Hydrogen

The missing piece to reach net zero emission targets

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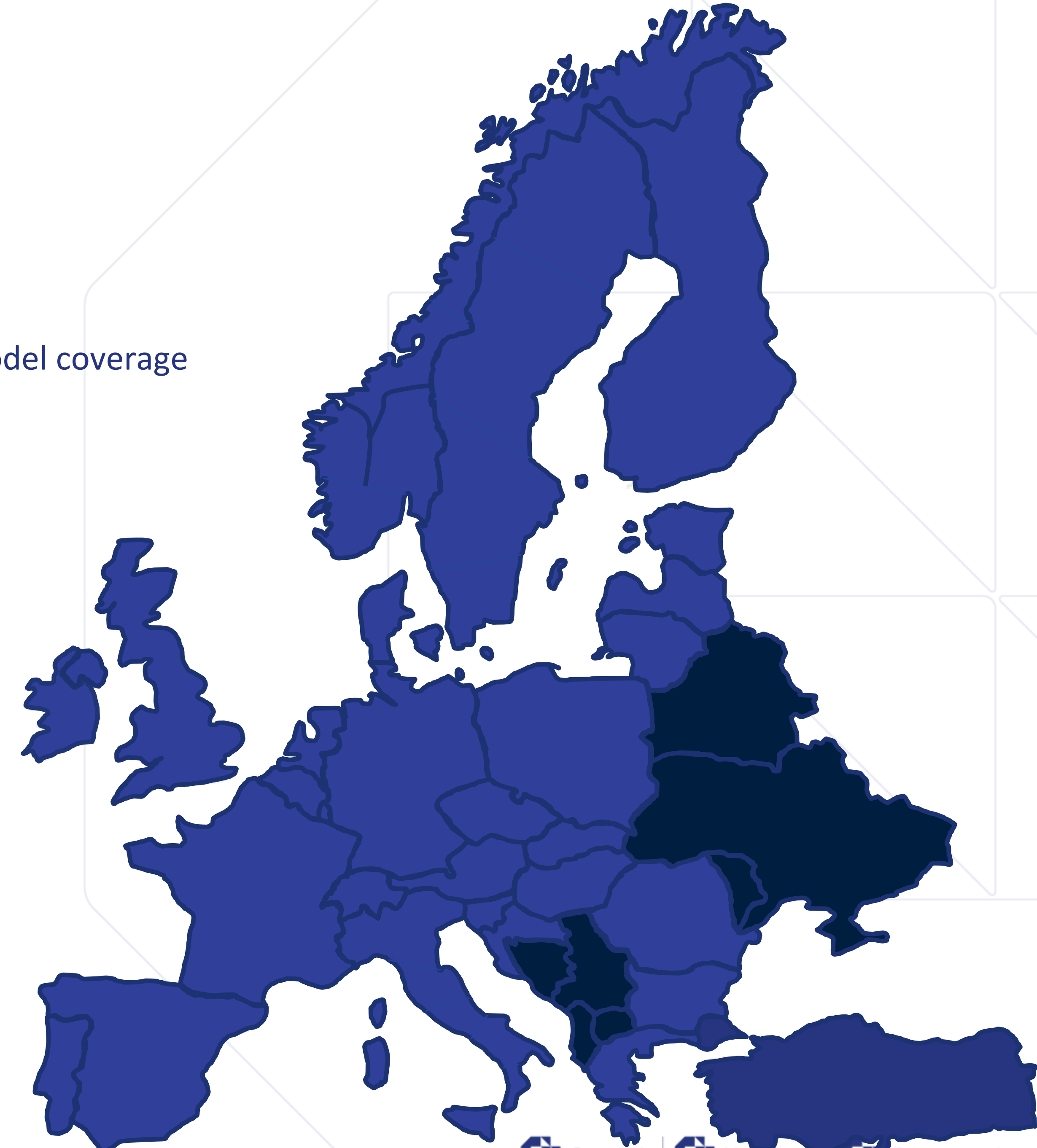
ICIS

ICIS Power and Hydrogen

- Consistent with ICIS carbon
- Portal and data access
- API and marketplaces

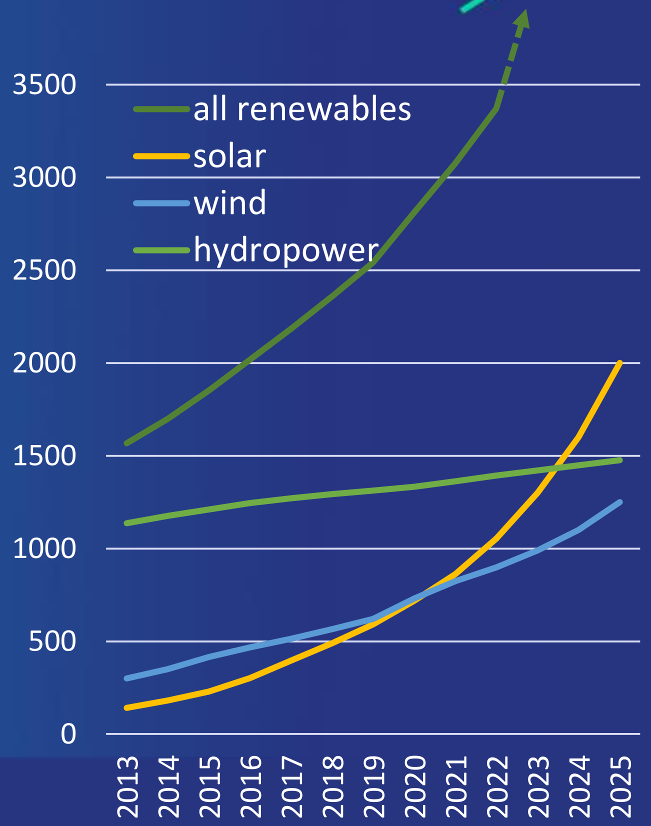
- Daily updates for the liquid curve
- Quarterly updates to 2050
- Hourly granularity

- Price: for power and hydrogen
- Demand: total consumption, sector breakdown where data available
- Weather: solar, wind, temperature, hydro
- Generation: hourly generation based on power plant database with 7000+ units
- Flows: cross-border transmission
- Storage: batteries, hydro storage
- Infrastructure: capacities, outages
- Capture rates: technology-specific
- PPA: analysis and valuation



Why renewables will succeed over fossil fueled plants

Global build-out in GW



Obstacles on the way

- Potential learning curve setbacks
- Raw material price shocks
- Trade war
- Natural build-out boundaries
- Country specific effects
- Canibalisation
- Grid restrictions

LCOE and learning curves

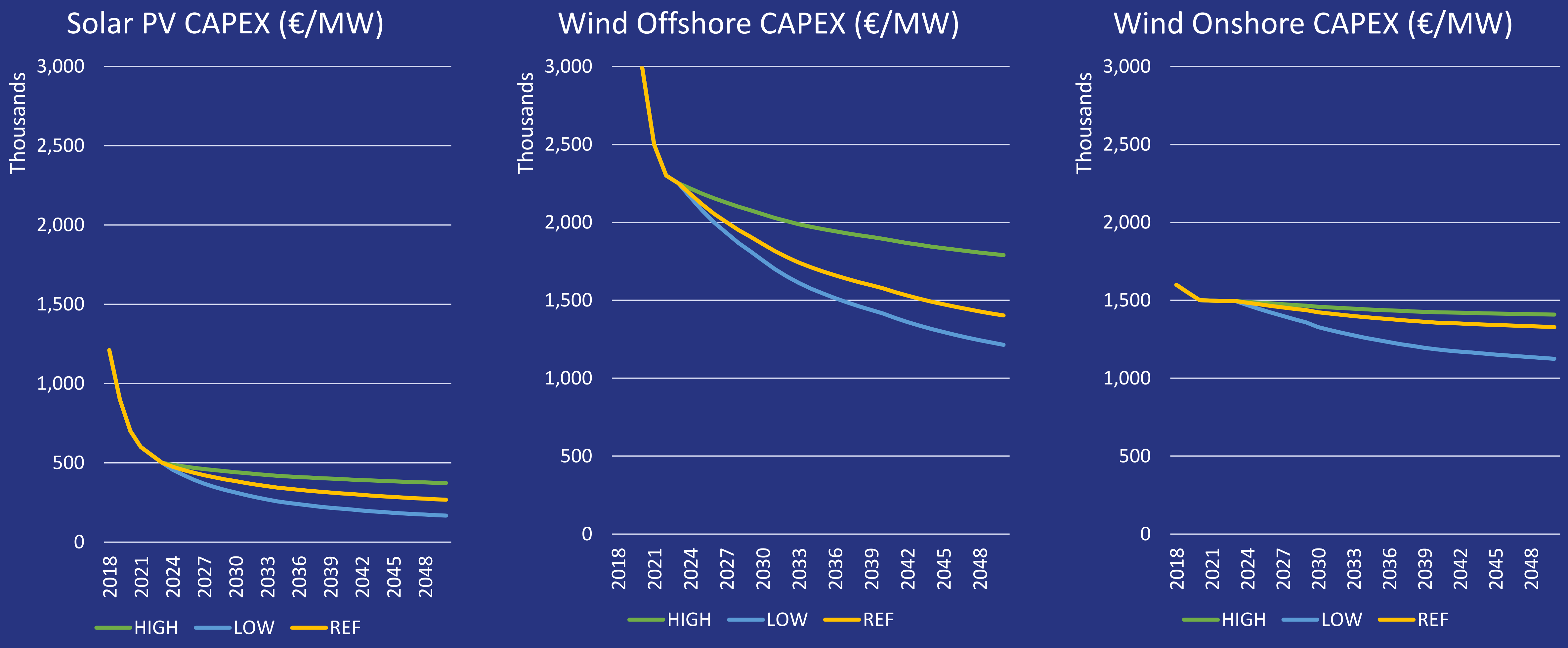
- The decrease in LCOE of reneable energy sources follows a typical learning curve behaviour
- The more global build-out the lower the costs
- LCOE of thermal power plants mostly depend on fuel prices and operating costs and do not follow a learning curve

What is the risk associated with this strategy?

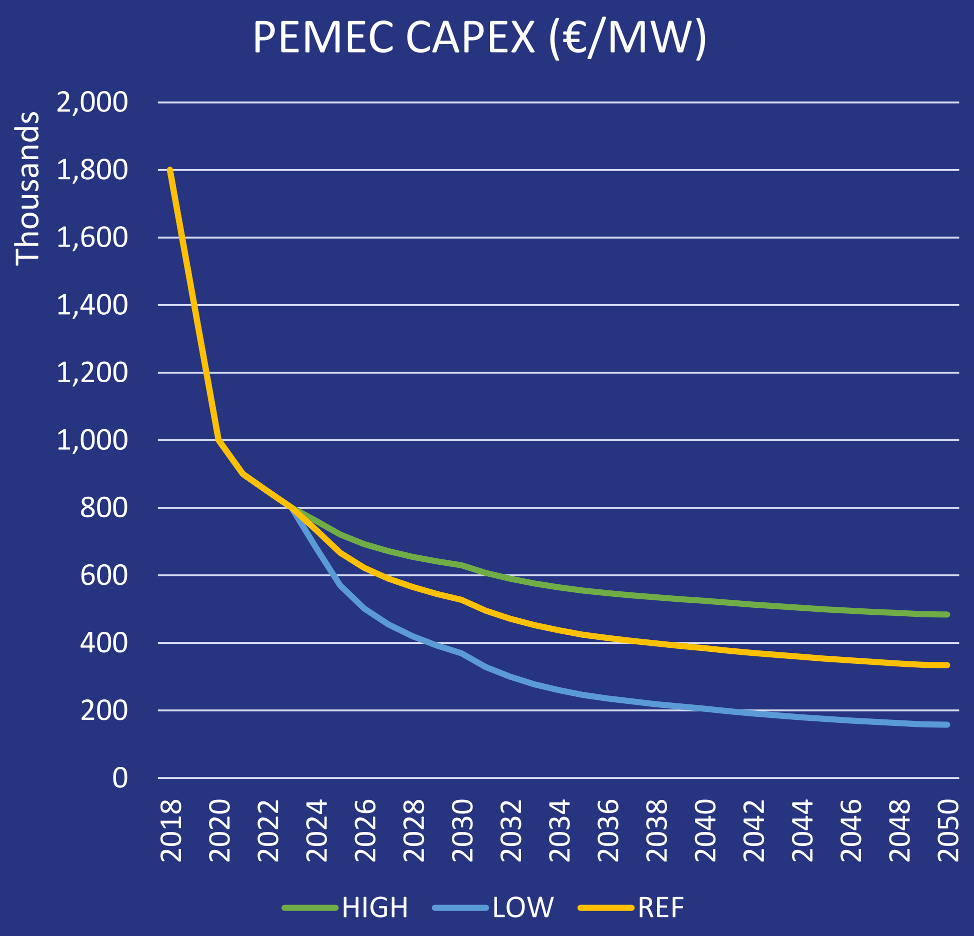
- Strategy: provide a predominant share of all primary energy demand with power and hydrogen in Europe by 2050
- We want to provide scenarios to understand the risk associated with the assumption of falling CAPEX
- We did a case study:
  - REF: our best guess
  - HIGH_COSTS: using very low learning curves
  - LOW_COSTS: using a very ambitious learning curves

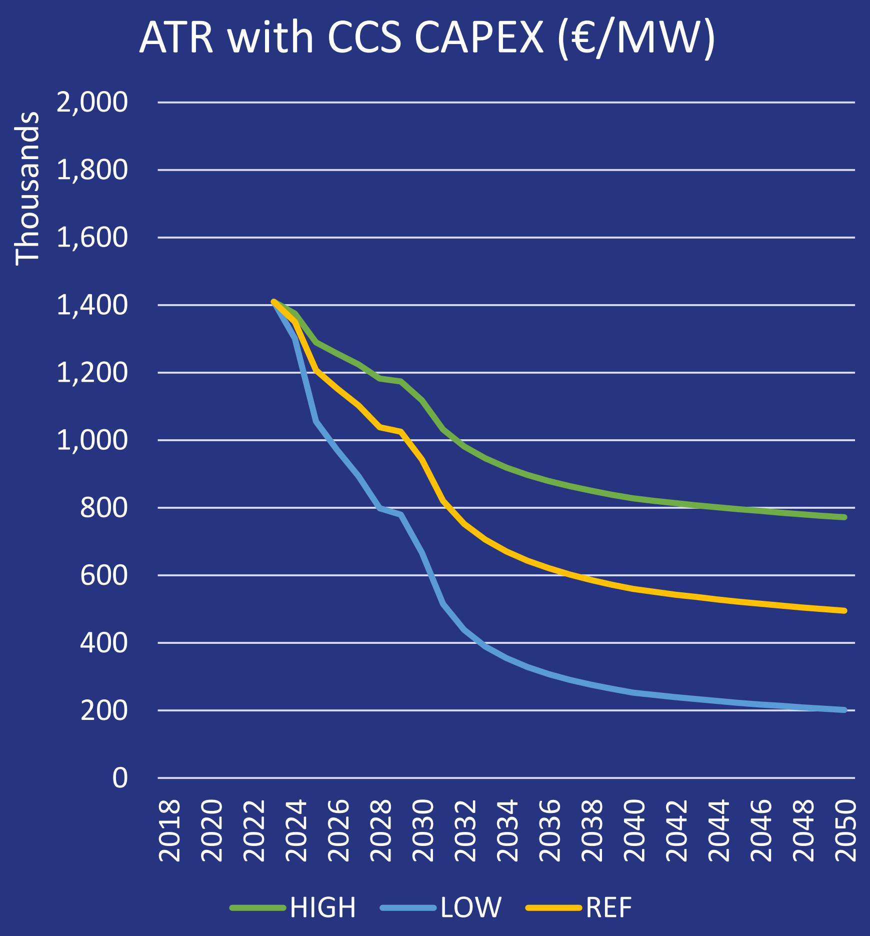
Scenario	Learning rate	CAPEX	Fuel prices	Capacity build-outs
REF	best guess	IEA average	WEO + own forecasts	Endogenous
HIGH_COSTS	high (worst case)	IEA high	WEO + own forecasts	Endogenous
LOW_COSTS	low (best case)	IEA low	WEO + own forecasts	endogenous

CAPEX Power Production - Learning curves for solar PV and wind



Clear trend CAPEX Hydrogen Production





Hydrogen the silver bullet of decarbonisation?

The role of hydrogen in decarbonisation is often overestimated

- Full decarbonisation is not possible with blue hydrogen using carbon capture and storage (CCS)
- Direct electrification is nearly always the first choice, especially in transport and house heating (Electrolysis efficiency of 65-75%)

Essential for scalability

- A hydrogen pipeline infrastructure
- Producing enough renewable electricity
- Gas reserves with carbon storage possibilities

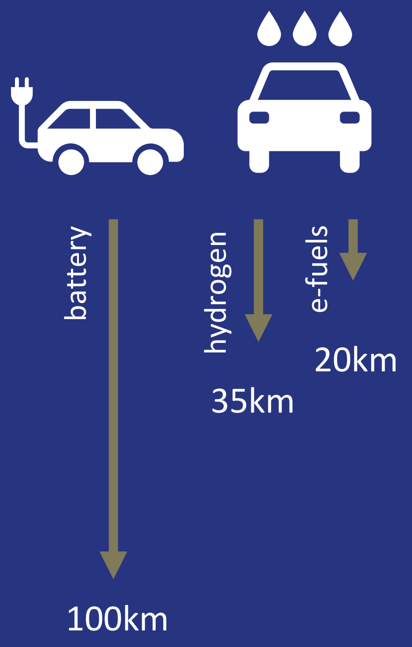
Usage:

- Direct demand: chemicals (ammonia), metals, heat and transport, power sector (fuel cell efficiency 40-60%)
- As many as possible applications will be directly electrified (often efficiency >90%)

The advantage of sector coupling

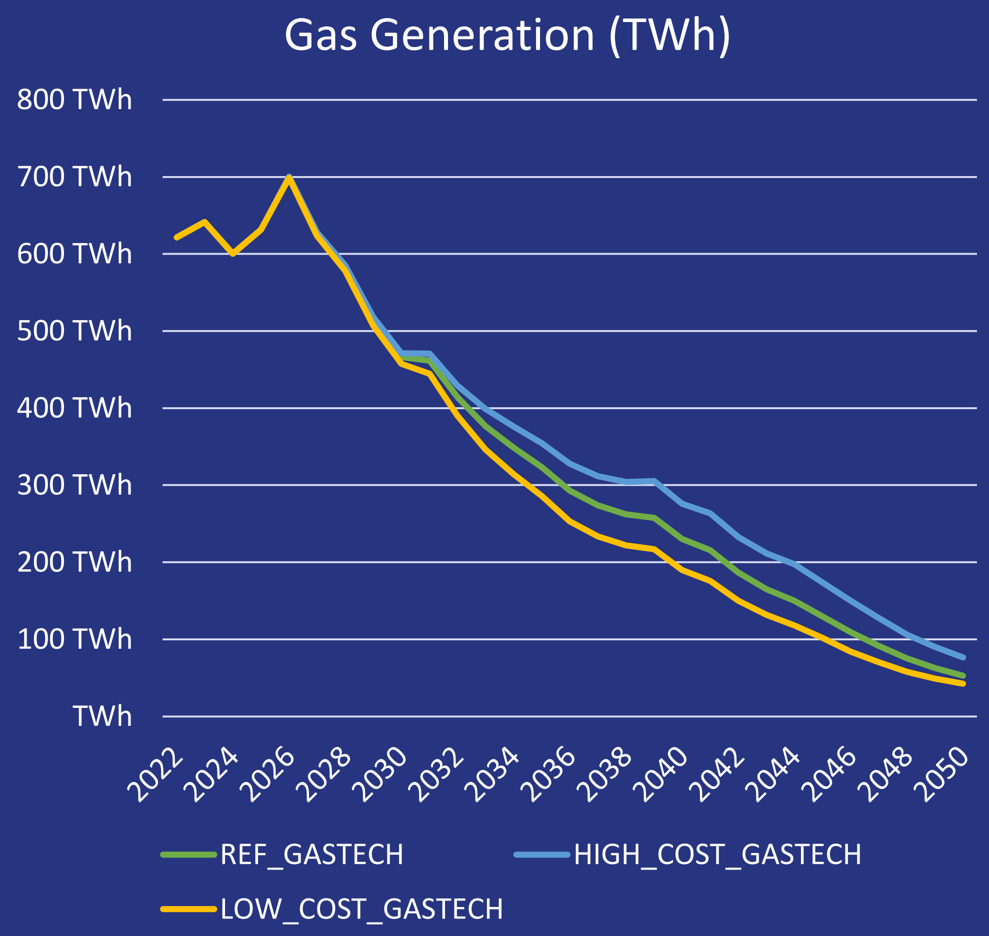
- Hydrogen will play a vital role for the power sector as a flexible demand
- A correlation of electrolysis demand and renewable power generation improves the economics
- Location decisions will be based on storage and transport costs and the comparative advantage of either hydrogen or power

Decarbonisation of transport: range with 15kWh electricity



source: research center for enery networks and energy storage

Gas will transition from a base load to a backup capacity – CAPEX changes with little impact

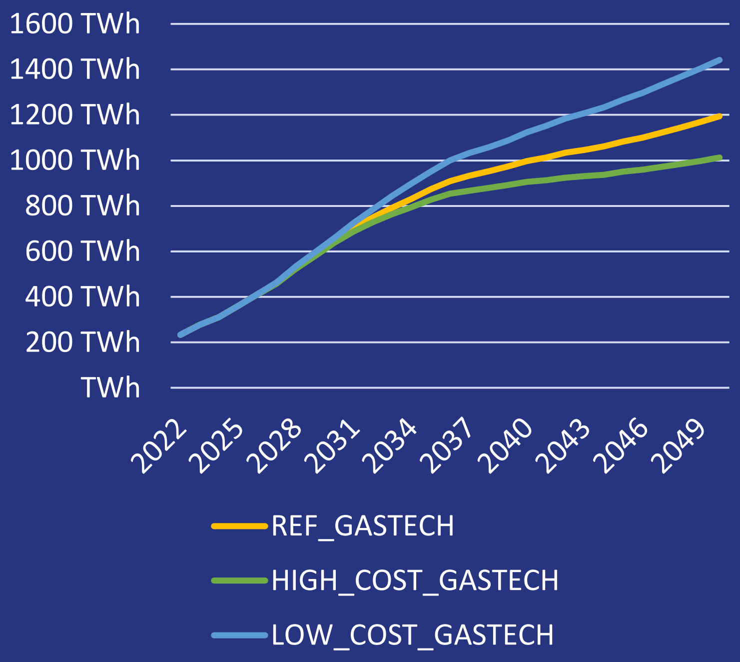


- Installed gas capacity still increasing (+30GW) and peaking in 2030 at around 246GW
- Gas power plants are used as back-up capacity for times with low wind and solar generation
- The utilization of the plants itself is strongly going down from 2026 onwards due to more and more low costs renewable generation
- A change in CAPEX e.g. due to raw material costs will not change this

Renewable generation in the 3 scenarios

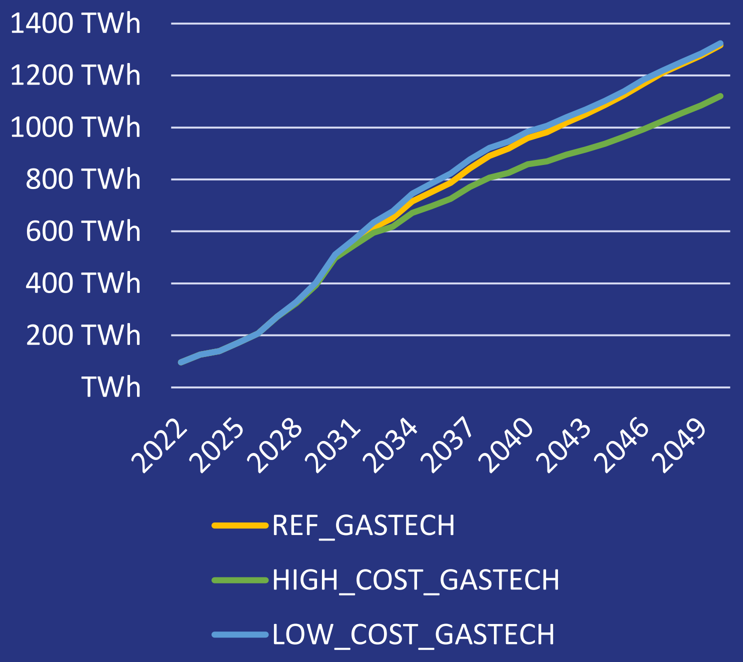
Solar Generation

- Variation of CAPEX with significant impact due to the steep learning curve
- Hydrogen as an enabler for more solar in LOW COST



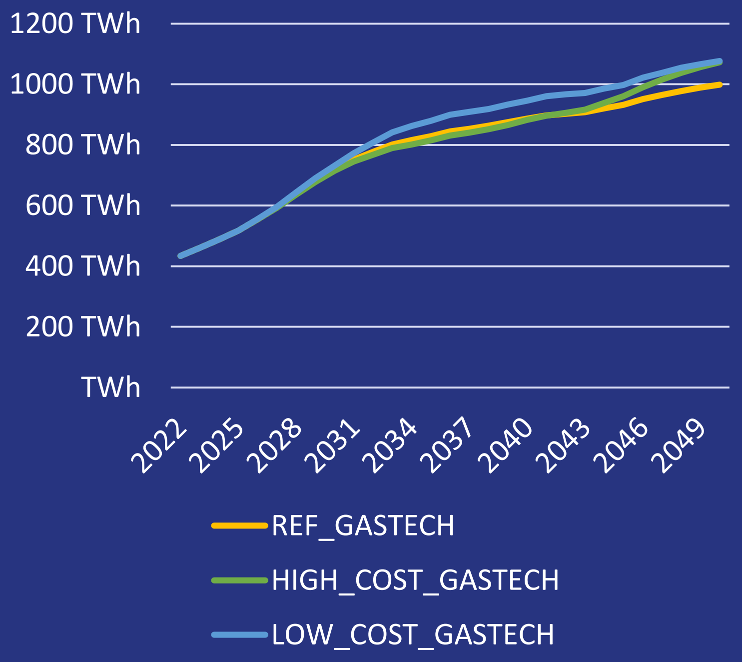
Wind Offshore Generation

- Natural boundaries hit in REF and LOW COST scenario
- HIGH COST leads to less generation

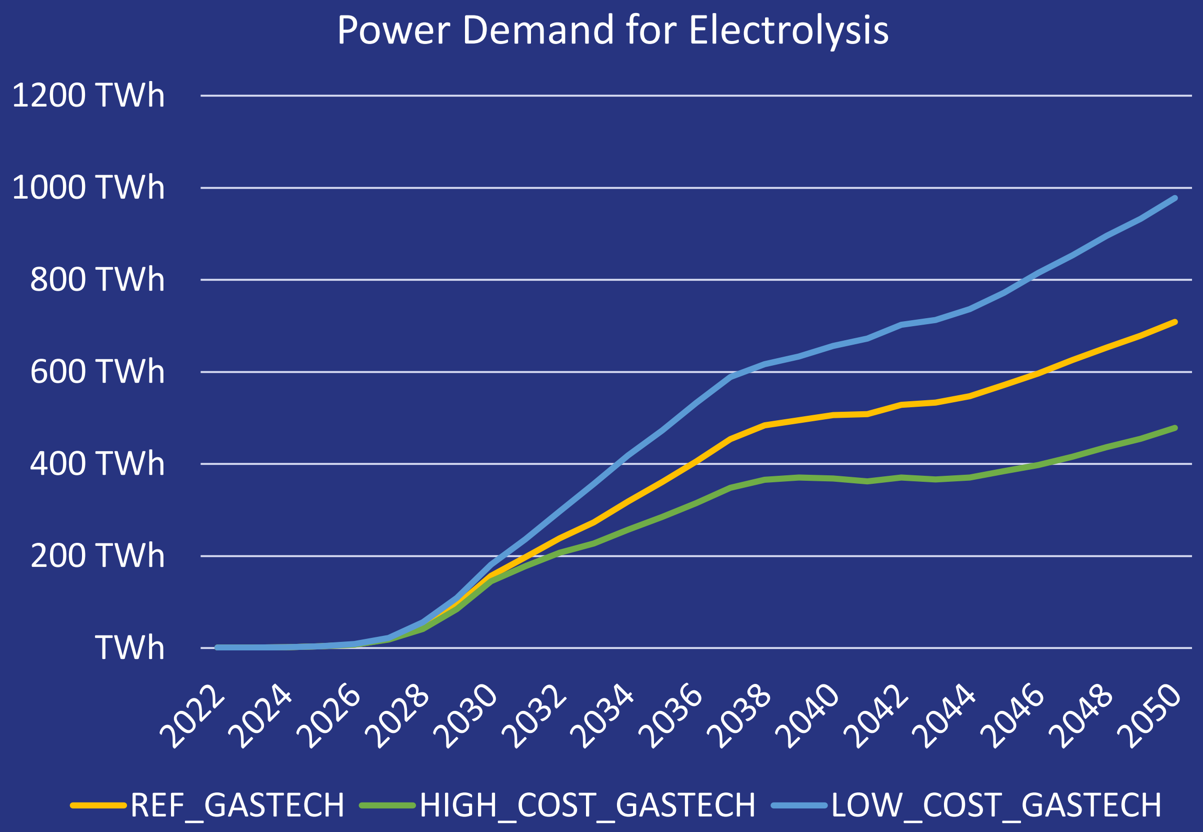


Wind Onshore Generation

- Less cost sensitive with flater learning curve
- More generation at HIGH COST to cover for missing solar and wind offshore

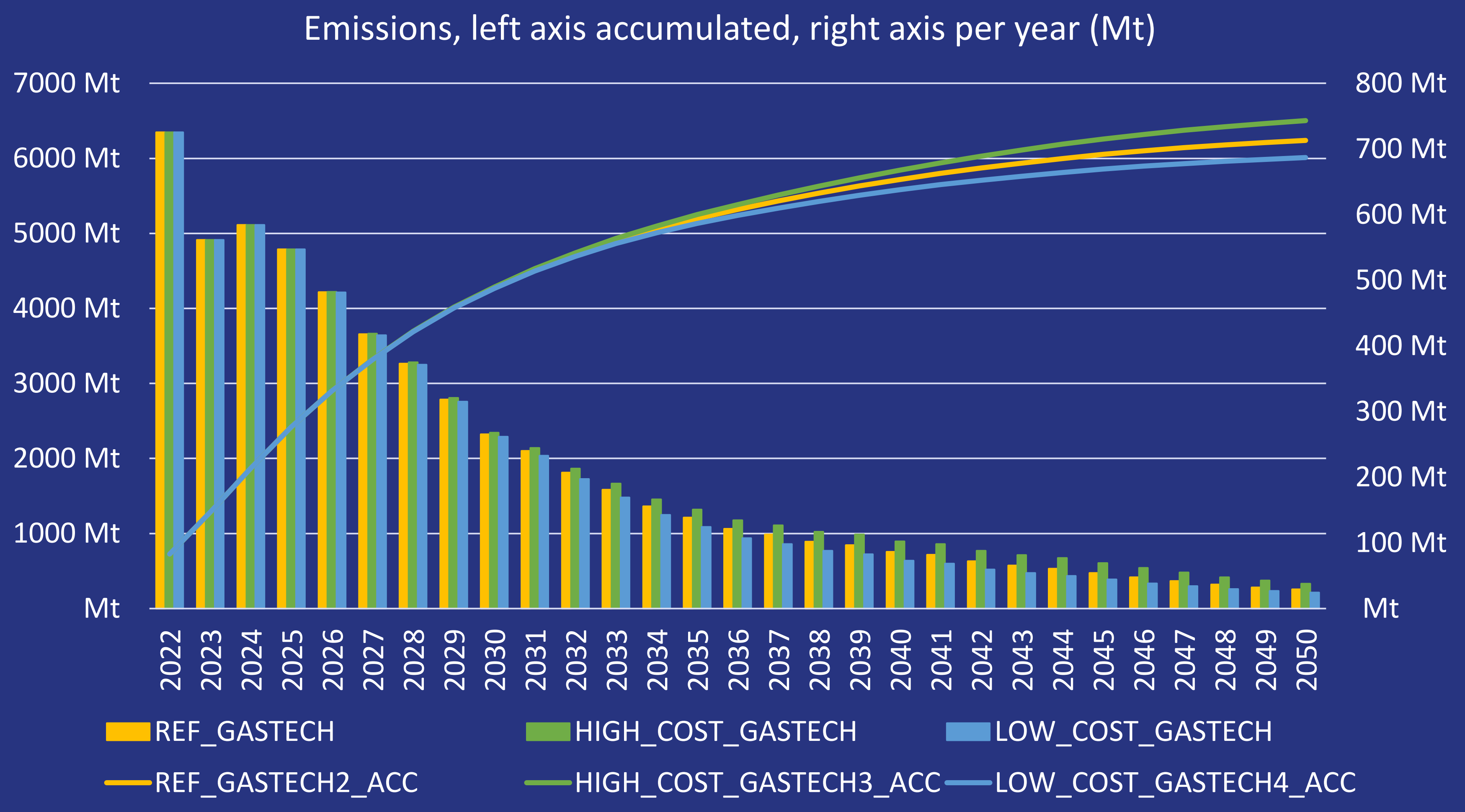


Low CAPEX for wind and solar will be key for a strong hydrogen economy



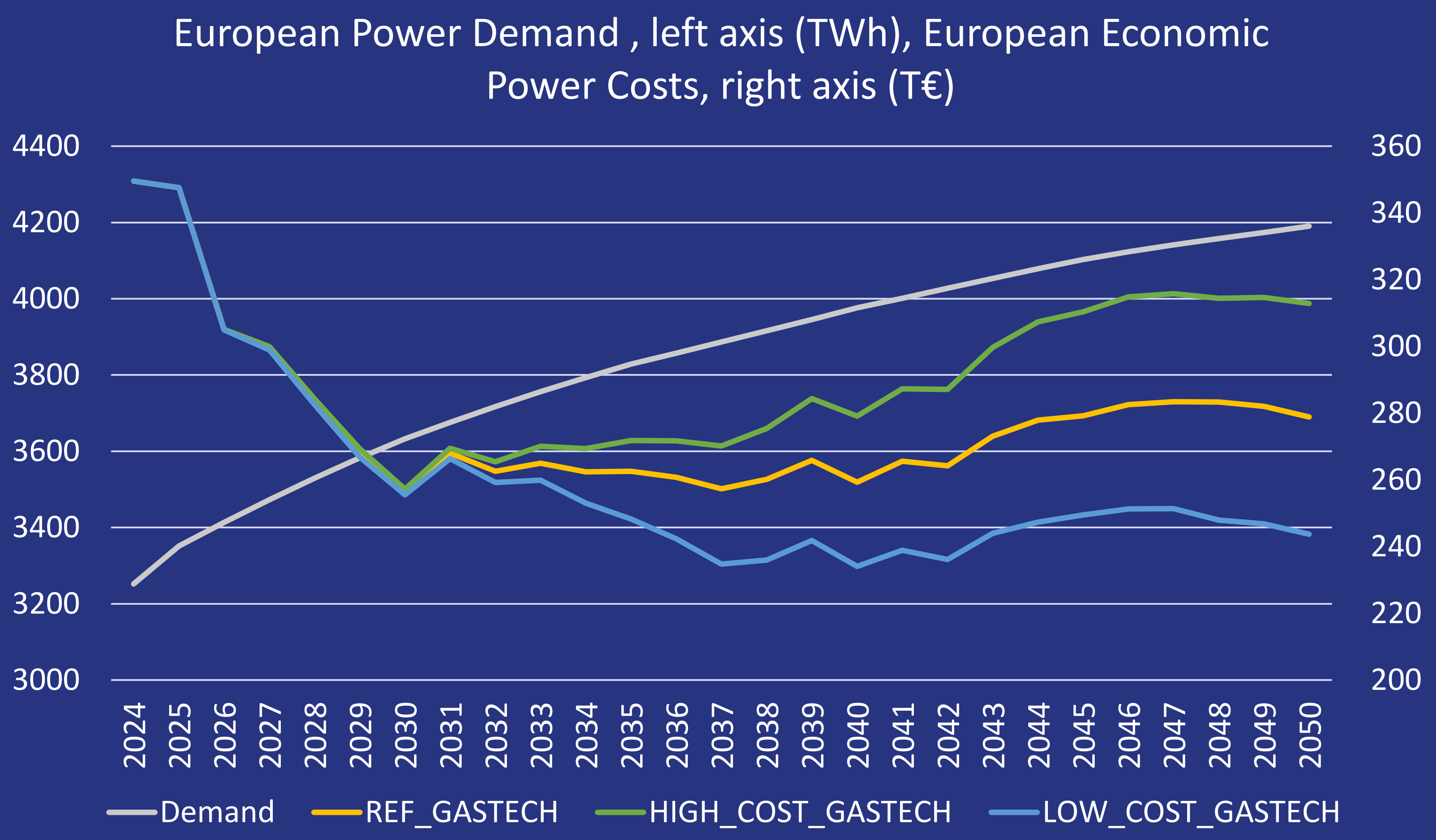
- CAPEX development of solar and wind is key for the European domestic hydrogen sector
- Cost for electricity more important than electrolysis CAPEX itself
- Hydrogen key to enable more renewables, low cost renewables key for hydrogen

Overall European power sector emission - impact less than 260 Mt



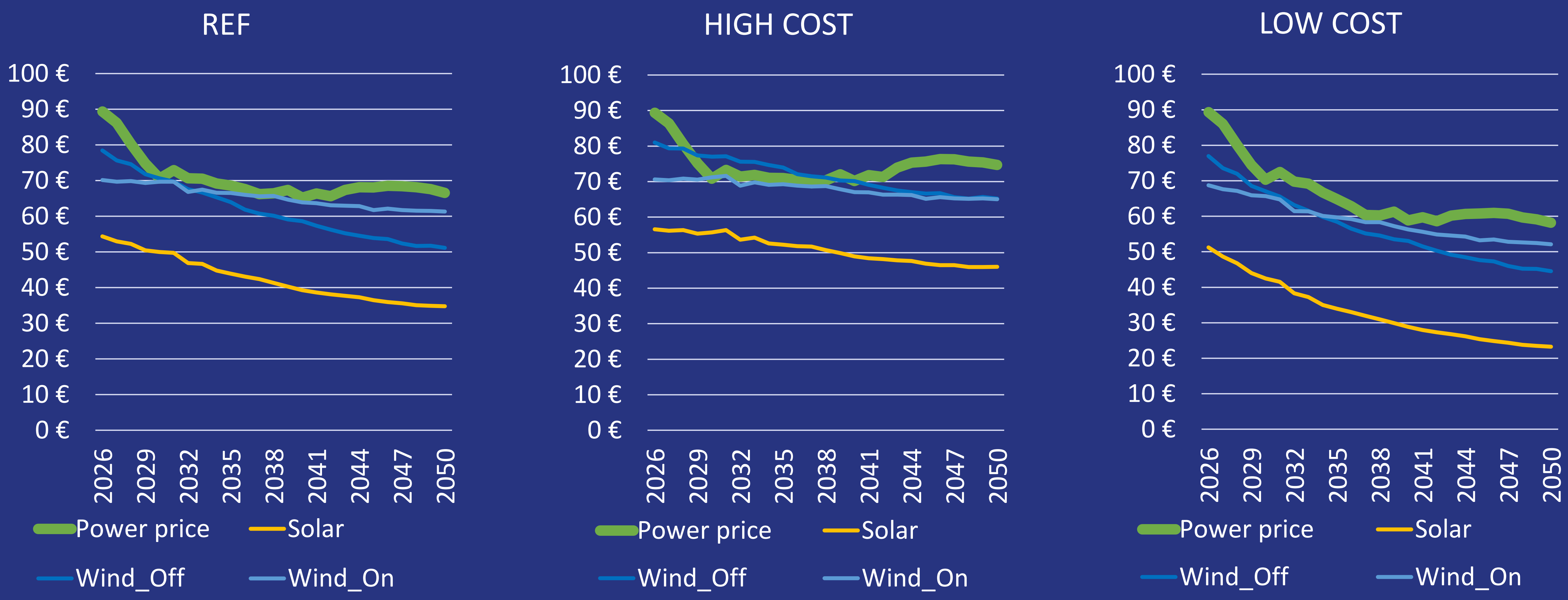
- Due to the massive installations and cost declines of renewables, power sector emissions show a strong downward trend.
- Even disruptions in the learning curves and higher installation costs can neither stop the trend nor delay it significantly in comparison the the overall

Higher Material Costs will cost Europe up to €35 billion/yr (about 0.23% of GDP)



- Overall European electricity supply costs will decrease although demand will grow
- Europe to spend about 2.33% of its GDP on electricity in 2024
- This will go down to 1.86% in 2050
- Even in a high costs scenario, the costs will be significantly lower as today

LCOE of new installations vs forecasted power price



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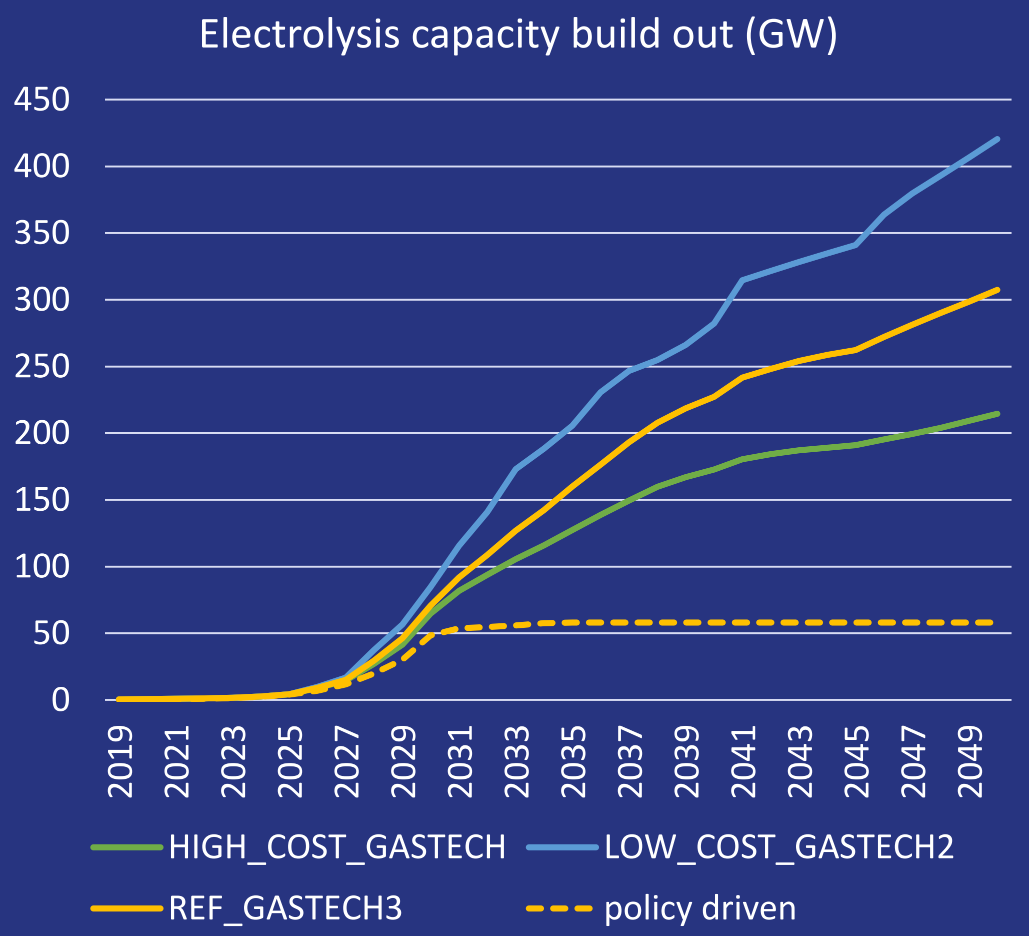
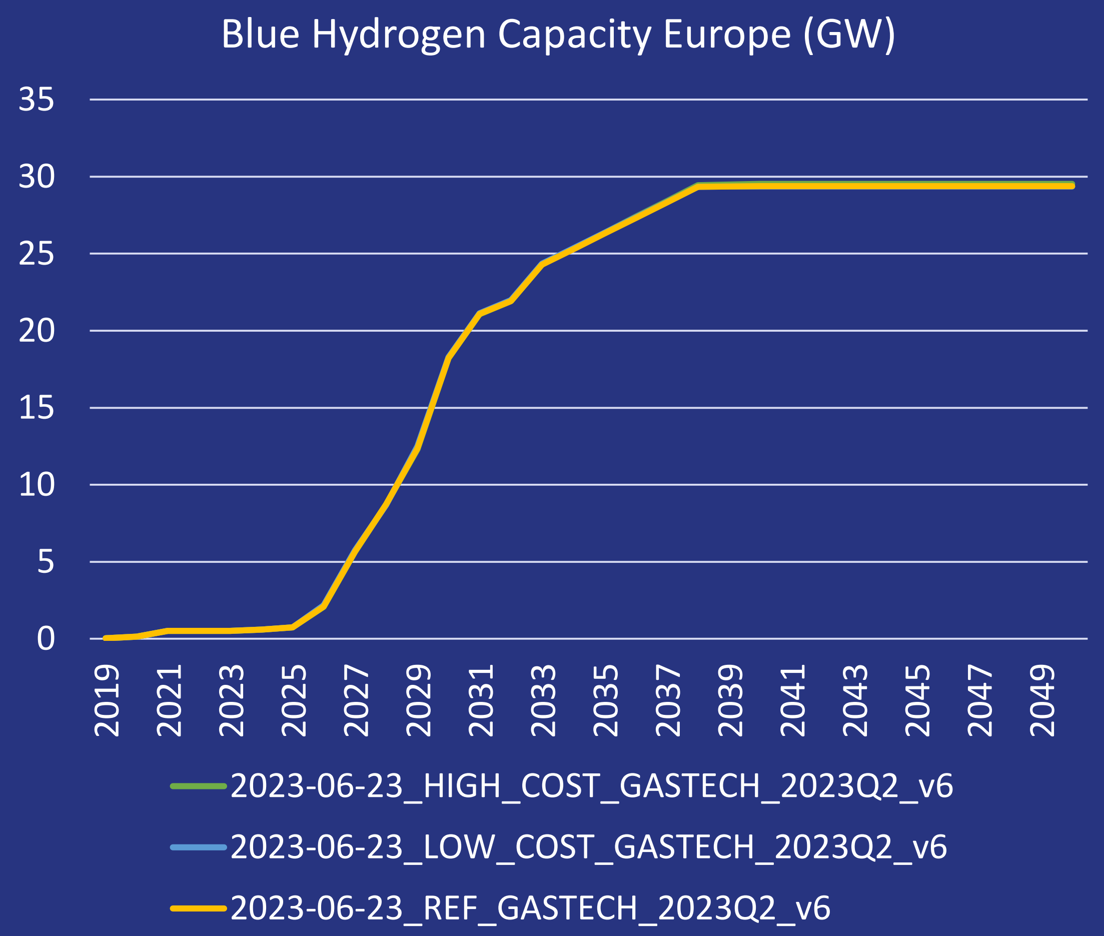
At least factor 10 between electrolysis and blue hydrogen capacity – regulatory framework unclear





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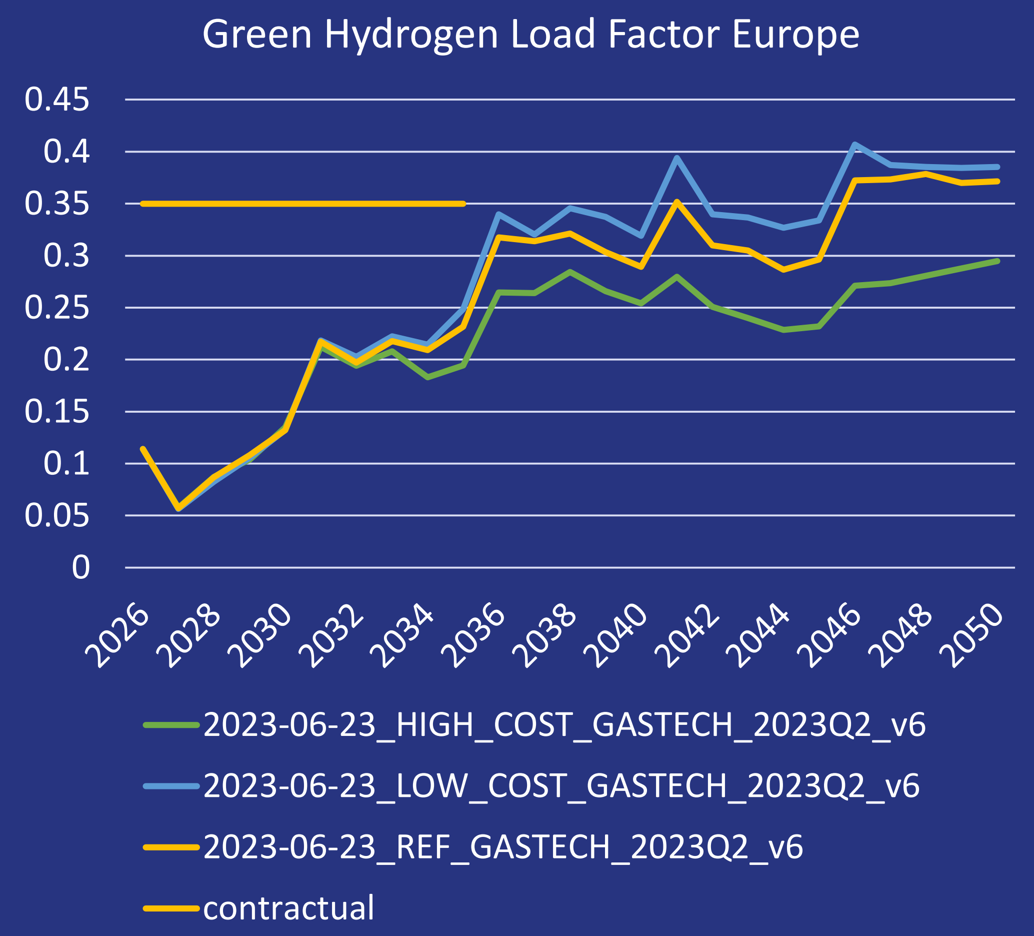
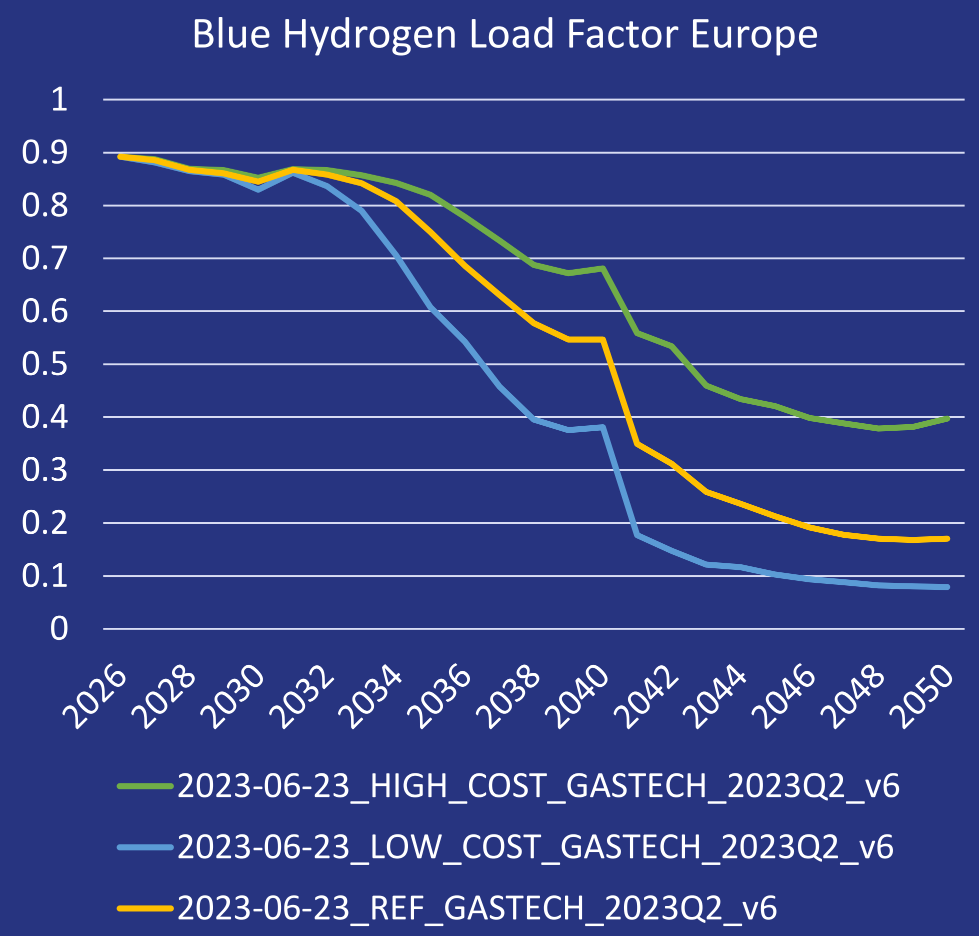
Utilization of green and blue capacities vs currently contracted projects





Conclusion

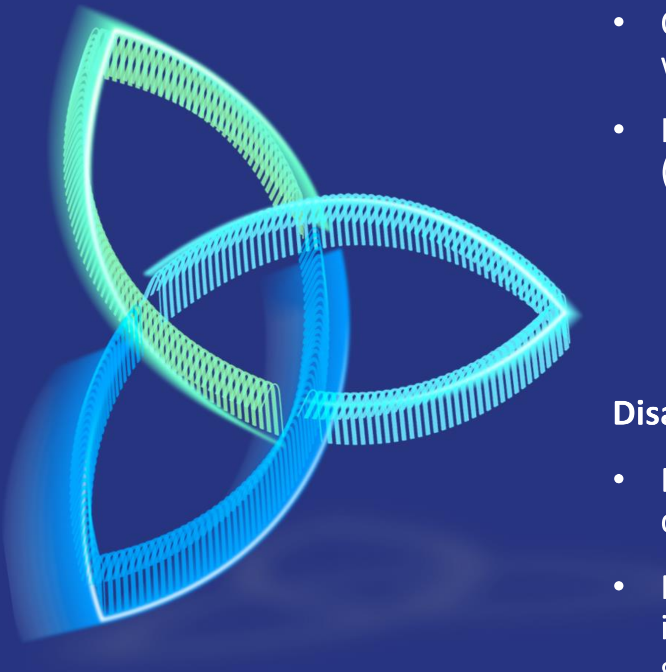
Hydrogen - The missing piece to reach net zero emission targets

Decarbonization of Power

- +1,400 GW (+116%) additional renewable capacity to 2050 in Europe
- +1,900 TWh (+63%) additional power demand for electrificaiton
- Power prices to decrease with CAPEX

Decarbonization of Hydrogen

- +700 TWh (+350%) additional hydrogen demand
- +250GW electrolysers capacity in Europe
- Blue Hydrogen mainly in UK and Netherlands
- Hydrogen prices to decrease with CAPEX



Advantages

- Resilience against fuel price changes
- CAPEX (raw material prices) changes with low impact
- Increased utilitsation of renewables (better load factors)

Disadvantages

- Electrolytic hydrogen expansive due to low full cycle efficiency
- Power and hydrogen infrastructure need to ramp up, gas infrastructure down
- Transport and stroage of power remains a challenge