




Large scale water electrolysis for decarbonized industry

Green hydrogen technology for multi- and gigawatt installations



Dr Malcolm Cook
malcolm.cook@thyssenkrupp.com

February 2021



engineering. tomorrow. together.



thyssenkrupp



thyssenkrupp: Two missions in the energy transition

Transition path to
green steel

-30% CO2 reduction
by 2030



Green hydrogen and
chemicals

GW electrolysis
manufacturing

10 GW installed in the
chemical industry

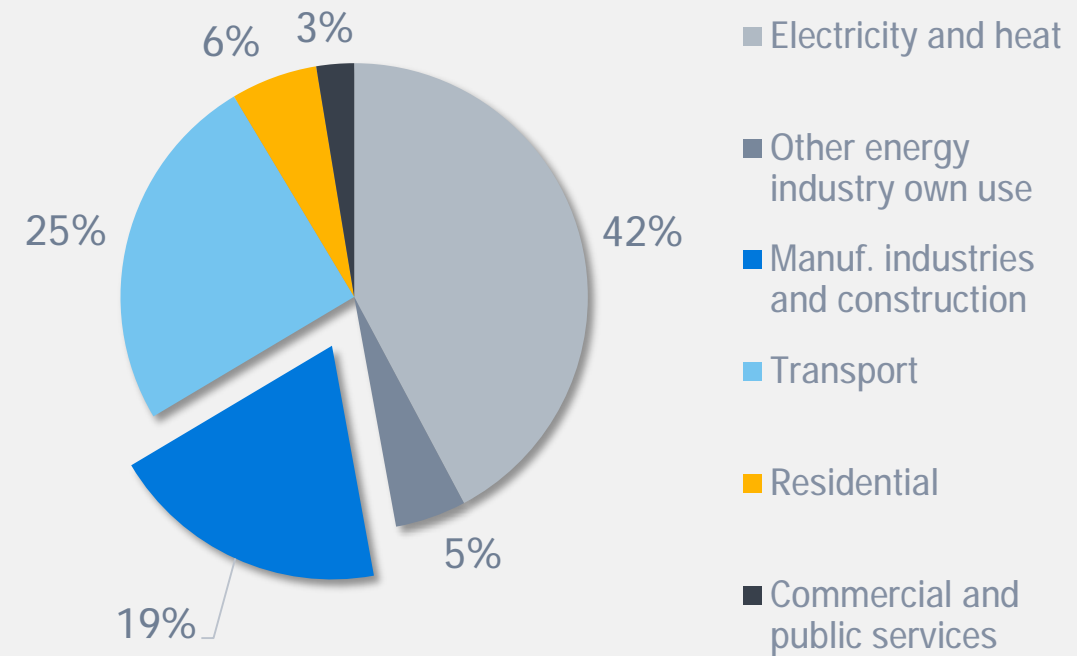


Green hydrogen is crucial energy carrier and base material for the decarbonization of the industry sector which represents about 20% of the global CO₂ emissions

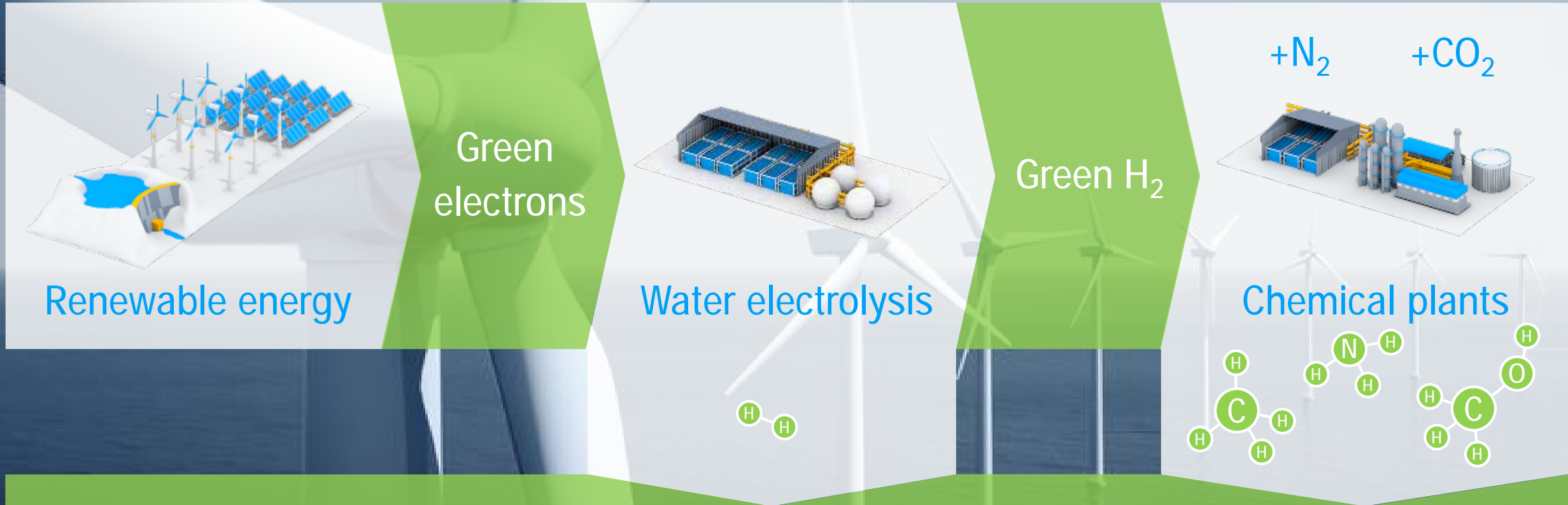
The next wave in the energy transition

- Electricity market is focus of the climate protection efforts
- Green hydrogen is the main energy carrier for decarbonization of the industry sector

Share of CO₂ emissions by sector

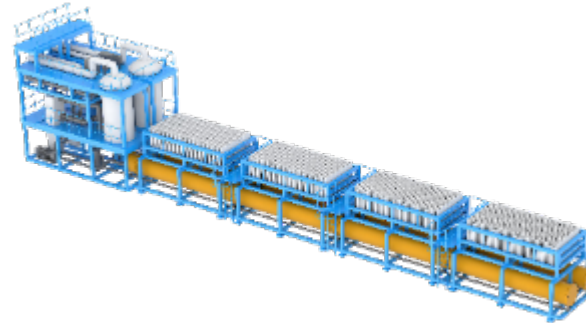
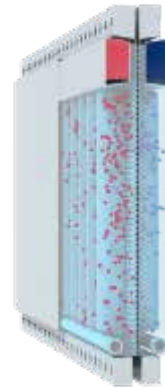


Smart solutions for climate protection – water electrolysis and beyond



Lean and cost effective solution for large scale water electrolysis...

...based on our market lead in electrolysis



AWE single element

Shared technology platform:

- Shared supply chain with scale advantage
- Optimized design based on decades of experience and innovation

Electrolyzer unit

Deployment of stand. units:

- Cost reduction for execution
- Integration of digital solutions
- Optimized operating conditions

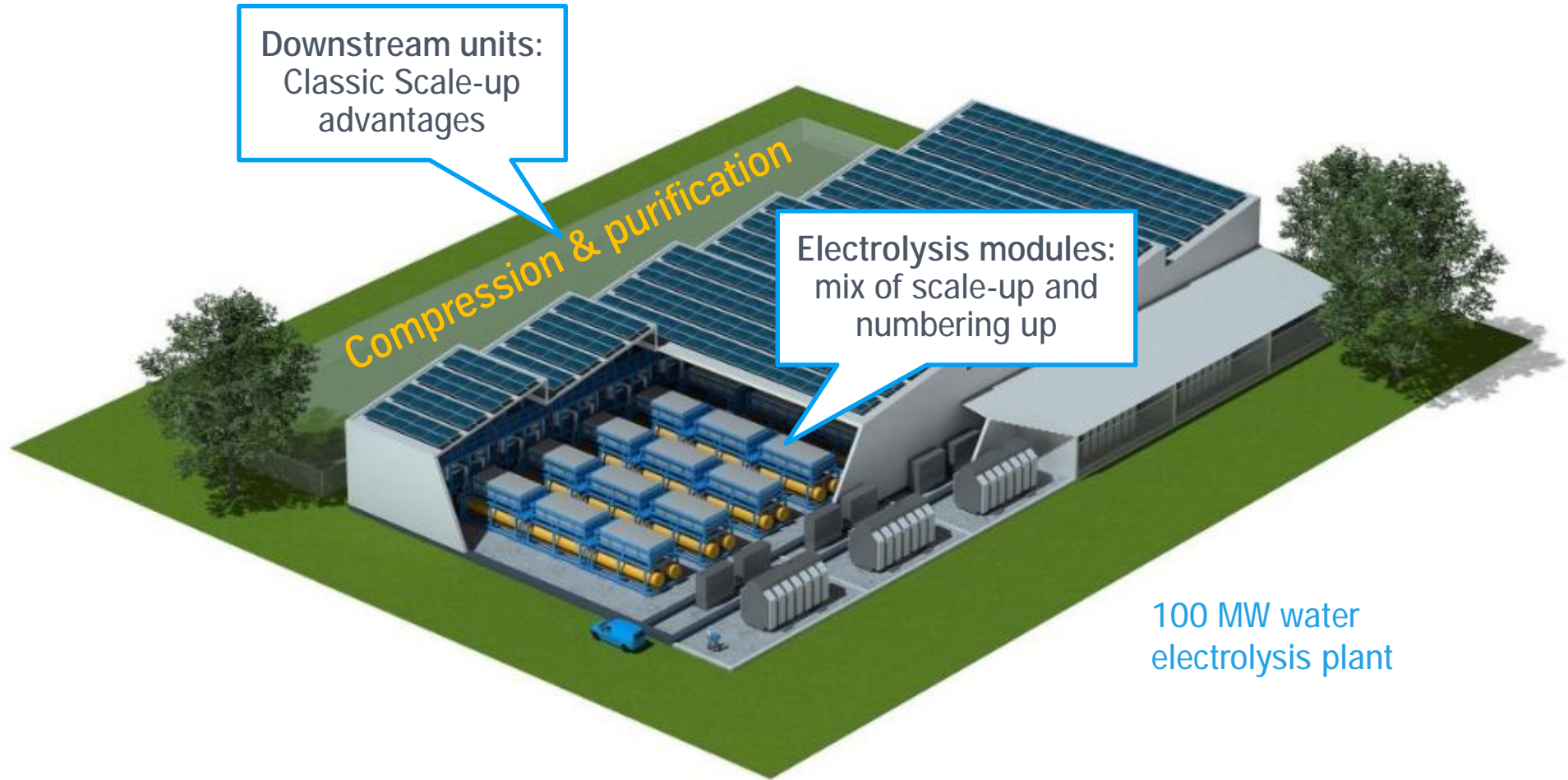
H2 production plant

Integrated plant concept:

- Optimized overall solution
- Utilizing EPC competence for efficient execution
- In-house competence for H₂ and O₂ handling

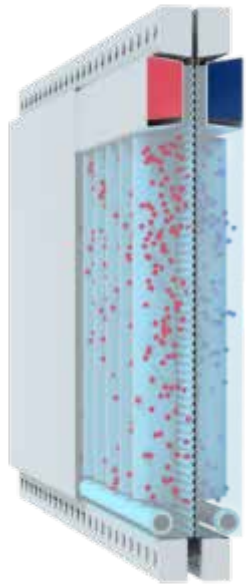


The benefits of economy of scale



We see a dynamic project market and aim for a 5 GW value chain

Build up more capacity together with established and new partners



- 1 Stack and cell development
- 2 Optimization and scaling of manufacturing
- 3 Optimization and automation of assembly

5 GW
annually



Transition from small scale pilots to industrial scale applications

- compete against grey hydrogen

Small scale pilots



- Small scale projects in the R&D context
- Expensive hydrogen due to high specific costs
- Focus applications have been mobility and usage of gas infrastructure
- No commercial hydrogen offtake available
- In general, little development of scaled technology and supply chains



Industry scale solutions

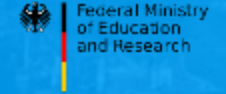
- Refineries, steel and ammonia plants request large volumes
- Scaling reduces costs below the benchmark of 2 €/kg: supply chains, high efficient equipment, efficient project development.



Carbon2Chem[®], Duisburg/Germany

From idea to commercial implementation

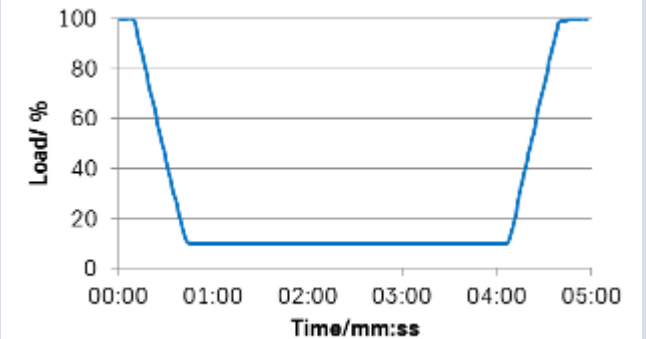
Carbon2Chem[®] supported by



BMBF funding numbers 03EK3037 to 03EK3043



Carbon2Chem[®]
Technical Center

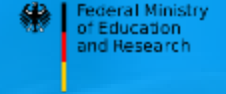


Fast ramping capabilities proven

- Load changes between 10% and 100% in less than 30 sec.
- Enables utilization for primary control reserve

Carbon2Chem[®], Duisburg/Germany
From idea to commercial implementation

Carbon2Chem[®] supported by



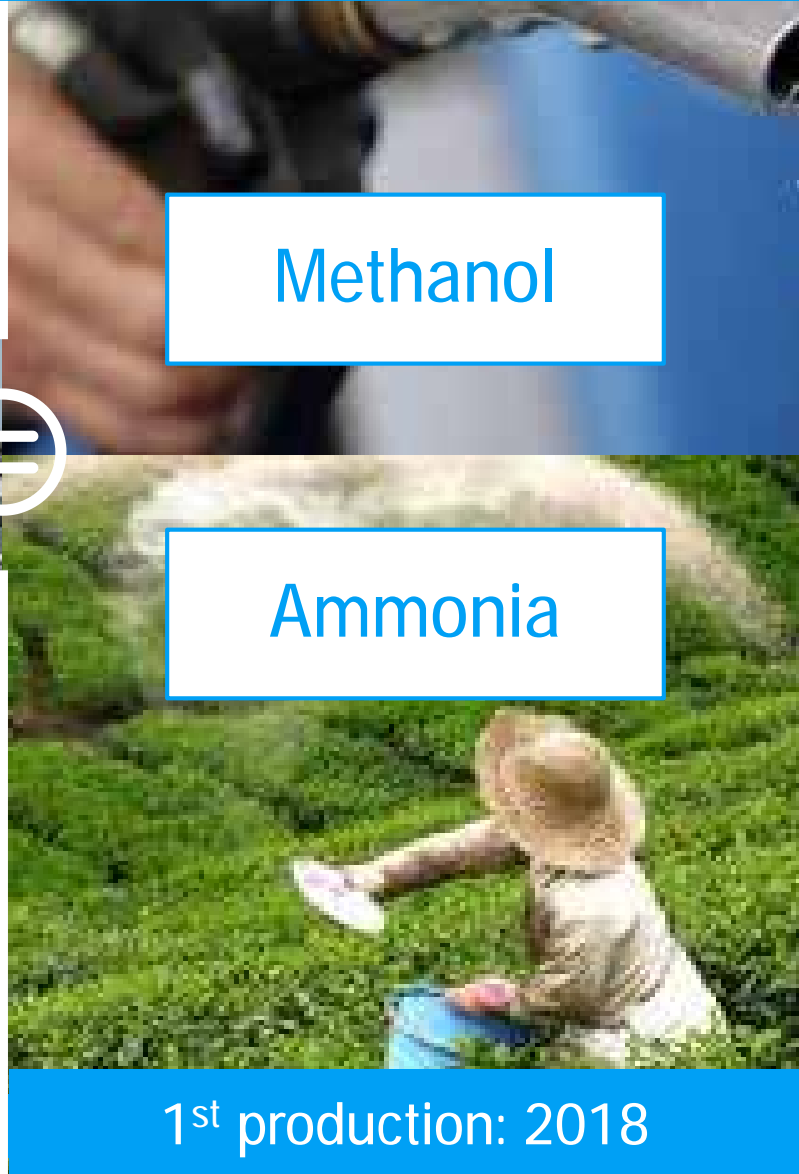
BMBF funding numbers 03EK3037 to 03EK3043



H₂



Syngas



Methanol

Ammonia

1st production: 2018

“ELAN” for Hydro-Québec in Varennes, Canada

Electricity with a strong green footprint

Capacity: 88 MW electrolysis

Location: Varennes, Canada
RE Feed: Hydroelectricity

Concept: Green hydrogen to green methanol, ethanol,
DME as bio fuels
Green oxygen as waste incineration aid

Startup: 2023



“Element ONE” in NEOM, KSA

Scaling up to 20 MW standard module

Supported by

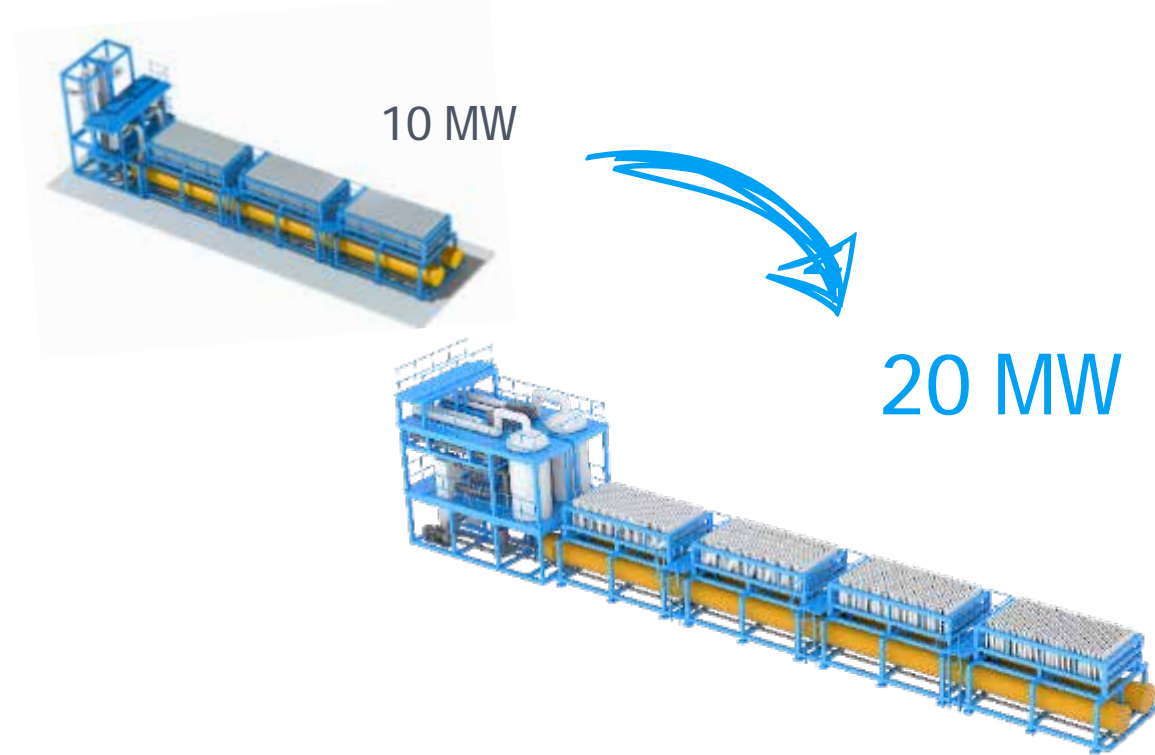


Capacity: 20 MW

Location: NEOM, KSA
RE Feed: Wind and PV

Concept: Green hydrogen, partially green methanol
Qualification of 20 MW module in three year test operation for direct use in the modular plant in the HyLIOS project

Startup: Test operation 2022
HyLIOS operation 2025



“HyLIOS” for Air Products in NEOM, KSA

Pioneering innovation lab – Major step for entering the global hydrogen market

Supported by
KSA government with
5bn Euro investment

Capacity: 650 t per day green hydrogen
(multi GW electrolysis)

Location: NEOM, KSA
RE Feed: Wind and PV

Concept: Green hydrogen feedstock to green ammonia
Green ammonia as energy carrier

Startup: 2025



**AIR
PRODUCTS**

ACWA POWER
أكوا باور

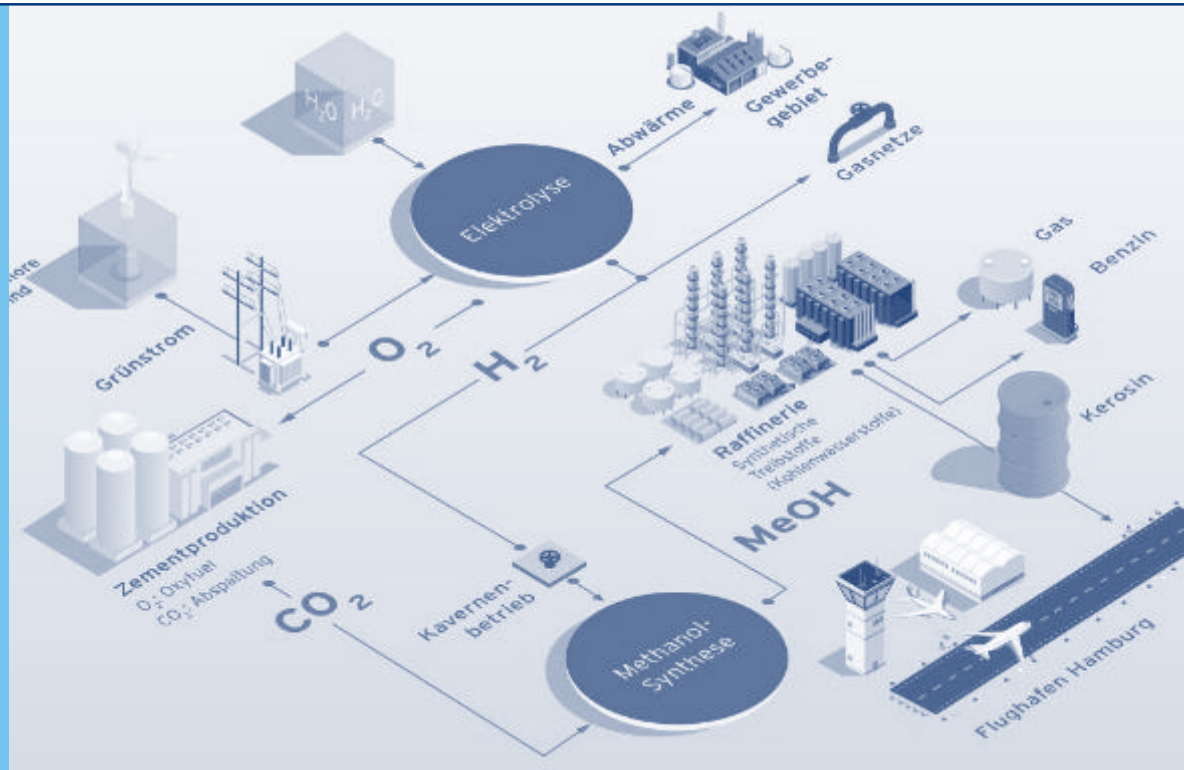

thyssenkrupp

“Reallabor Westküste 100” in Heide, Germany

Complete sector coupling



Phase 1:	30 MW electrolysis
Phase 2:	700 MW electrolysis green methanol and fuel for aviation
Location:	Heide, Germany
Funding:	by BMWi
RE Feed:	Offshore wind
Concept:	Green hydrogen feedstock to refinery of Heide Green methanol / fuel production by refinery Green hydrogen for fueling stations
Startup:	2023



Driver for Green Hydrogen: Scale up and innovation

Substitution of grey hydrogen in existing value chains already requires **gigawatt scale**

Already
600
GW

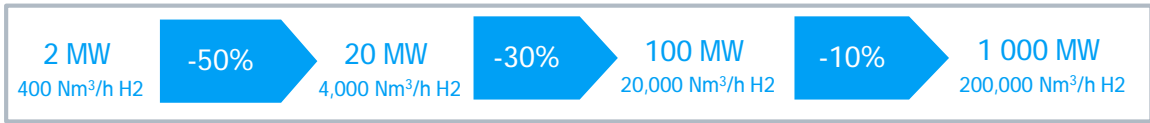
1

Power-to-X applications require **scale** to compete against grey commodity prices

2

Scaling up electrolysis plants shows **significant cost reduction**

3



4

Only at gigawatt scale **global transport chains** operate efficiently

