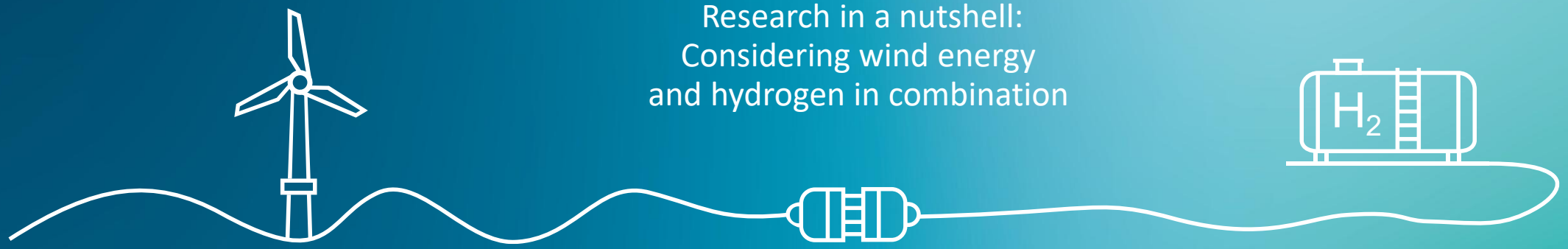
Fraunhofer IWES



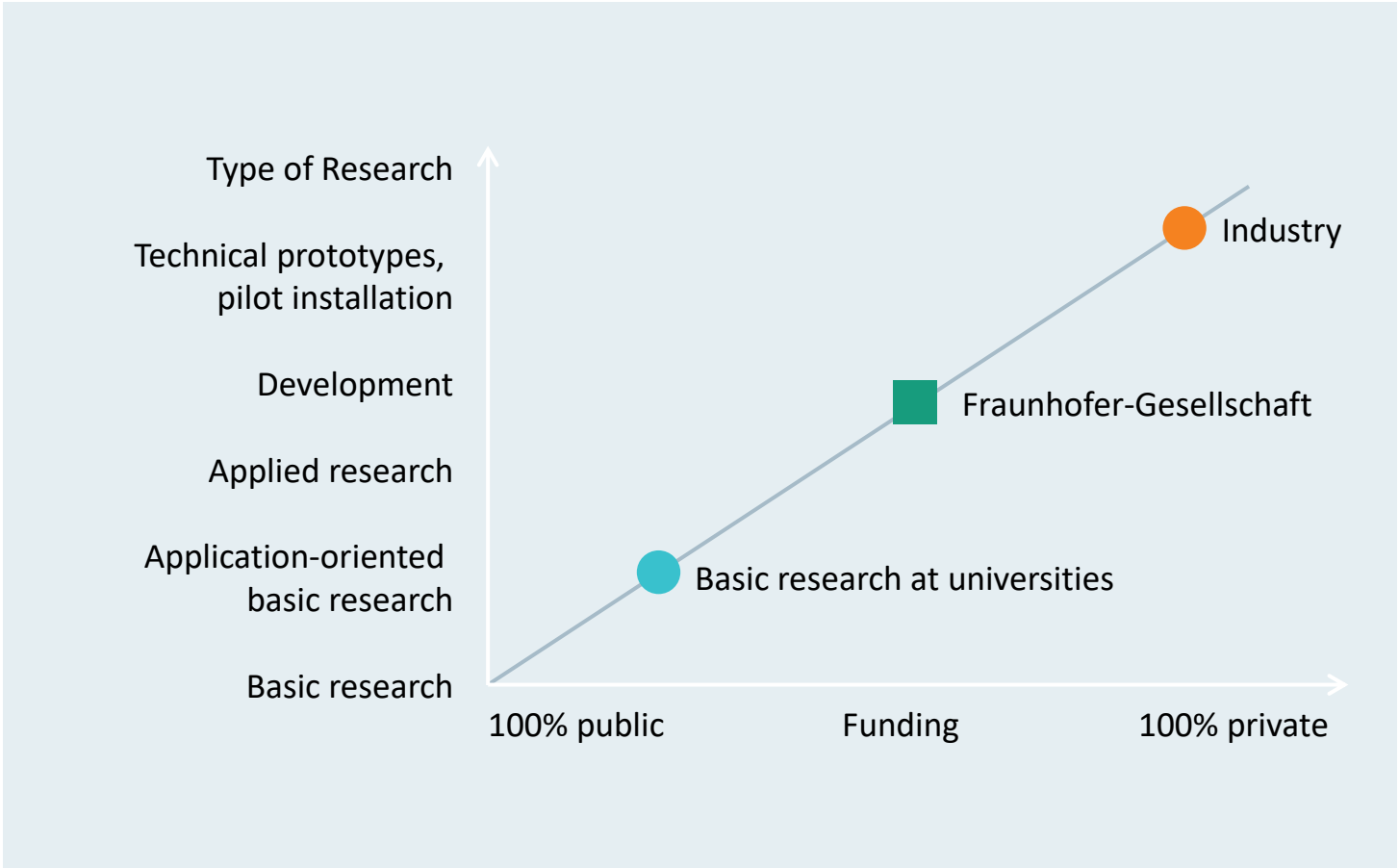
19. Symposium Energieinnovation 2026

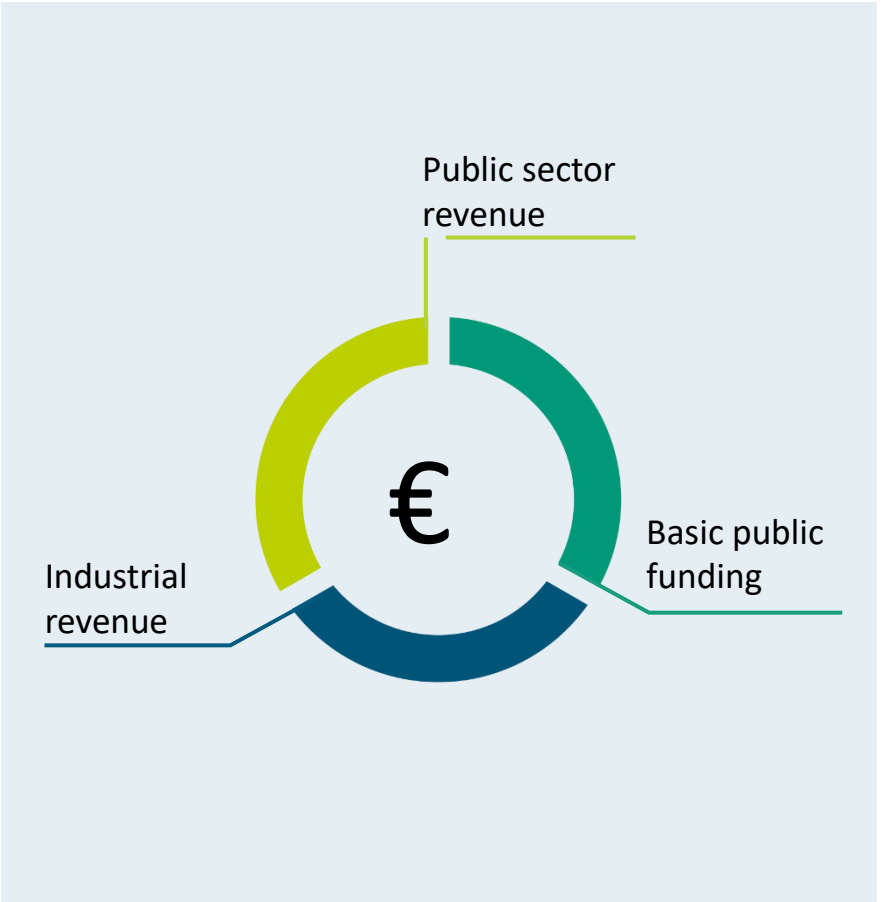
MW-electrolysers for the hydrogen economy: test strategies and validation at industrial scale

Dr. Johannes Höflinger, Group Manager Hydrogen Lab Leuna and Görlitz

Research with added value for the industry

Fraunhofer-Gesellschaft´s business model



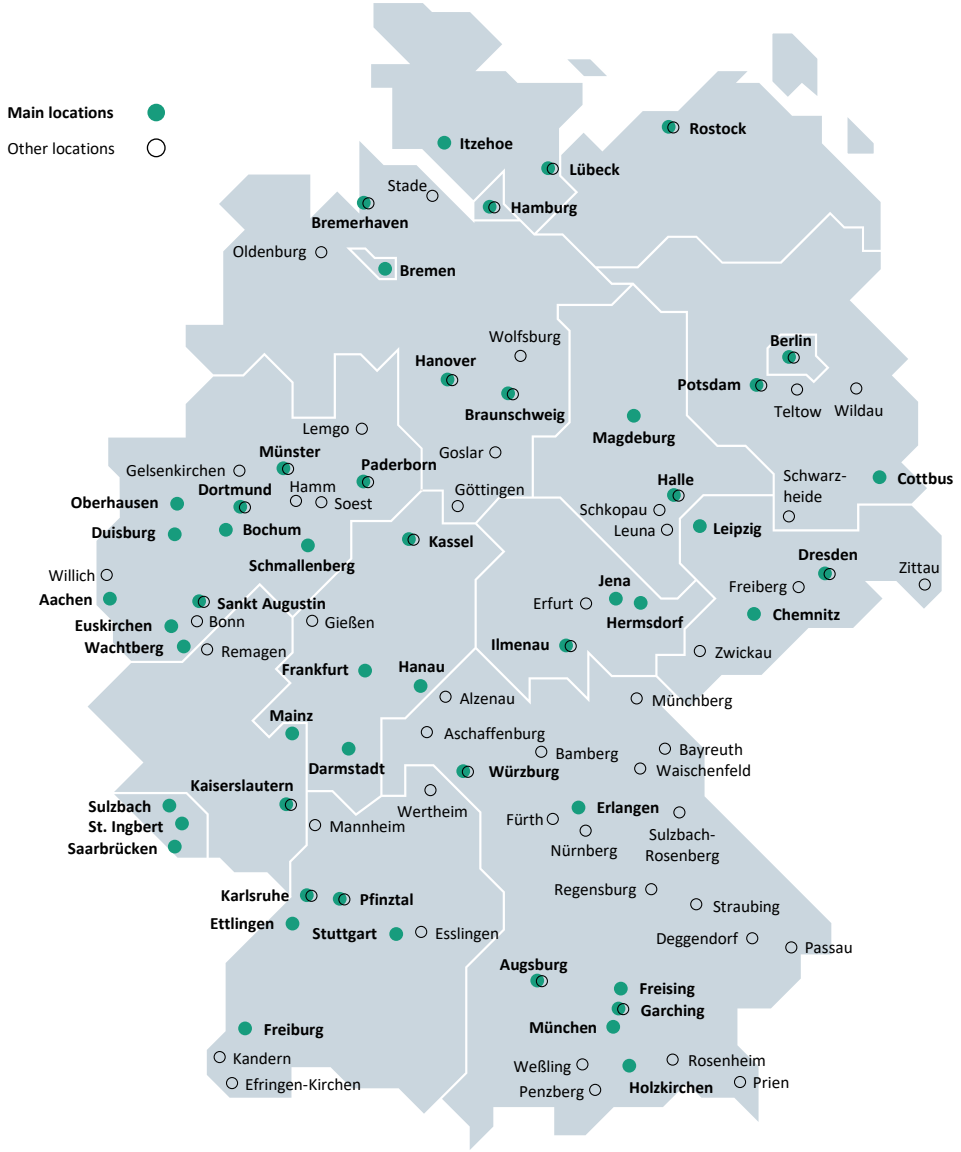


Fraunhofer IWES

Fraunhofer-Gesellschaft

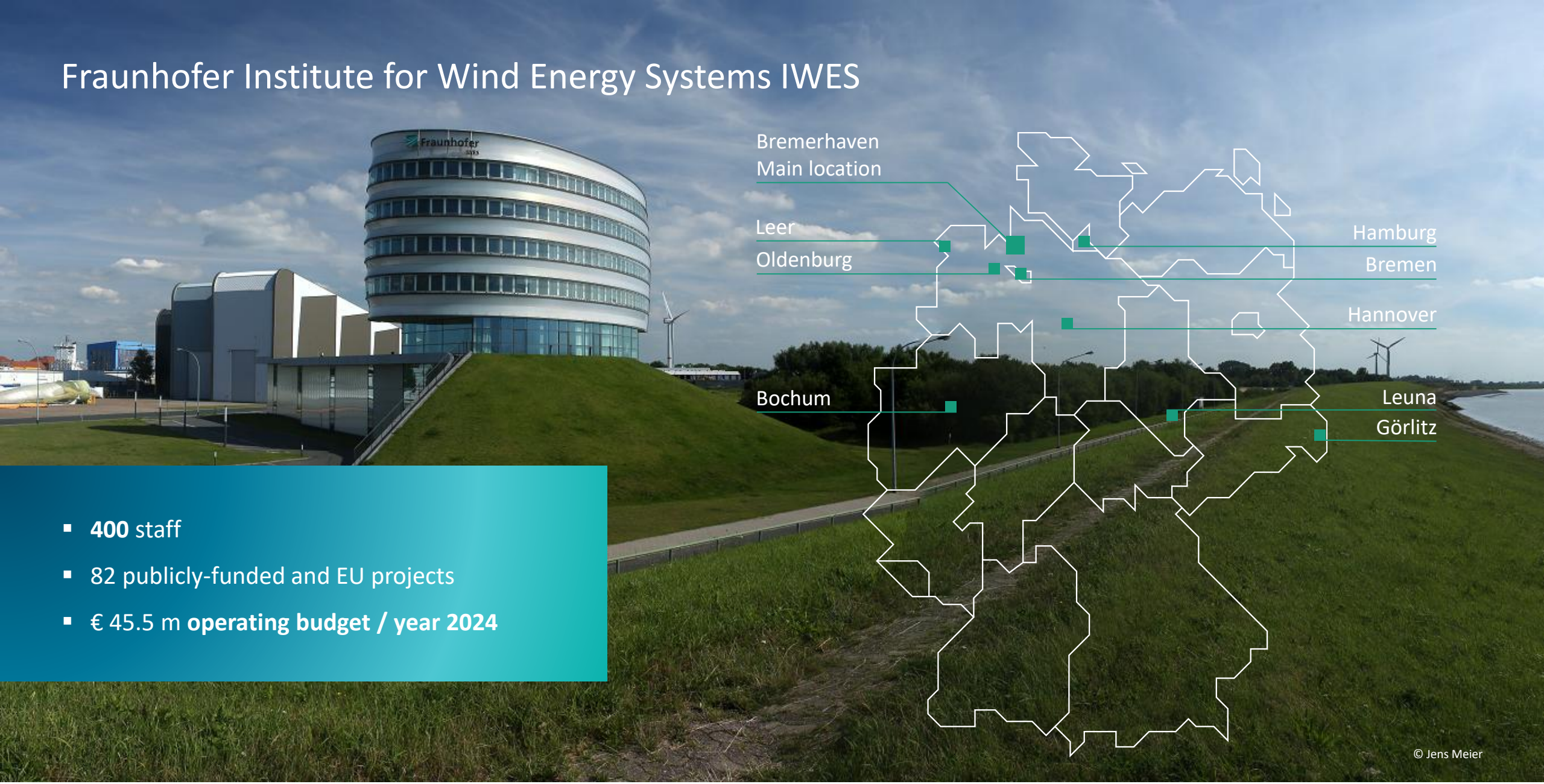
Locations in Germany

- 76 institutes and research facilities
- 30,000 employees in total
- € 2,9 bn research volume / year



Fraunhofer IWES

Fraunhofer Institute for Wind Energy Systems IWES



- **400** staff
- 82 publicly-funded and EU projects
- € 45.5 m **operating budget / year 2024**

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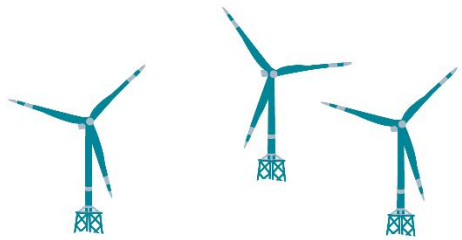
Fraunhofer IWES

Our testing infrastructure

2009–2025



Assessment of Soil Conditions Bremen

2009

70m Rotor Blade Hall

90m Rotor Blade Hall Bremerhaven

2011

1st Lidar Measuring Buoy Bremerhaven

2012

Engineering Building

2013

Test Center Support Structures Hannover

2014

DyNaLab Bremerhaven

2015

Application Center for Field Measurements Bremerhaven

BladeMaker Bremerhaven

2016

Research Windturbine Bremerhaven

2017

Large Bearing Laboratory Hamburg

2019

Application Center for Integration of Local Energy Systems Hamburg

HiL-GridCoP Bremerhaven

2020

Hydrogen Lab Leuna

2021

Hydrogen Lab Bremerhaven

2023

115m+ Rotor Blade Test Rig Bremerhaven

Mobile Grid Bremerhaven

2024

PQ4Wind Bremerhaven

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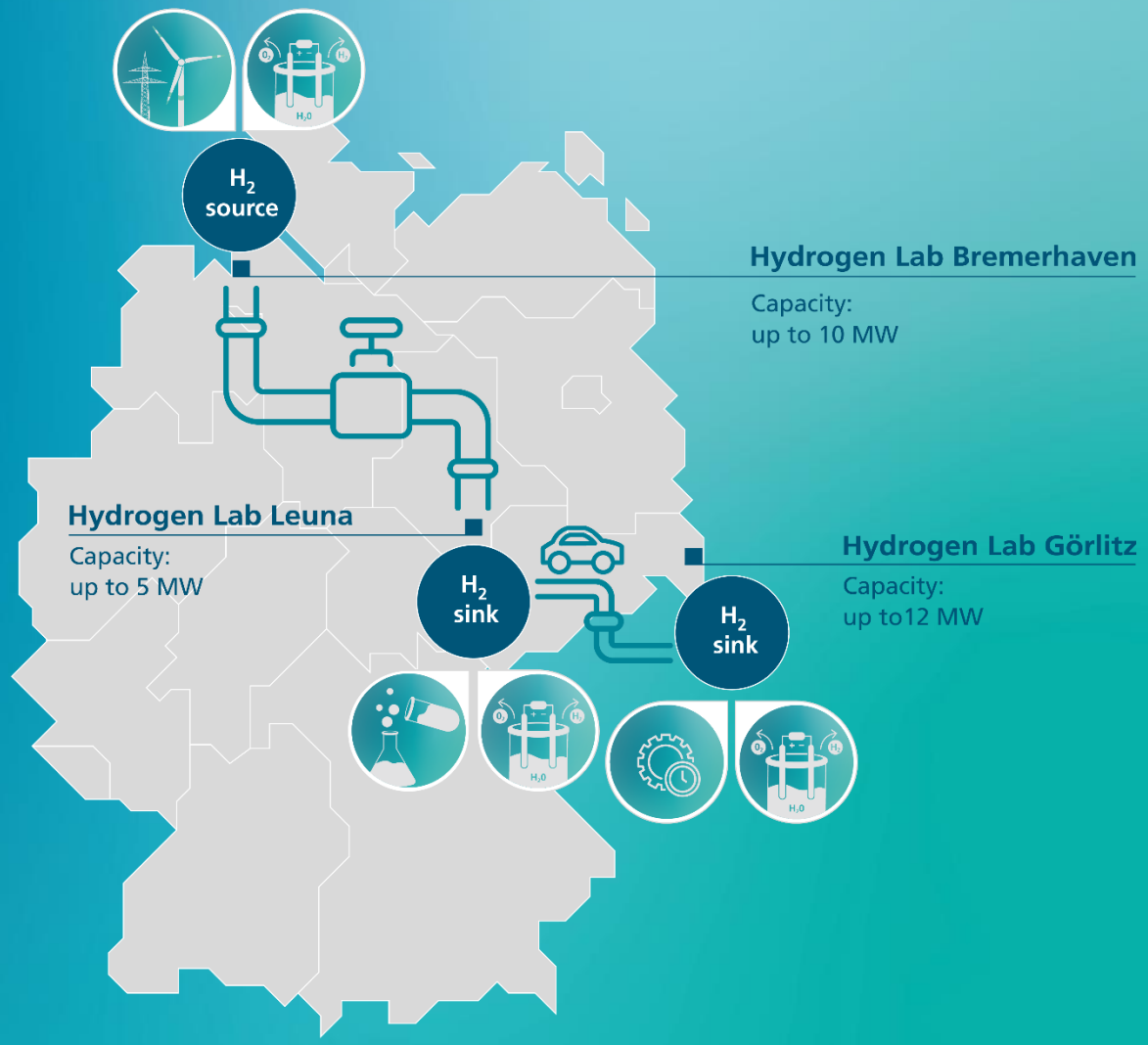
Hydrogen Labs by IWES

Thinking of wind energy and hydrogen together

Wind
- Regenerative power generation
- Production of green hydrogen

Chemistry
- Material use of hydrogen
- Defossilization of industry

Industry
- Energetic use of hydrogen
- Decarbonization of industry



www.hydrogen-labs.fraunhofer.de/en.html

Fraunhofer IWES

Thinking wind energy and hydrogen together

Each Hydrogen Lab with its special focus areas

HYDROGEN LAB
LEUNA

- Elektrolyzer system tests up to **5 MW**
- Different technologies (AEL, PEM, SOEC)
- Hydrogen utilisation via local pipeline in chemical park Leuna and refinery processes
- Electrolyzer stack test benches up to 46 kW and 2MW
- Research operation since 2022

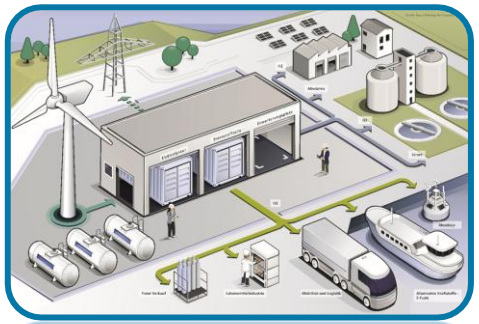
HYDROGEN LAB
GÖRLITZ

- Focus on applications in industrial production and decarbonisation
- Electrolyzers stack test benches up to 2 MW
- Site power supply of **12 MW**
- Commercial equipment: electrolysers, fuels cells, H2 storage tanks, etc.

Fraunhofer IWU

HYDROGEN LAB
BREMERHAVEN

- Electrolysis with coupling to wind energy
- Test benches up to **10 MW**
- Coupling to virtual grid of Dynamic Nacelle Testing Laboratory
- Research operation since 2023



Fraunhofer Hydrogen Lab Görlitz
Fraunhofer IWU
Fraunhofer IWES

Overview of research priorities

Hydrogen Labs

SACHSEN-ANHALT

EUROPÄISCHE UNION
EFRE
Europäischer Fonds für regionale Entwicklung

Electrochemistry

- Evaluation and benchmarking of new materials and components
- **Trace analysis of reactants and products**
- Electrochemical analysis
- Development of test protocols and model-based data analysis

Industrial scale

- Validation and certification
- Testing of auxiliary units, e.g. H2 compressors, H2 storage systems
- Testing of electrolyser systems (5 MW) and stacks (3.5 kW - 2 MW)

Power-to-X

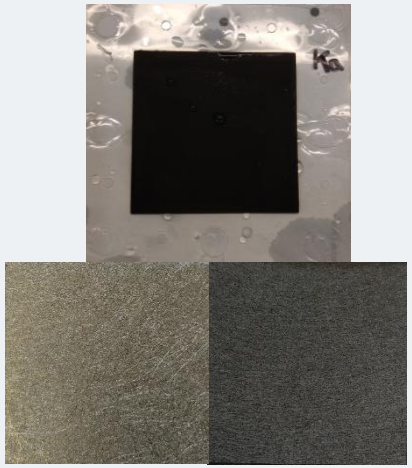
- Techno-economic analyses
- Operation under real conditions (load profiles of wind, PV)
- Testing of PtX processes on a pilot scale (e.g. methanol, eFuel)
- **Green H2 usage in Processes and Production**

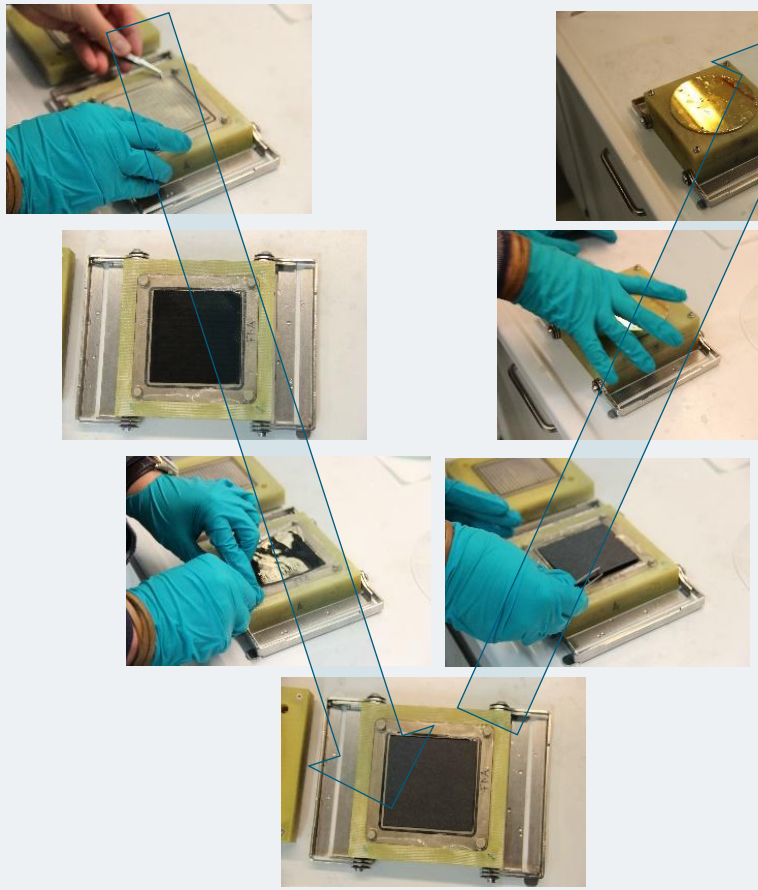
Fraunhofer IWES

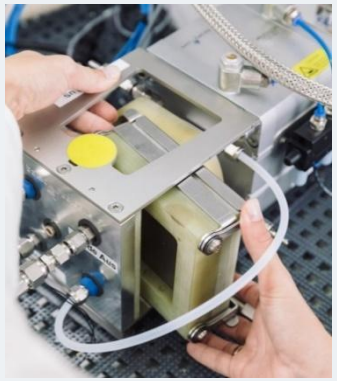
Electrochemical Analytics

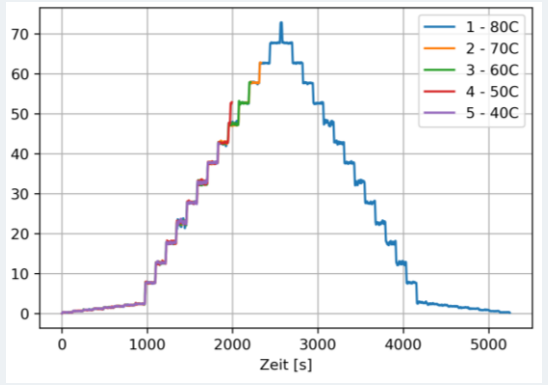
Research focus

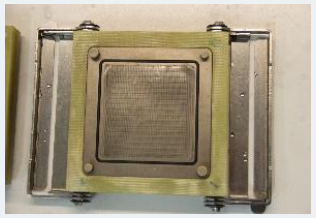
Experimental and model-based analysis of electrolysis cells, from component to stack level

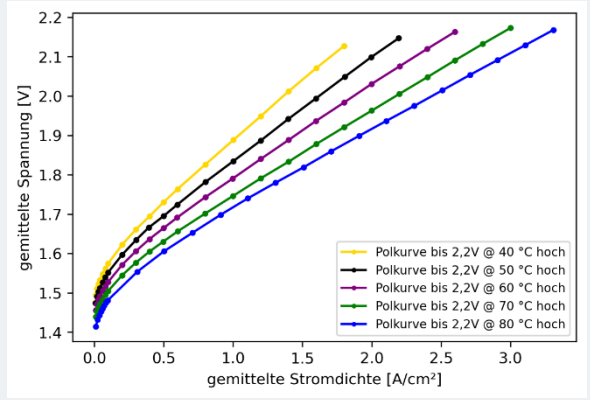








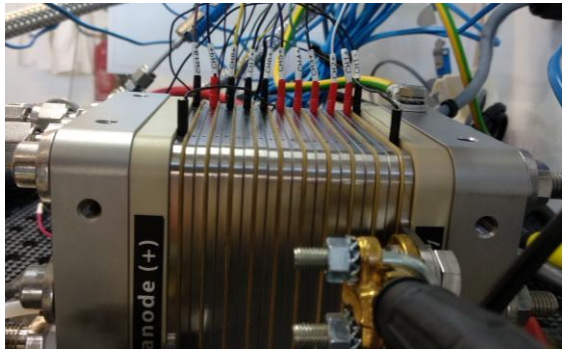


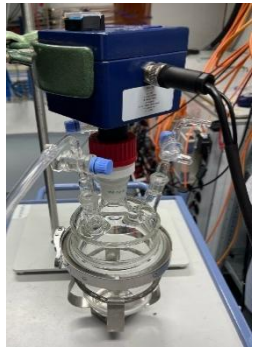


Electrochemical Analytics

Research focus

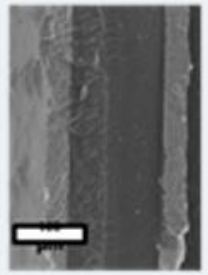
- Development and validation of test protocols for evaluation and comparison of electrolysis technologies, for example for direct coupling with wind turbines
- Cell and stack testing for material and component design developmer evaluation and diagnostic
- Educt and product analysis
- Material analysis and defect diagnostics by corrosion and microstructural analyses (in cooperation with IMWS)
- Model-based data evaluation and correlation for cells and stacks
- H2 removal and corrosion measurements of different materials



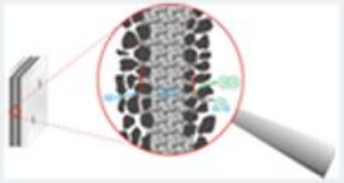


Optimisation of components and systems

(e.g. catalyst, membranes, GDLs, stacks)

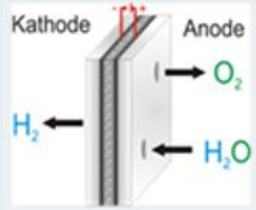


Diagnostics



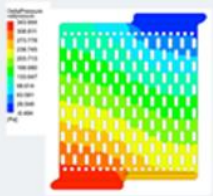
In and ex situ diagnostics on microscopic scale

Electrochemistry



Investigations of single cells and stacks

Simulation

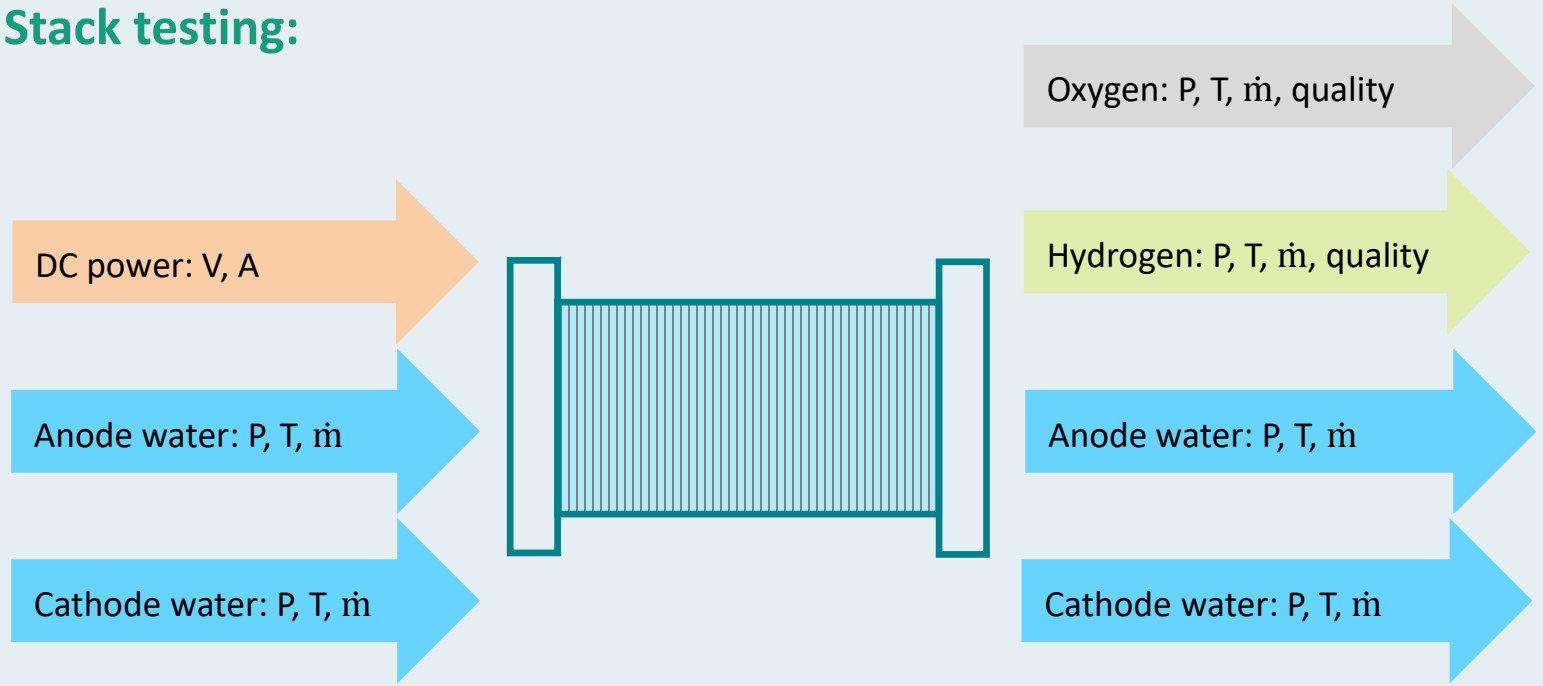


e.g. of current density distribution

Hydrogen Labs Electrolyser Stack Testing

Overview of technical capabilities

Stack testing:



Test parameters:

- Variable load profile
- Variable pressure difference (anode/cathode)
- Variable temperature
- Variable water mass flow
- Electrochemical Impedance Spectroscopy (EIS)

Results:

- Efficiency (diff. load points)
- Energy balance
- Mass balance
- Hydrogen quality
- Degradation
- Dynamics
- Temperature influence
- Pressure influence
- Thermographics
- Vibration

Hydrogen Lab Electrolyser System Testing

Overview of technical capabilities

System testing (PEM, AEL, SOEC):

AC power: V, A

Water (steam): P, T, $\dot{m}$

Other media: P, T, $\dot{m}$

Hydrogen: P, T, $\dot{m}$, quality

5 MW

Test parameters:

- Steady state load points
- Variable load profile (wind, solar, …)
- Variation of internal system parameters

Results:

- Efficiency (diff. load points)
- Internal system parameters (DC; waste heat, …)
- Energy balance
- Mass balance
- Hydrogen quality
- Degradation
- Dynamics
- Acoustics
- Thermographics
- Vibration

Overview of Electrolyser Test Infrastructure

Technical specifications

	5 MW system	3,75 kW stack	46 kW stack	46 kW stack	46 kW stack	2 MW stack	2 MW stack
Type	-	PEM + AEM	PEM	PEM	PEM + AEL	PEM	PEM + AEL
Voltage	-	25 V	30 V	30 V	30 V	800 V	800 V
Current	-	150 A	1500 A	1500 A	1500 A	8000 A	16000 A
Pressure	-	30 bar	35 bar	35 bar	35 bar	35 bar	35 bar
Additional functions	-	EIS	EIS	-	Climate chamber + vibrating table	Climate chamber	-

Gefördert vom Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

Freistaat SACHSEN

Supported by: Die Bundesregierung on the basis of a decision by the German Bundestag

Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

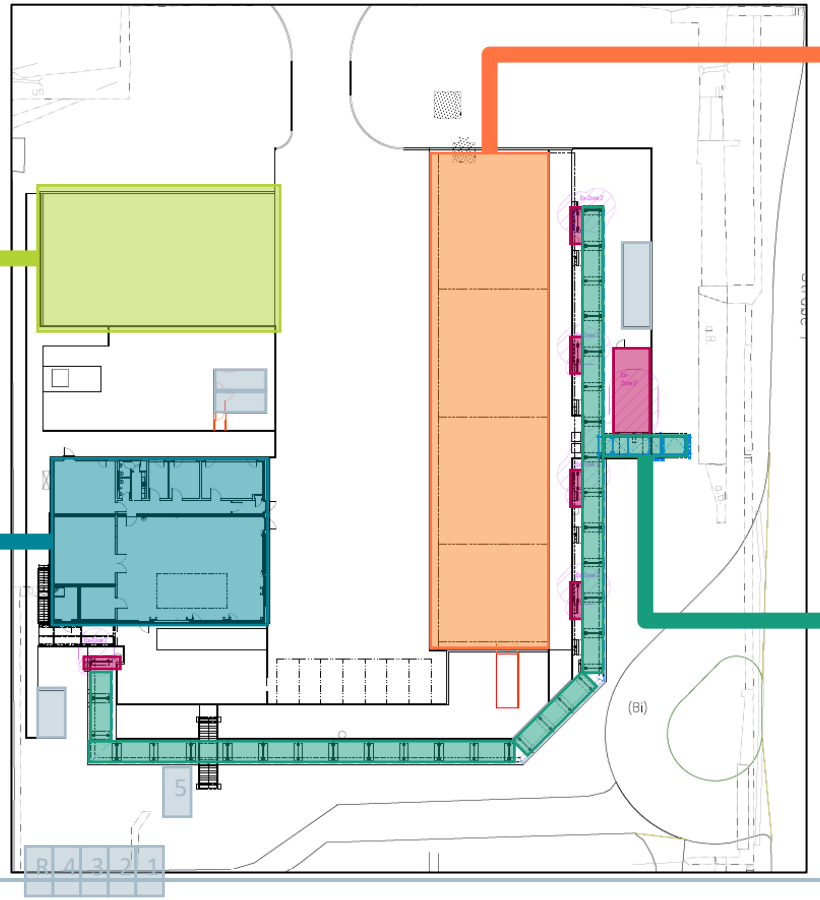
Diese Masnahme wird gefordert aufgrund eines Beschlusses des Deutschen Bundestages und wird mitfinanziert aus Steuermitteln auf Grundlage des vom Sachsischen Landtag beschlossenen Haushaltes.

Hydrogen Lab Leuna (HLL)

Overview of the location

Power to Liquid Platform

Technical Center



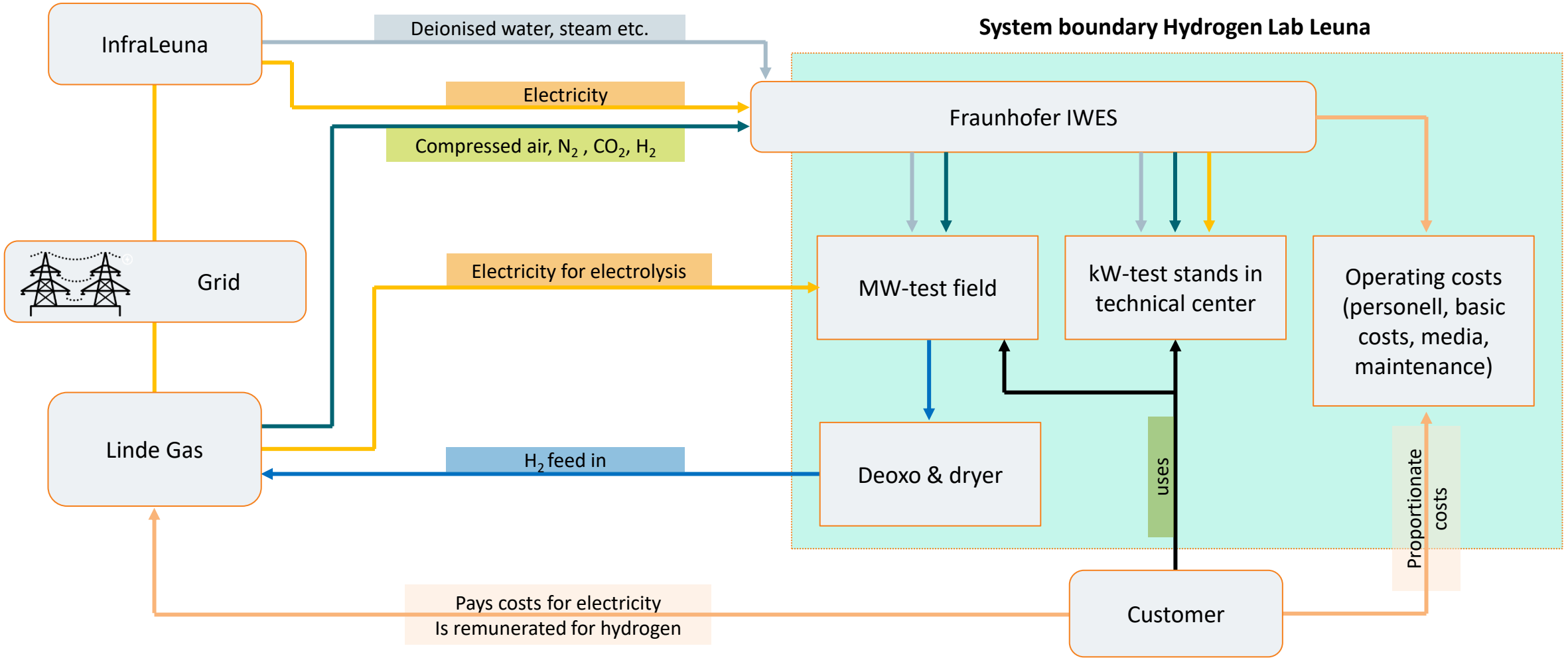
Open-air test field

On-site analytics department & pipeline connection

Fraunhofer IWES

Hydrogen Lab Leuna (HLL)

Overview of technical capabilities



Hydrogen Lab Electrolyser Testing

Test strategies

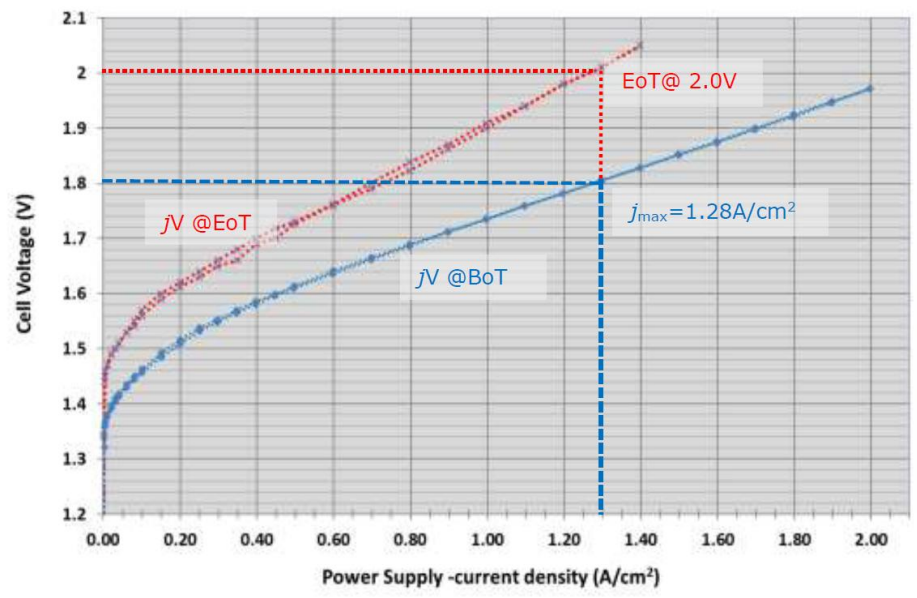
Steady state and dynamic test profiles for stack/system performance and degradation assessment

1. Steady state operation at different load points for performance and degradation assessment
2. Dynamic load profiles (real world degradation profiles → simple representation of various service applications) for degradation assessment
3. Accelerated testing: operating conditions influence efficiency and durability (temperature, pressure, high load, dynamic operation, cell compression, vibrations, cold start, sub-zero temperatures)
4. Accelerated testing: increased current ramp rates and increased frequency of load profile

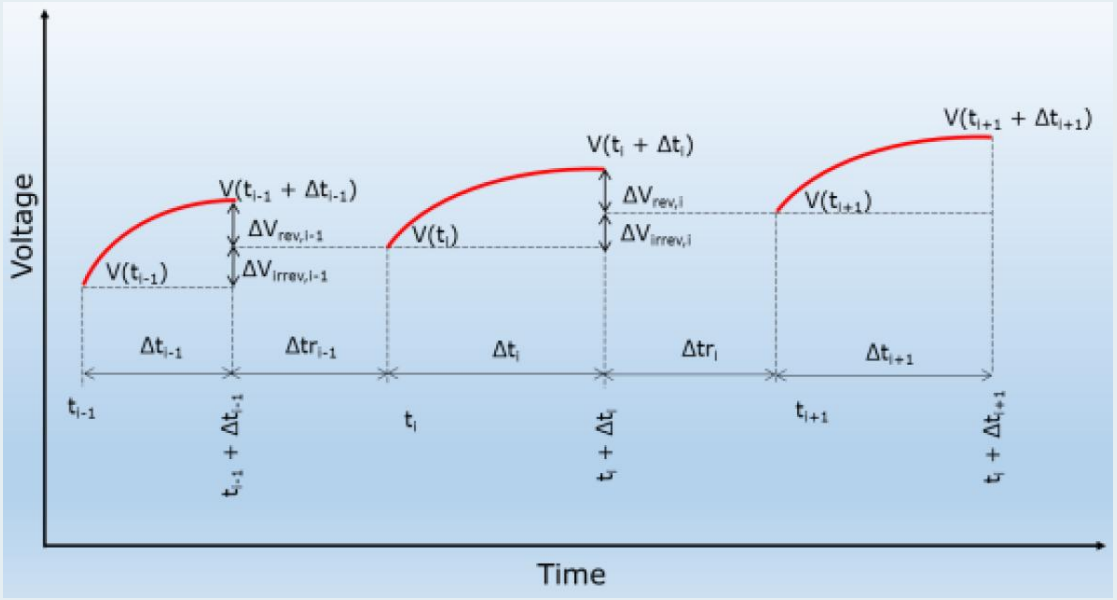
Hydrogen Lab Electrolyser Testing

Test strategies

Cell/stack voltage increase rate as durability indicator (steady state test >1000h or dynamic load/real world degradation profile for 160 h)



Reversible (after shut down, 60 min rest and restart) and irreversible voltage increase

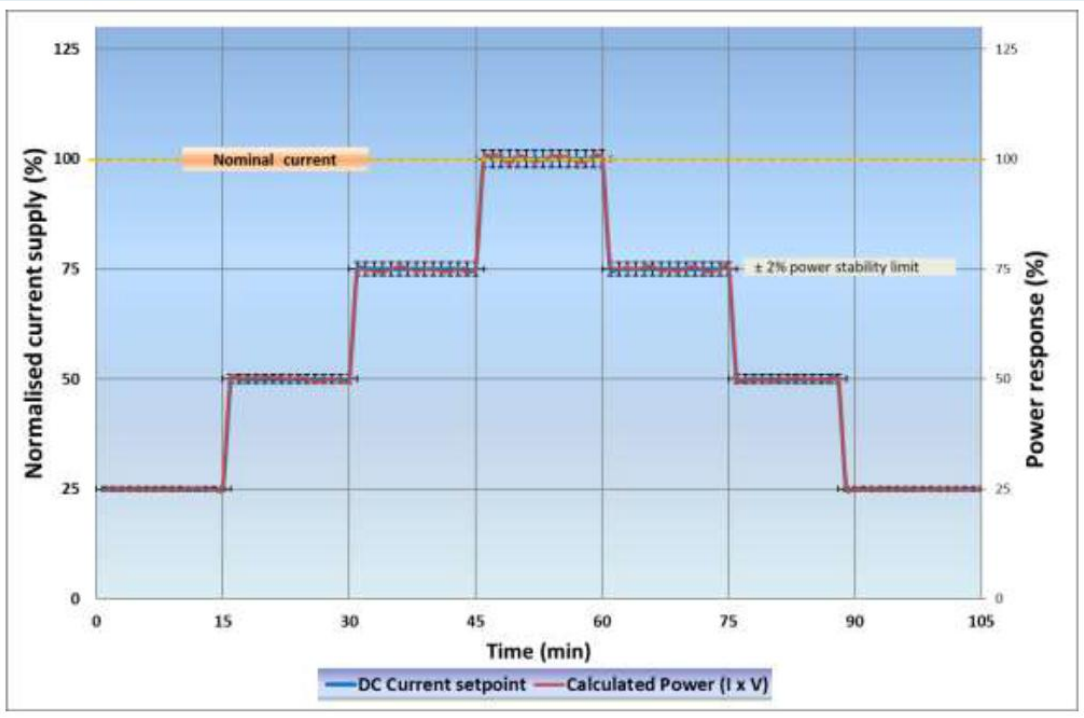


Source: Tsotridis, Georgios, and Alberto Pilenga. EU harmonised protocols for testing of low temperature water electrolysers. 2021.

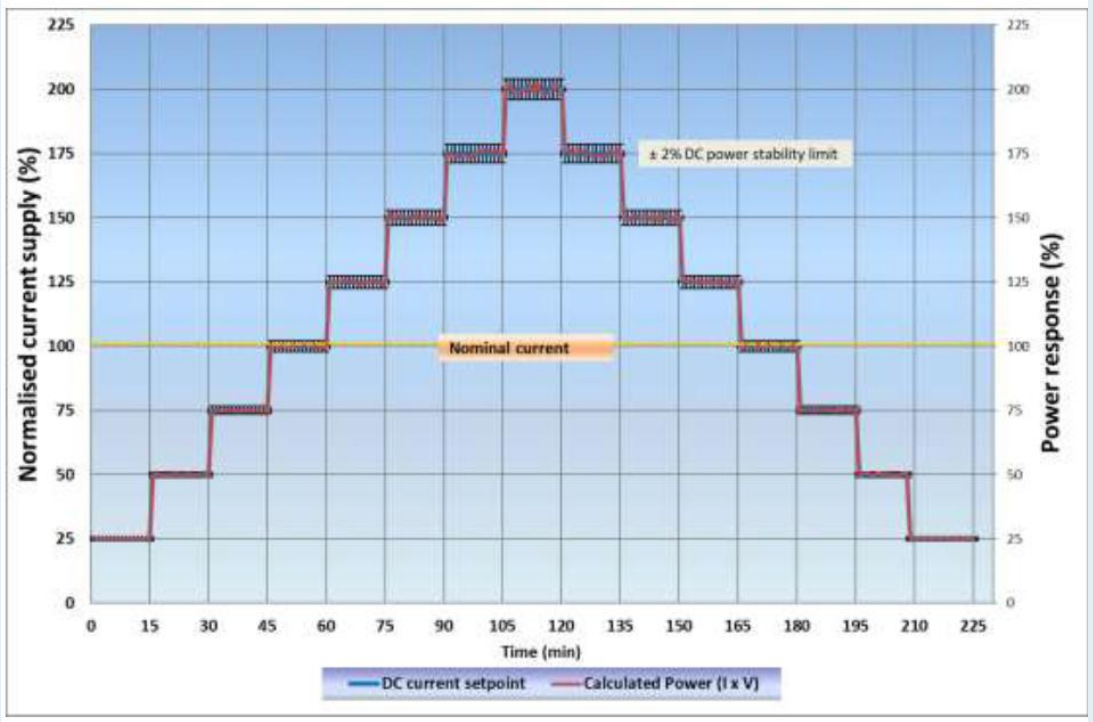
Hydrogen Lab Electrolyser Testing

Test strategies

Accelerated tests: high ramp rates



Accelerated tests: high ramp rates and higher power (200%)

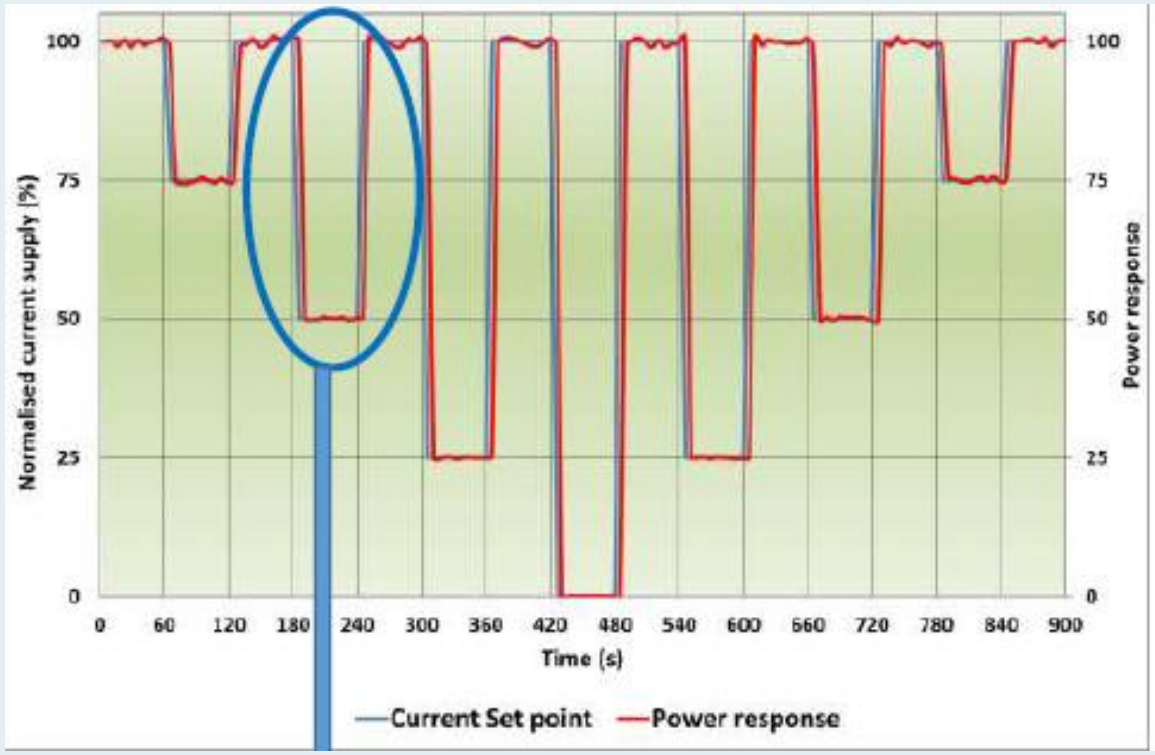


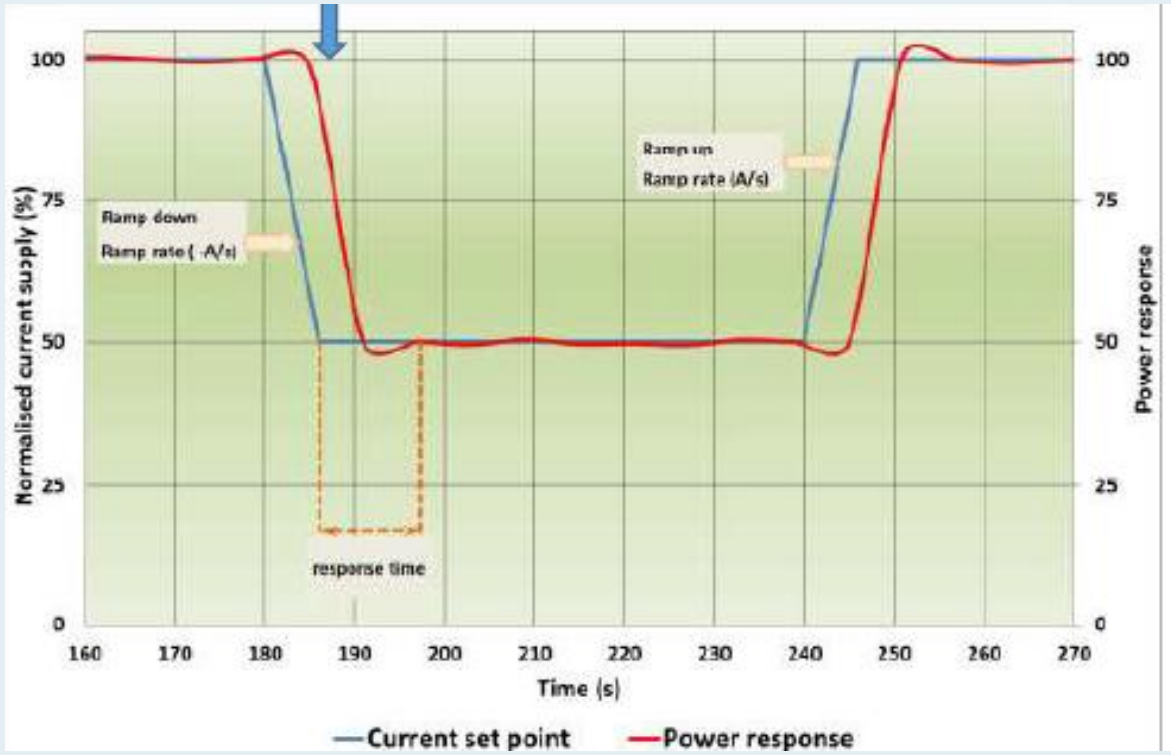
Source: Tsotridis, Georgios, and Alberto Pilenga. EU harmonised protocols for testing of low temperature water electrolysers. 2021.

Hydrogen Lab Electrolyser Testing

Test strategies

Accelerated tests: high ramp rate and high frequency (short steady state loads)





Source: Tsotridis, Georgios, and Alberto Pilenga. EU harmonised protocols for testing of low temperature water electrolysers. 2021.

Hydrogen Lab Electrolyser Testing

Test strategies

System performance criteria

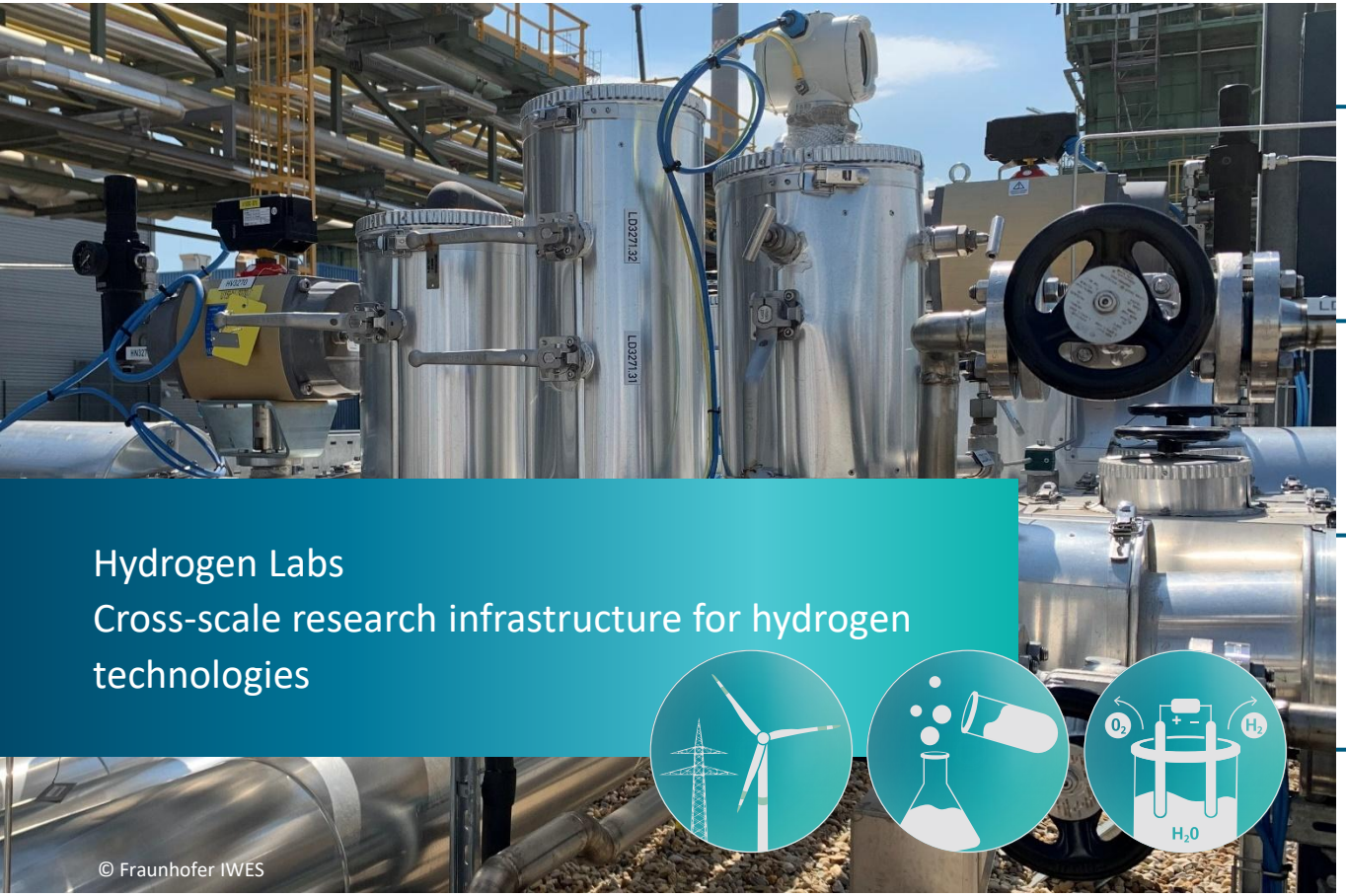
	CRITERIA	unit
1	System (stack) Voltage	V
2	System (stack) Current	A
3	Current density	$A.cm^{-2}$
4	Hydrogen production rate	$kg.h^{-1}$
5	System outlet hydrogen pressure	MPa or Bar
6	Hydrogen Quality	%
7	System Efficiency as $\eta^{(HHV\ or\ LHV)}$	%

	CRITERIA	unit
8	System Efficiency as ε_{system}	%
9	System Efficiency with AC/DC conversion as ε_{system}	%
10	Specific energy consumption	$kWh.kg^{-1}$
11	Response time	s
12	Minimum partial load operation	%
13	Start-up time (cold) to nominal power load	s
14	Minimum part load to full load rate	$\%.s^{-1}$
15	Full load to minimum part load rate	$\%.s^{-1}$

Source: Tsotridis, Georgios, and Alberto Pilenga. EU harmonised protocols for testing of low temperature water electrolysers. 2021.

From materials to industrial plants

Hydrogen research at IWES



Single-cell electrolyser tests on laboratory scale (up to 3.5 kW)

Electrolyser stack tests on pilot plant scale (up to 46 kW)

Electrolyser stack tests on pilot scale (up to 2 MW)

Complete plant tests (up to 5 MW)

Fraunhofer IWU Fraunhofer IWES

Fraunhofer IWES

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