HYDROGEN

October 13th, 2020

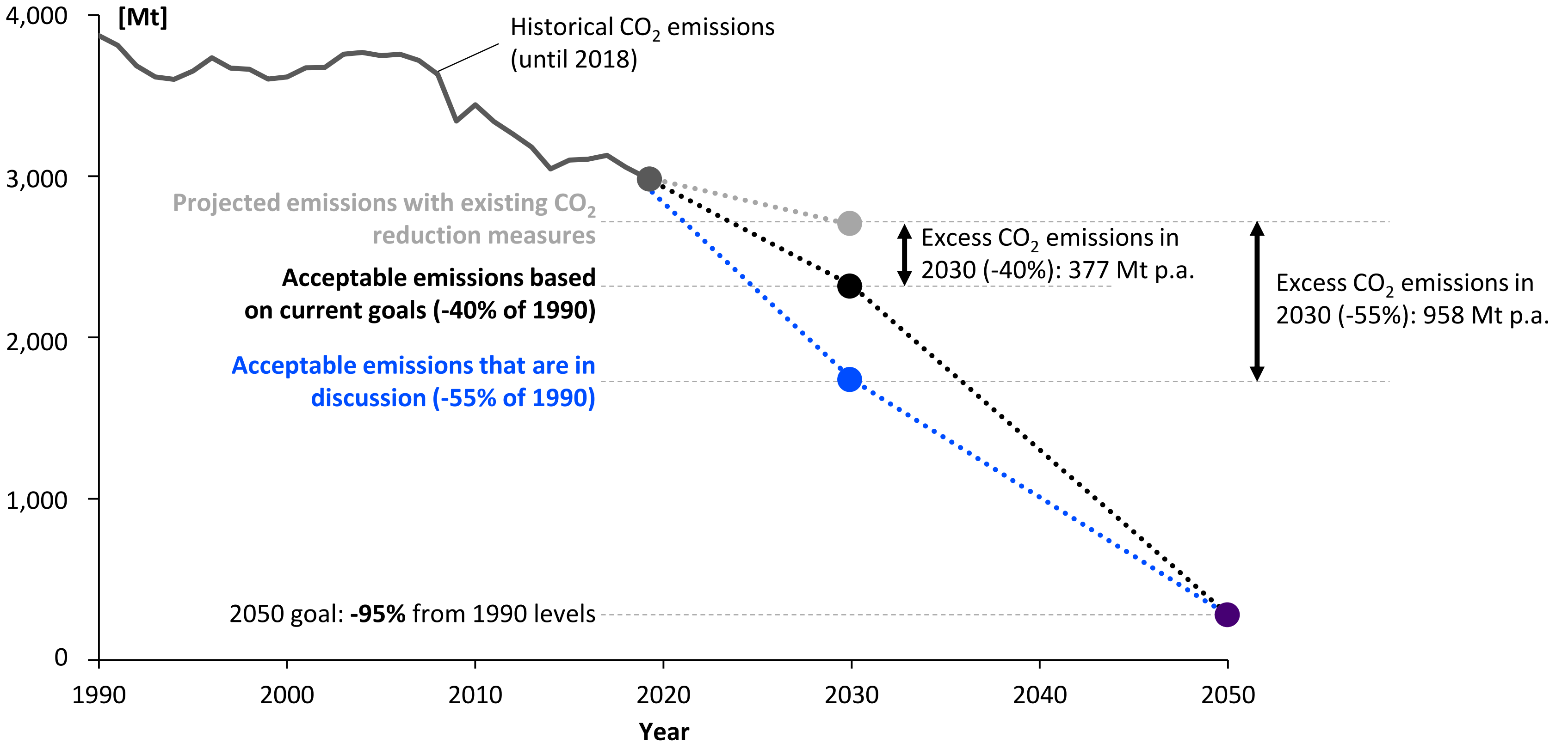
A successful European chemical industry shows…

- Growth
- Competitiveness
- Climate-neutrality by 2050

Addressing CO_2 emissions is the name of the game: Europe is raising the pressure to act

Projected vs. targeted CO_2 emissions in Europe

Total CO_2 emissions in Europe p.a., without LULUCF [Mt]



Source: Accenture analysis based on data from EEA | LULUCF: Land-use, land-use change and forestry | [1] includes e.g., energy for commercial/institutional, residential, agriculture & CO_2 from biomass

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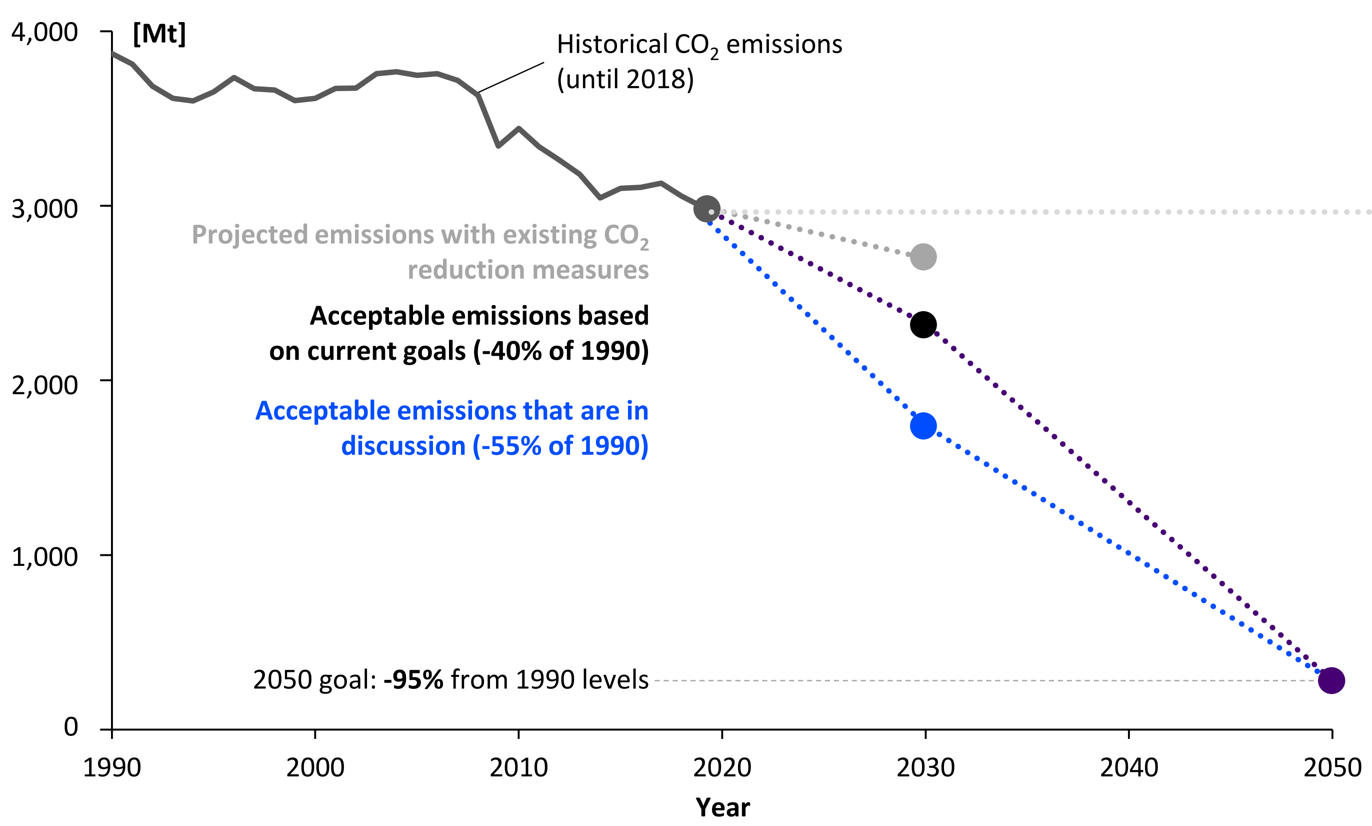
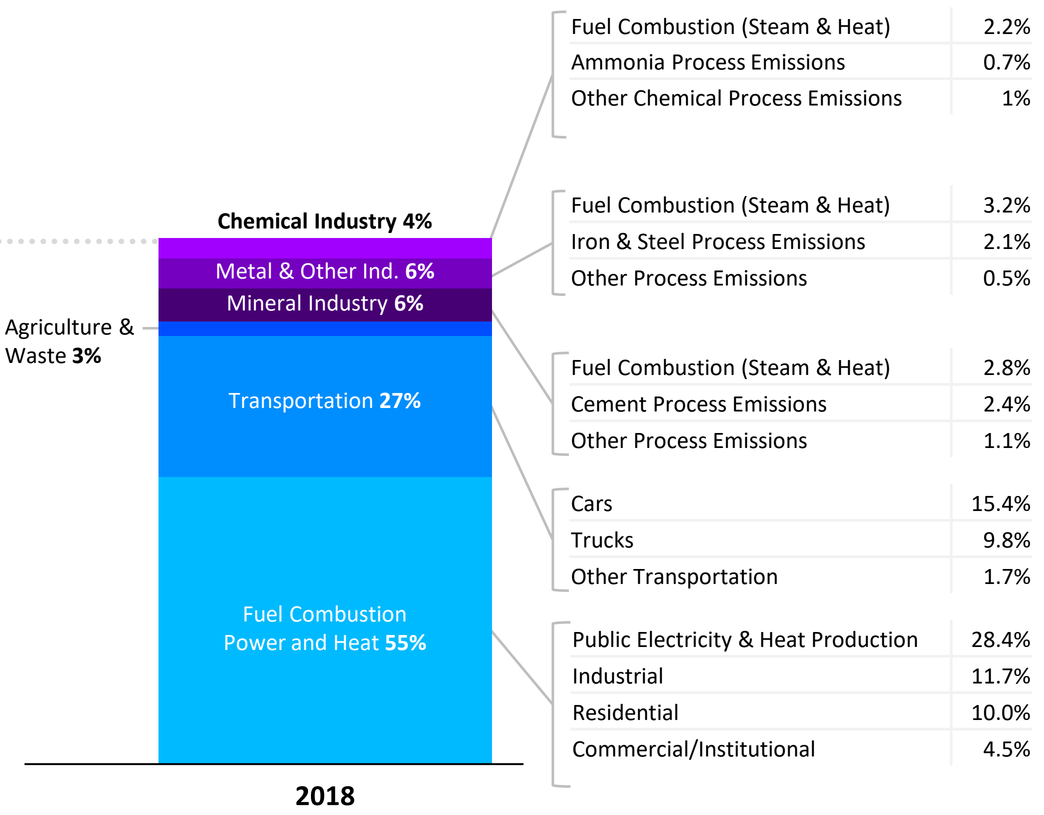


Split of total CO_2 emissions in Europe, 2018



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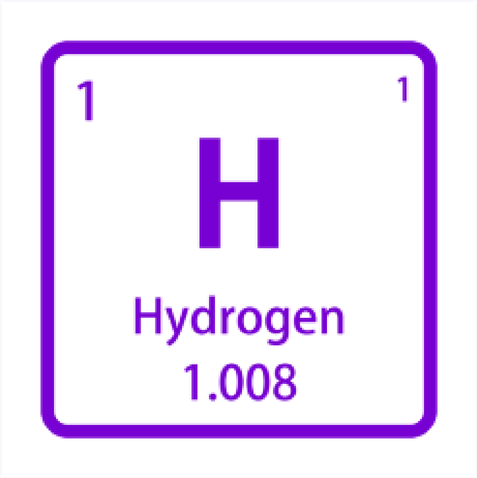
Is hydrogen the solution molecule?

Unique opportunities and limitations

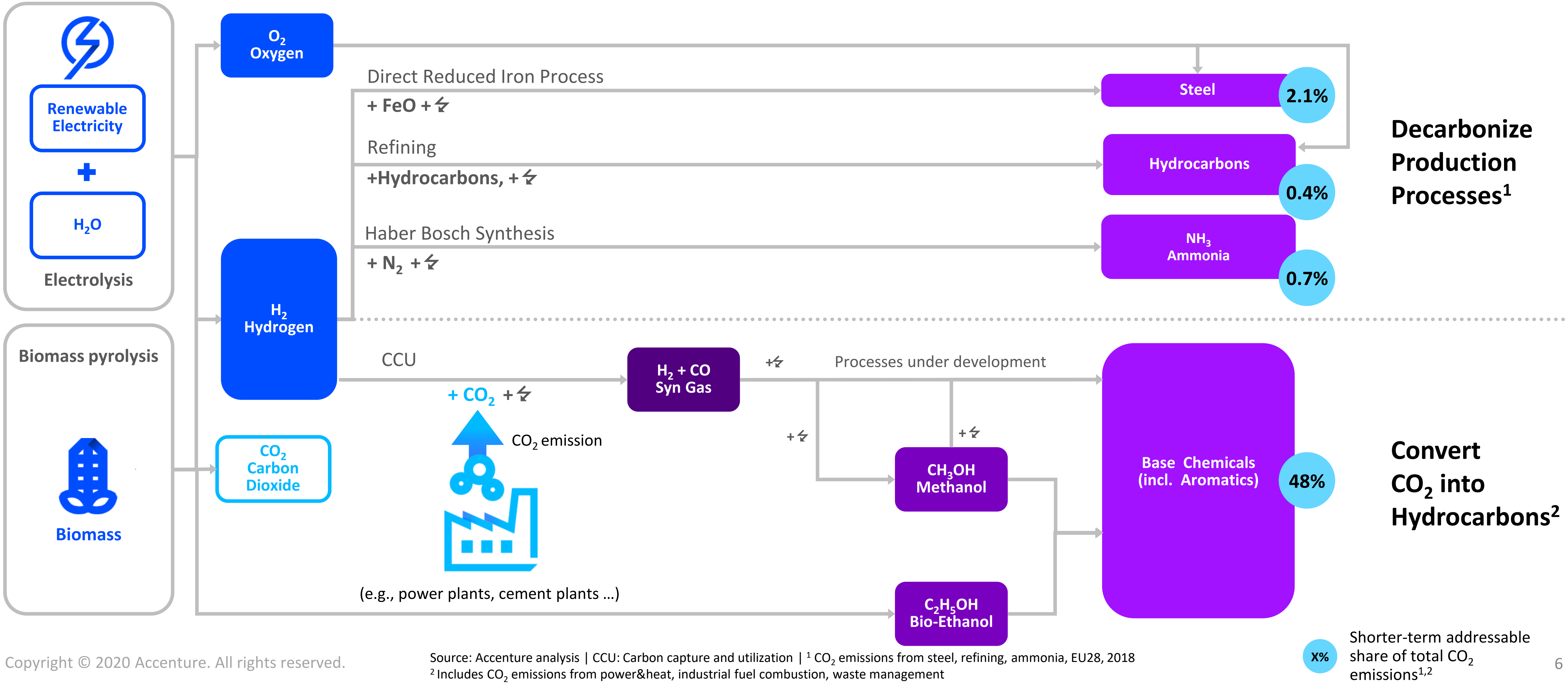
Hydrogen stands out from other energy carriers in a unique way…



1	… can **decarbonize production** processes (Iron, Ammonia etc.) …	but	… industrial use requires hydrogen at competitive prices
2	… can **convert CO_2** into hydrocarbons …	but	… conversion losses and energy need constrain economics
3	…can **replace fossil fuel** combustion …	but	… its conversion cascades require an optimization of the overall system
4	… has **multiple production paths** (renewable, fossil etc.) …	but	… renewable hydrogen is not cost competitive today

Large-scale decarbonization and CO_2 conversion will only be solved with hydrogen

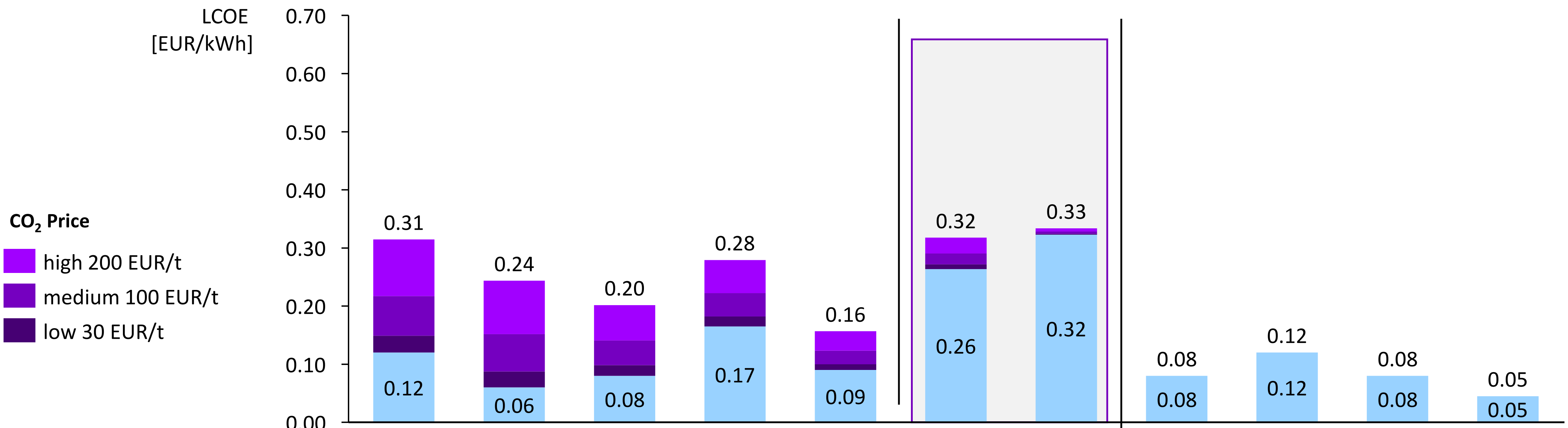
Chemicals synthesis routes using renewable H_2 as a non-fossil feedstock alternative



Source: Accenture analysis | CCU: Carbon capture and utilization | [1] CO_2 emissions from steel, refining, ammonia, EU28, 2018
[2] Includes CO_2 emissions from power&heat, industrial fuel combustion, waste management

Analysis of current cost structure shows the need for cheaper renewable energy

Levelized cost of electricity by energy source and CO_2 price scenarios



[kg CO_2 /kWh]	Oil	Brown coal	Hard coal	Natural gas turbine	Natural gas CC	Fossil H_2	Decarb. fossil H_2	Nuclear power	Wind offshore	Wind onshore	Solar (PV utility scale)
CO_2 intensity[3]	0.97	0.92	0.61	0.57	0.33	0.27	0.05	0.0	0.0	0.0	0.0
Energy source	Fossil							Nuclear	Renewable		

Source: Accenture analysis based on data from Fraunhofer, IEA, Lazard, Quaschning | [1] CO_2 European Emission Allowances | [2] EU, Thomas Reuters: “The MSR: Impact on market balance and prices”) | Renewable H_2 from renewable energy. decarbonized fossil H_2 with carbon capture. Fossil H_2 from natural gas | [3] CO_2 intensity only considers use phase | LCOE: Levelized cost of electricity

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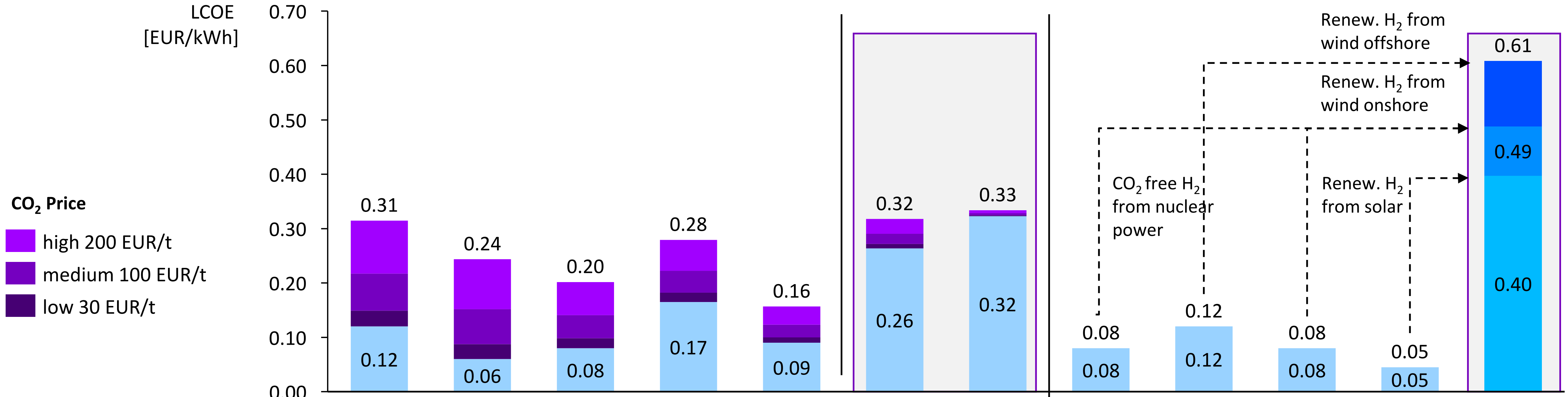

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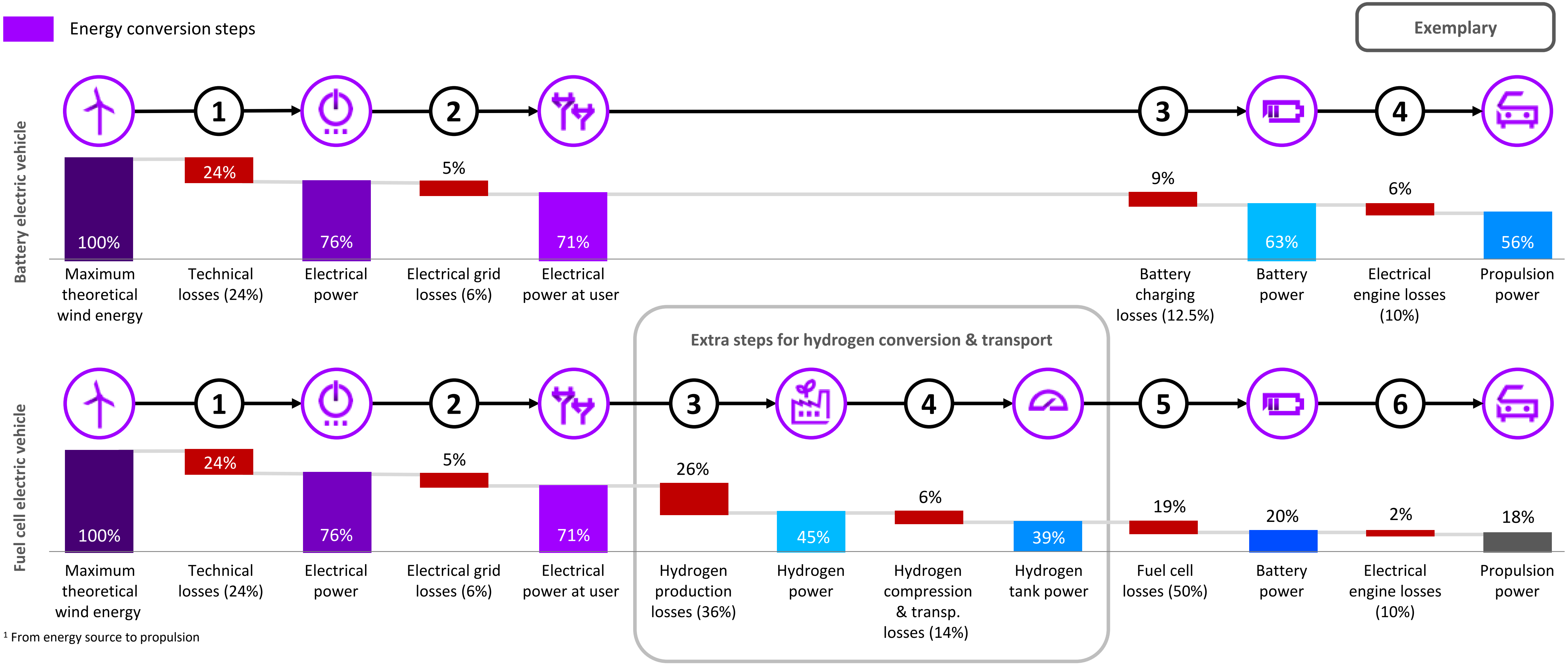
A system perspective "well-to-wheel" is needed

Comparison of well-to-wheel[1] efficiency



[1] From energy source to propulsion

Virtually any new technology is initially met with great skepticism…

Aversion against new technologies

“It is impossible to fly objects that are heavier than the air“

Lord Kelvin, Chairman of the Royal Society (1895)

“Worldwide demand for motor cars will not exceed one million – for a lack in available chauffeurs alone“

Gottlieb Daimler, Motor car inventor (1901)

“I think there is a worldwide market of about five computers“

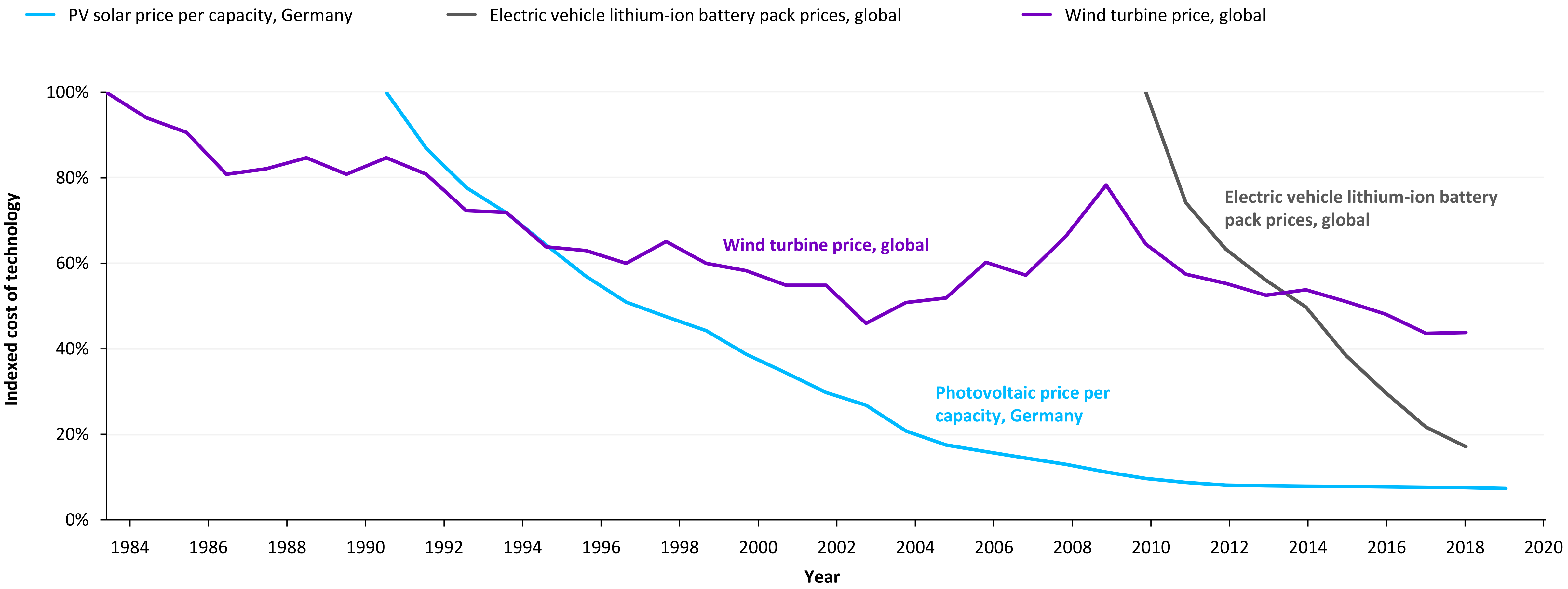
Thomas Watson, CEO of IBM (1943)

“The iPhone has no chance to gain significant market share“

Steve Ballmer, CEO of Microsoft (2007)

In hindsight we see that technology evolution is difficult to predict

Price trend of wind turbines, photovoltaic solar plants, and electric vehicle lithium-ion batteries



Source: Fraunhofer, German Federal Ministry of Economic Affairs and Energy, IRENA, Bloomberg New Energy Finance | Prices indexed in 2015 | PV: Photovoltaic

There are significant commitments: Stimuli and production targets

Selected H_2 targets and strategies

Non-Exhaustive

	H_2 target (selection)	H_2 Production in GW	Stimulus size in EUR bn	Year announced[3]
EU H_2 Strategy	2x40 GW production capacity and 10 Mt H_2 production by 2030	80.0	25-30[1]	2019/20
H_2 Economy roadmap	6.2 mn FCEV production capacity and deployment of 40,000 FC buses by 2040	N/A	50.7 for "Green New Deal" incl. H_2	2019/20
German H_2 Strategy	0.4 Mt H_2 production by 2030	2.3	9[4]	2020
French H_2 Strategy	6.5 GW H_2 production capacity by 2030 (equals ~1.14 Mt[2])	6.5	7.2[4]	2020
Portuguese H_2 Strategy	1 GW H_2 production capacity by 2030 (equals ~0.175 Mt[2])	1.0	7[4]	2020
Basic H_2 Strategy	Deployment of 800,000 FCEV and use of 0.3 Mt H_2 by 2030	1.7	1.3[4]	2017/19
Spain H_2 Strategy	4 GW H2 production capacity by 2030 (equals ~ 0.7 Mt[2])	4.0	N/A	2020
Dutch H_2 Strategy	Up to 4 GW H_2 production capacity by 2030 (equals ~0.7 Mt[2])	4.0	< 0.1[4]	2020
∑ **TOTAL**		**~ 100 GW**	**Min. EUR 25[4] bn**	

Source: Accenture analysis based on data from IEA | [1] Hydrogen Europe, 2020 "Green Hydrogen for a European Green Deal a 2x40 GW Initiative" | [2] Assumed a facility utilization of 91% | FC: Fuel cell, FCEV: Fuel cell electric vehicle | [3] Release/ update | [4] Exclusive hydrogen stimulus

The race has started on both supply and demand side

Example projects involving the supply (generation) and demand (usage) of hydrogen

H_2 Project scale (in MW, approximate figures)

Non-Exhaustive

Supply

Projects involving the generation of hydrogen

2023 – Centurion
EU,
Power-to-gas
& Others
100 MW

2024 – Hynetherlands
EU,
Power-to-gas
100 MW

2025 – H_2 plant
APAC,
H_2 prod. & Feedstock
1360 MW

2026 – Hynet/ Heating UK
EU, CCUS
& Others
514 MW

2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026

Demand

Projects involving the usage of hydrogen

Tri-Gen
Americas,
H_2 mobility
& Others
2 MW

JHyM
APAC,
H_2 mobility
& Others

H_2 FC Trains
EU,
H_2 mobility
& Others
3 MW

Hynet
APAC,
H_2 mobility
& Others

H_2 FC Trains
EU,
H_2 mobility
& Others
3 MW

Magnum
EU,
Power gen.
1320 MW

Renew. Prod. Ammonia
APAC,
Feedstock
& Others

Hybrit
EU,
CO_2 free steel
1 MW

Source: Accenture analysis based on data from Bloomberg Quint | CCS: Carbon capture and storage, CCUS: Carbon capture and utilization/storage

There are multiple roles for the chemical industry in the emerging hydrogen value chain

Business model options for the chemical industry

Non-Exhaustive

Business models	H_2 generation	H_2 storage	H_2 distribution	H_2 application/ decarbonization
Material and system supply	Electro-lyzer; Catalysts; Electrodes; Membranes; License design	Polymers; Absorbents; Carbon fibers; Complexes; Lining; ...	PFA; PTFE; FEP; FRP; Pipelines; Carbon fibers; ...	Catalysts; Electrodes; Membranes; License design; Fuel cells
Operate and handle H_2	Operate electrolyzers; Produce & sell H_2	Operate H_2 pipelines, liquification, fuel stations, etc.		Operate fuel cells; Fuel cell as a service
	Generate H_2 and operate H_2 pipelines, liquification, fuel stations, etc.			
	Generate H_2 and operate H_2 pipelines, liquification, fuel stations and operate fuel cells			
Decarbonize chemicals	Utilize by-product H_2 (e.g., chlorine, etc.); Produce H_2 via excessive process energy	Store and distribute H_2 in local network (Verbund); Store and distribute H_2 via existing trans-regional network		Green ammonia production; Green syngas as feedstock; ...
Decarbonize other industries	Sink carbon emissions of other industries via CCU and CCS; Provide H_2 to sink or avoid carbon emissions to other industries			CCU and CCS as a service; Green steel via DRI; ...

Source: Accenture analysis | PFA: Perfluoroalkoxy alkanes, PTFE: Polytetrafluoroethylene, FEP: Fluorinated ethylene propylene, FRP: Fiber-reinforced plastic, CCS: Carbon capture and storage, CCU: Carbon capture and utilization, DRI: Direct iron reduction

Capture your share of the hydrogen opportunity

Summary

- Hydrogen is a huge opportunity
- There is a clear political will to build a hydrogen market
- Hydrogen is a solution molecule for decarbonization
- There is a clear sweet spot for the chemical industry to make hydrogen competitive
- Don't leave this opportunity to other industries

Call for action

1. Get your share of the opportunity
2. Set-up your pilot (electrolyzer, decarbonization or supply project, etc)
3. Direct research, process & business development to hydrogen

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