Entwicklung des Wasserstoffmarktes

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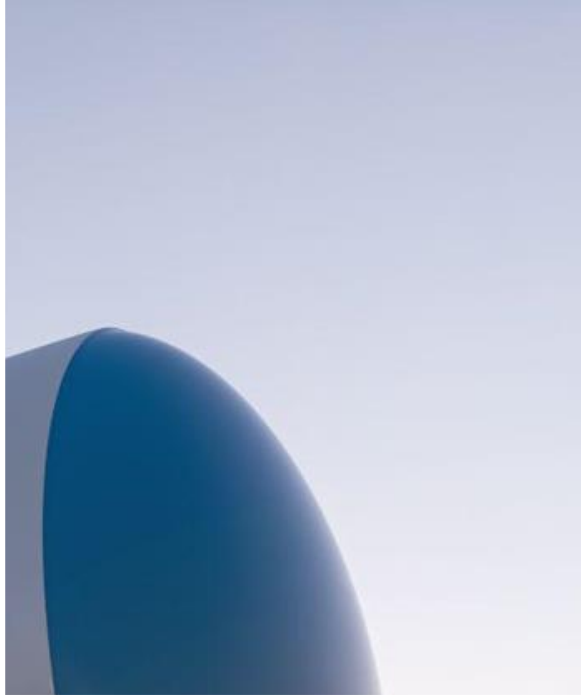
Agenda

1. Drivers of the Hydrogen economy
2. Market and demand development
3. Deep Dive: Sustainable Aviation Fuels

Drivers



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The green hydrogen market is evolving – four main drivers are influencing both demand and supply side

H2 market main drivers

Regulatory push

Regulatory support for green hydrogen is **growing throughout the world**

20 countries (44% of global GDP) either already have or are currently developing **a national hydrogen strategy**

Capital market push

Large investment companies are **shifting capital towards "green" assets**

Declining investments in **fossil based energy businesses** and increasing pressure on top level management

Decarb. pull

Global trend to **reduce CO_2 emissions** with impact on **all relevant industrial sectors**

Strong pull **across energy intensive industries** to **decarbonize using green hydrogen**, e.g. chemicals, steel, transportation, etc.

LCOE

LCOE for renewable electricity are a main driver for the price of green hydrogen

Due to the achievable full load hours, countries with a **large share of hydropower** and/or **geothermal generation** (e.g. Norway, Iceland) will be among the first to be able to **offer cost competitive green hydrogen**

The EU has established ambitious decarbonization targets as well as independence from Russian gas

EU Green Deal
Jan - 2020

- **EU** to become **climate neutral** b **2050, net zero emission of green house gasses**
- **Reduction** of **50% of GHG** (vs. 1990) **by 2030**
- Roadmap covering all sectors of the economy
- Targets signed by all EU countries
- Total **financing** stream **of at least €1 trillion**

EU H2 Strategy
Jul - 2020

- EU H2 role for aimed decarbonisation
- **2025: Market initiation**
  - 6 GW ELY
  - 1 Mtons renewable H2
  - Regulatory framework
- **2030: Market develop**
  - 40 GW ELY
  - 10 Mtons renew. H2
  - Regulatory framework
- **2050: Market matured**
  - Hard to decarb. sectors
  - Up to €470 billion
  - Expected REs demand for H2 reach 25% of EU electricity prod.

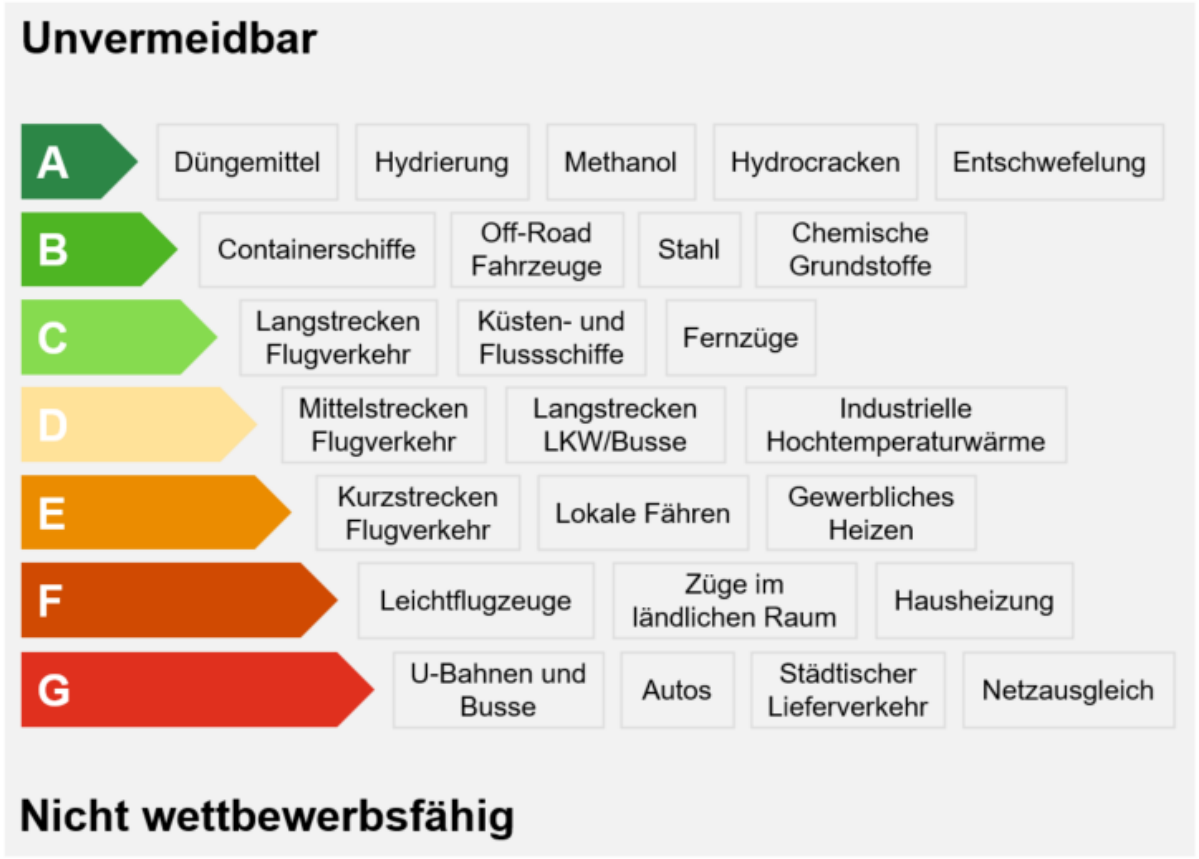
EU Gas Package
July/Dec - 2021

- **Definition of main axes of H2 network regulatory framework**
- Part of Fit455 (-55% of GHG vs. 1990 by 2030). Other initiatives:
  - RED revision
  - EU ETS
  - Energy Efficiency
  - Energy Taxation
  - Alternative Fuel Infra.
  - ReFuel EU Aviation
  - Fuel EU Maritime

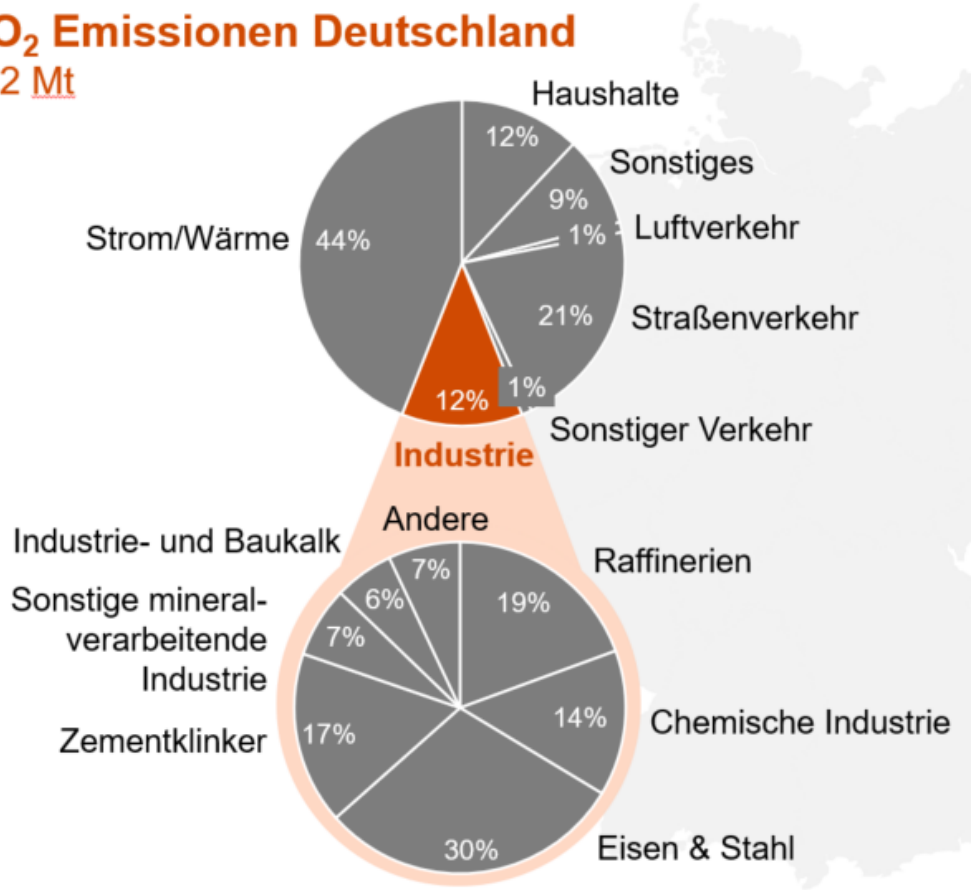
Re-Power EU
Mar-2022

- Joint EU action for reducing dependence on Russia fossil fuels
- Industry decarbonization through electrification and renewable H2
- **Accelerate biomethane & H2 production,** together with speeding of REs permitting
- Diversification of gas supply
- **Accelerate building electrification** through **heat pumps,** solar PV and energy efficiency

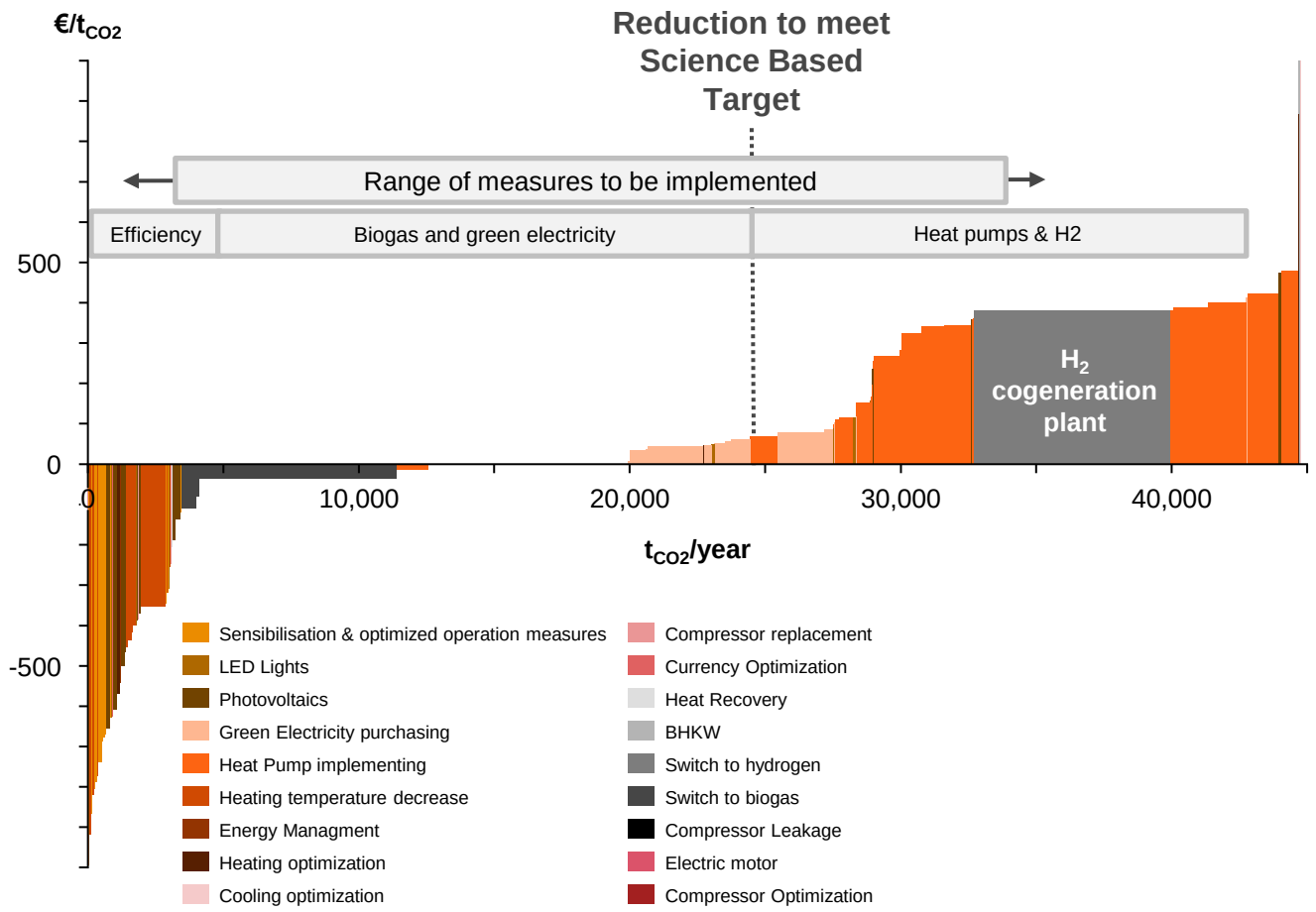
Hydrogen can lead to significant emission reductions in industrial sectors



Quelle: Umweltbundesamt & Liebreich Associates



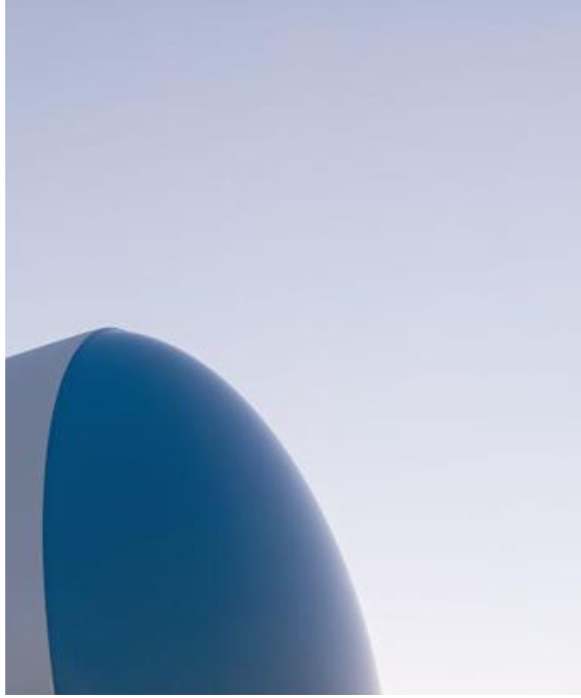
Hydrogen is one of many options, but has significant impact on achieving climate goals



Key takeaways

- Hydrogen will play a key role in reducing GHG emissions in several industrial sectors
- Combination of measures with negative abatement cost (e.g. renewable electricity own generation, compressor optimization, heating temperature decrease) with limited positive total cost (e.g. switch to heat pumps) secures **overall cost neutrality**
- **Europe** can serve **as a blueprint** to identify and roll out cost-efficient measures globally

Demand development



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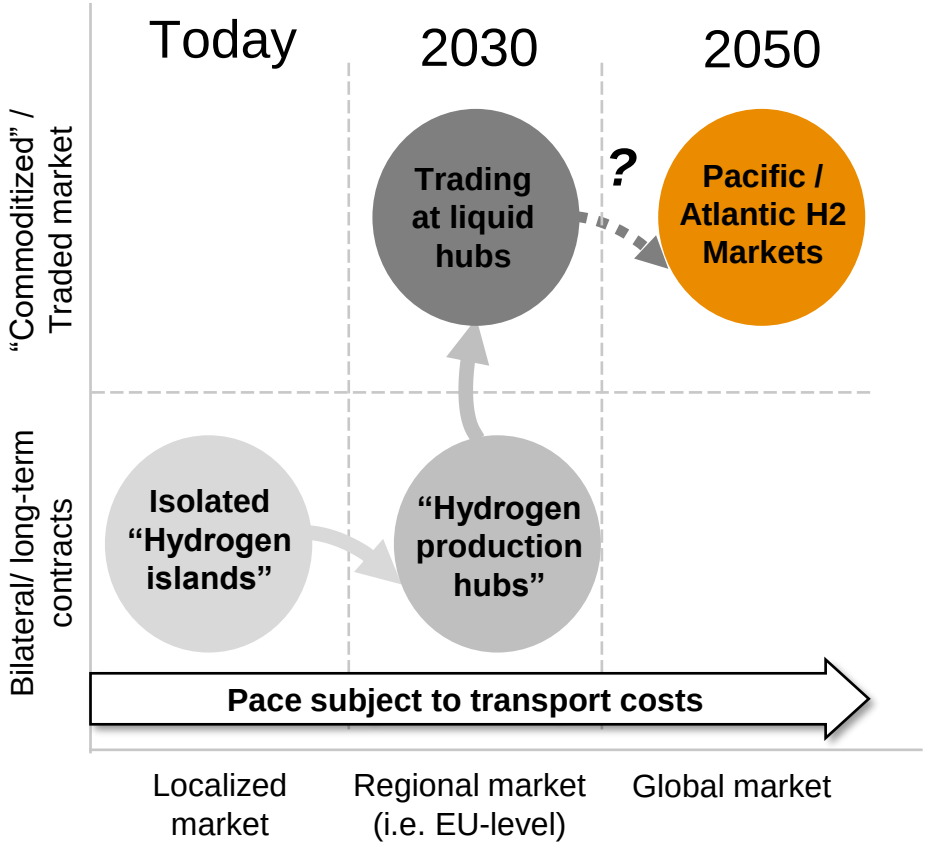
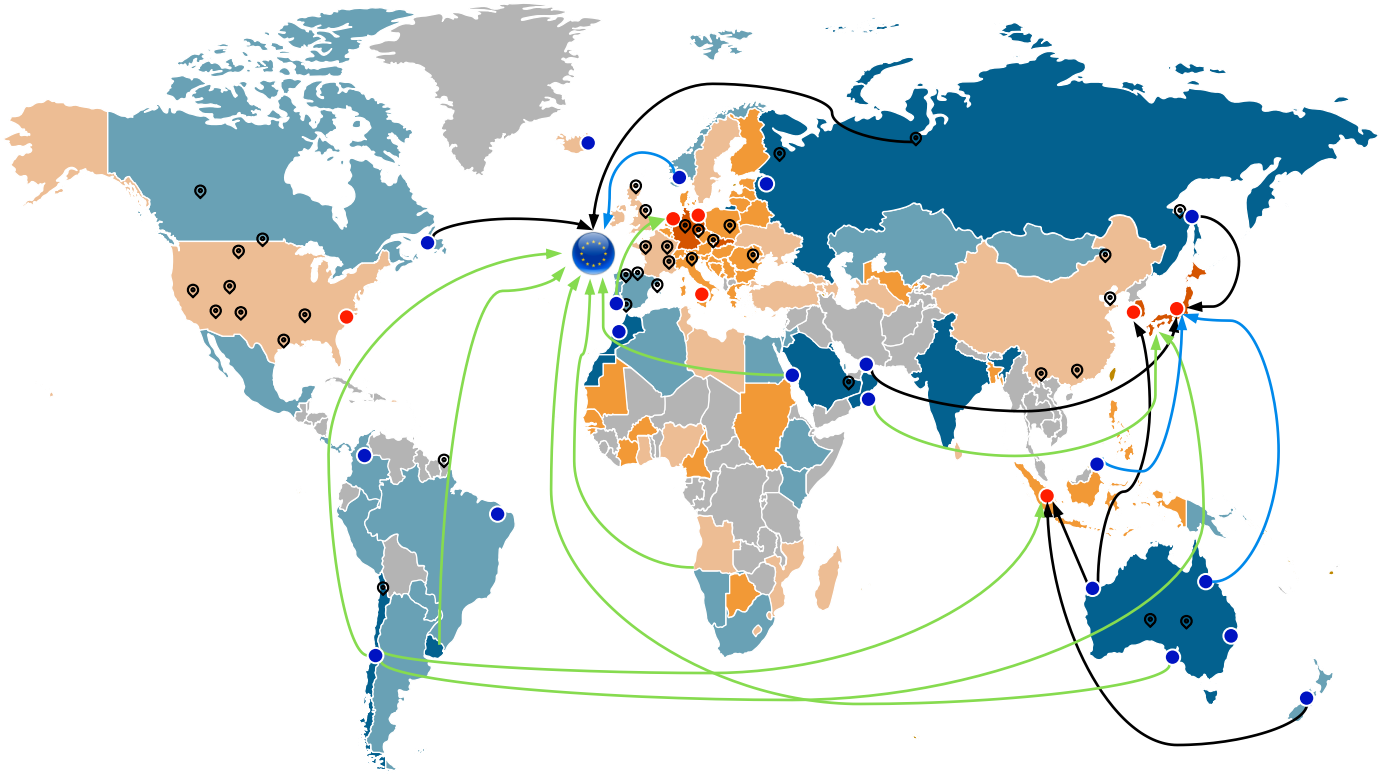
H2 market will gradually evolve from local demand pools to commoditized which will result on a global trading system

Potential development routes for H2 market
Illustrative / Not exhaustive



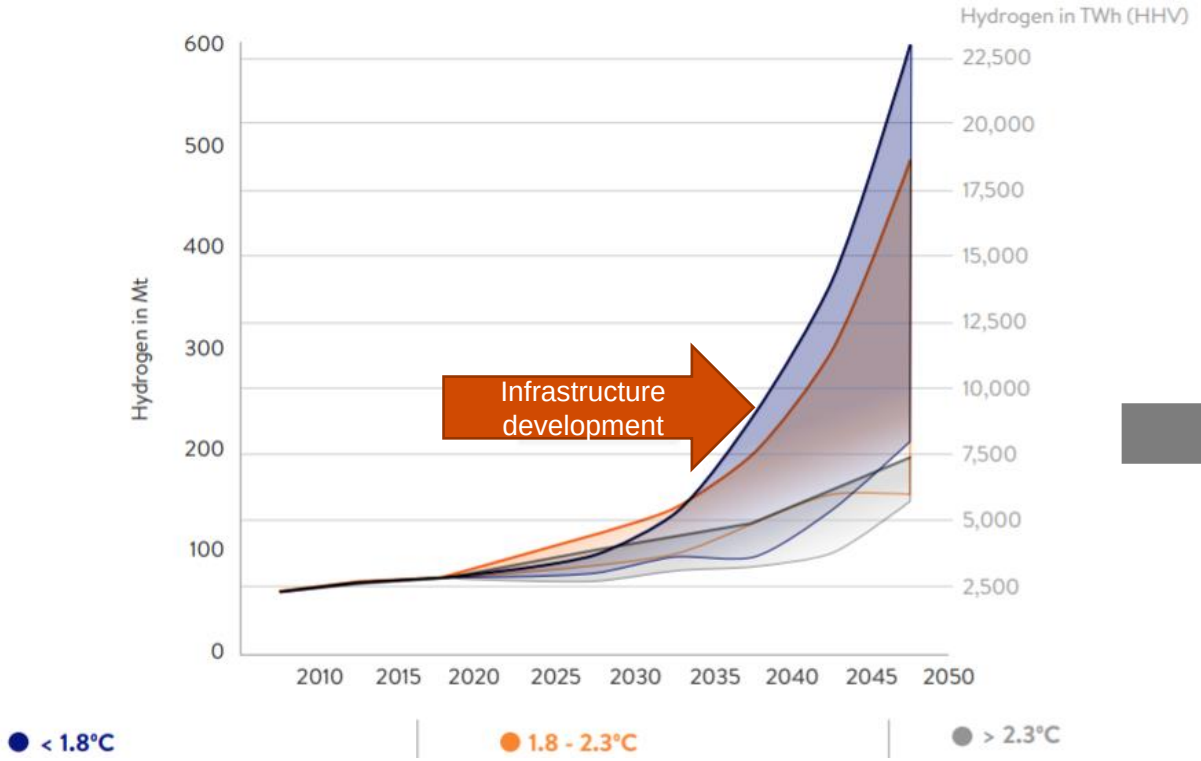
International H2 imports outlook 2040/50

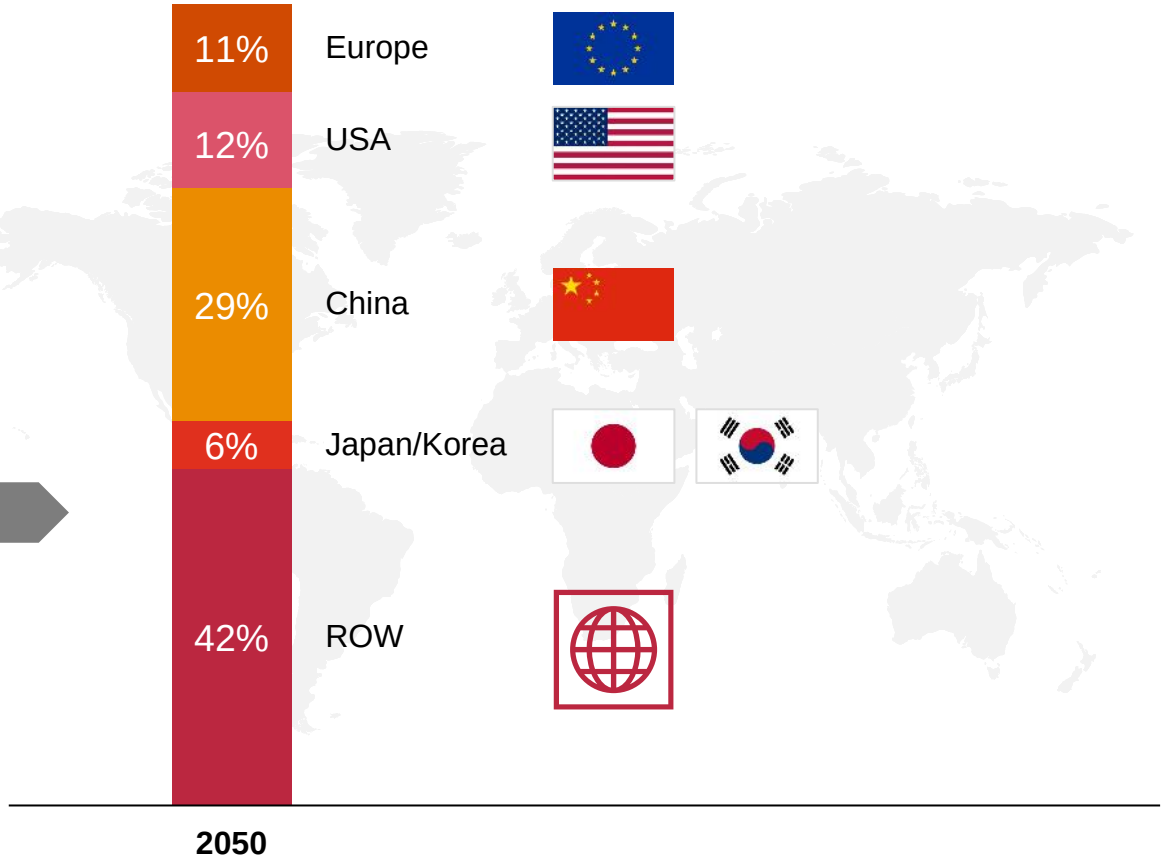


1) Additional gas savings estimations vs Fit for 55 expected impact; 2) Considers that from 660 TWh expected H2 production, 275 TWh is employed for replacing natural gas; 3) Excluding indirect impact through H2 generated; 4) Excluding demand concerning power and energy storage | Source: European Commission; Strategy&

Hydrogen demand will increase sharply from 2030 onwards - depending on the ambition of the climate target pursued

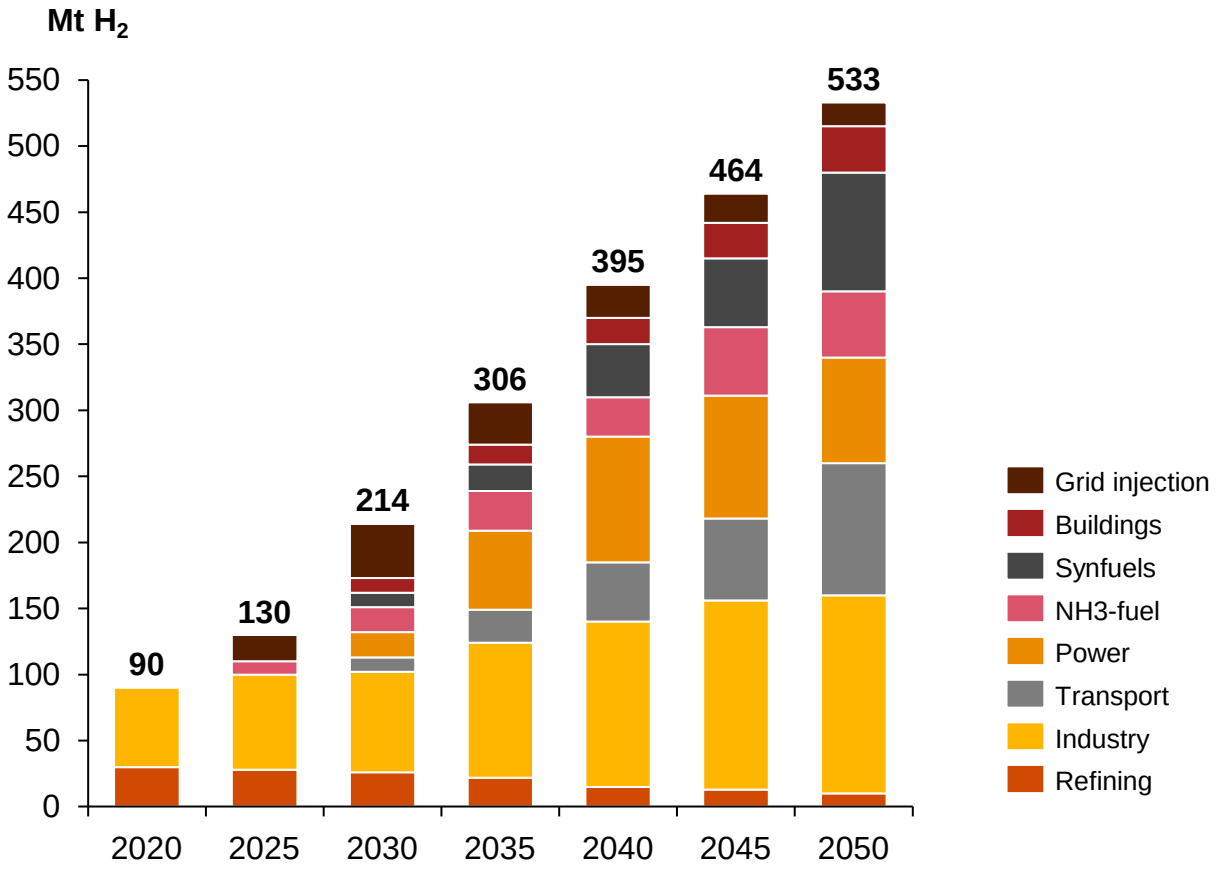
Global hydrogen demand





Hydrogen as energy carrier of the future is expected to play a key role across industries, transportation and buildings

Global hydrogen demand by sector in the IEA Global Hydrogen Review 2021

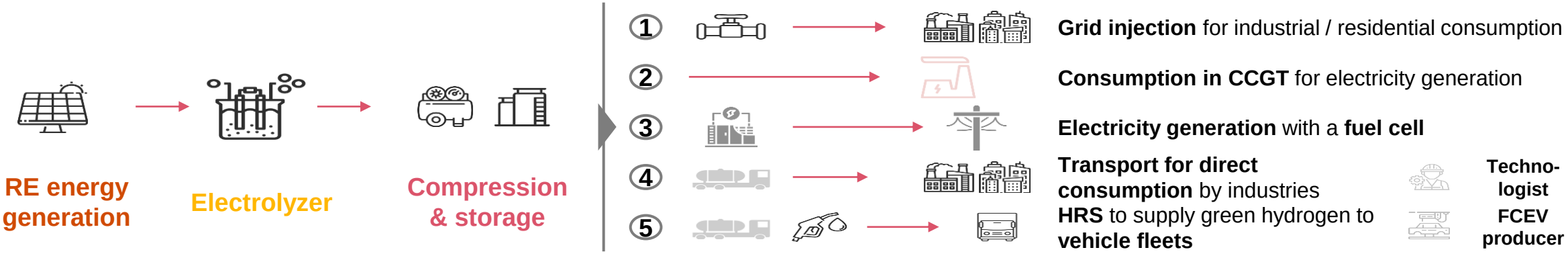


Key insights

- Global Hydrogen Review shows the required development of clean hydrogen demand in order to achieve the Paris agreement goals
- Growth in clean hydrogen comes from replacement of grey by clean hydrogen and overall growth in hydrogen demand and
- As more and more countries' and regions' legislations set and enhance their decarbonization targets, this scenario is likely to become also the actual development

Local H2 projects are being structured through consortiums, to complement capabilities and dilute risks

H2 project value chain



RE gen. | **H2 product.** | **Logistics & Supply** | **Commercial** | **OEMs**

Financing

Positioning (Communication, Public Administrations)

Consortiums with flexible structures, "Collaborative mode" to adapt to partners' preferences / roles in the project:

- Equity investors across different segments in the value chain
- Services provider agreement ("core" capabilities each partner can bring to the project, i.e. RE producer, ELY technology provider + Build Operate Own model,…)
- Off-takers as part of the consortium, diluting commercial risk of the Project
- Traders
- Financial investors

Source: Strategy& analysis

Hydrogen hubs with several companies are increasingly developing

Inspira Madrid

- **Replacement of 1,000 taxis by ‘26** as well as **public transport buses** in Madrid
- Development of the **end-to-end infrastructure for green H2 production, transport and supply** to final consumers through **public Hydrogen Refueling Stations (HRS) at a competitive price**

- **PwC S& role**:
  - ✓ Overall Program Management support
  - ✓ Financial model / Business Plan support
  - ✓ Off-taker agreements: Value proposition for taxi and bus stakeholders
  - ✓ Partnership strategy
  - ✓ Public administrations management: Subsidies maximization

Promoters

frv; Madrileña Red de Gas; Grupo Ruiz

H2 off-takers

- Taxi
- Bus
- Commercial fleet: SEUR
- Cash management: Loomis
- Waste management: Lyma getafe
- Other vehicles (public HRSs)

Collaborators

- Strategic Advisory NGEU: pwc
- Energy, emissions, value chain: INSIA, Instituto IMDEA Energía, Leialta
- Social economy: full audit, Fundación Prevent
- Electricity supply: Flexidao, nexer
- H2 Stations: galp energia, SICIAT, afenoil, GasLowCost, + Others
- H2 Transport: Messer Gases for Life
- H2 investor Taxi “as-a-service”: Toyota

Public administrations and other agents

- Madrid Regional gov’t: Comunidad de Madrid
- Madrid Council: Madrid
- Other councils: Ayuntamiento de Villanueva del Pardillo, Leganés, + Others
- Other stakeholders: AeH2, Hidrógeno, Industrial, AMDA, Geesinknorba Group, appa renovables, gasnam, Repsol, aspa, MCONDE, CONFEBUS

Source: Strategy& analysis

Projects with high investment volumes are increasingly being realized in the market

One of the largest green hydrogen projects in the world: thyssenkrupp signs contract to install over 2GW electrolysis plant for Air Products in NEOM

Fortescue wird durch Milliarden-Deal mit Eon zu Europas größtem Anbieter von grünem Wasserstoff

Die Vereinbarung zwischen Fortescue Future Industries und dem deutschen Energiekonzern sieht vor, dass das australische Unternehmen bis 2030 fünf Millionen Tonnen grünen Wasserstoff nach Deutschland, in die Niederlande und andere europäische Städte liefert. „Für uns ist das eine Ausgabe von mindestens 50 Milliarden Australische Dollar. Und das begrüße ich“, sagte Fortescue-Gründer Andrew Forrest auf einer Pressekonferenz in Berlin.

30. MÄRZ 2022 BELLA PEACOCK

WASSERSTOFF AUSTRALIEN DEUTSCHLAND

Case Study | Production of renewable hydrogen and sustainable fuels

Case study

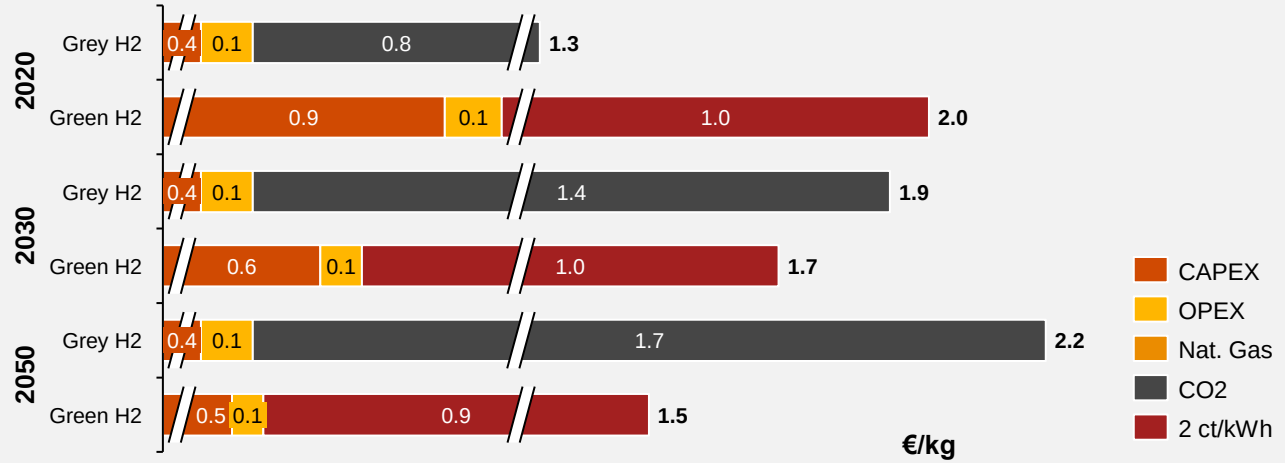
Company	Lingen Green Hydrogen
Year	From 2022
Involved stakeholders	bp, Ørsted

Description

Lingen Green Hydrogen will operate a **50 MW electrolyzer** with the associated infrastructure at the bp refinery in Lingen. It will use **renewable electricity** from Ørsted **offshore wind farms** in the North Sea:

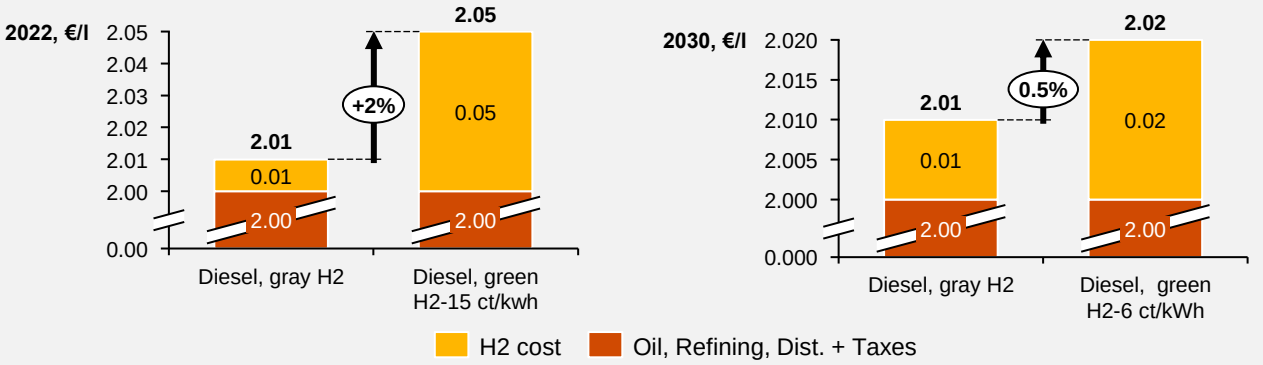
- The electrolysis capacity could be expanded to 150MW.
- Long-term bp's goal is to replace all fossil-generated hydrogen at the Lingen refinery contributing to a significant reduction in CO2 emissions in fuel production.
- In a further project step an electrolysis capacity of more than 500MW could be added for the production of synthetic fuels (e-fuels)

Comparative green hydrogen development cost (€/kg)



Note: CO_2 Cost €/t: 30 (2022), 180 (2030), 180 (2050)

Price increase of diesel due to the use of renewable hydrogen in refining (€/l) – 2022 and 2030

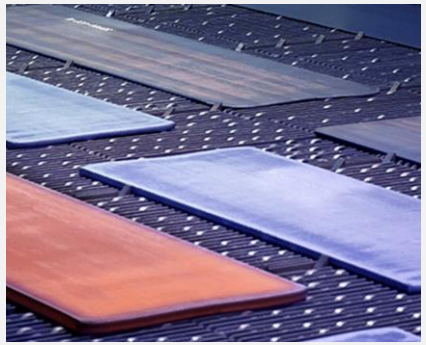


Source: PwC Strategy Analysis; Lingen Green Hydrogen, 2022 "Decarbonising industry together"; Own calculation based on eia, 2022. "Petroleum and Other liquids" & "Oil and petroleum products explained"

Case Study | Green steel by the use of renewable hydrogen

Case study

Company	HYBRIT
Year	Since 2016
Involved stakeholders	SSAB LKAB VOLVO VATTENFALL

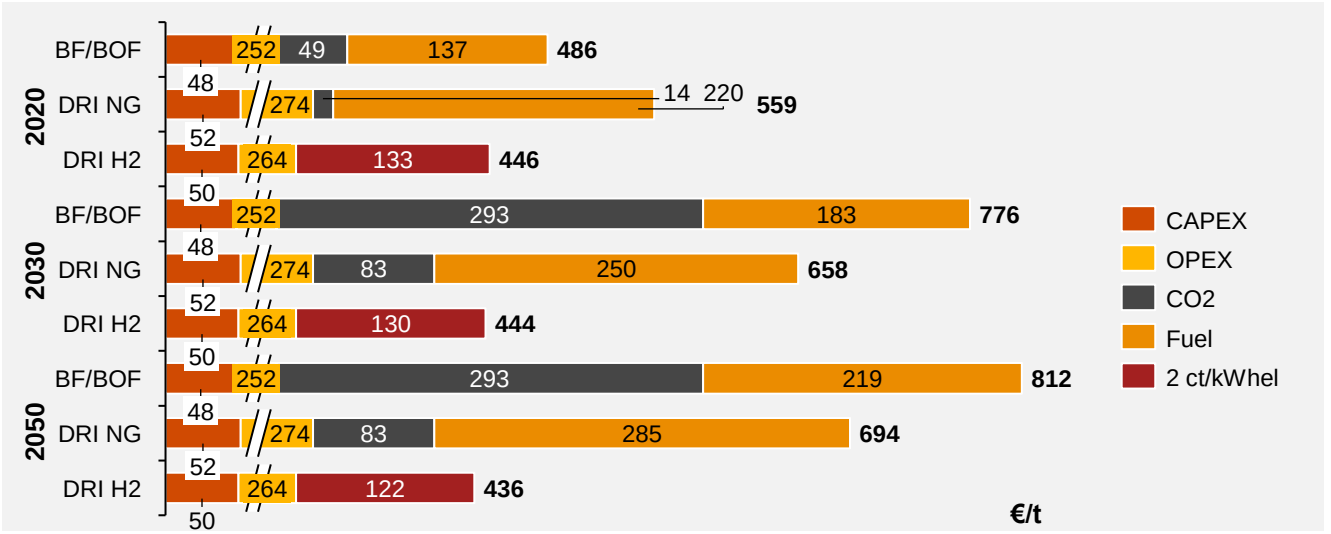


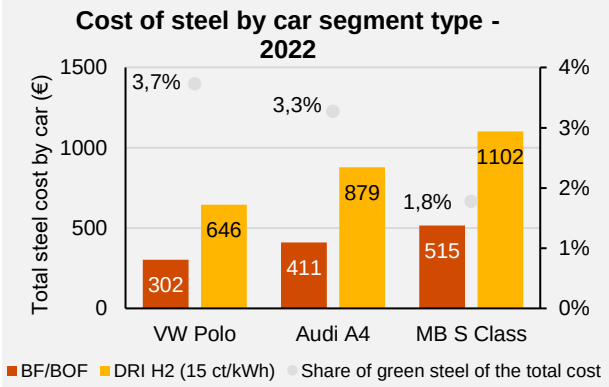
Description

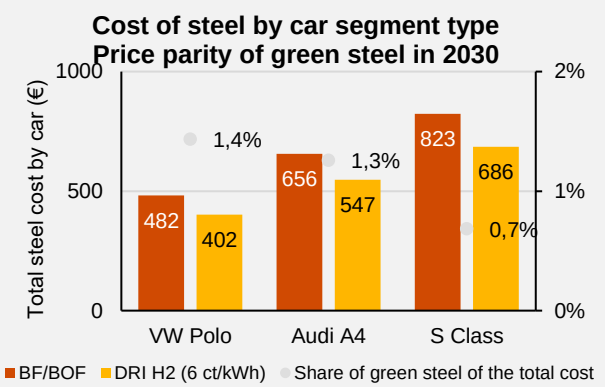
The HYBRIT project aims to be the first in the world, already in 2026, with a **fossil-free steel value chain**. The project aims to demonstrate full-scale production with a **capacity** of over **one million tonnes of iron a year**. Project characteristics[1]:

- It will produce sponge iron, a crucial ingredient for its steel-making process
- Hydrogen and zero-carbon electricity will be used as a substitute for coking coal and other fossil fuels traditionally used to make steel

Comparative Steel development Cost (€/t)







Note: CO_2 Cost €/t: 30 (2022), 180 (2030), 180 (2050)

Source: PwC Strategy& Analysis; SSAB, 2022. A new revolutionary steelmaking technology

Sustainable Aviation Fuels

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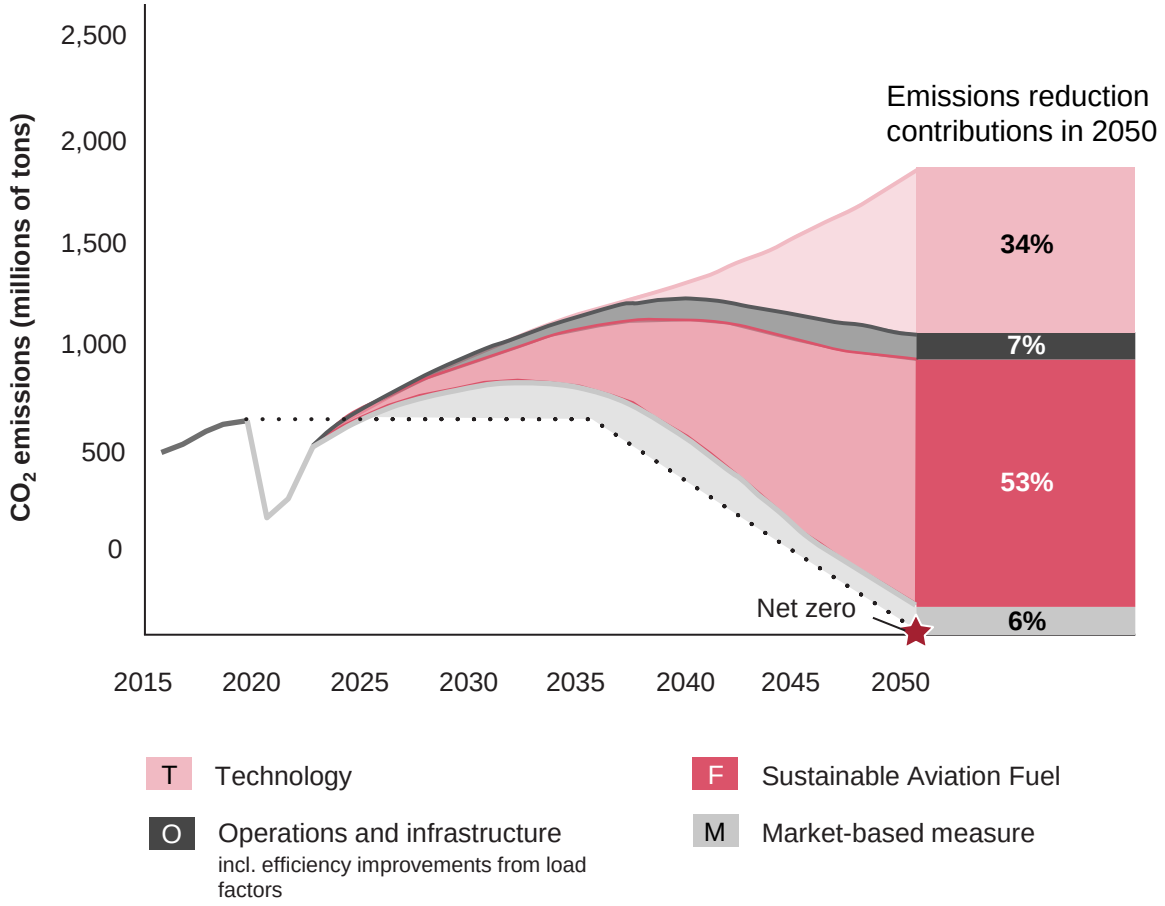
Sustainable aviation fuels are a key means for the aviation sector to meet its climate goals

Overview of GHG emission reduction measures



Technology	• Increasing propulsion and aerodynamic efficiency • Achieving lightweight system construction • Electric and hybrid-electric propulsion • Hydrogen-powered aircrafts
Operations and infrastructure	• In-flight, flight planning, and air traffic management measures • Airport ground operations
Sustainable aviation fuel (SAF)	• Is a substitute for fossil jet fuels • Large GHG-emission reduction potential • Can be used with existing infrastructure: technical changes in aircrafts, engine fuel systems, distribution, and storage facilities are not required

GHG = Greenhouse gas
Source: Waypoint 2050 (2021)

Whilst SAF can significantly reduce CO_2 emissions, they are currently less than 1% of aviation fuels

Introduction to SAF

SAF current situation

<1% of aviation fuels **used in Europe are SAFs**

3 **families** of **conversion pathways**

HEFA: hydro-processed esters and fatty acids

ABtL: advanced biomass to liquids

PtL: power to liquids

SAF pathway characteristics

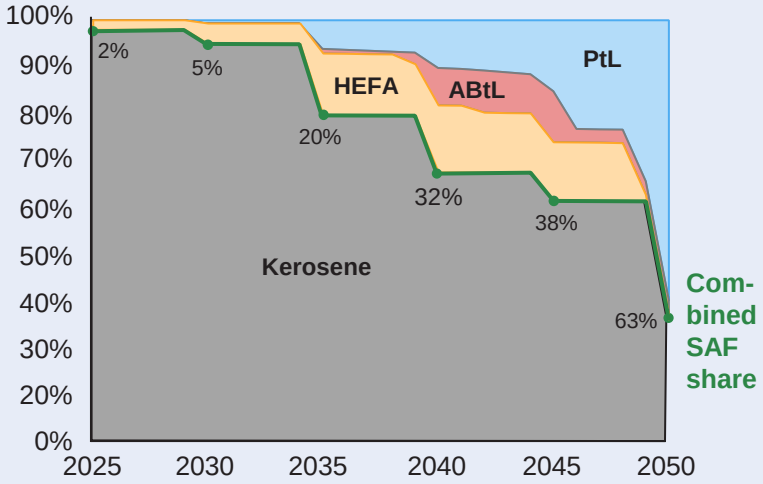
	HEFA	ABtL	PtL
Feedstock			
Feedstock Availability in Europe	**Constrained** by resource availability and demand competition	**Constrained** by resource availability and demand competition	**Least restricted**, due to large hydrogen production potential
GHG Emissions Savings			
Readiness Level	**Up to 10**	**Up to 6**	**Up to 5**

Source: EASA (2022), IEA (2021), Strategy& analysis

The SAF shares between scenarios vary between 63% and 75% by 2050, resulting in different fuel cost increases up to ~16%

Scenario overview

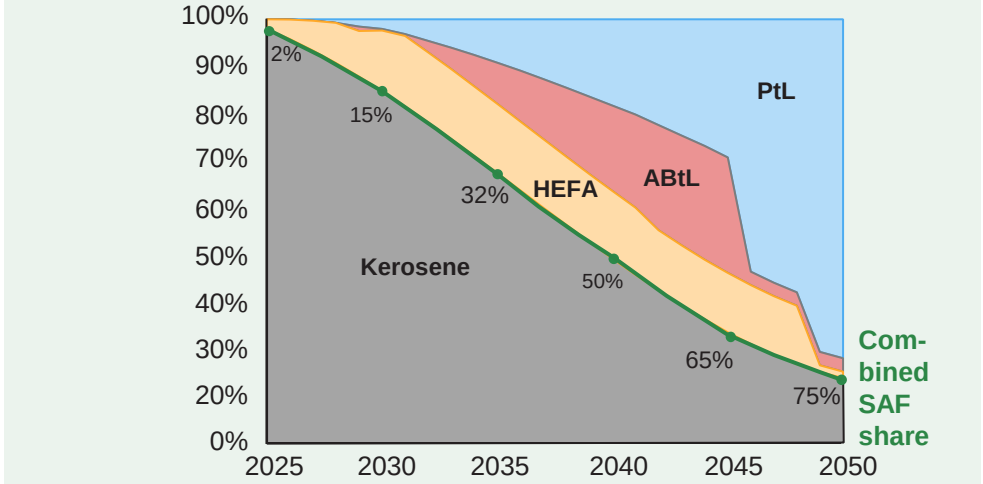
Scenario 1: *ReFuelEU aviation regulation*



	2025	2030	2035	2040	2050
SAF share	2%	5%	20%	32%	63%
PtL share	*/*	*0,7%*	*5%*	*8%*	*28%*

Max cost markup: 8.9% (2040) Min cost markup: -3.6% (2050)

Scenario 2: Following the *IEA net zero scenario 2050*



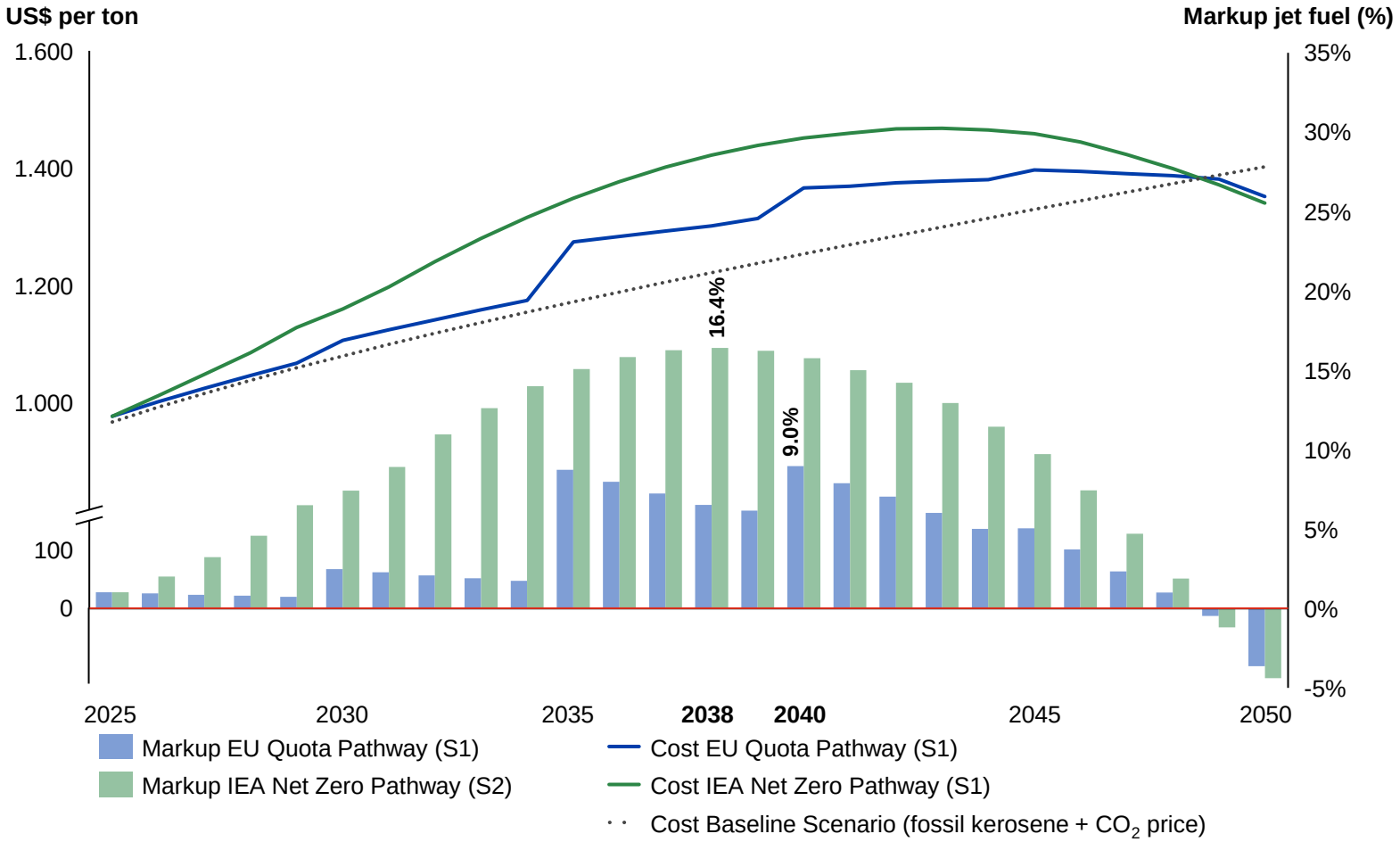
	2025	2030	2035	2040	2050
SAF share	2%	15%	32%	50%	75%
PtL share	*/*	*2%*	*7,5%*	*15%*	*30%*

Max cost markup: 16.2% (2038) Min cost markup: -4.4% (2050)

HEFA = hydro-processed esters and fatty acids; ABtL = advanced biomass to liquids; PtL = power to liquids
Source: Strategy& analysis

With a maximum of 16% cost markup in 2038 for the IEA Net Zero Pathway, the cost implications are rather moderate

Cost markup of jet fuel



Comments

- **Assuming a SAF-mix based on the EU Quota Pathway the maximum markup is reached in 2040 with 9%**
- **Following the IEA Net Zero Pathway the maximum markup is reached in 2038 with ~16%**
- **After 2040, the price of jet fuel including the SAF share will decrease due to two main factors:**
  1. The cost for **PtL** will become **significantly cheaper**
  2. **CO_2 prices** are constantly rising leading to a remarkable **cost increase for fossil kerosene** closing the gap to SAF

HEFA = hydro-processed esters and fatty acids; ABtL = advanced biomass to liquids; PtL = power to liquids
Source: Strategy& analysis

Together, we as a society can succeed in achieving the climate targets through innovation and ambitious action

Thank you!

Prof. Dr. Jürgen Peterseim
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PwC Deutschland