# Update on electrolysis technologies for green hydrogen production

Benoît Barrière, Chief Technology Officer, McPhy Energy – Nov. 21, 2022

# McPhy | A leading Green $H_2$ Equipment Manufacturer

## History

- **2022** – Innovation acceleration & Industrial scale up
- **2020** – 180M€ raised | Technip & Chart partnerships
- **2018** – "Augmented" equipment | EDF partnership
- **2013** – Stations diversification | Enertrag's electrolyzer acquisition
- **2012** – Electrolyzers diversifcation (PIEL acquisition)
- **2008** – Incubation with CEA + CNRS (solid storage)

## People & footprint

**150+ people**

- 25+% women
- 20+ nationalities
- 50+% PhD / Eng



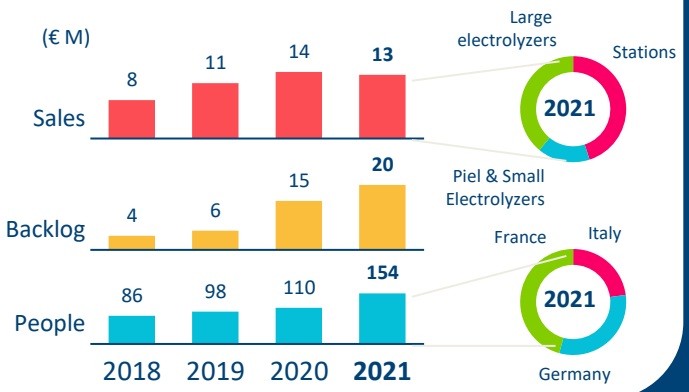

- Engineering/R&D of large electrolysers

- HQ & Station factory
- 150 HRS/yr by 2022



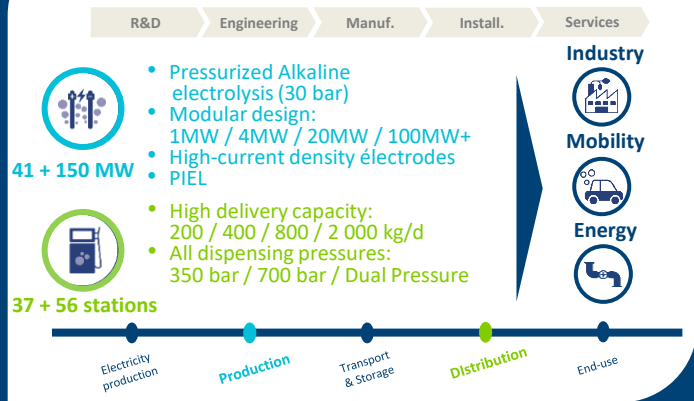
- Electrolyzer factory
- 100 to 300MW/yr by 2023

## Key figures




## Ecosystem


## Products & Markets




## Strategy

- **Invest in TECHNOLOGY**
  Technology leadership, superior safety, innovation
- **Improve COMPETITIVENESS**
  Cost out, economies of scale
- **Build up strong REFERENCES**
  Emblematic references across end-markets
- **Invest in PEOPLE**
  Professionalize, Recruit & Grow

## Truly Pan European High-Growth Pure Player

***References as of 30/06/2022:***
***41 + 150 MW*** *among which 41 are signed projects* and 150 MW for which McPhy has been selected as preferred partner***
***37 + 56 stations*** *among which 37 are signed projects* and 56 stations for which McPhy has been selected as preferred partner***

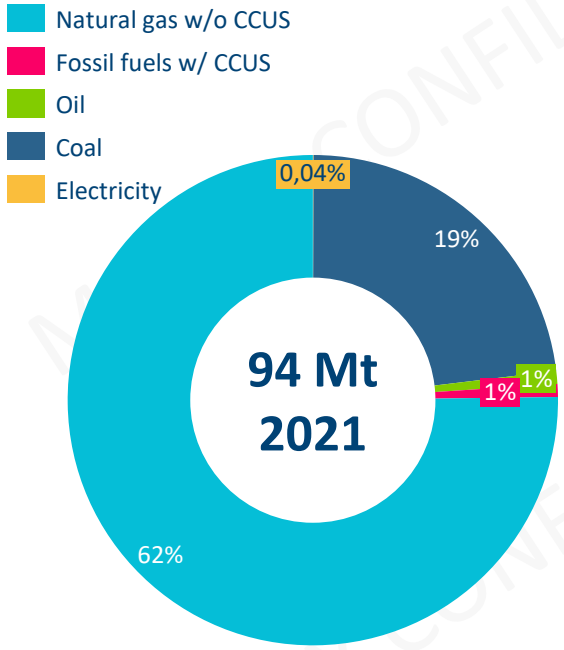
**"Signed projects": orders with signed purchase orders*
***"Preferred partner": preferred partner and subject to the project's success, considering that some of these projects should have an impact on the revenue as of 2023*

# Market Overview

# Why Hydrogen production is crucial

## The role and need of hydrogen in decarbonization

### 2021 Hydrogen production




### Applications today & future

**Enable the renewable energy system**

1

- **Fit with Renewable energy farms**
- **Electricity generation and distribution**
- **Grid injection allow system resilience**

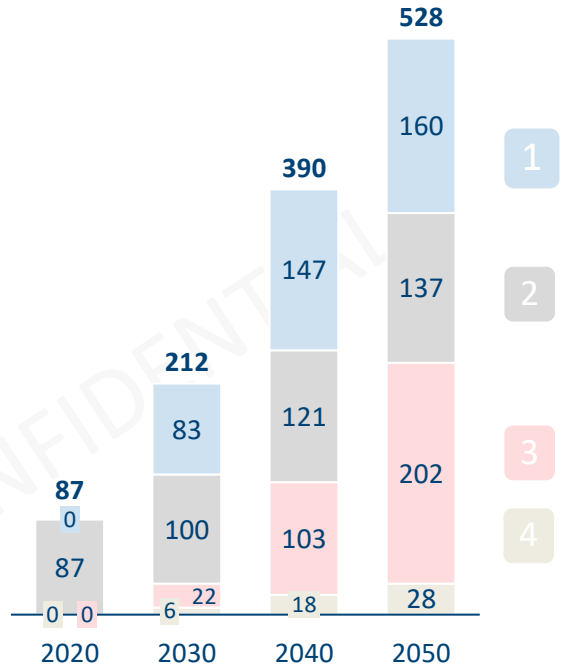
**Decarbonize end uses**

2 **Serve as clean industrial feedstock, fuel for energy use**

3 **Serve as clean fuel to decarbonize mobility (road, rail, shipping, aviation)**

4 **Help decarbonize building heat and power**

**$H_2$ consumption in the IEA's Net Zero Emission (NZE) Scenario [Mt]**




**Hydrogen is the main industrial feedstock used today and will find new uses in the future**

1) I.e. for green molecules ($H_2$ and its derivatives such as NH3, MeOH, ekerosene, etc.) for climate neutrality, in addition to green electrons

*Source: IEA*

# Hydrogen is a good lever for decarbonization if it is Green

## Great opportunities as Hydrogen is the main feedstock in the industry

### Differences in Hydrogens

**H2 Grey**

- Negative $CO_2$ footprint due to fossil resources,
- Big facilities required,
- Most common way to produce hydrogen worldwide (+99%),
- **1 kg of Grey Hydrogen emits 10 kg of CO2**

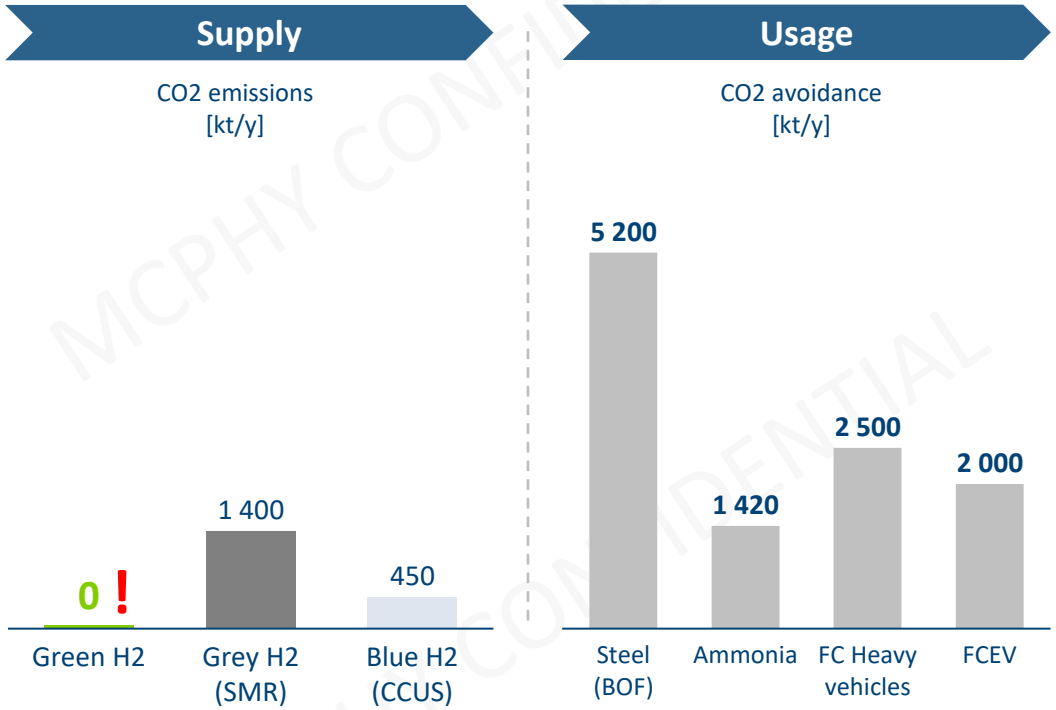
**H2 Blue**

- Needs CO2 Emission certificates,
- Negative CO2 footprint due to fossil resources,
- Carbon can be stored in caverns,
- **Captures ~70% of CO2 emission**

**H2 Green**

- Produced by electrolysis using renewable or decarbonated electricity,
- Modular platforms from low scale (mobility) to large scale (industry),
- **No CO2 if decarbonated electricity**
- Cost competitivity w/ Grey hydrogen by 2030

### CO2 *ratios* for 1 MW ELY = 140+ kt H2




METHODOLOGY
- 90% load 52 kWh/kg
- No capex related GHG emission included
- Consideration of 100% use of green hydrogen

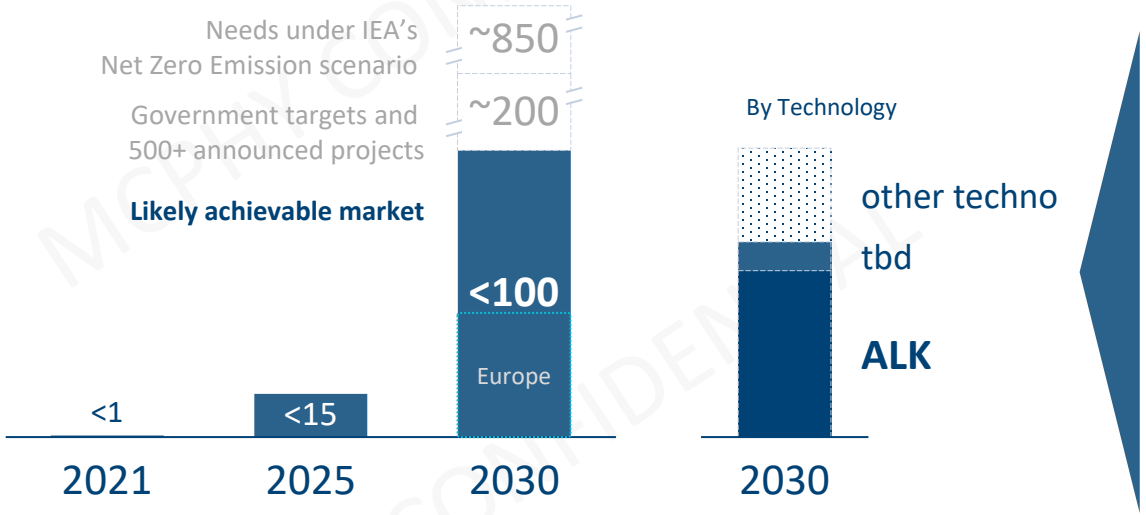
**Green hydrogen offers better ways to decarbonise a range of hard-to-abate sectors – including long-haul transport, chemicals, and even food processing– where it is proving difficult to significantly reduce emissions.**

*Source: Hydrogen Council Report "Hydrogen Carbonization pathways" (2021), IEA, McPhy Analysis*

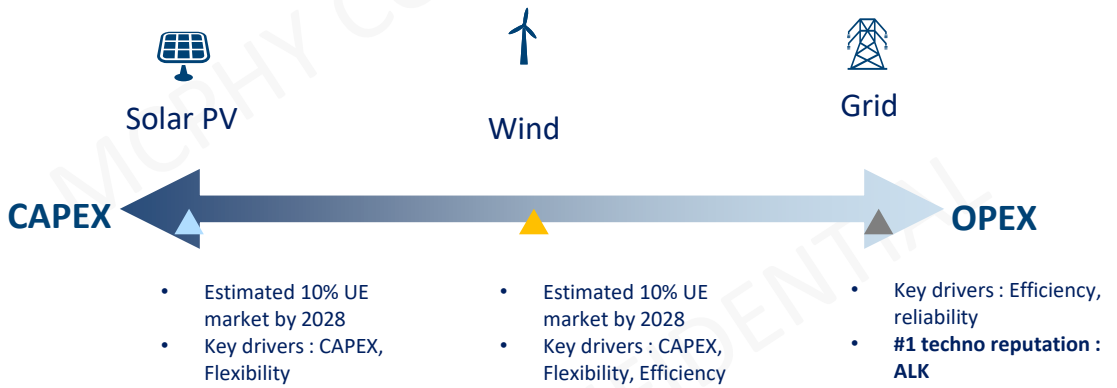
# A huge market driven by decarbonation urgency

## Est. cumulative global installed electrolysis capacity

2021-2030 (GW




## Customer segments and technology decision criteria




**Commercial projects seen today materialize multi-GW installed base of the decade**

*Source : IEA, Hydrogen Council, Press announcements, Desk research*

# Strong long-term fundamentals underlying H2 markets …

## … with limited short term bottle necks

### Very strong tailwinds

**Climate urgency**

- limit GHG
- H2 for decarbonation

**Public ambitions**

- REPowerEU : EU target x2-3
- Worldwide H2 roadmaps

**Structuring regulatory**

- Fit for 55
- CO2 taxes

**Financing is there**

- Billions € committed by Governments (e.g. IPCEI)
- Private funds going in H2

**Projects driving demand**

- 500+ projects WW by 2030
- From MW to GW

**Strong Technology bricks**

- Low LCOE
- Nuclear getting revived

### Some headwinds

**Delays**

- Regulatory discussions
- Financing postponed

**Potential bottlenecks**

- Renewable energy to feed Electrolyzers
- Social acceptance

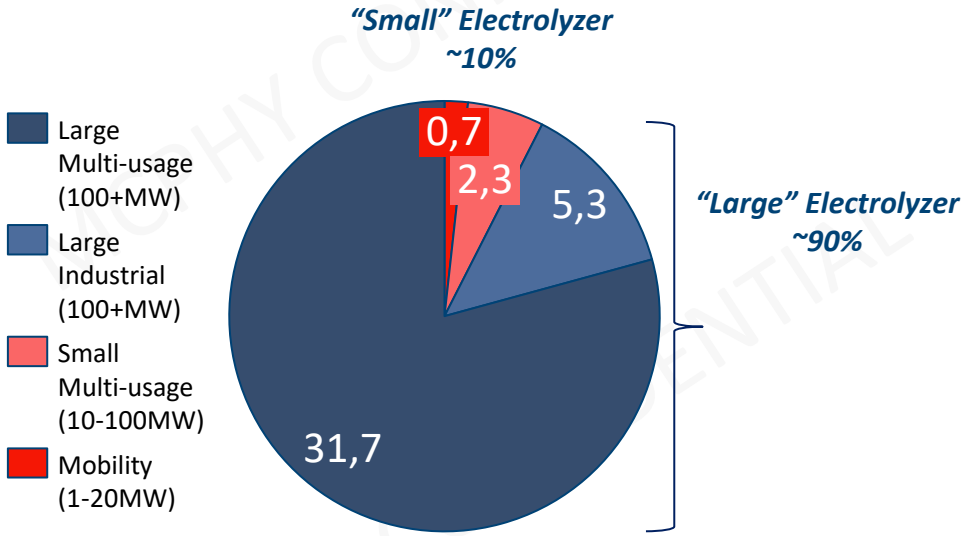
**All aspects of a mega-trend, likely to materialize in coming years**

*Source : McPhy analysis*

# Eur. market will be focused on large capacity electrolyzers

|European Electrolyzers Installed Base in 2030 – European Strategy Scenario (GW)

## Split by Type of Electrolyzer




## Split by Country


**7 markets concentrating 70+% of expected future H2 production equipment**

*Sources: Hydrogen Europe*

# Electrolyzers attracting many players …

## … primarily European, but not only


- Dynamic markets with a multitude of players, increasing competition and price pressure
- Mix of Large diversified Corporates and small Pure Players, with limited consolidation so far
- 1-3 national champions per major H2 country, supported by their Government (e.g. IPCEI, ..)
- Primarily European, but North American and Asians contemplating various entry strategies
- Most have announced plan for GigaFactories, but so far, only 5-10GW capacities by 2025 confirmed by relevant FIDs

**Competitive markets, requiring scale, Tech. differentiation and speed**

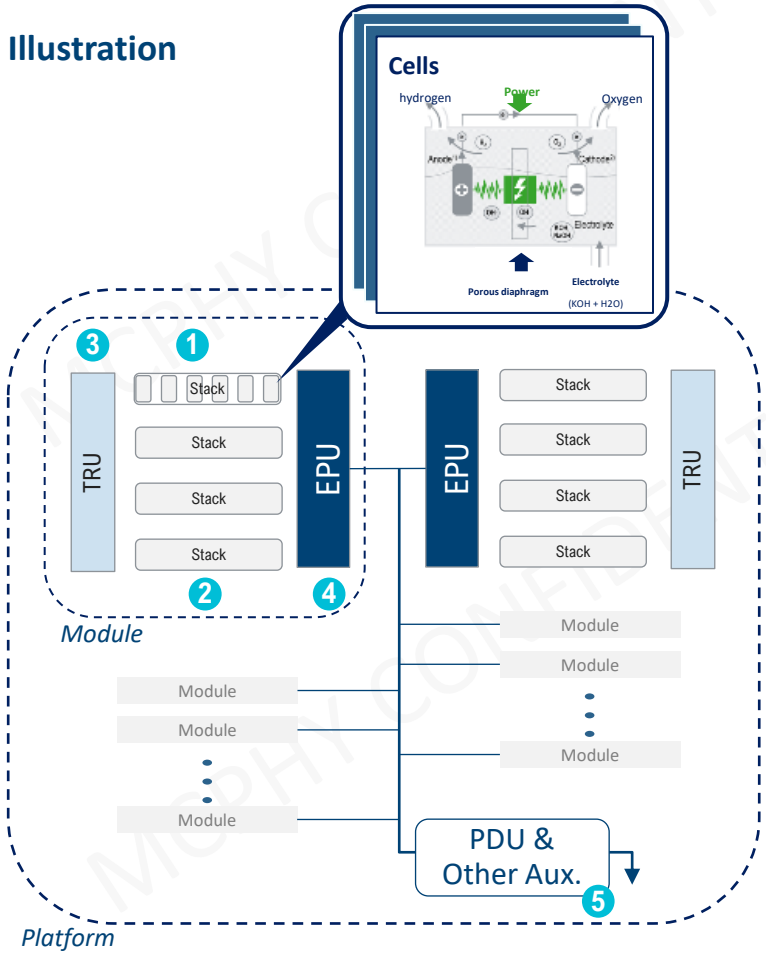
*Source : McPhy analysis*

# Technology Overview

# From the cells to the electrolyser platform

## An assembly of several modules, each of which includes several stacks, the EPU and the transformer/rectifier

**Illustration**




| | Item | Components | Function |
|---|---|---|---|
| 1 | **Cell** | **Cell package, cell frame, membrane/diaphragm** | **Allows the electrolysis reaction ($H_20$ -> $H_2$ + ½ $0_2$)** |
| 2 | Stack | Cells, Balance of Stack, pressure rings and end flanges | Multiply the electrolysis reaction |
| 3 | Transformer & Rectifier Unit (TRU) | Transformer & rectifier | Transfo. allows increasing or decreasing AC while a rectif. converts AC to DC |
| 4 | Electrolyzer Process Unit (EPU) | $H_2/O_2$ separators, $H_2/0_2$ coolers, electrolyte coolers, pumps, electrolyte (KOH) tanks, power & control cabinet | Separate the biphasic flow existing in the stack into gas ($H_2$ + $0_2$) and liquid |
| 5 | Purification & Drying Unit (PDU) | Dryer, generation heater, hydrogen blower, hydrogen/water separator | Bring the hydrogen purity to the level required |

**An “electrolyzer” includes several components provided by different parties**

*Sources : McPhy analysis*

# Total Cost of Ownership (TCO)

## TCO defines the cost structure of the electrolyzer and the installed system, then the LCOH

### TCO [€]

**CAPEX** + **OPEX**

**Electrolyser**

**Stack (30%)** (1 2) + **EPU + TRU + Utilities (40% )** (3 4 5) + **EPC (30%)**

*Where is the electrochemical reaction of the electrolysis*

- **Electrodes**
- Structural layers
- Stack assembly
- Transport layers
- Bipolar plate
- Frame/Sealing

*Components and auxiliaries for power and gas managements*

- **Power supply**
- Water management
- Hydrogen process
- Cooling

*Design, building and erection of the area before commissioning*

- Construction engineering
- Procurement
- Logistic and transport
- Civil engineering
- Building construction
- …

*Simplified calculations that could by more accurate with Discount rate and additional calculations*

**Cost of electricity**

*Levelized cost of electricity [€/MWh]*

- LCOE includes production costs, tax…
- Efficiency conversion of electricity into $H_2$
- Depends on the electricity sourcing :

Grid-fed

Solar

Wind

…

**Operation & Maintenance** (1 2 3 4 5)

*Labors associated with the operations and repairs, replacement of components [%CAPEX]*

- Stack replacement
- Water feeding
- KOH replacement

…

**Assessing the total cost of ownership represents taking a bigger picture look at what the product is and what its value is over time. It allows to the client to clearly identify the cost breakdown**

*Sources : Irena "Green Hydrogen Cost Reduction", McPhy analysis. NB : all % in % of CAPEX*

# Levelized Cost of Hydrogen

## The discounted cost of the CAPEX + OPEX per unit of hydrogen produced

$$LCOH\ [€/kgH_2] = \frac{TCO}{H_2\ produced}$$

The OPEX vs CAPEX %share can vary regarding the sourcing strategy : grid, wind, solar...

**CAPEX (35% LCOH)**

TCO

Electrolyser

- Stack
- EPU – PDU
- EPC

$H_2$ production

- Stack Capacity [kg/h] — *Nominal production per Stack in kg/h*
- ✖
- Load factor [%Annual hours] — *Annual hour of operation*
- ÷
- Efficiency [kWh/kg] — *Conversion of the electricity into $H_2$*

**OPEX (65% LCOH)**

- Cost of electricity* (60%)
- O&M (3-5%)

Actual: 4 – 6 €/kg

**Target 2030: ≤ 2 €/kg**

LCOH price & target defined on early 2022 electricity price basis. Theses LCOH don't correspond to the current prices

*Simplified calculations that could by more accurate with Discount rate and additional factors*

**CAPEX (equipments) is only one part of the equation**

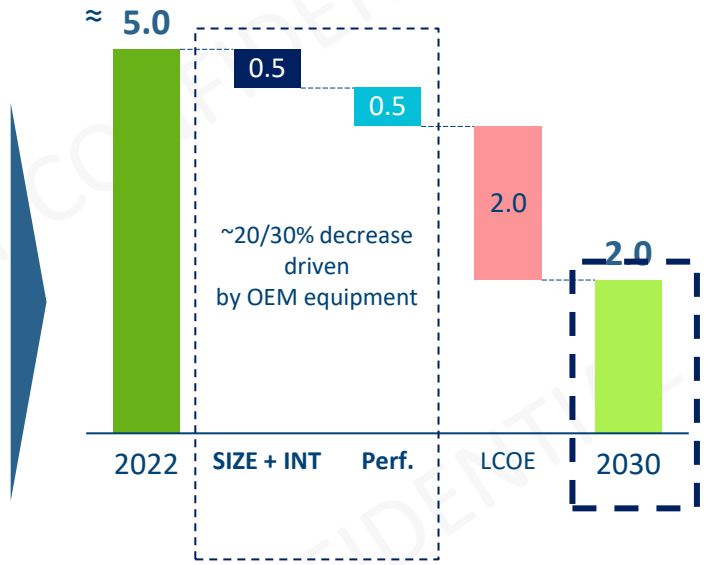
**Based on beginning 2022 figures*

*Source : McPhy analysis*

# Cost-Out strategy to cut LCOH by ≈ 50%

| | CAPEX | OPEX |
|---|---|---|
| SIZE | • Expansion of production capacities to reach scale economies<br>• Develop larger modules and platforms in order to amortize the cost of the system | • Increase of productivity and synergies of supervision and O&M activities |
| INTEGRATION | • Work on the value chain and better sourcing strategy for key components (such as noble metals)<br>• Benefit from synergies with EPC players/partners for better integration on site | • Invest in training to improve efficiency during maintenance and operation |
| PERFORMANCE | • Increase the production capacity per stack in order to produce more $H_2$ per Stack | • Increase lifetime of components to reduce cost of maintenance and replacement<br>• Develop more efficient stack to increase electricity conversion |

## LCOH evolution* [€/kg]




Cost-Out Strategy forecast defined on early 2022 electricity price basis. It doesn't correspond to the current prices

**Electrolyzer OEMs working on their scopes of costs reduction**

**Based on beginning 2022 figures*

*Source : McPhy analysis*

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