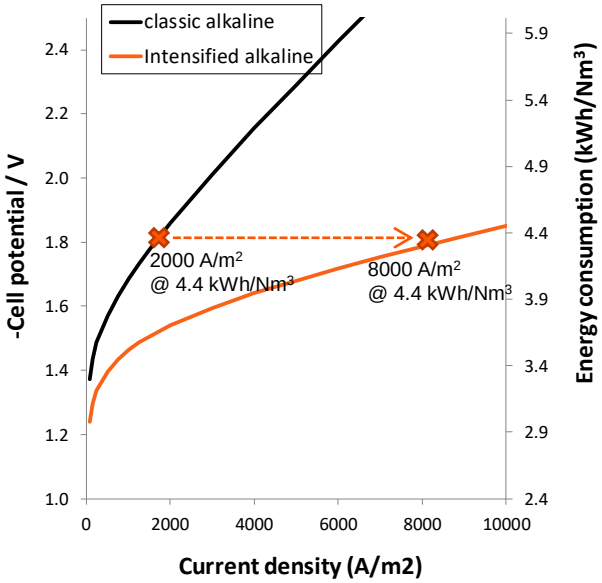
- **Automation** in stack production to reduce manufacturing costs
- **Increased capacity** allows reduction of overhead costs




## Innovations

- **Increased current density and lower material costs** through new electrode materials, membranes and cell designs and increased temperature

# Alkaline: increasing current density

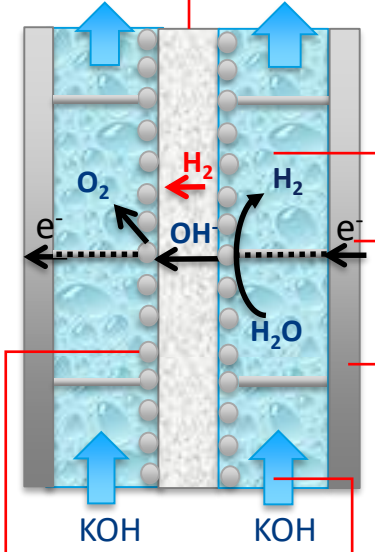



| | Combined overpotentials @ 0.2 A/cm² | Ohmic resistance |
|---|---|---|
| Current | 0.45 V | 1.25 Ωcm² |
| Target | 0.35 V | 0.25 Ωcm² |

- Low resistance separators are already on the market with better ones being developed.
- Reducing overpotentials without making use of noble metals is a subject of intensive research, but remains a challenge especially with regard to stability.
- Research into new cell designs to reduce non-membrane ohmic resistances is still scarce and is hampered by a lack of understanding of gas-liquid flow and current profiles
- A temperature increase can also reduce ohmic resistances, but does results in more corrosion challenges and probably requires more expensive materials

# Technical challenges alkaline

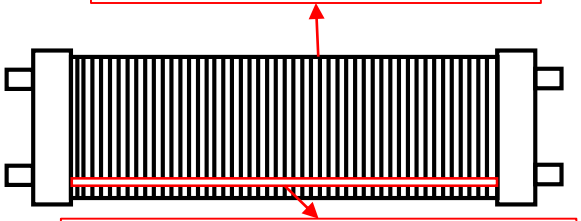
- Overpotentials
- Ohmic resistance
- Gas crossover
- Shunt currents
- Electrode stability & corrosion
- Changes in gas hold-up
- Heat management
- Mechanical strength
- Operation pressure




**Diaphragm thickness:**
Resistance vs. gas crossover

**Operating temperature:**
Efficiency vs. stability & corrosion

**Plate and frame thickness:**
Mechanical strength vs. material costs



**Stack length:**
Higher potential (cheaper power conversion) vs. shunt currents

**Electrode area:**
Heat management vs. material efficiency & footprint

**Electrode material:**
Max. efficiency vs. robustness

**Electrolyte flow rate:**
Heat management vs. BoP size

# Finding the optimum in scaling up versus numbering up


Source: Gigawatt green hydrogen plant, ISPT Oct 2020

# Flexibility limitations

Alkaline systems can be flexible, when the following aspects are properly addressed in the design:

- The power supply system should be design in such a way that excessive harmonics at low load are avoided
- The system needs to be designed to handle the changes in gas hold-up caused by changes in current density
- A high-quality separator is needed to ensure sufficient gas purity at low load

# Conclusions

- Green hydrogen is essential to achieve the energy transition and convert to a circular economy
- To make green hydrogen competitive we need to achieve significant cost reductions
- We believe there is still plenty of room to further improve alkaline technology

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# Thank you!

**Thijs.deGroot@Nouryon.com**