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Fraunhofer Institute for Manufacturing Engineering and Automation IPA

Universität Stuttgart
Institut für Energieeffizienz in der Produktion EEP

20. Juni 2023 | Laura Jung

Hydrogen Integration in the Industry

Fraunhofer-Institute Stuttgart

Strong Partner for Various Industries

At a Glance:

- Second largest Fraunhofer research center in Germany
- 65,000 m² of space for applied research
- 5 institutes with over 1,800 employees
- Various research focuses:
  - Technology management
  - Biotechnology and environmental technology
  - Organizational and automation tasks
  - Urban planning and regional development
  - Innovation and IP management
- Close collaboration with S-TEC Stuttgart Technology and Innovation Campus.

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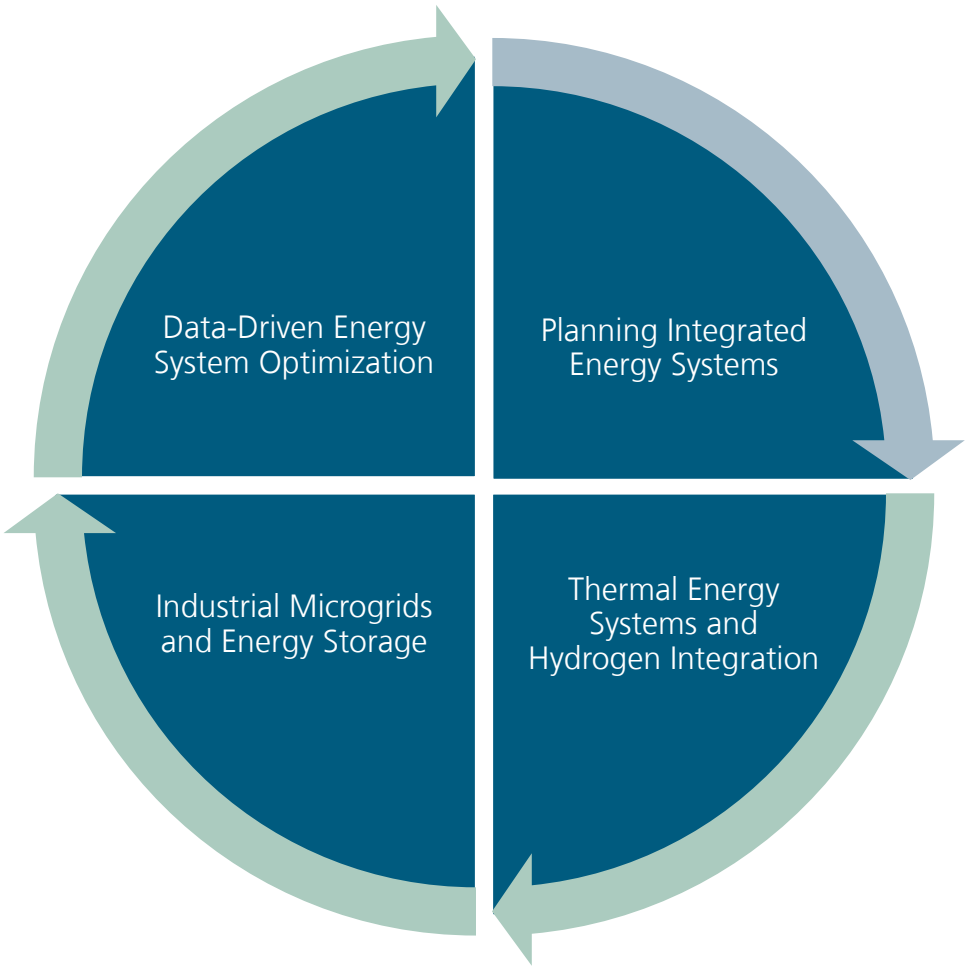
Industry Energy Systems at Fraunhofer IPA

Production in a CO2-Free Energy System



The Department Industry Energy Systems aims to ensure that industrial production in Germany can be carried out in a CO_2-free, cost-effective, and secure manner within the energy system of the future.

4 research groups collaborate on the following topics:

- Planning Integrated Energy Systems
- Thermal Energy Systems and Hydrogen Integration
- Industrial Microgrids and Energy Storage
- Data-Driven Energy System Optimization

2 cross-cutting themes are being pursued across the groups

- Energy Flexibility
- Energy Management

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Agenda

1. Green hydrogen as an alternative energy carrier
2. Hydrogen role in industrial applications
3. Examples of industrial energy system transformation
4. Wrap-Up

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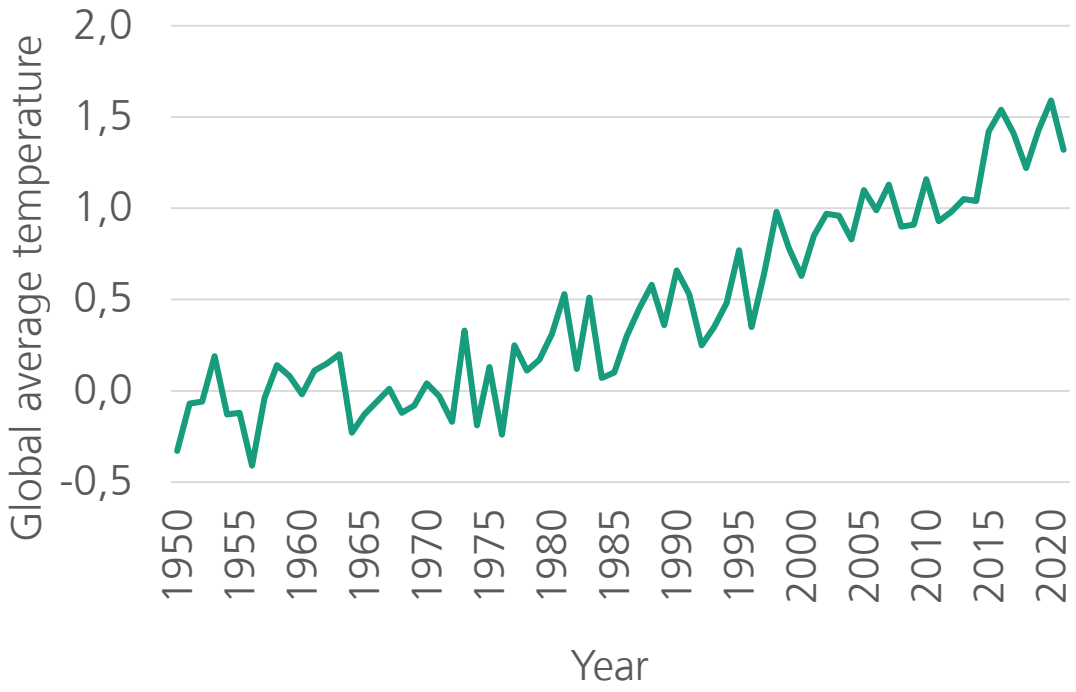
Striving Towards Climate Neutrality: Motivation for Change

Massive Greenhouse Gas Emission Reductions

- Global warming continues to increase
- Increase of climate disasters
- Considerable economic losses
- Goal: meet 1.5 °C limit
- **Until 2030:**
  Reduction of greenhouse gas emissions to at least 55% compared to 1990 levels
- **Until 2050:**
  Climate neutrality in the European Union

Anomalies in Global Average Temperatures from 1950 to 2021 [°C]

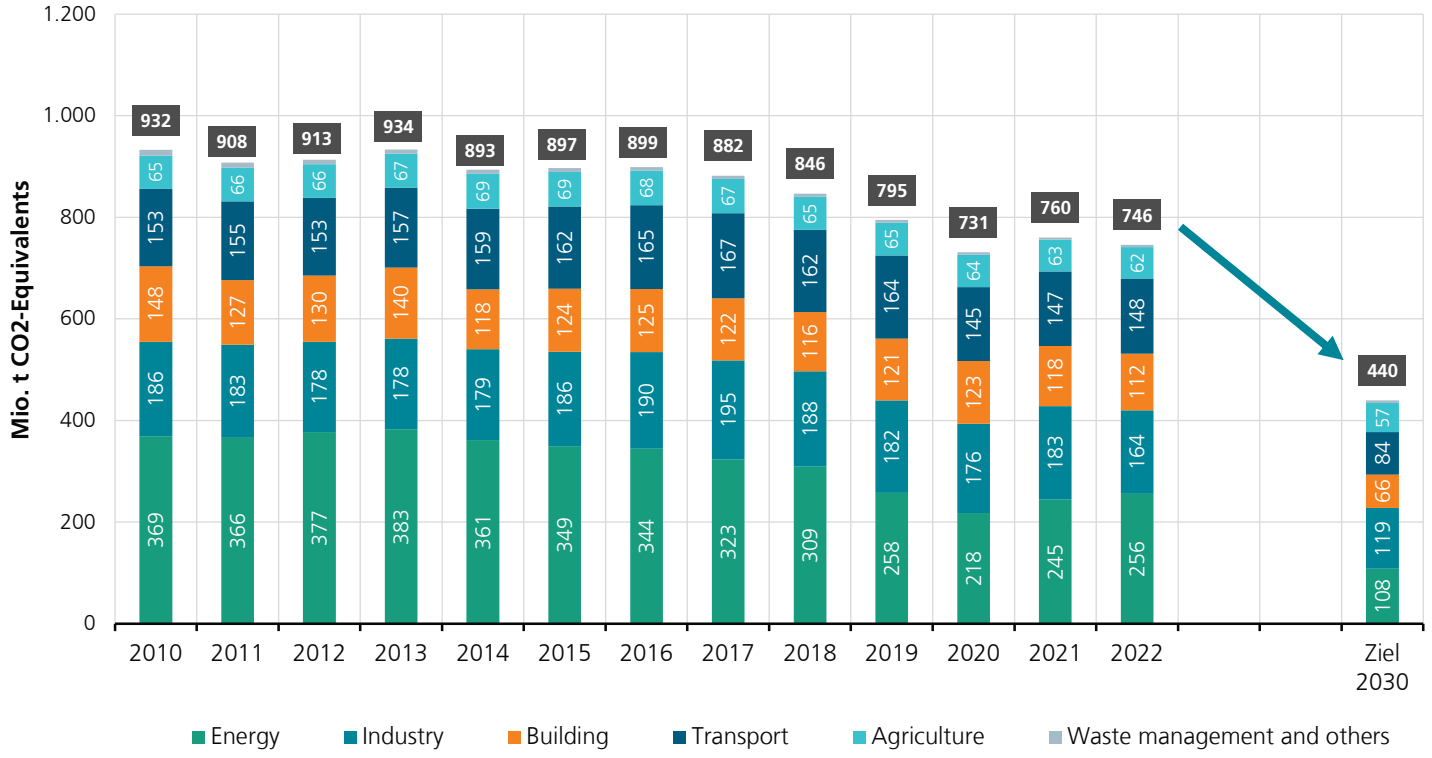


Source: NCDC, Anomalien der globalen durchschnittlichen Kontinental-Temperaturen bis 2021 https://de.statista.com/statistik/daten/studie/579481/umfrage/anomalien-der-globalen-durchschnittlichen-kontinental-temperaturen/

Hydrogen: A Key Element for the Energy Transition

Massive Reduction of Greenhouse Gas Emissions Across All Sectors

Development of greenhouse emissions in Germany



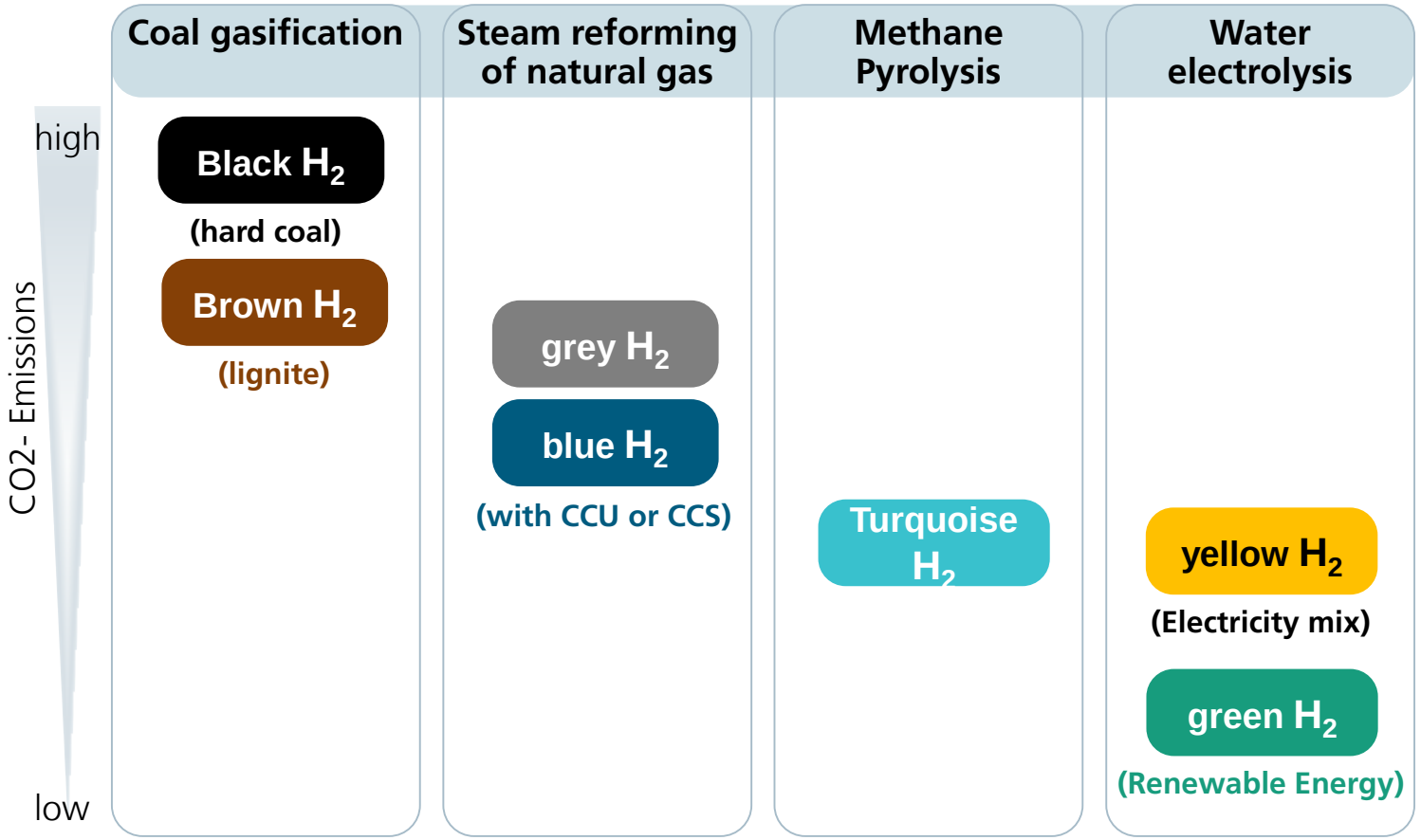
Use of hydrogen in industry

- Decarbonization of non-electrifiable industrial processes
- Multiple applications
- Increase of energy flexibility
- Good transportability and storability
- Reduction of dependence on fossil fuels

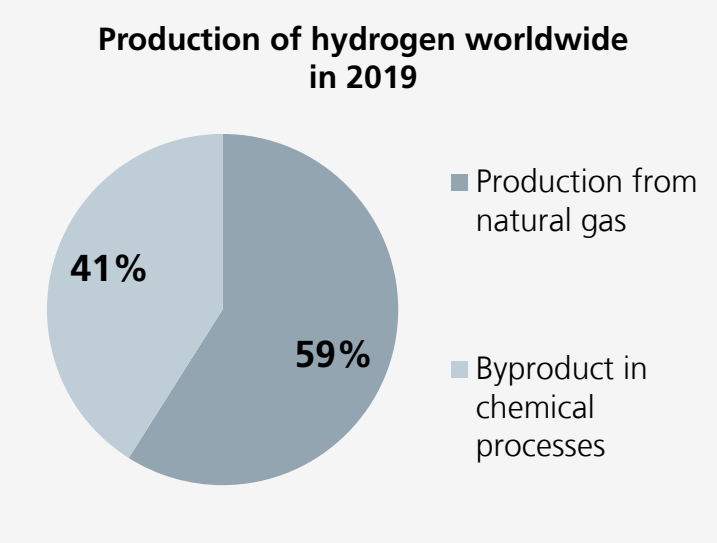
Source: Umweltbundesamt, Emissionsübersichten nach Sektoren des Bundesklimaschutzgesetzes: 1990 - 2022. https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen

Green Hydrogen: An alternative energy carrier

Production Methods and Color Palette



The current production of hydrogen relies on fossil fuels



Target
Turning grey into green

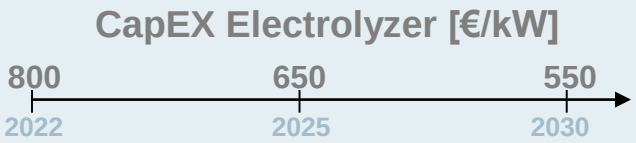
Source: IKEM https://www.ikem.de/wp-content/uploads/2021/03/IKEM_Kurzstudie_Wasserstoff_Farbenlehre.pdf. Statista: https://de.statista.com/statistik/daten/studie/1195241/umfrage/produktion-und-verwendung-von-wasserstoff-weltweit/

Green Hydrogen Cost Production

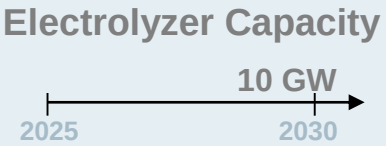
Cost Development of Green Hydrogen for Sustainable Energy Solution

The price will be influenced by the following factors:

1) Expansion of renewable energies such as solar or wind
   → Electricity becomes cheaper
2) Scale effects of electrolyzers
   → Investment costs decrease [1)]

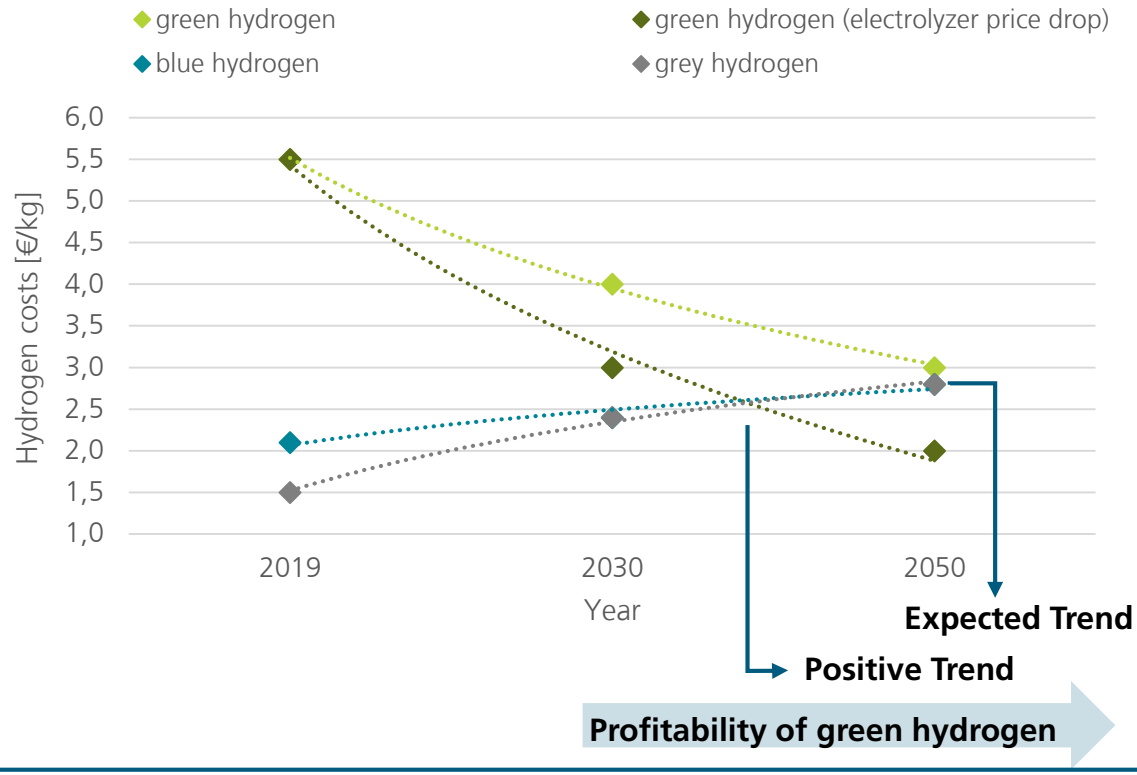


3) National Hydrogen Strategy
   → Expansion of Electrolyzer Capacity [2)]



4) Development of CO2 price
   → Fossil fuels become more expensive

Production cost by hydrogen type in Germany [3)]



Source: 1) Fraunhofer ISE, Eine Wasserstoff-Roadmap für Deutschland, 2019; 2) BMBF, Nationale Wasserstoffstrategie, 2020; 3) Statista, Wasserstoff: Produktionskosten nach Typ bis 2050, 2020

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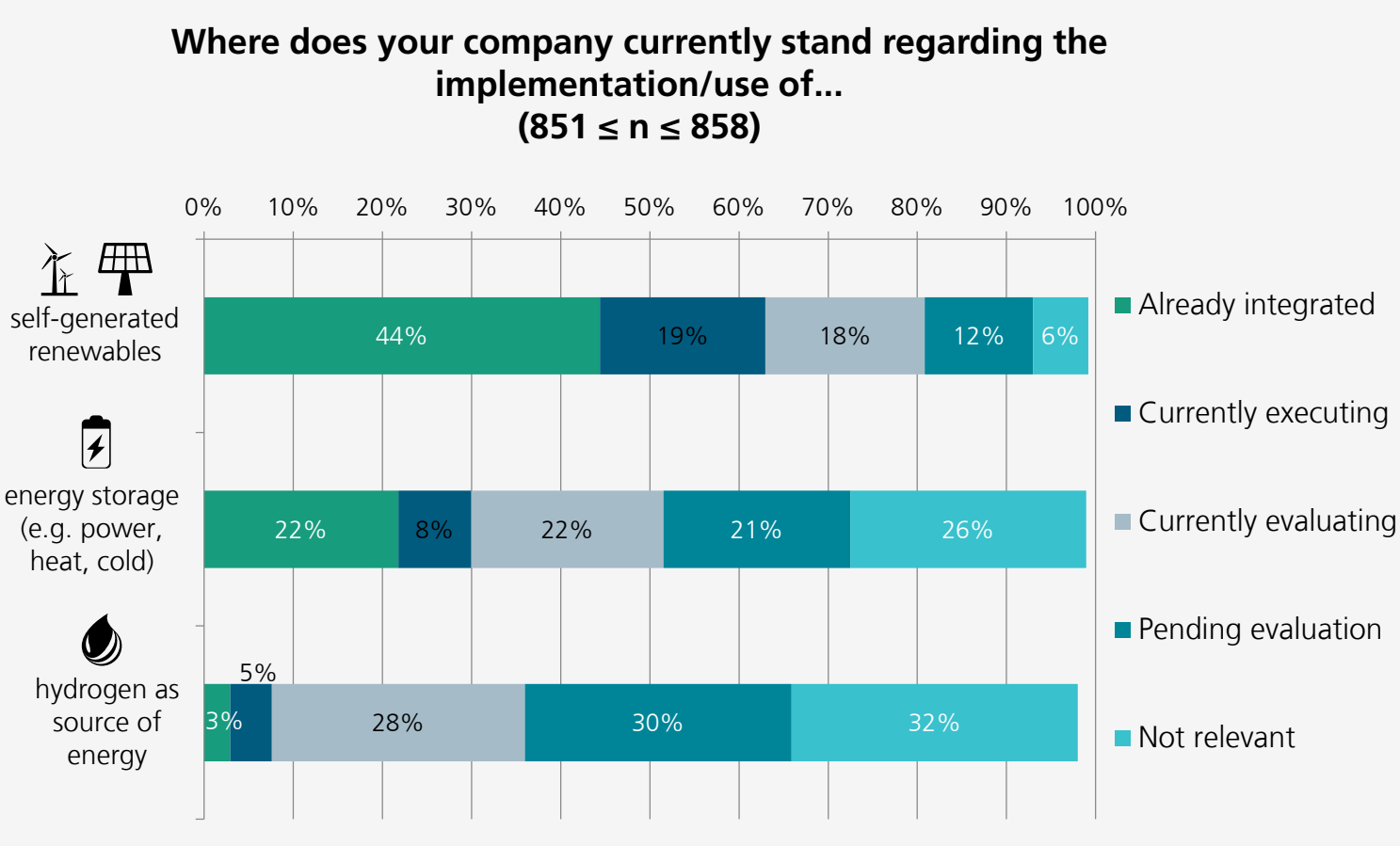
Hydrogen Integration in the Industrial Sector

Creating Framework Conditions



Source: Energieeffizienzindex der deutschen Industrie: 2021/1, EEP(2021)

Results of the surveyed companies

- More than 60% have already integrated renewable sources within the company
- More than 30% have access to energy storage solutions.
- Approximately 50% are currently investigating or planning to investigate the use of hydrogen as an energy carrier

Framework conditions for hydrogen production and storage are in place

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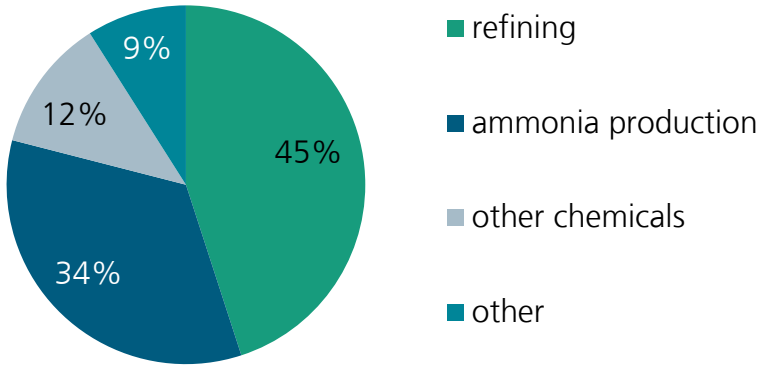
Industrial Transformation with Hydrogen

Green Hydrogen Integration for Carbon-Neutral Manufacturing

Today

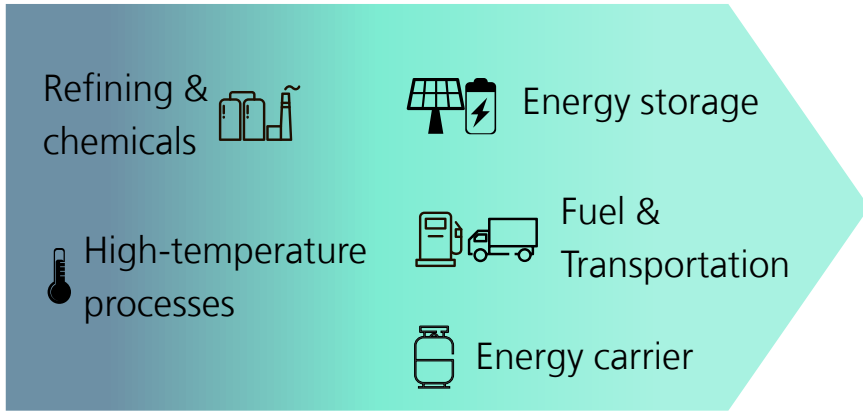
Global use of hydrogen in 2019 [1)]



- Mainly used for chemical industry processes
- Primarily grey hydrogen

Future

Transition from grey to green Hydrogen



- Higher percentage of green or blue hydrogen replacing grey hydrogen
- Use where electrification is not feasible due to high demand in all sectors

Source: 1) Statista, Wasserstoff: Produktion und Verwendung weltweit 2019, 2020. https://de.statista.com/statistik/daten/studie/1195241/umfrage/produktion-und-verwendung-von-wasserstoff-weltweit/

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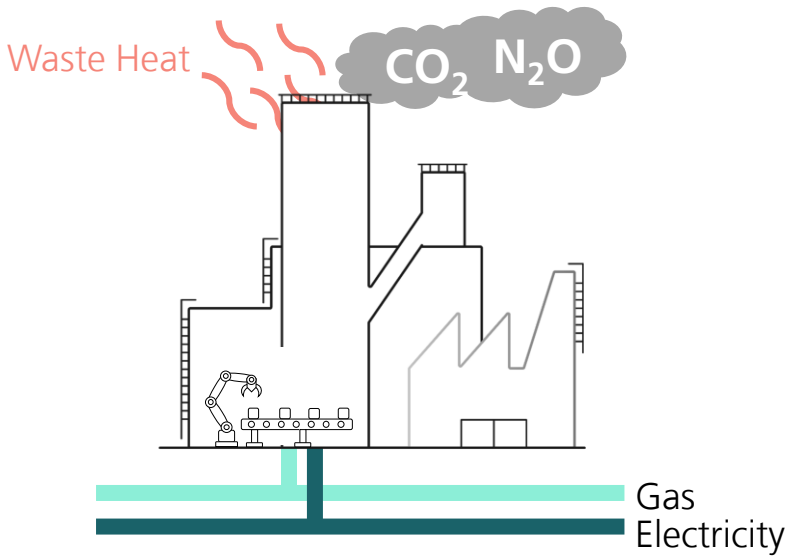
Transformation of the Industrial Energy System

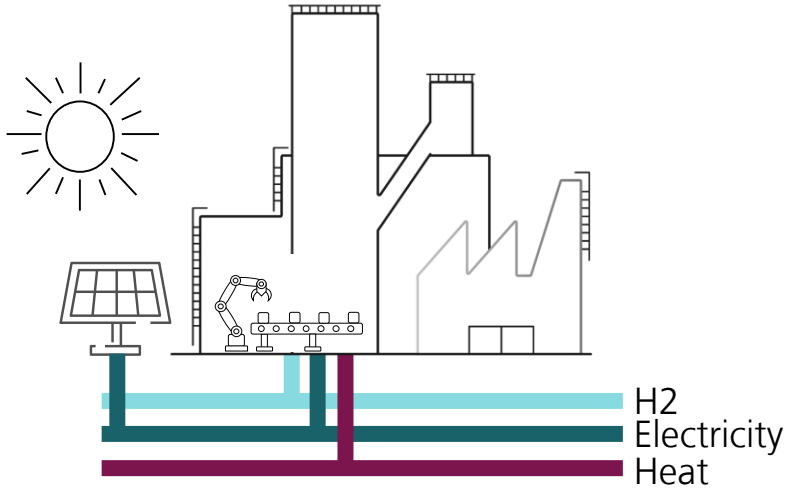
Hydrogen for a Carbon-Neutral Energy Supply

Today



- Combustion of fossil fuels such as oil or natural gas
- Release of waste heat into the environment
- Utilizing electricity from non-renewable sources

Future



- Replacement of fossil energy sources with hydrogen as energy carrier or electricity from renewable sources
- Sector coupling of heat and renewable power grids enabling a flexible energy system

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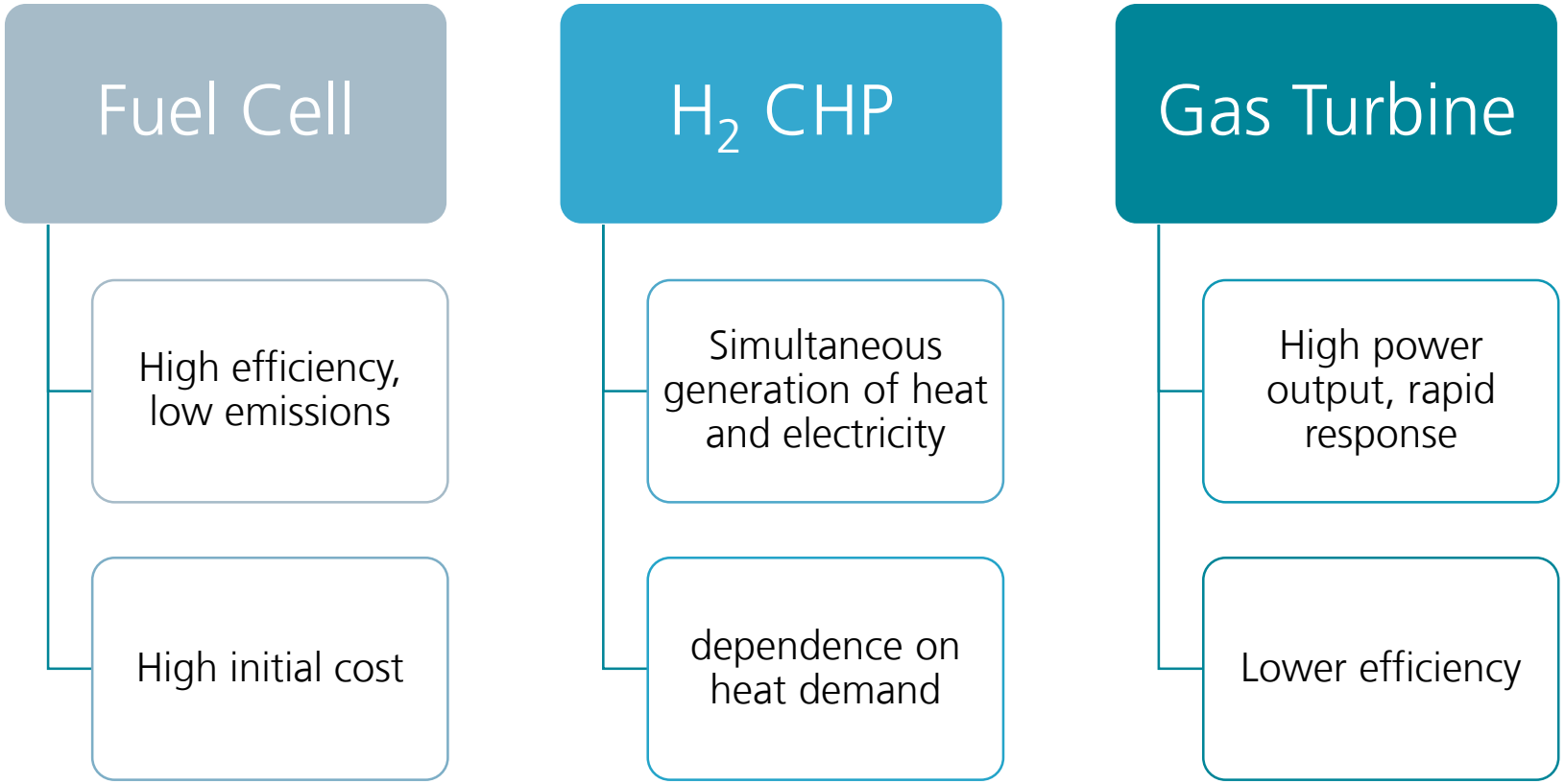
Use of Hydrogen in Energy System

Comparison of Hydrogen Utilization Technologies



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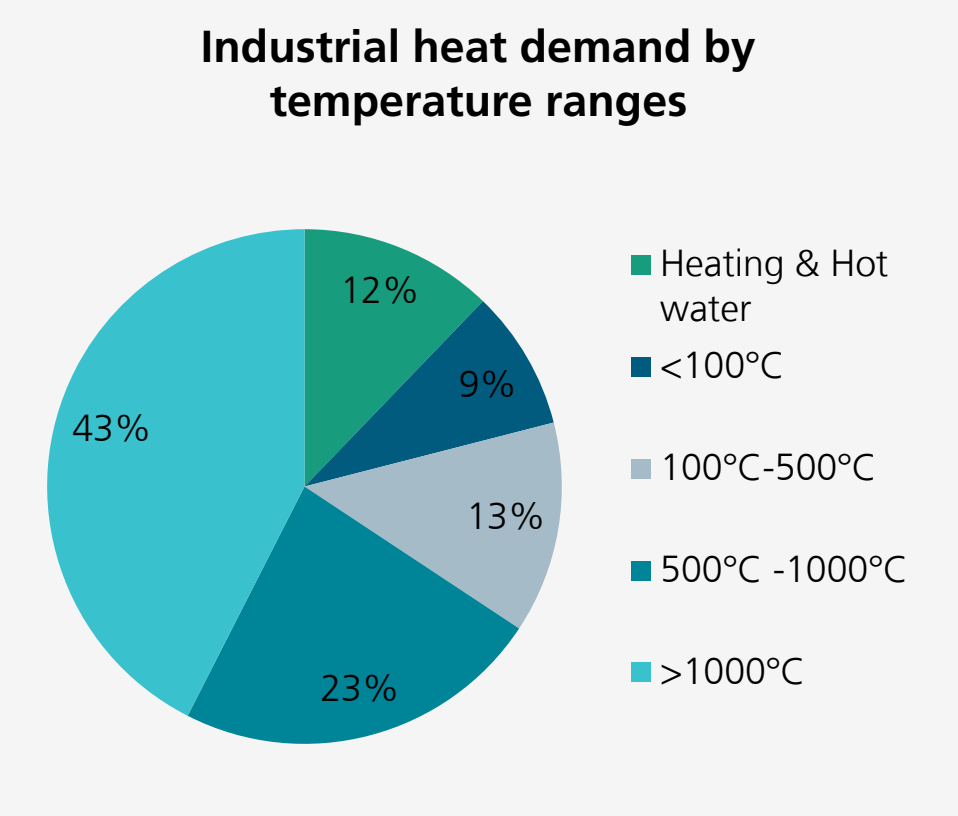
Use of Hydrogen for Heat Supply

Process Heat Transformation



heating, hot water and process heat <100°C

process heat 100°C - 500°C

process heat 500°C- 1000°C

Waste heat from fuel cell or CHP	Use of heat transfer medium	Burner using hydrogen combustion	Waste heat from fuel cell
PEM FC: 60°C -75°C	Thermal oil heaters using hydrogen combustion: 300-350°C	die casting of non-ferrous metals: magnesium 620-680°C	SOFC: 500°C-700°C
CHP: 40°C- 90°C			MCFC: 600°C – 700°C

Source: Universität Kassel, Das Potential solarer Prozesswärme in Deutschland. https://www.uni-kassel.de/maschinenbau/institute/thermische-energietechnik/fachgebiete/solar-und-anlagentechnik/downloads

Agenda

1 Green hydrogen as an alternative energy carrier

2 Hydrogen role in industrial applications

- 2.1 Industrial power generation and heat production
- 2.2 Raw material for industrial processes
- 2.3 Industrial transportation

3 Examples of industrial energy system transformation

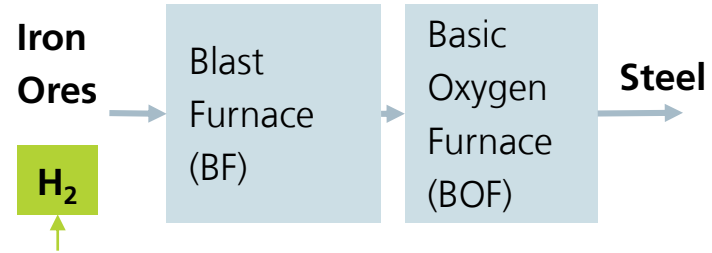
4 Wrap-Up

Use of Hydrogen as Raw Material

Transformation of Industrial Processes

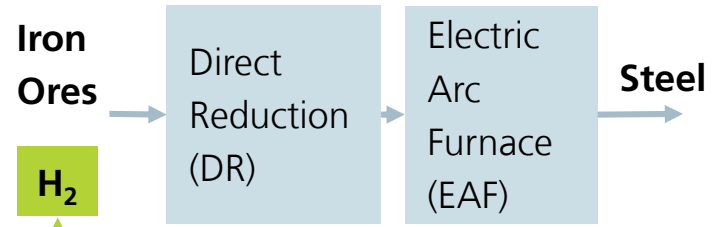
Steel production

Option 1: BF/BOF



(Instead of coal)

Option 2: DR/EAF



(Instead of natural gas)

Chemicals

Ammonia production

$$3H_2 + N_2 \rightarrow 2NH_3$$

Methanol production

$$2H_2 + CO \rightarrow CH_3OH$$

$$3H_2 + CO_2 \rightarrow CH_3OH + H_2O$$

Refinery

Desulfurizing of fuels

Hydrocracking to refine heavy oils

Productions of naphtha and LPG as by-products

H_2

(Instead of grey Hydrogen)

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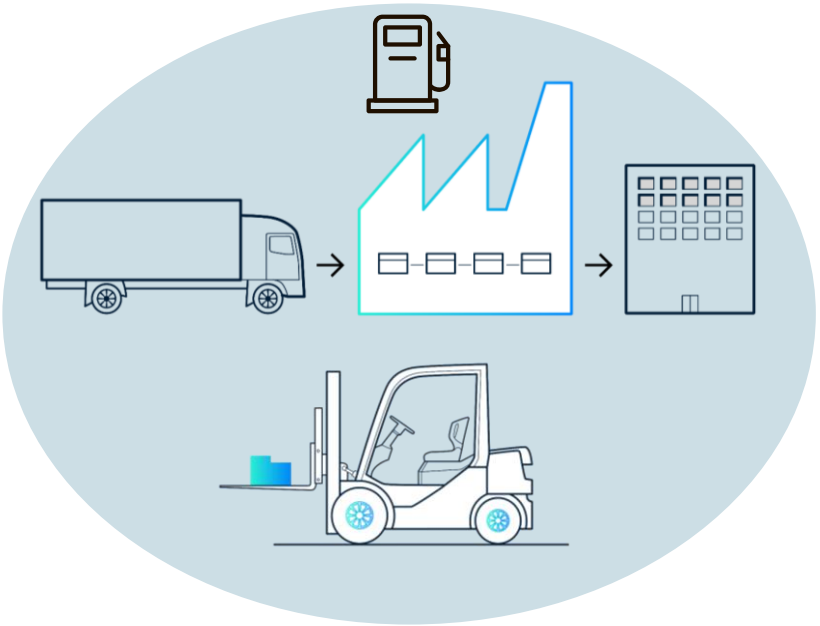
Use of Hydrogen for Industrial Transportation

Approaches to Industrial Logistics

For Freight Transport:

- heavy-duty trucks
- long-haul vehicles
- forklifts within logistics centers
- H_2 powered aircraft
- H_2 powered ship



Benefits compared to batteries:

- High energy density
- Quick refueling → faster than recharging
- Weight can be lighter than large battery packs
- Compatibility with existing infrastructure → fueling stations and gas grid

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Hydrogen as an Energy Carrier for Decarbonization

WAVE-H2 Project

Project target

- Decarbonization of the industry through energy-flexible and interconnected hydrogen systems
- Representation and analysis of various complex energy systems using digital twin
- Development of bivalent production plants and substitution of fossil energy sources

Project objectives and innovation

- Construction of an interconnected and energy-flexible ***H_2 industrial research platform*** for the study of hydrogen-based energy supply on an industrial scale
- Technical investigation of the operation of interconnected hydrogen systems, for production, storage, conversion and utilization

WAVE-H_2

„WAVE-H2“

Wandlungsfähige, energieflexible und vernetzte H_2-Industrieforschungsplattform

Adaptable, energy-flexible, and interconnected H_2 industrial research platform

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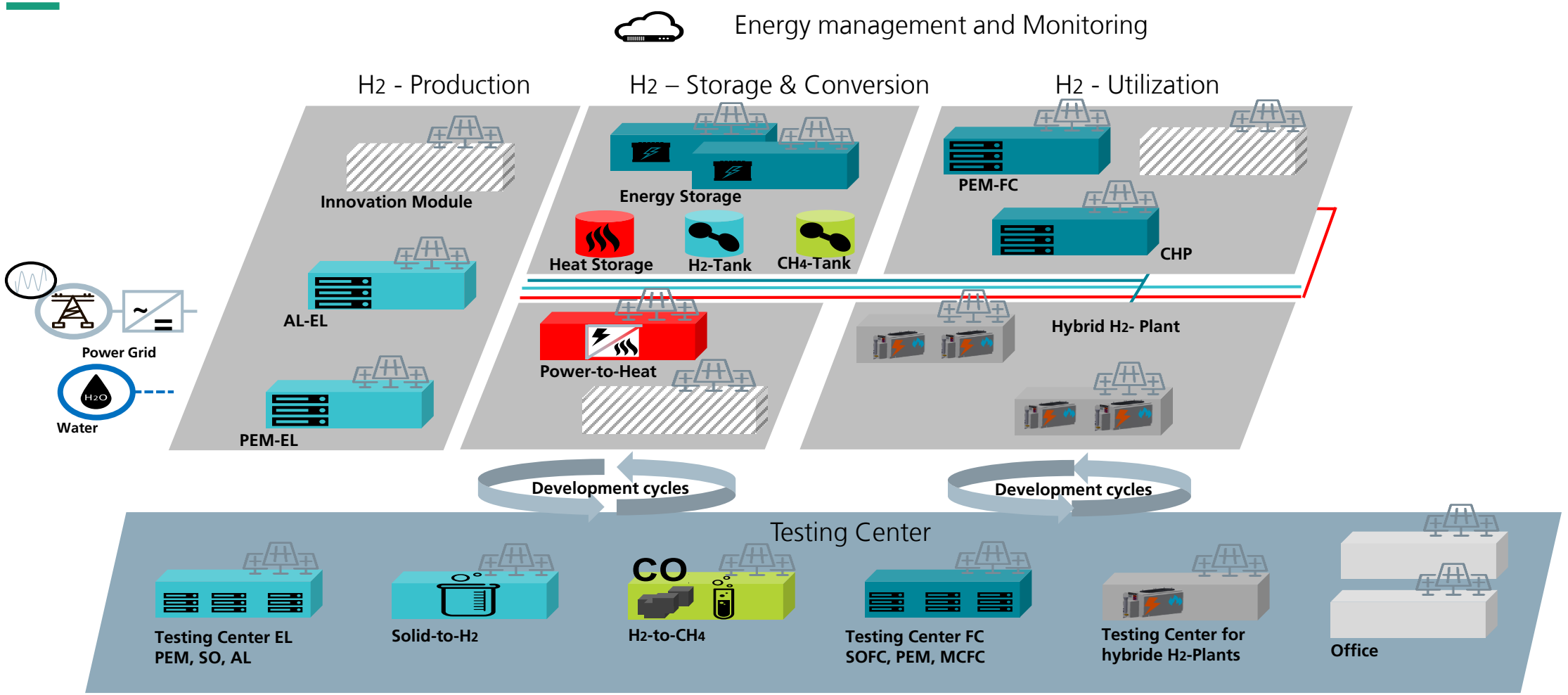
WaVe-H2

Knowledge Exchange between Innovation and Research Modules



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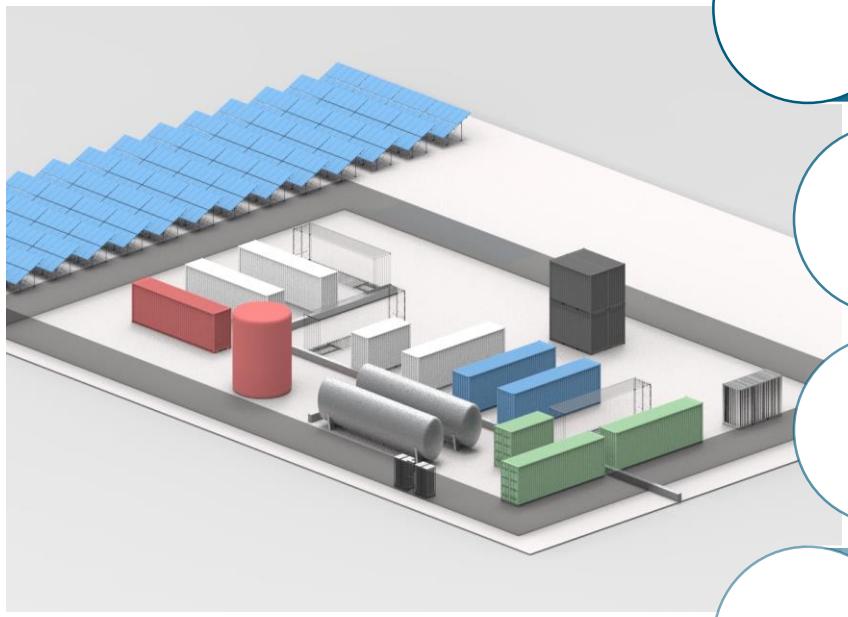
WAVE-H2

Project Process



Requirements definition and platform concept development

- Identification and grouping of main components
- Definition of usage scenarios

Development of measurement and control concepts

- Measurement concept for intelligent grid management/monitoring
- Flexible and autonomous energy management concept

Construction and operation of the H2 industrial research platform

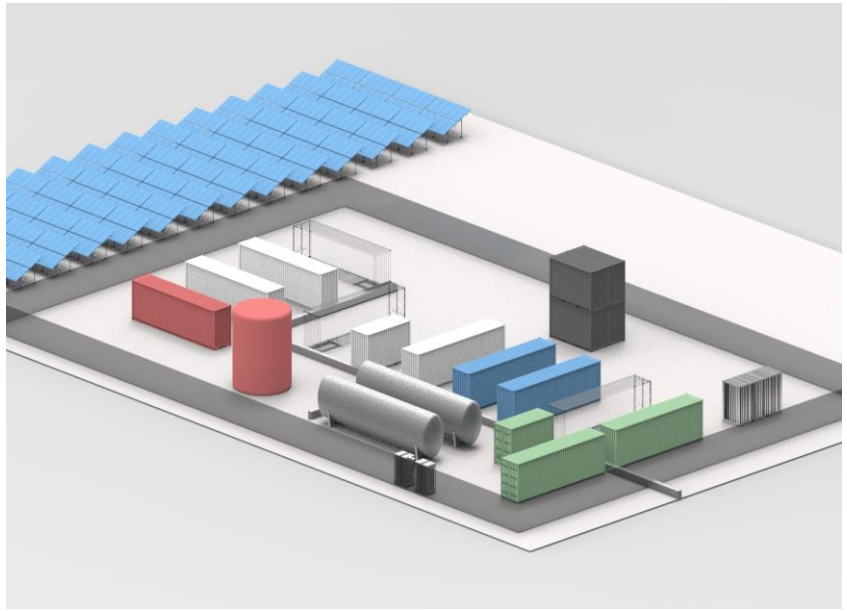
- Commissioning of the H2 industrial research platform
- Investigation of test and usage scenarios (creation of a digital plant model and an energy flow simulation)

Establishment of a digital information system

- Creation of the digital twin (implementation of data management infrastructure & energy data management)

WAVE-H2

Service Offerings: Unlocking Possibilities



Consulting and Supporting the Integration of Hydrogen Utilization and Decarbonization in Industrial Processes

Simulative and/or Physical Integration in a Laboratory Environment.

Problem Solutions & Applications for Customers in Relation to Hydrogen

Innovative Component Interaction Analysis within a Hydrogen Network

Concept Development for Hydrogen-Powered Technologies: Design of Industrial Power and/or Heat Microgrids

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Hydrogen For Hybrid High-Temperature Heat Generation

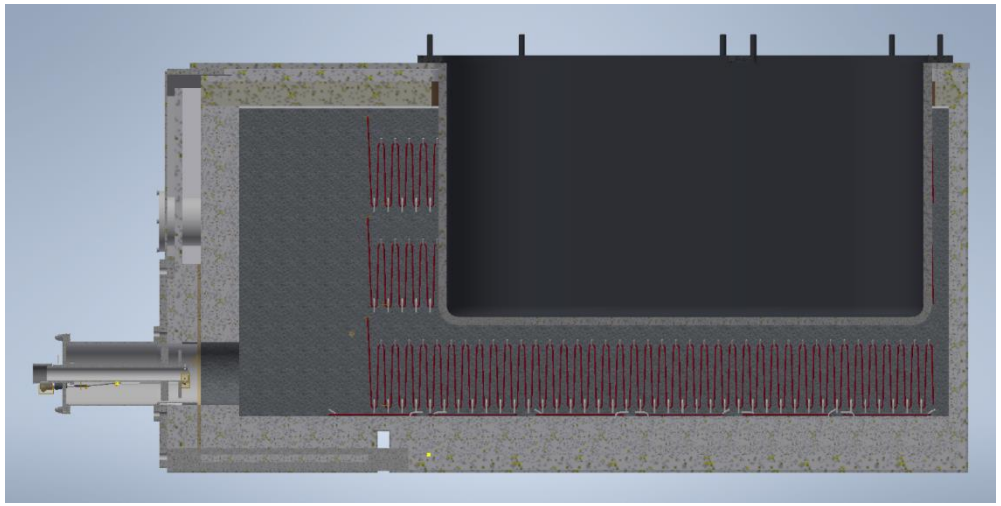
HybridH2: Simulation Study on Hydrogen Combustion

Project Target

- hybrid crucible furnace: Operation with electricity or with hydrogen
- Substitution of fuels such as oil or natural gas for the generation of process heat

Project objectives and innovation

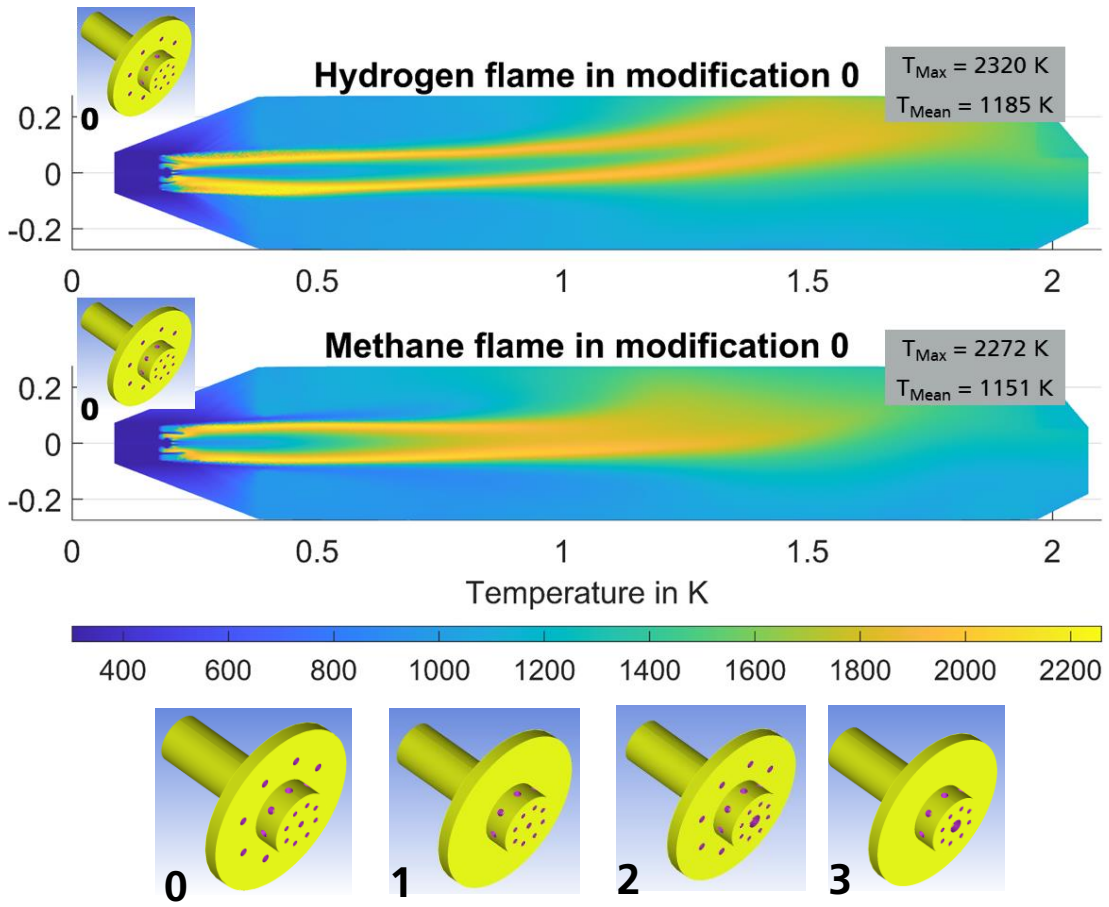
- Adaptation of a natural gas burner for an operation with hydrogen
- ***Numerical simulation for hydrogen combustion*** investigating an adaptation of the operation
- Deriving measures for the adaptation of burner geometry and crucible furnace



Hybrid melting furnace for the die casting industry

HybridH2: Simulation for Hydrogen Combustion

Challenges of Hydrogen Combustion



Faster and hotter reaction compared to natural gas

- ➢ **Formation of hotspots**
- ➢ **Higher temperatures**
- ➢ **Increased NOx emissions**

→ **Modification of the burner unit combustion chamber to reduce temperatures**

→ **Modification of the combustion parameters**

→ **Incorporation of an exhaust gas recirculation to reduce temperatures**

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Wrap-Up

Hydrogen can support decarbonization

- There are many technologies available for decarbonization or defossilization in industrial processes

- Hydrogen can and will play a significant role in industrial energy supply. Therefore, it is advisable to engage with the topic early on and consider acquiring technologies that are "H_2-ready"

Please feel free to contact us if you need any information or assistance regarding the planning and design of your system.

Thank you for your attention!

Kontakt

Laura Jung, M.Sc.
Planung integrierter Energiesysteme
Tel. +49 711 970-1215
laura.jung@ipa.fraunhofer.de

Fraunhofer IPA
Nobelstraße 12
70569 Stuttgart
www.ipa.fraunhofer.de

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Nachhaltig. Personalisiert. Smart.

Backup: New Agenda

