

HYDROGEN ACADEMY, HYDROGEN DENMARK

UPSCALING OF ELECTROLYSER PRODUCTION AND INDUSTRIAL POLICY

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23 February 2024

TOPSOE



AGENDA

- 1. INTRO TO TOPSOE**
- 2. HOW WE ARE SCALING-UP OUR OWN SOEC TECHNOLOGY?**
- 3. ELECTROLYSER MFG CAPACITY AT GLANCE**
- 4. INCENTIVES TO SCALE-UP ELECTROLYSER MFG (EU, US AND CHINA)**
- 5. IS THE EU LOSING MOMENTUM IN THE ELECTROLYSER TECH RAISE AND WHAT COULD BE DONE?**
- 6. Q&A SESSION**

TOPSOE AT A GLANCE

Topsoe is a leading developer and provider of solutions and technologies to produce fuels and chemicals essential to the energy transition.

For more than 80 years, we've been perfecting chemistry to help industries produce more efficiently. Today, it's our ambition to lead the global transition of hard-to-abate sectors to a zero-carbon future.

Guided by our purpose, 'Perfecting chemistry for a better world', we work to deliver solutions that will leave the world in better shape for future generations.

#1

In renewable fuels



#1

In low carbon hydrogen



6,845

In revenue
(DKK million)

+500

Patent families

8.6%

Of revenue
invested in R&D

2,800

Employees



TOPSOE AREAS OF EXPERTISE

ELECTROLYZERS

**PROCESS DESIGN,
ENGINEERING
AND
LICENSING**

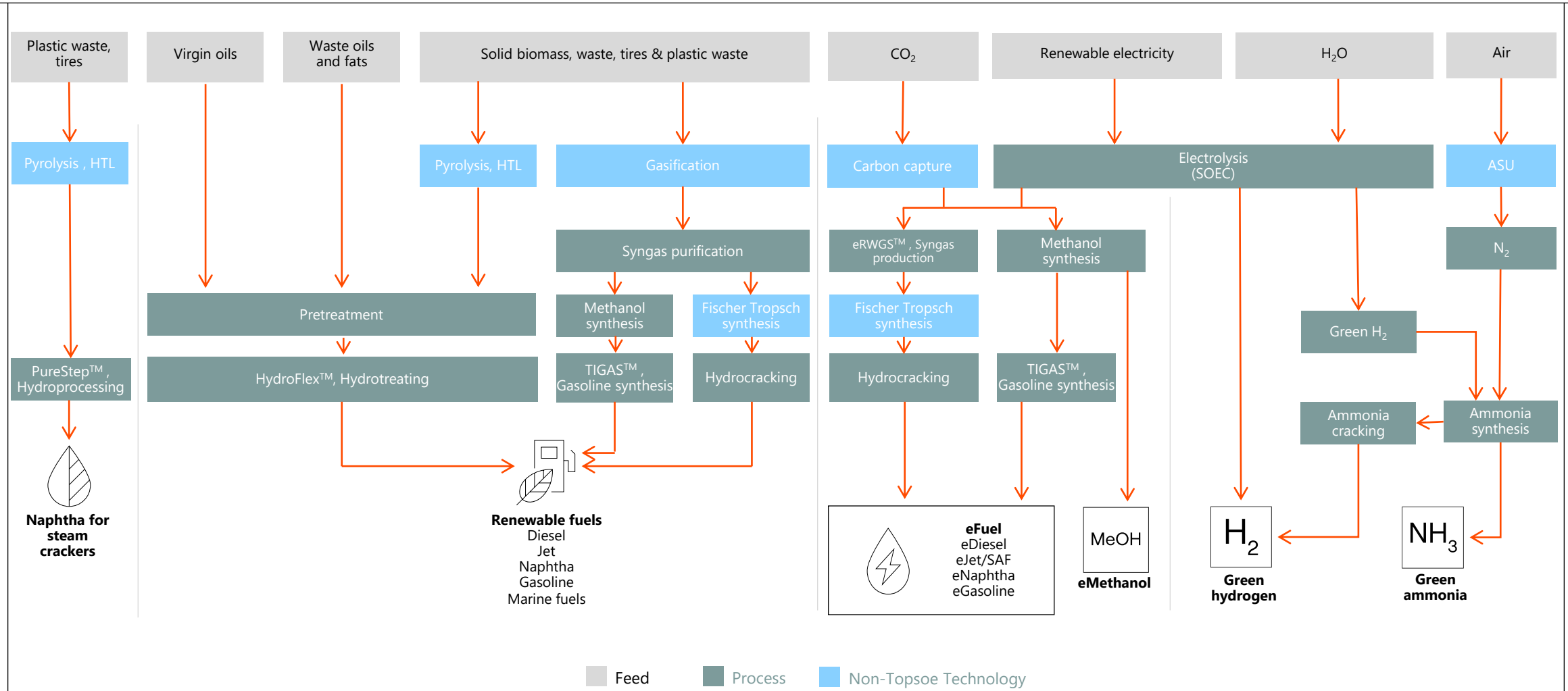
**HIGH-
PERFORMANCE
CATALYSTS**

**PROPRIETARY
EQUIPMENT**

**BUSINESS
AND TECHNICAL
SERVICES**

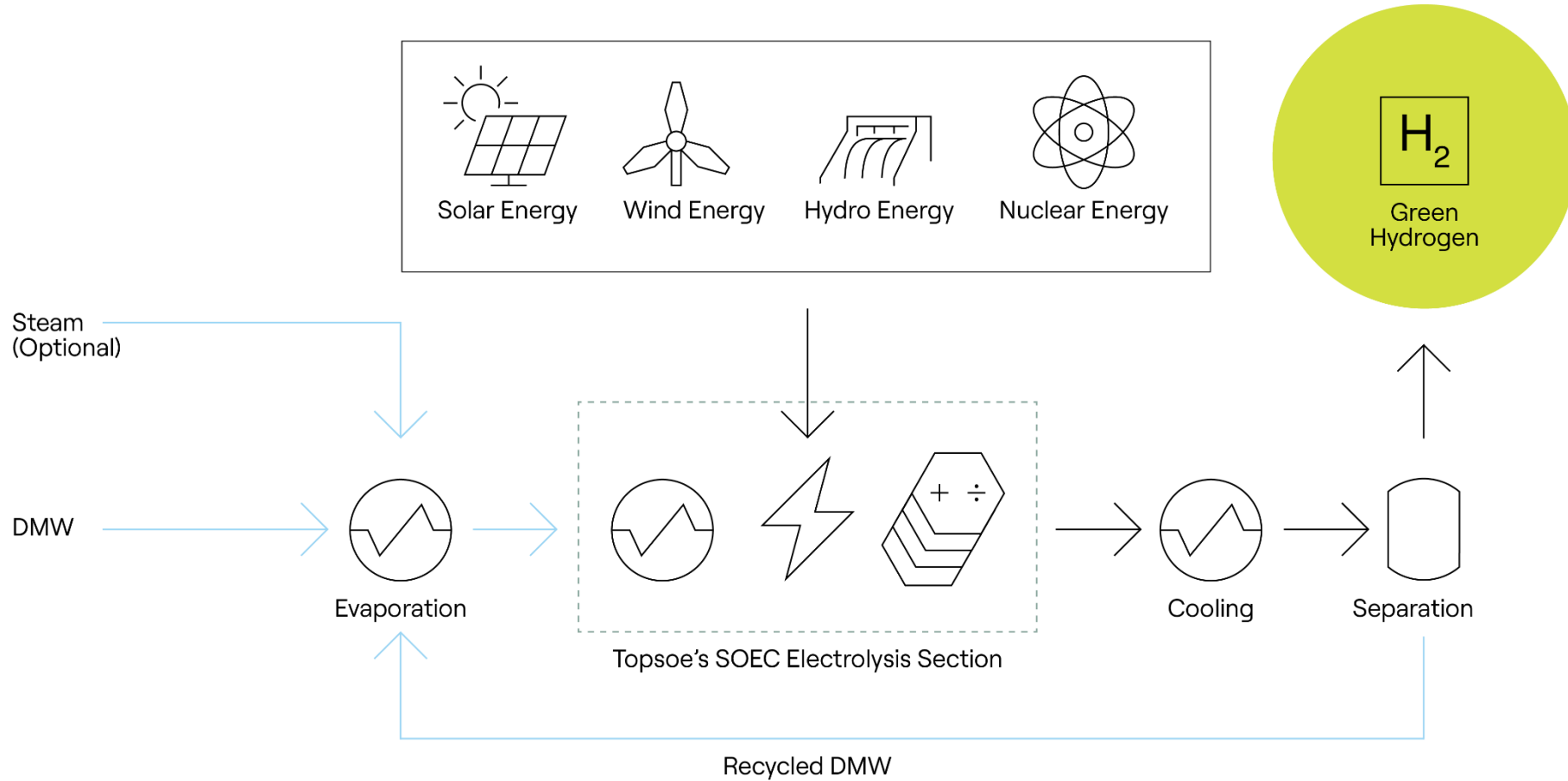


HARNESS THE POWER OF OUR UNMATCHED CONVERSION CAPABILITIES TO TRANSFORM ALMOST ANY FEED INTO GREENER FUEL, ENERGY, OR CHEMICALS



POWER-TO-X

GREEN HYDROGEN PRODUCTION THROUGH SOEC



**OUR VISION
2024**

SECURE UNDISPUTED MARKET LEADERSHIP IN LOW-CARBON AND E-FUELS

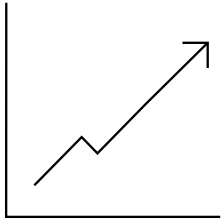


02

SCALING-UP OUR SOEC TECHNOLOGY

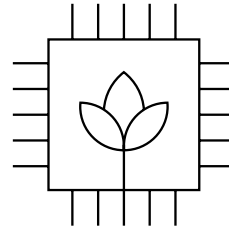
SOEC ELECTROLYSIS OFFERS A WIDE RANGE OF ADVANTAGES

Lower power consumption



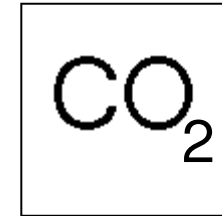
- SOEC has the highest efficiency of all electrolyzers
- Without heat integration, SOEC is 20 % more efficient than alkaline and PEM
- With heat integration, SOEC is 30 % more efficient than alkaline and PEM

Non noble materials



- SOEC consists of materials that are abundant in nature and can therefore easily be scaled up without material availability constraints
- The use of non noble materials will benefit cost as the raw materials will not become more expensive due to scarcity

Syngas creation



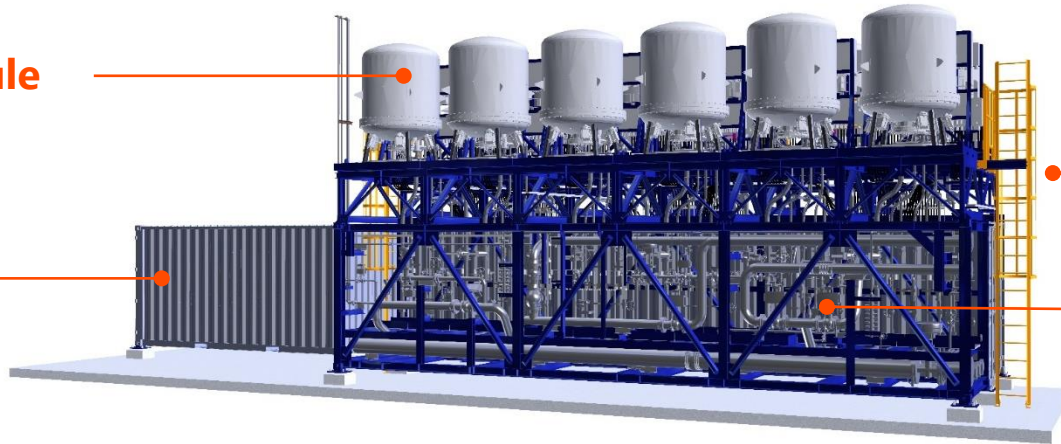
- In addition to the electrolysis of steam, SOEC can electrolyse CO_2 and thereby generate CO
- CO_2 electrolysis enables carbon capture & utilization from a point source and provides advantages for making eFuels such as eJet, eDiesel and methanol

FROM CONCEPT TO NEXT GENERATION

HOW WE GOT HERE AND WHAT COMES NEXT

Electrolyzer core module
Containing SOEC stacks

Transformer



Power module Containing converters, instrumentation and required electrical components.

Piping module

DEVELOPMENT TIMELINE

1980

Solid Oxide Fuel Cell (SOFC) developed

SOFC cell and stack can also be used as SOEC

Electrolysis of both water and CO₂

2015

Focus Shifts to SOEC

Demonstration and industrial SOEC units since 2015

Continuous optimization & innovation

Market leading efficiencies

2025

Worlds biggest SOEC manufacturing facility in Herring, Denmark

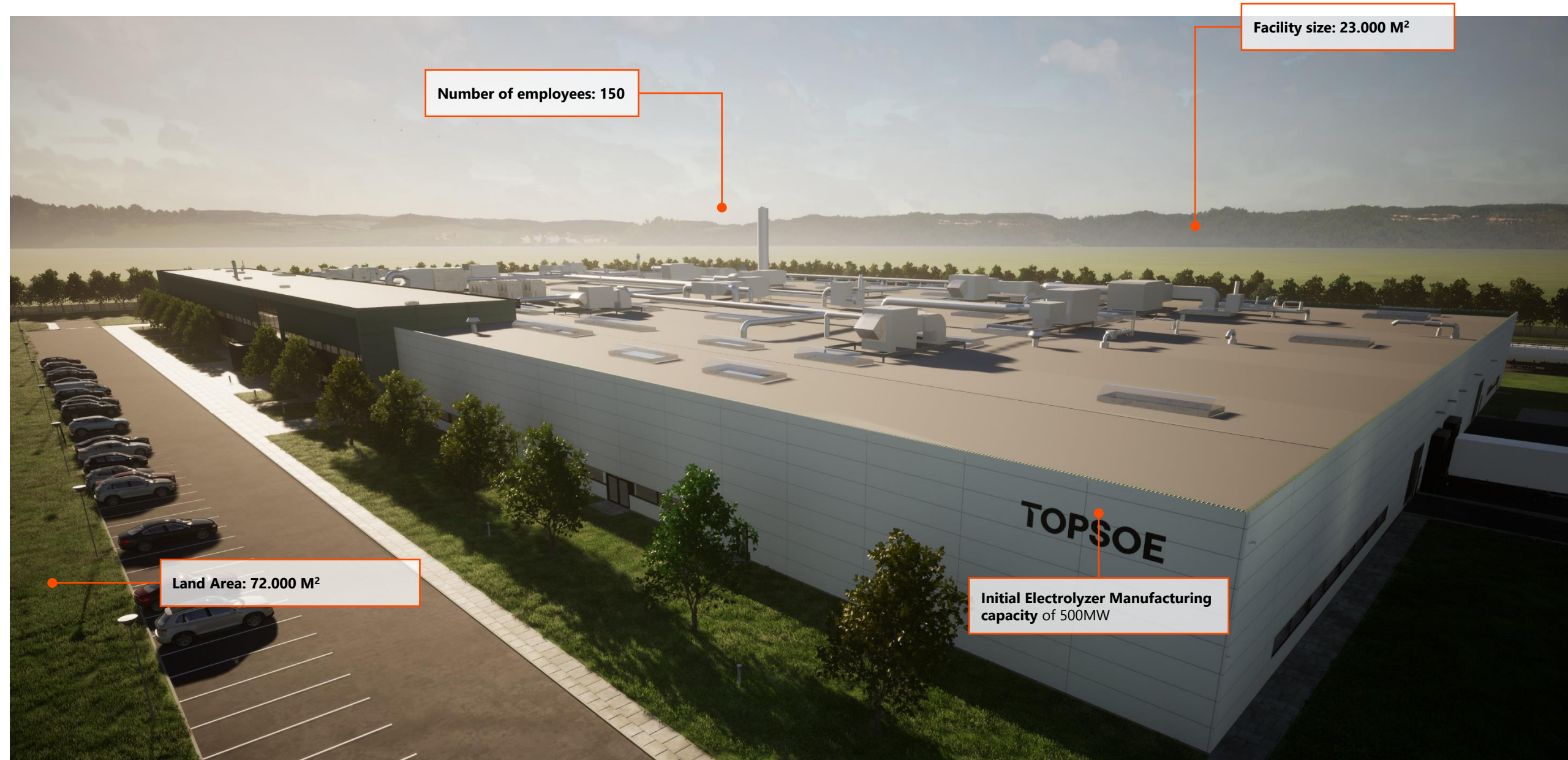
Initial 500 MW annual production capacity

Expansion to 1,2GW Annually by 2031

Potential extension to 5 GW capacity

TOPSOE SOEC MANUFACTURING FACILITY ONE

 HALDOR TOPSOE'S VEJ 2, HERNING, DENMARK



Number of employees: 150

Facility size: 23.000 M²

Land Area: 72.000 M²

Initial Electrolyzer Manufacturing capacity of 500MW



HERNING IS JUST THE BEGINNING!

**WE'RE EXPANDING
OUR SOEC
MANUFACTURING
CAPACITY TO SERVE
THE US MARKET**

03

ELECTROLYSER MFG CAPACITY AT GLANCE

DEFINITIONS

Electrolyser capacity

Announced clean hydrogen production plants in pipeline, not FID

Installed electrolyser capacity

Clean hydrogen production plants in operation (FID, constructed and installed)

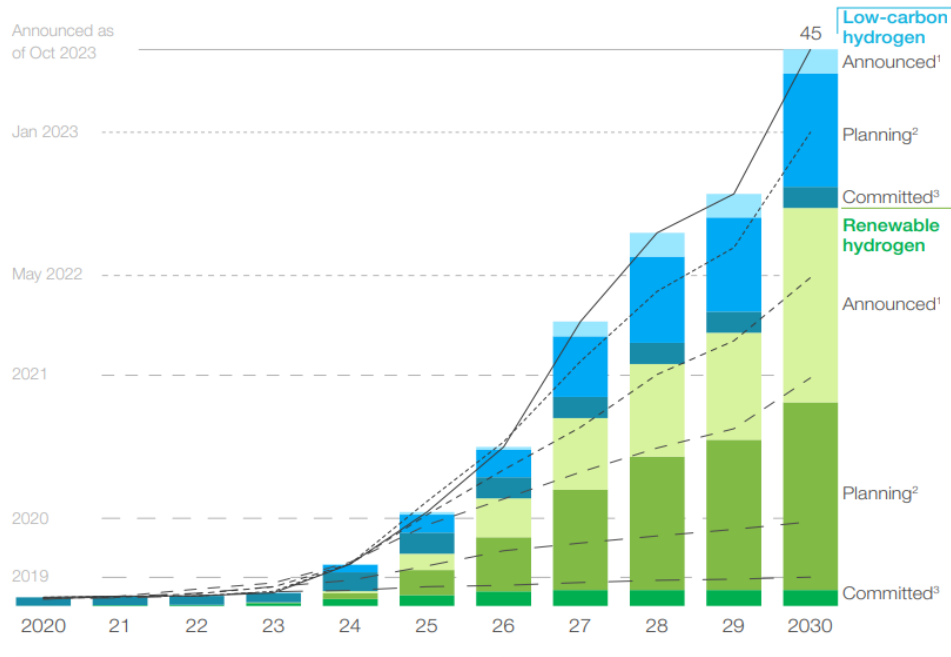
Electrolyser manufacturing capacity

Announced manufacturing of SOEC, PEM or Alkaline electrolyser technology

CLEAN HYDROGEN PRODUCTION FORECAST 2030

Electrolyser capacity (preliminary, engineering and FID)

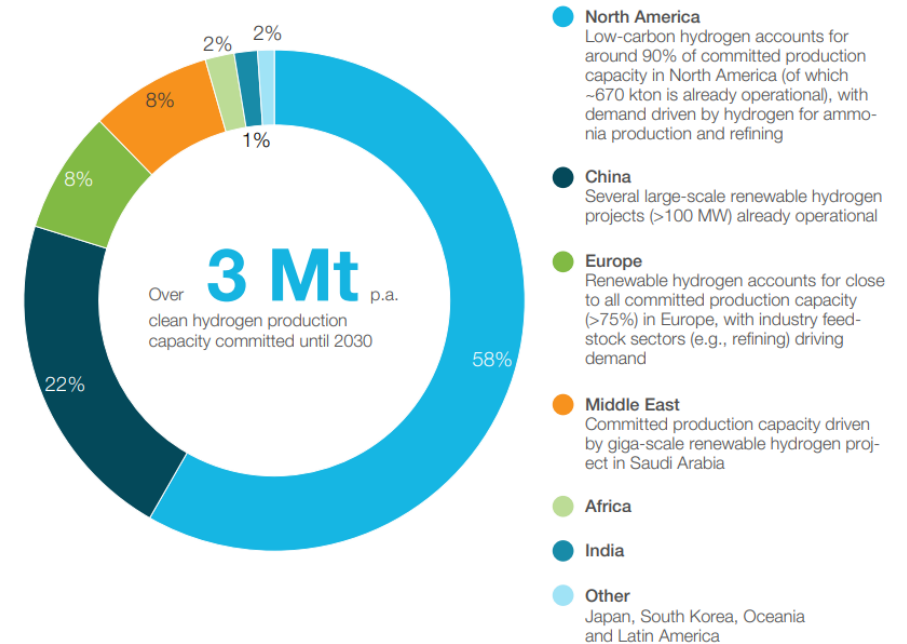
Cumulative production capacity announced, Mt p.a.



1. Preliminary studies or at press announcement stage
2. Feasibility studies or at front-end engineering and design stage
3. Final investment decision has been made, under construction, commissioned or operational

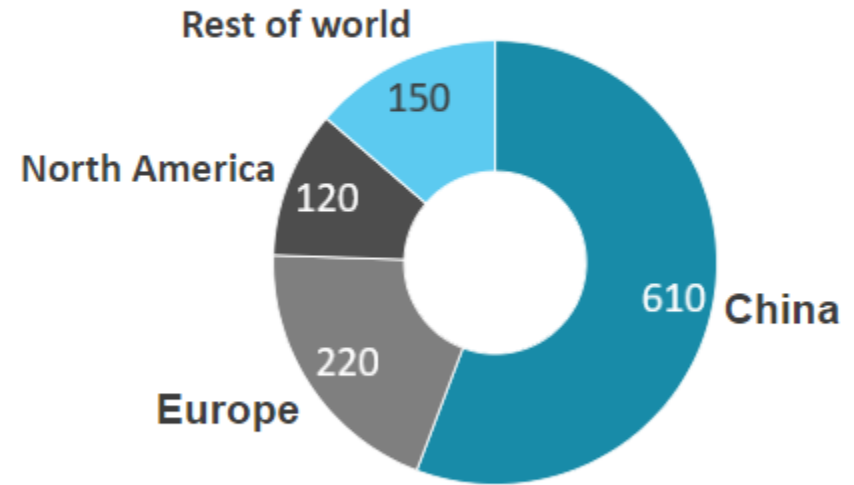
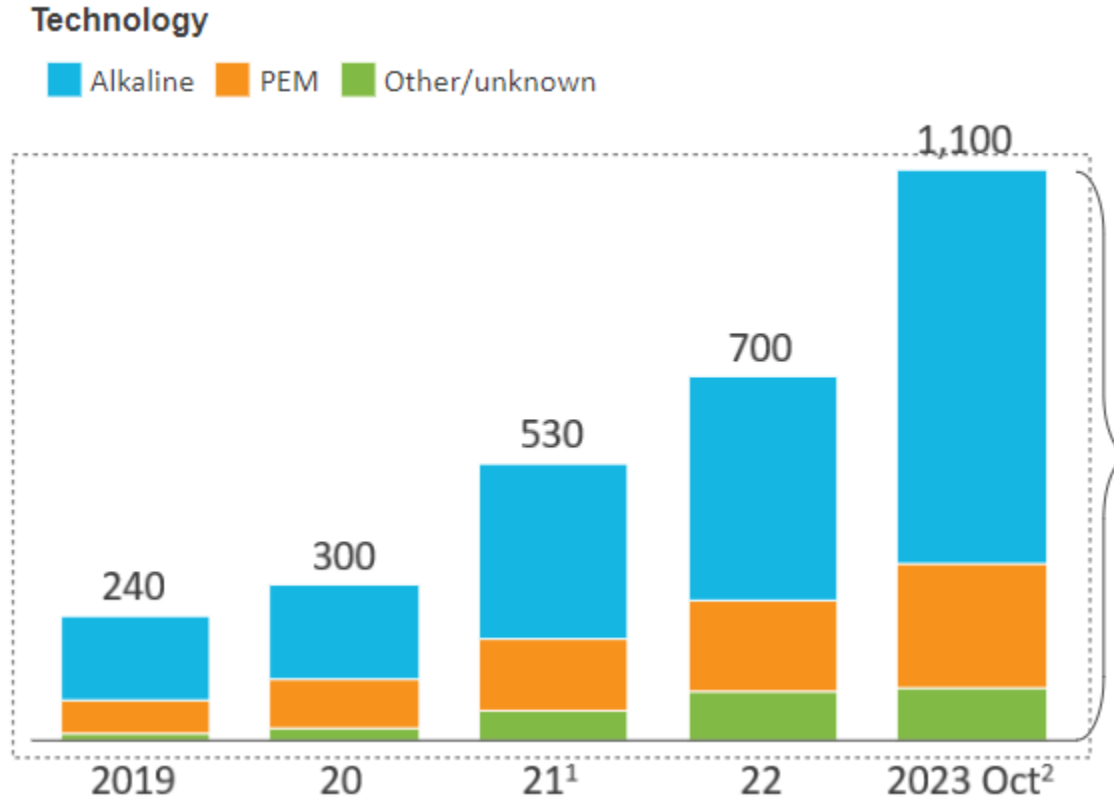
Installed electrolyser capacity

Committed¹ production capacity until 2030, %



- North America**
Low-carbon hydrogen accounts for around 90% of committed production capacity in North America (of which ~670 kton is already operational), with demand driven by hydrogen for ammonia production and refining
- China**
Several large-scale renewable hydrogen projects (>100 MW) already operational
- Europe**
Renewable hydrogen accounts for close to all committed production capacity (>75%) in Europe, with industry feedstock sectors (e.g., refining) driving demand
- Middle East**
Committed production capacity driven by mega-scale renewable hydrogen project in Saudi Arabia
- Africa**
- India**
- Other**
Japan, South Korea, Oceania and Latin America

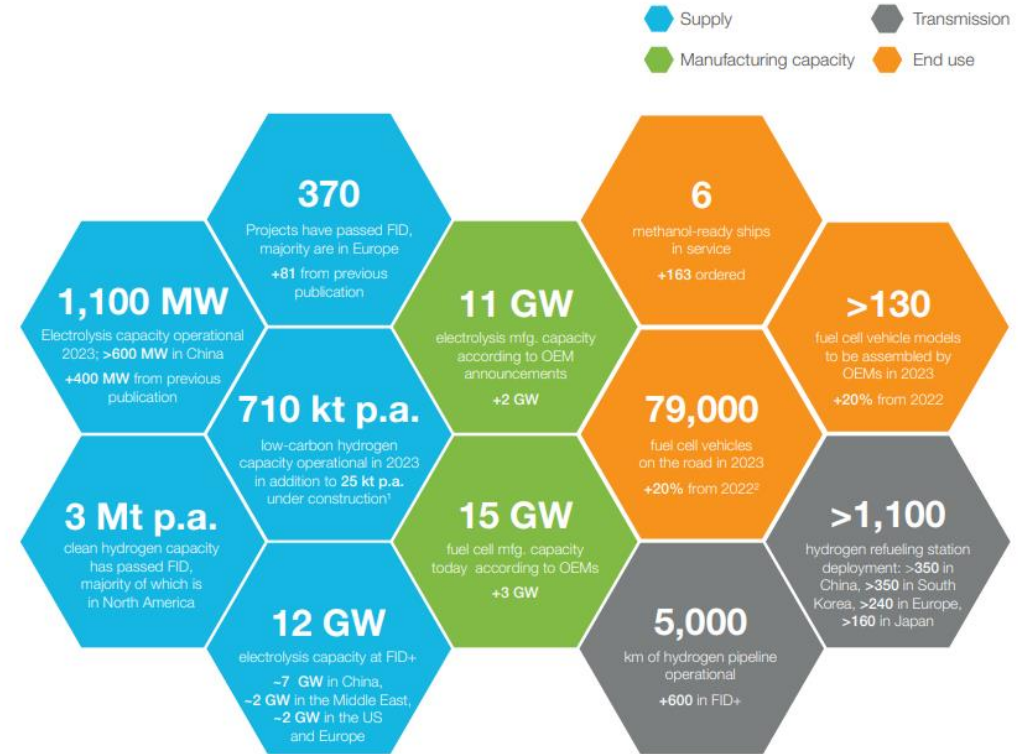
1.100 MW ELECTROLYSER CAPACITY INSTALLED IN 2023 – CHINA IS LEADING THE GLOBAL DEPLOYMENT



Source: IEA Global Hydrogen Review 2021 & 2022; Project & Investment tracker, as of Oct 2023, McKinsey

ELECTROLYSER MFG CAPACITY AT GLANCE

Manufacturing capacity: Electrolyzers and fuel cell manufacturers are preparing to scale up. Electrolyzer manufacturing capacity has reached nearly 11 GW (up from 9 GW previously) according to OEM statements. For fuel cell manufacturing, the total global capacity stands at 15 GW (up from 12 GW), with South Korea, China, and Japan as the largest supply markets.



Source: Hydrogen Insights 2023, Hydrogen Council

04

INCENTIVES TO SCALE-UP ELECTROLYSER MFG

INDUSTRIAL DRIVERS IN THE EU

Green Deal Industrial Plan

Predictable and simplified regulatory framework

Net Zero Industry Act (NZIA)
Reform of the Electricity Market
Critical Raw Materials Act (CRM)

Faster access to funding

Temporary Crisis and Transition Framework
General Exemption Regulation
Strategic Technologies for Europe Platform (STEP)

Enhancing skills

Net Zero Industry Academies

Open trade for resilient supply chains

Net Zero Industry Partnerships
Critical Raw Materials Act Club and Strategic Partnerships

THE NET-ZERO INDUSTRY ACT

Main objectives of NZIA

1. Ensuring security of supply to address the EU's vulnerabilities in the energy sector as a response to IRA in the U.S. and Chinese Cleantech-dominance. Today, more than 80% of EU's supplies in CleanTech stem from China.
2. Upscale European manufacturing capacity of strategic net-zero technologies to meet at least 40% of EU's annual deployment needs by 2030

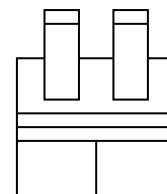
Key measures

- Faster permitting and net-zero strategic projects
- Enhancing skills
- 50M tons CO2 injection capacity
- Attracting investments (i.e. Hydrogen Bank)

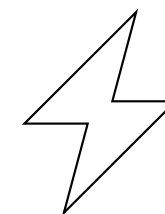
Meet at least
40%
of the EU's annual deployment needs
by 2030

8 STRATEGIC NET-ZERO TECHNOLOGIES

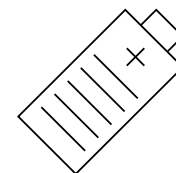
1. Solar photovoltaic and solar thermal technologies
2. Onshore wind and offshore renewable technologies
3. Battery/storage technologies
4. Heat pumps and geothermal technologies
5. **Electrolysers and fuel cells**
6. Sustainable biogas/biomethane technologies
7. Carbon capture and storage (CCS) technologies
8. Grid technologies



SOEC solution



eSMR™



battery materials



**TEMPORARY
CRISIS AND
TRANSITION
FRAMEWORK
(TCTF)**

**VALID UNTIL 31
DECEMBER 2025**

STATE AID FOR THE MANUFACTURING OF NZIA TECHNOLOGIES:

BATTERIES, SOLAR PANELS, WIND TURBINES, HEAT PUMPS, **ELECTROLYSIS** AND CARBON CAPTURE AND STORAGE, [NUCLEAR POWER]

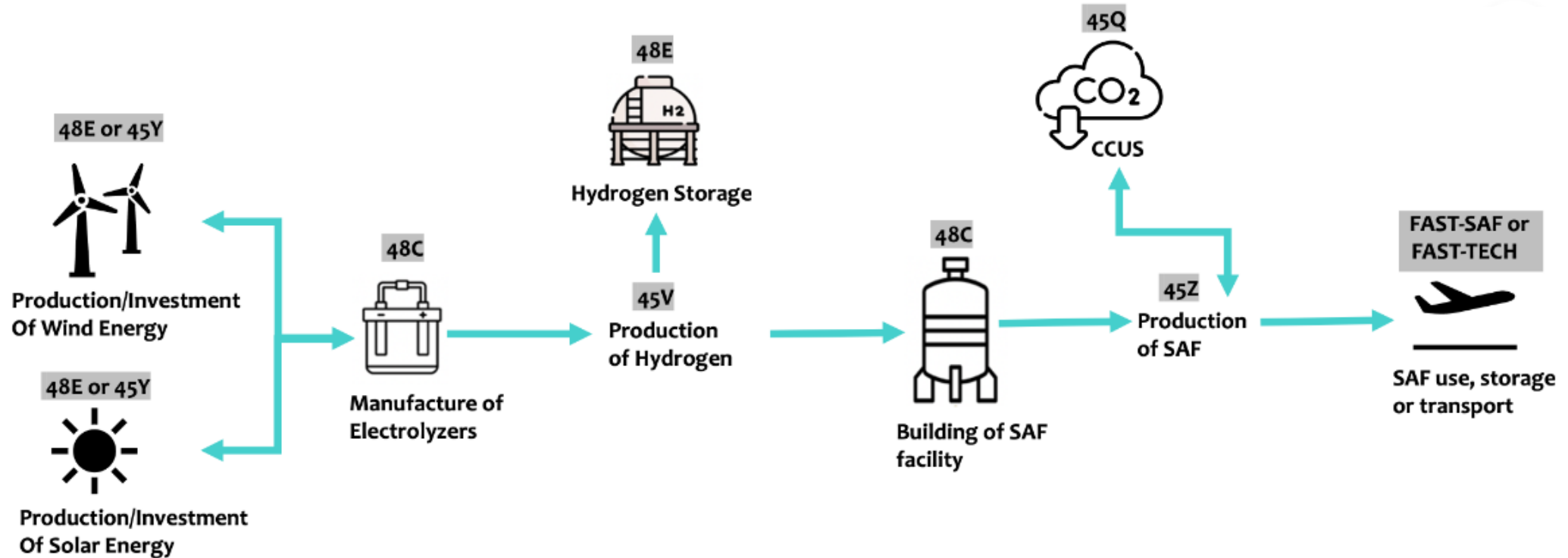
INVESTMENT SUPPORT AND OPERATING SUPPORT FOR PRODUCTION OF **CRITICAL RAW MATERIALS**

- SMEs and companies **located in regional support areas**
- Only for companies in **regional support areas** or projects **in at least 3 MS** where at **least one MS is regional support region a**; [> 75 per cent of EU GDP or overseas regions] + only for investment in state-of-the-art technology

- **Aid-matching**: evidence must be if there is a risk of ex-EU delocalization (in example as consequence of IRA) and there must be **safeguards against delocalization within the territory of the EU**
- Only support for the funding gap – but support for both CAPEX and OPEX

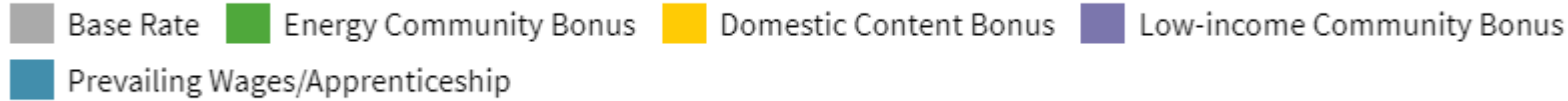
US 48C ADVANCED ENERGY PROJECT TAX CREDIT

A USD 10 BN EXPANSION OF INVESTMENT UNDER THE INFLATION REDUCTION ACT OF 2022

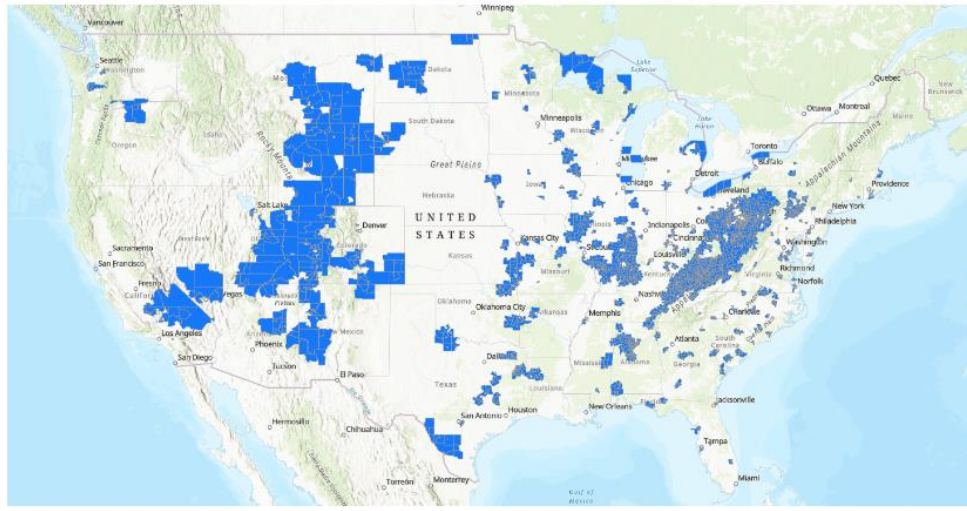


48C ADVANCED ENERGY PROJECT TAX CREDIT

UP TO \$4 BILLION IN A FIRST ROUND OF TAX CREDITS FOR PROJECTS



48C % of investment



USD 1.6 billion of the 48C allocation is set aside for projects in designated energy communities

05

IS THE EU LOSING MOMENTUM IN THE ELECTROLYSER TECH RAISE AND WHAT COULD BE DONE?

HYDROGEN, PTX AND EU COMPETITIVENESS

Strengths	Weaknesses
<ul style="list-style-type: none"> • EU frontrunner in announced H2 + regulatory framework almost in place • Ambitious H2 targets/mandates in industry and transportation • Very advanced regulatory framework to ensure the credibility of renewable hydrogen and RFNBOs • EU is role model for the rest of the world when it comes H2 regulatory framework 	<ul style="list-style-type: none"> • Not enough electrons • High energy prices – high costs of H2 produced in the EU • H2 tenders based on price and volume only • Lack of easy access to funding at EU level • Lack of H2 infrastructure • Lack of enforcement mechanisms for non-compliance
Opportunities	Threats
<ul style="list-style-type: none"> • Mandates in EU will drive demand • More focus on "Made in Europe" frontrunners • More focus on non-price criteria • More focus on ensuring a level playing field between EU and non-EU competitors (CBAM, Foreign Subsidies Reg etc.) 	<ul style="list-style-type: none"> • The Green Agenda is under pressure + slow build-out of RE • Lack of off-take of H2, willingness to pay the green premium • State aid vs. fair competition, best products in the EU • IRA pulling investments in cleantech across the Atlantic • China very well could take over global electrolyser market with cheap alkaline electrolysers

MAKING THE
ENERGY
TRANSITION
HAPPEN



THANK
YOU