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# Hydrogen Economy: Perspectives and Potentials


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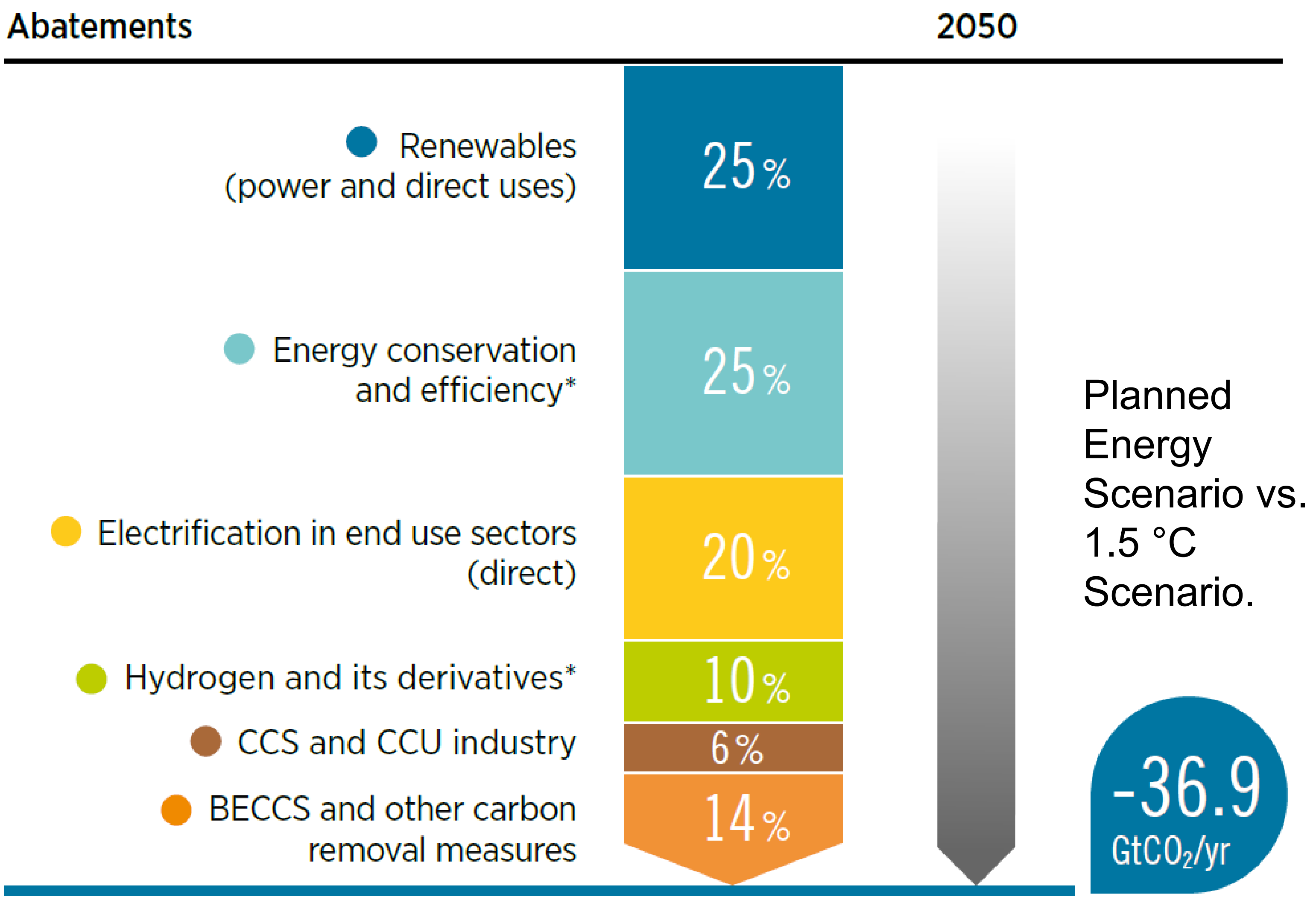
# Renewables will dominate the power generation mix




- Over 90% of the solutions shaping a successful outcome in 2050 **involve RE**
- The technological avenues dominated by solutions that **can be deployed** rapidly and at scale
- Hydrogen important to decarbonise, energy-intensive sectors
- Also to help **balance renewable electricity supply** and demand and provide **long-term seasonal storage**

# Renewables will dominate the power generation mix

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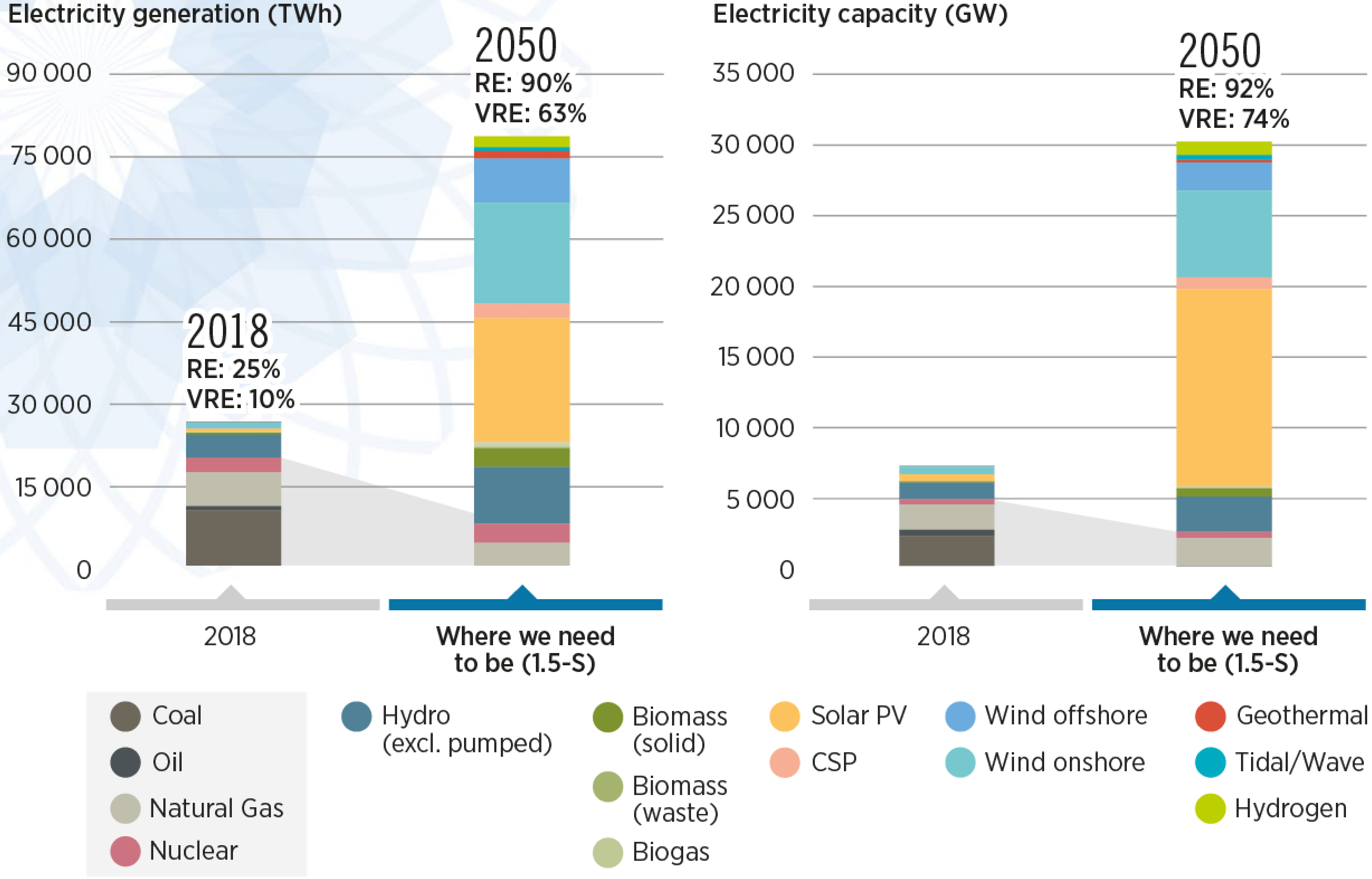
| Abatements | | Overview of policies to support energy transition by technological avenue | |
|---|---|---|---|
| Renewables (power and direct uses) | 25% | Deploy renewables in power and direct uses | • Regulatory measures that create a market for solutions<br>• Fiscal and financial incentives that make them more affordable<br>• The choice of instrument and its design should be context specific and consider broader policy objectives |
| Energy conservation and efficiency | 25% | Increase energy conservation and efficiency | • Energy efficiency policies (e.g. strict building codes, appliance standards) in buildings and industrial processes.<br>• Shift from energy-intensive modes to low-carbon modes in transport |
| Electrification in end use sectors (direct) | 20% | Electrify end uses | • Targets for renewable power should consider rising demand from electrification<br>• Policies and power system design to support electrification in achieving its potential for providing system flexibility |
| Hydrogen and its derivatives | 10% | Support green hydrogen | • Enabling policy framework with four key pillars: a national green hydrogen strategy, priority setting, guarantees of origin and enabling policies |
| CCS and CCU industry | 6% | Ensure the sustainable use of bioenergy | • Policies to address sustainability concerns |
| BECCS and other carbon removal measures | 14% | | |

- 12% of TFEC in 2050 to come from hydrogen and two-thirds of the total hydrogen will be green
- Some 5 000 GW of electrolyser capacity will be needed by 2050, up from 0.3 GW today

# Renewables will dominate the power generation mix




- By 2050, power generation triples compared to today's level,
- **Renewables supply 90%** of total electricity up from 25% in 2018.
- Solar and wind to lead the way
- Installed capacity of solar PV power would reach 14 000 GW.

Competitive RE electricity → Competitive electrolysers → Competitive green hydrogen

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## 10 years ago…


The Daily W

Sunday, August 30, 2010

**Renewables too expensive!**

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Competitive RE electricity → Competitive electrolysers → Competitive green hydrogen

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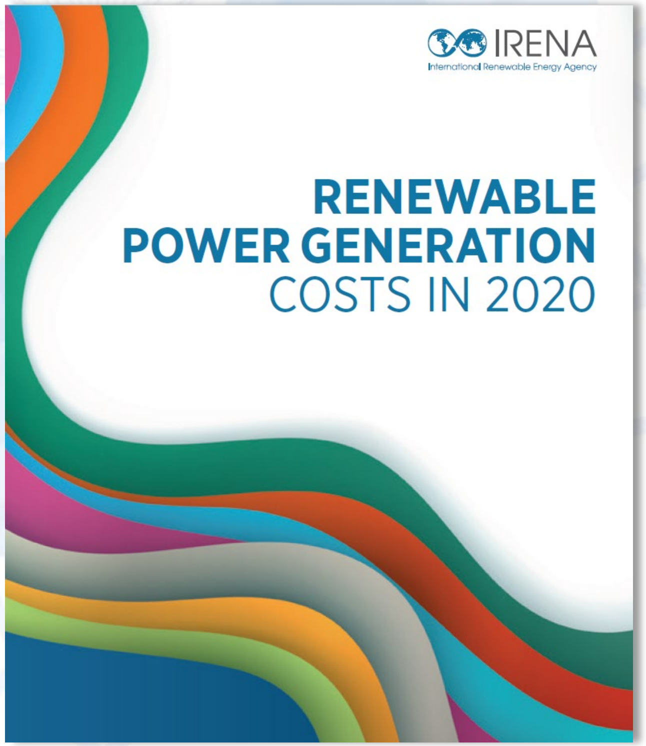
# RE power: A decade of declining costs




In most parts of world **RE least-cost source** of new electricity:

- 62% of utility-scale capacity added in 2020 cost less than cheapest new coal option

Will **increasingly undercut** even operating costs of existing coal

Low-cost renewable electricity to be backbone of electricity system:

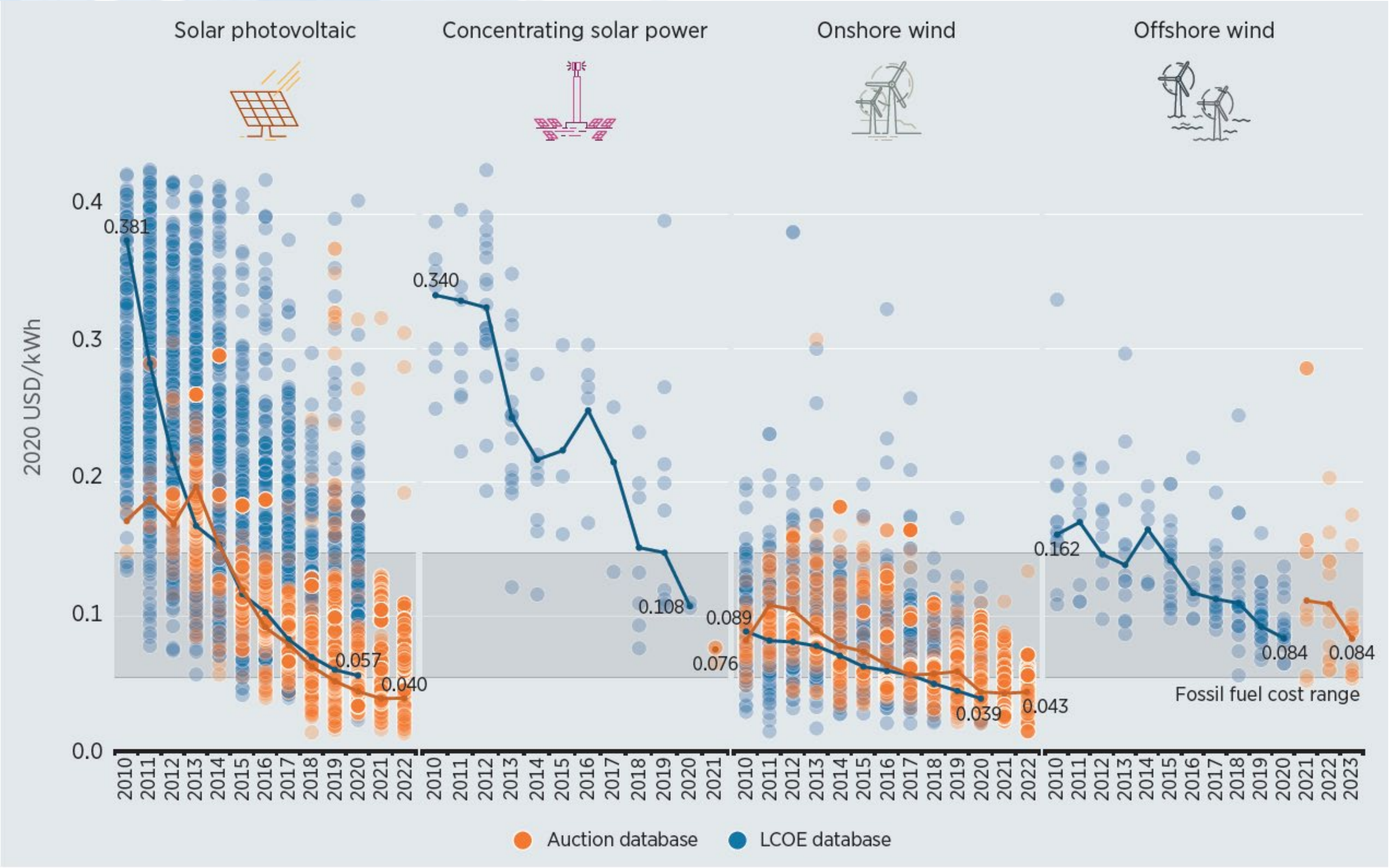
- But is also the key to decarbonising the wider energy system

# Today's strong business case for renewable power:
## Levelised Cost of Electricity Declines

| | 2019 - 2020 | 2010 - 2020 |
|---|---|---|
| **Solar PV** | **-7%** | **-85%** |
| **CSP*** | **-16%** | **-68%** |
| **Offshore wind** | **-9%** | **-48%** |
| **Onshore wind** | **-13%** | **-56%** |

Source: IRENA. Note CSP LCOE in 2019 excludes projects in Israel.

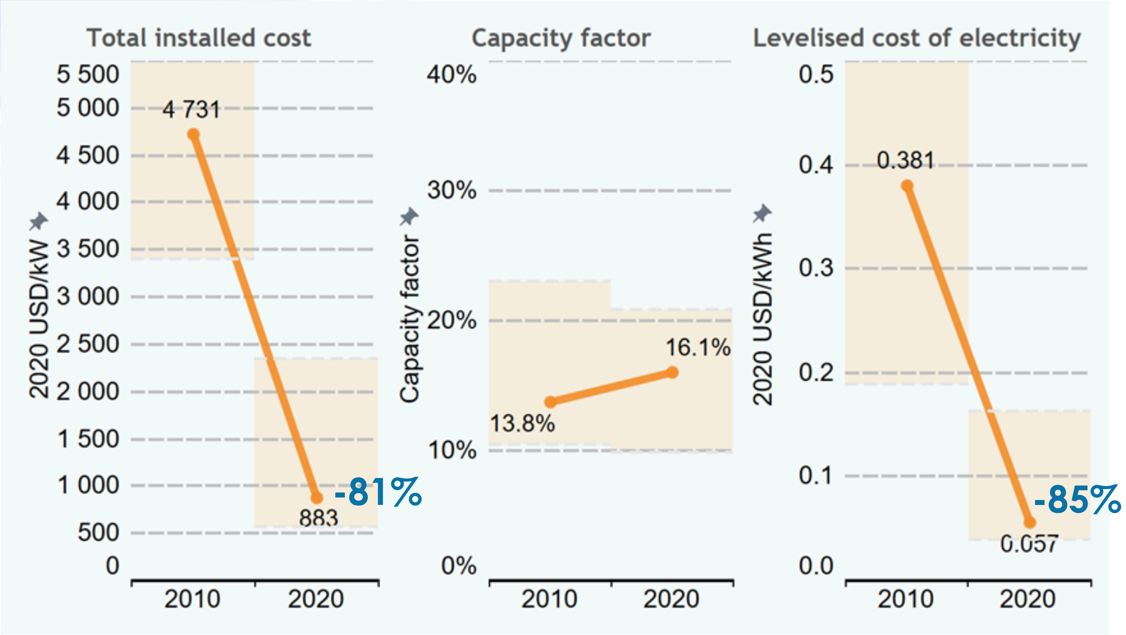
# Recent cost evolution




*Source: IRENA Renewable Cost and Auction and PPA Databases*

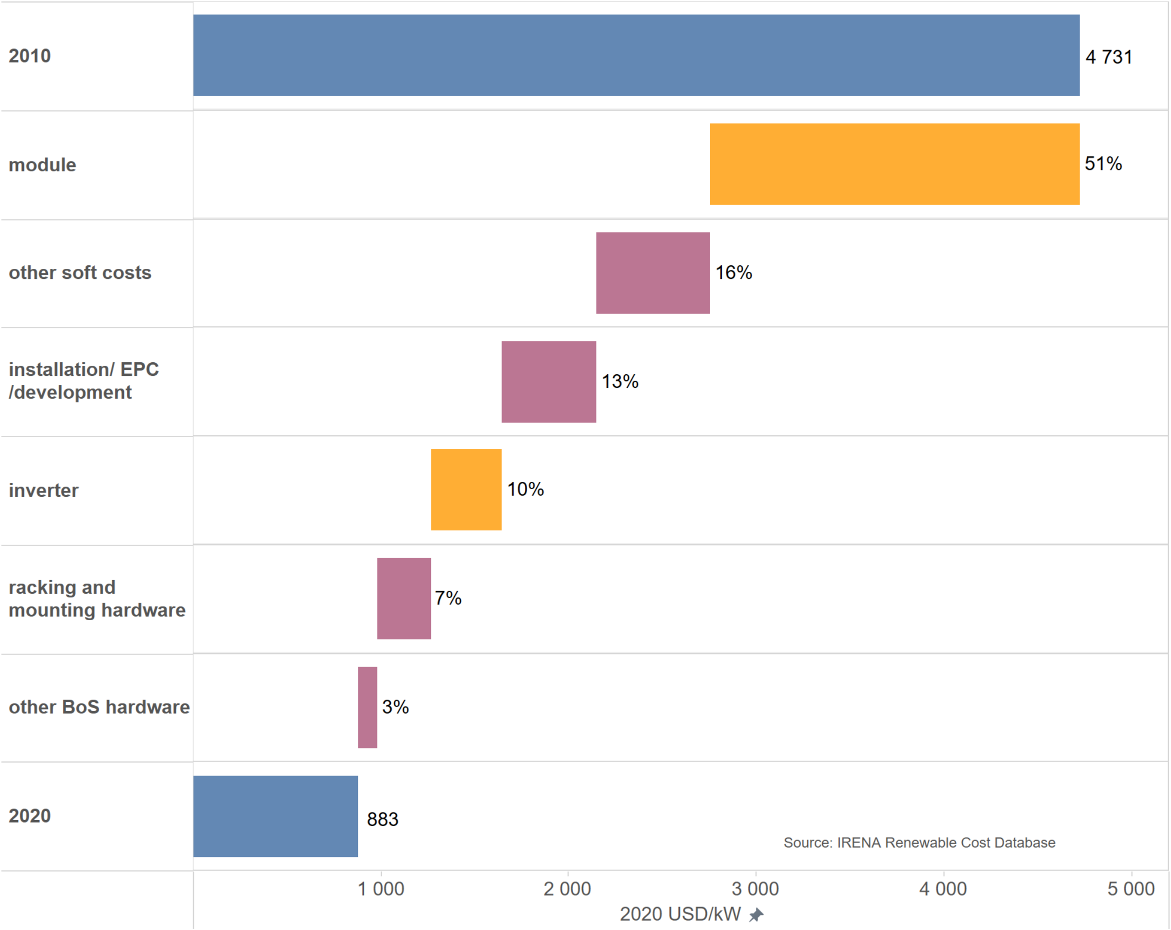
- Insights help identifying market direction and what is possible in best possible conditions
- Utility-scale solar PV projects – to be commissioned in **2022** – could have an **average** price of **USD 0.04/kWh**
- An **increasing number of projects** with very low electricity costs, at **below USD 0.03/kWh**
- LCOE learning rate of PV at 39% (2010-2021)

# Solar PV: key cost metric trends




- The w avg TIC in 2020 was **USD 883/kW** (13% lower than in 2019 and **81%** lower than in **2010**).
- CF: a shift to deployment in areas with **higher solar irradiation**, the increased use of **single-axis tracking** and technical improvements reducing system losses
- **Reduced land area** are required for the same project output. From 2.7 hectares/MW in 2010 to 1.9 hectares/MW in 2020

- Most TIC cost decline can be attributed to **module reductions**, though BoS also important/ policy relevant



# Levelised cost of electricity: on shore wind

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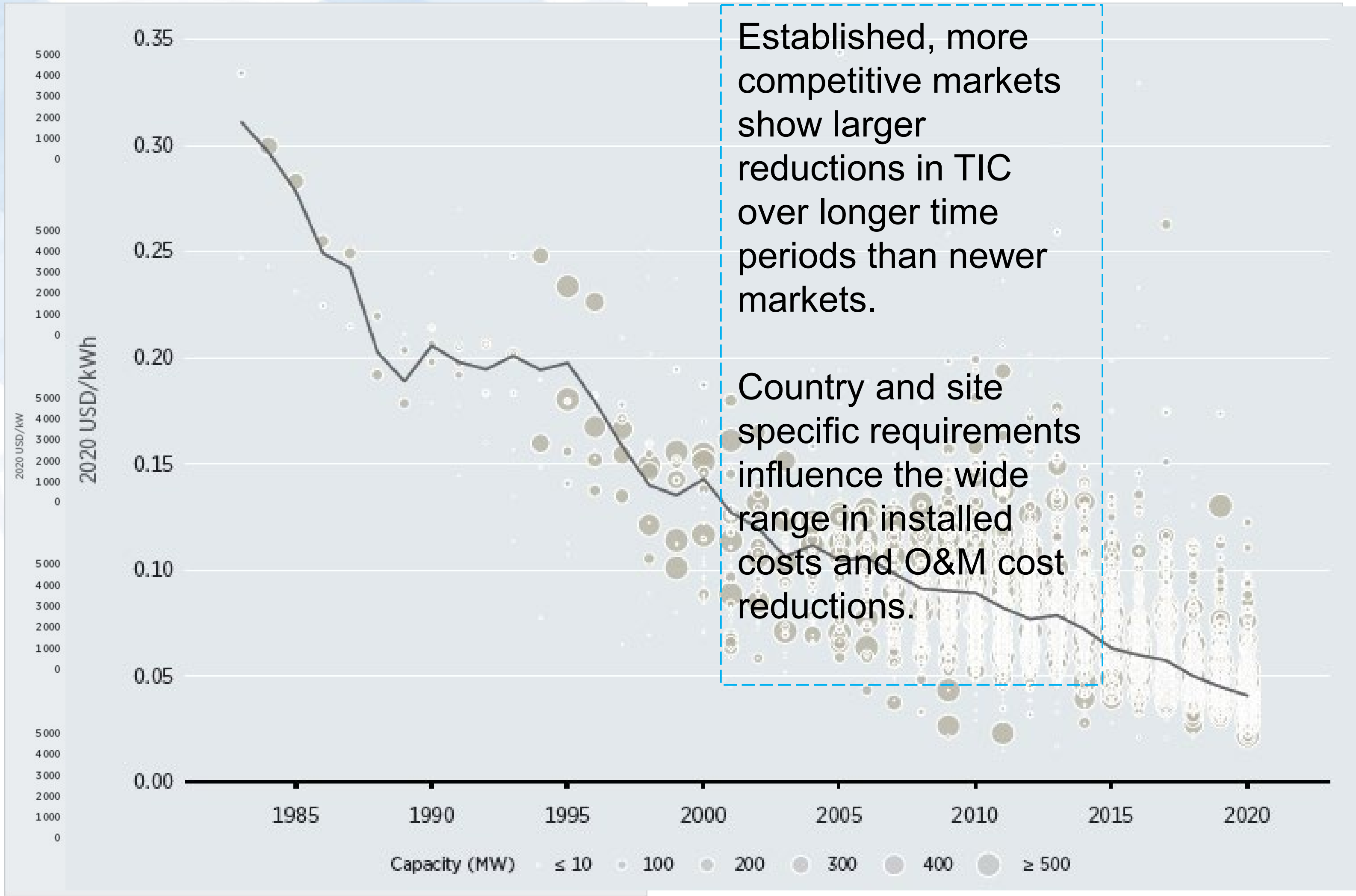
## Total installed costs

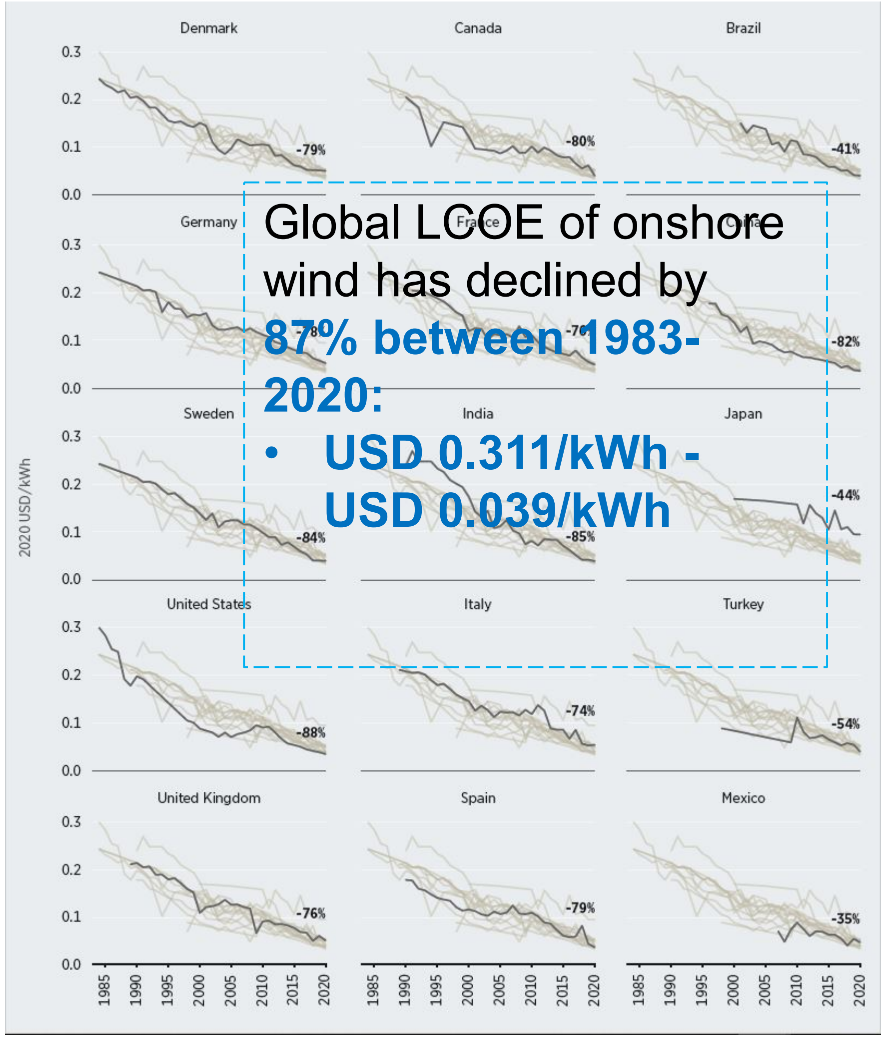
## Capacity factors




Established, more competitive markets show larger reductions in TIC over longer time periods than newer markets.

Country and site specific requirements influence the wide range in installed costs and O&M cost reductions.

## LCOE

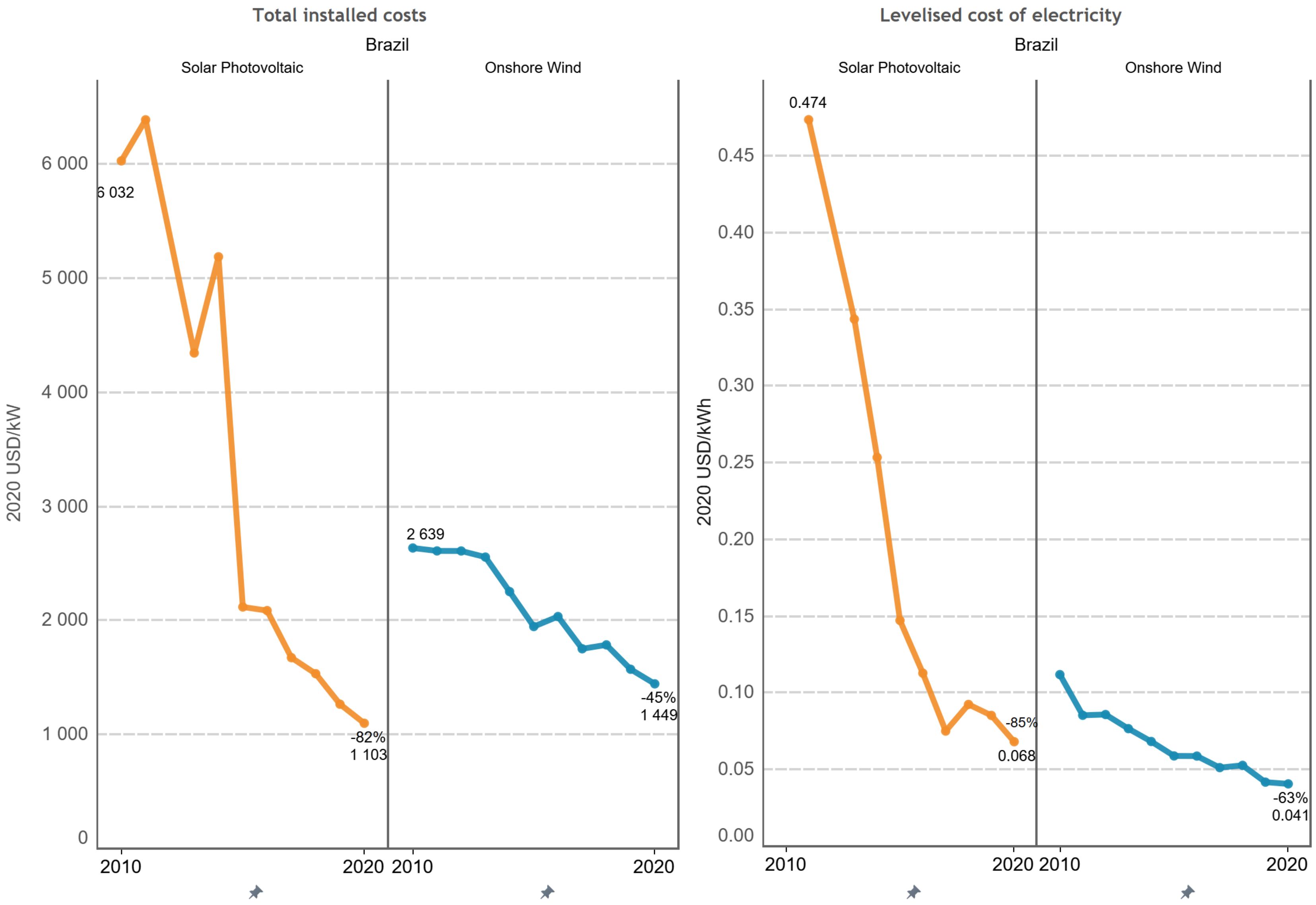



Global LCOE of onshore wind has declined by **87% between 1983-2020:**

- **USD 0.311/kWh - USD 0.039/kWh**

# Recent cost evolution

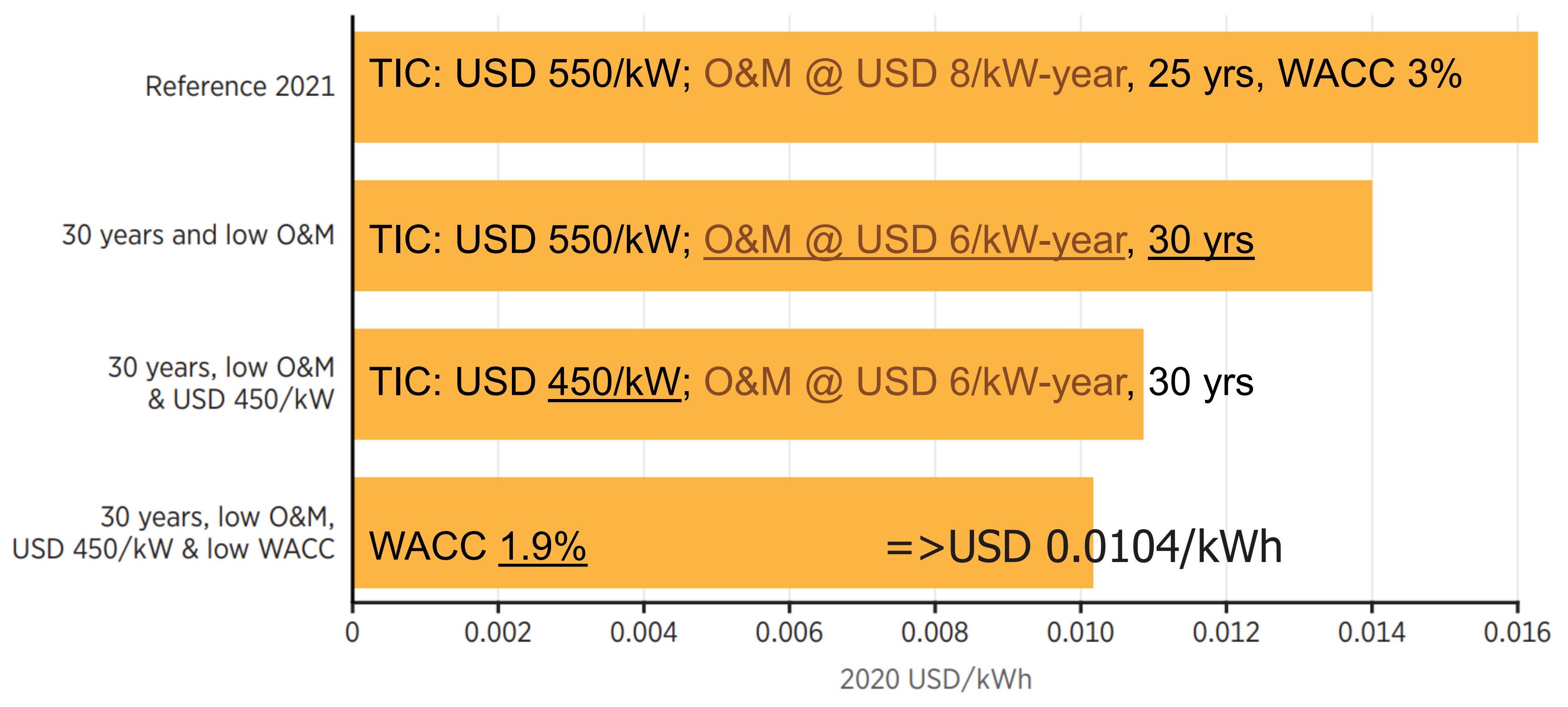
- Brazil has been no exception to the decline of renewable costs
- RE electricity now available in the range of USD 41-68/MWh
- But is this enough?



# Solar PV below 2 U.S. cent per kWh?

## If everything is at its 'best' it may actually be possible....

Scenarios for utility-scale solar PV LCOE under different input assumptions in Saudi Arabia




*Source: IRENA Renewable Cost Database*

- How realistic is it? Surprisingly, it looks possible:
- USD 450/kW, 30 year life, low O&M costs and 1.9% real WACC. Bifacial single-axis tracking CF = 28%

- Competitive O&M structures:
  - increasing use of large amounts of data for preventative O&M
  - use of drones for inspection
  - automated cleaning

Competitive RE electricity → Competitive electrolysers → Competitive green hydrogen

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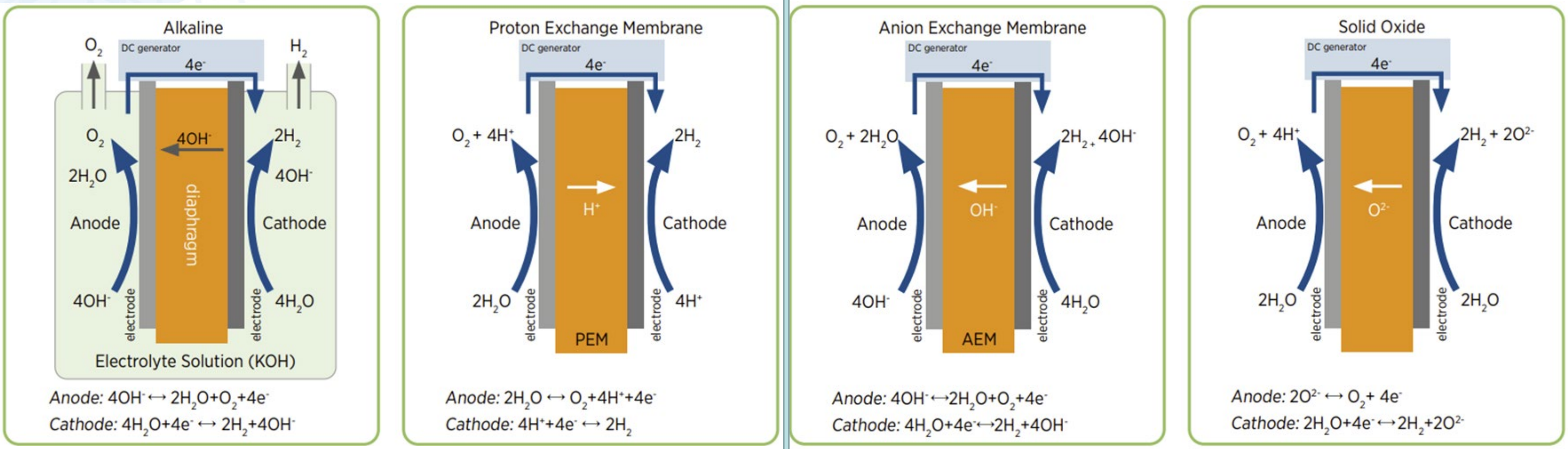
# There are four electrolyser technologies




TRL 8-9 | TRL 8-9 | TRL 2-3 | TRL 5-6

**Two technologies are ready for commercial deployment and two other technologies have promising performance but have a lower technological development**

# Hydrogen electrolysers

**-60%** Reduction in Alkaline electrolyser costs (2005-20)

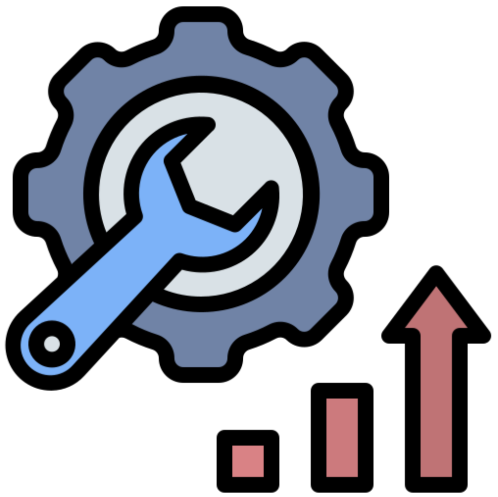
## COSTS

**-67%** Reduction in PEM electrolyser costs (2005-20)

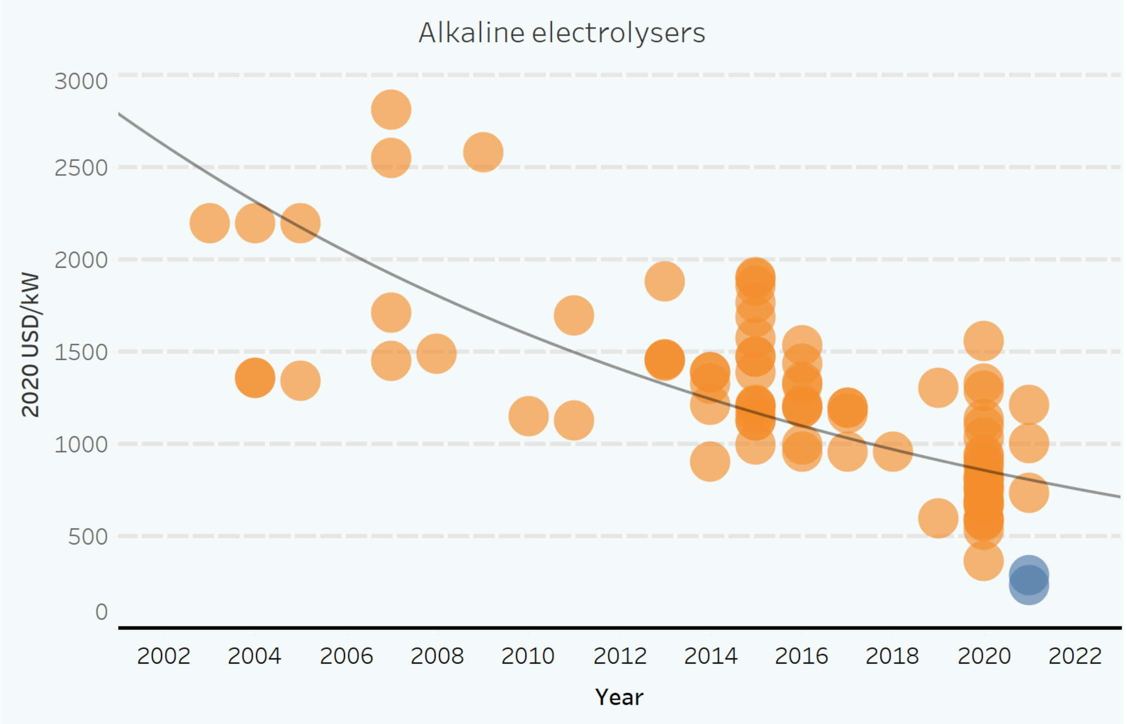
Alkaline electricity consumption **52 kWh/kg $H_2$**

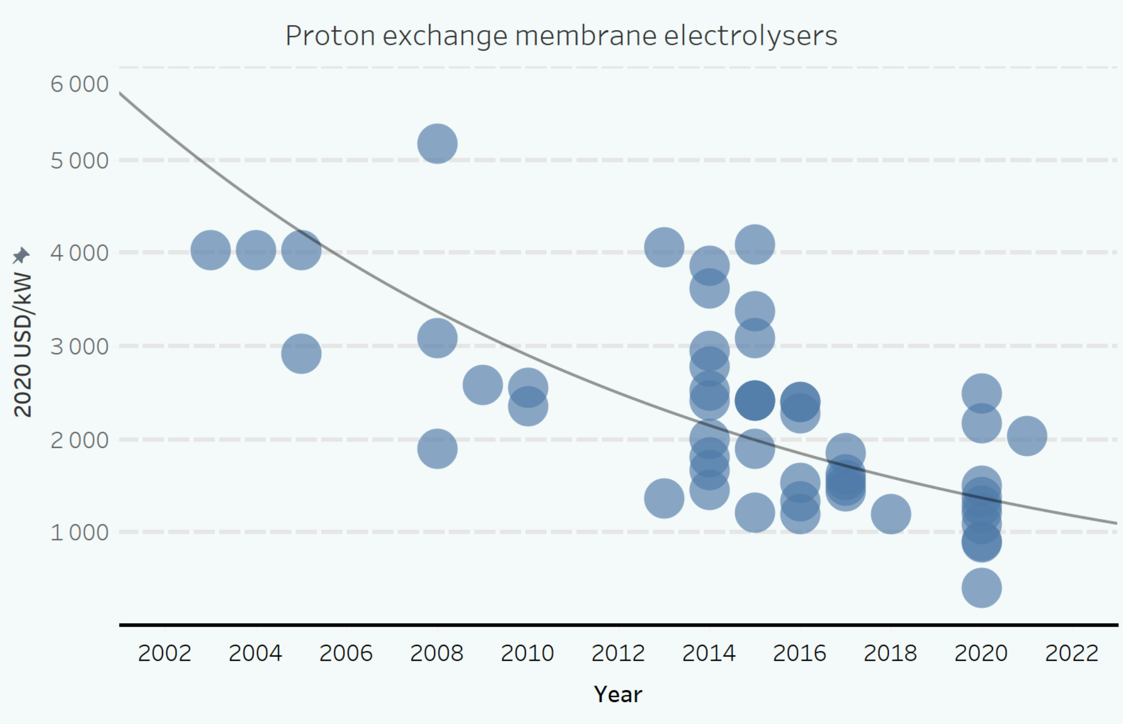
PEM electricity consumption **54 kWh/kg $H_2$**

## PERFORMANCE



# Hydrogen electrolysers: costs have fallen through time




**AEL electrolyser costs** have fallen through time, from between USD 1 340 to 2 190/kW between 2003 and 2005, to between **USD 350 to USD 1 660/kW in 2020**.

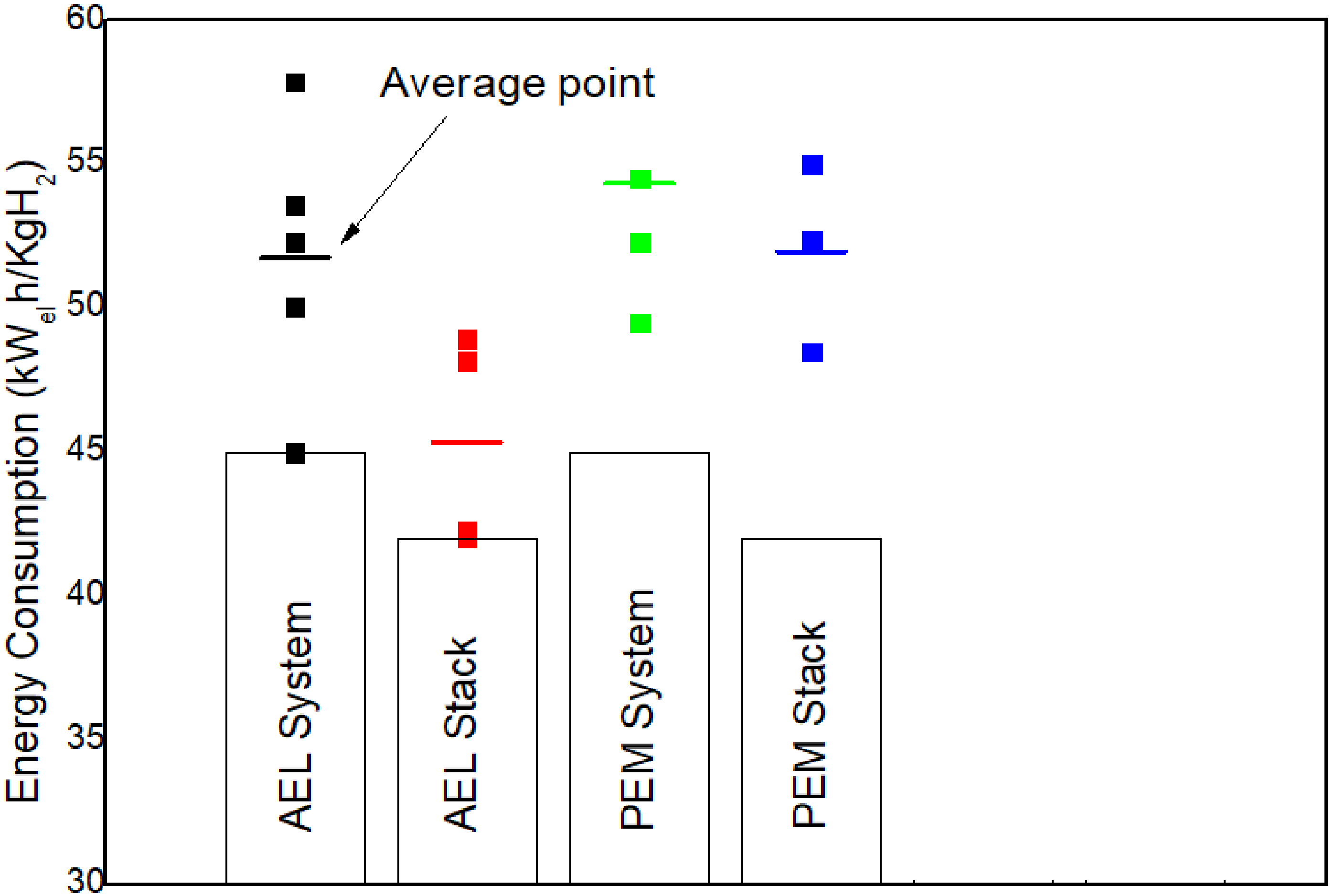
The trendline suggests a reduction in costs of 61% between 2005 and 2020. A number of very low EPC quotes have been seen in China (blue dots), but may not have the same boundary conditions as elsewhere.

**PEM electrolysers cost** between USD 2 920 and 7 450/kW between 2003 and 2005, falling to between **USD 400 to USD 2 494/kW in 2020.**

The higher costs for PEM, relate to a lack of economies of scale in manufacture and a more expensive bill of materials than AEL systems (e.g., including iridium and platinum). The harsh oxidative environment also necessitates a range of costly solutions to ensure optimal electron conductivity and cell efficiency.

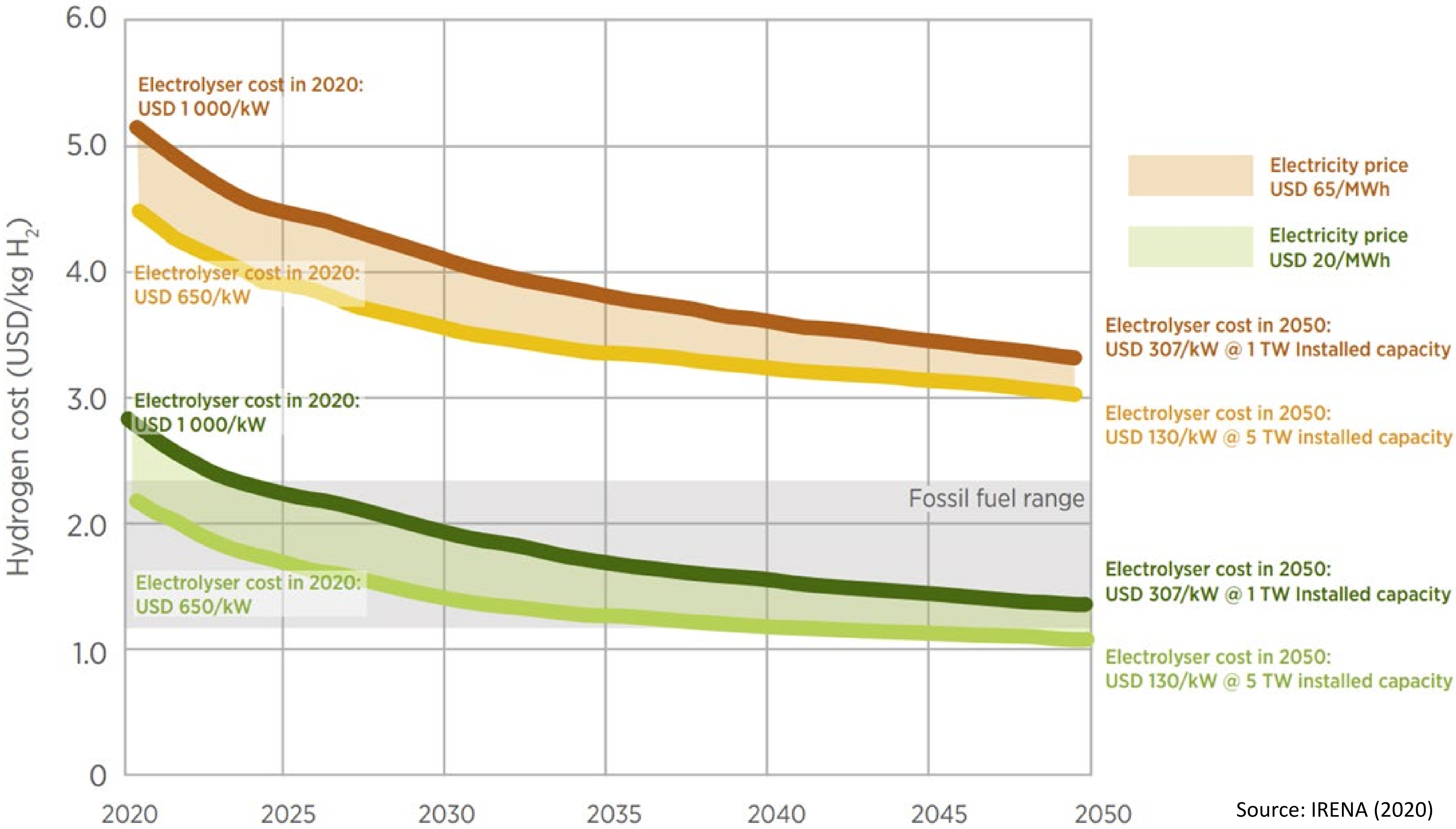
# Hydrogen electrolysers: performance improving

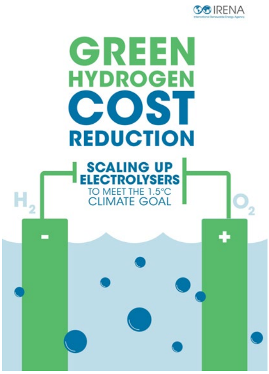
- Today's average technology solution for AEL systems is around 52 kWh/kg $H_2$ , but with a wide range
- AEL efficiency difference from stack to system is pronounced given more complex system components
- PEM systems tend to be much simpler, and that explains the smaller efficiency gap between system and stack



Bars are the targets from IRENA 2021 Report for 2050

Competitive RE electricity → Competitive electrolysers → Competitive green hydrogen




Source: IRENA (2020)

# How to reduce electrolyser costs

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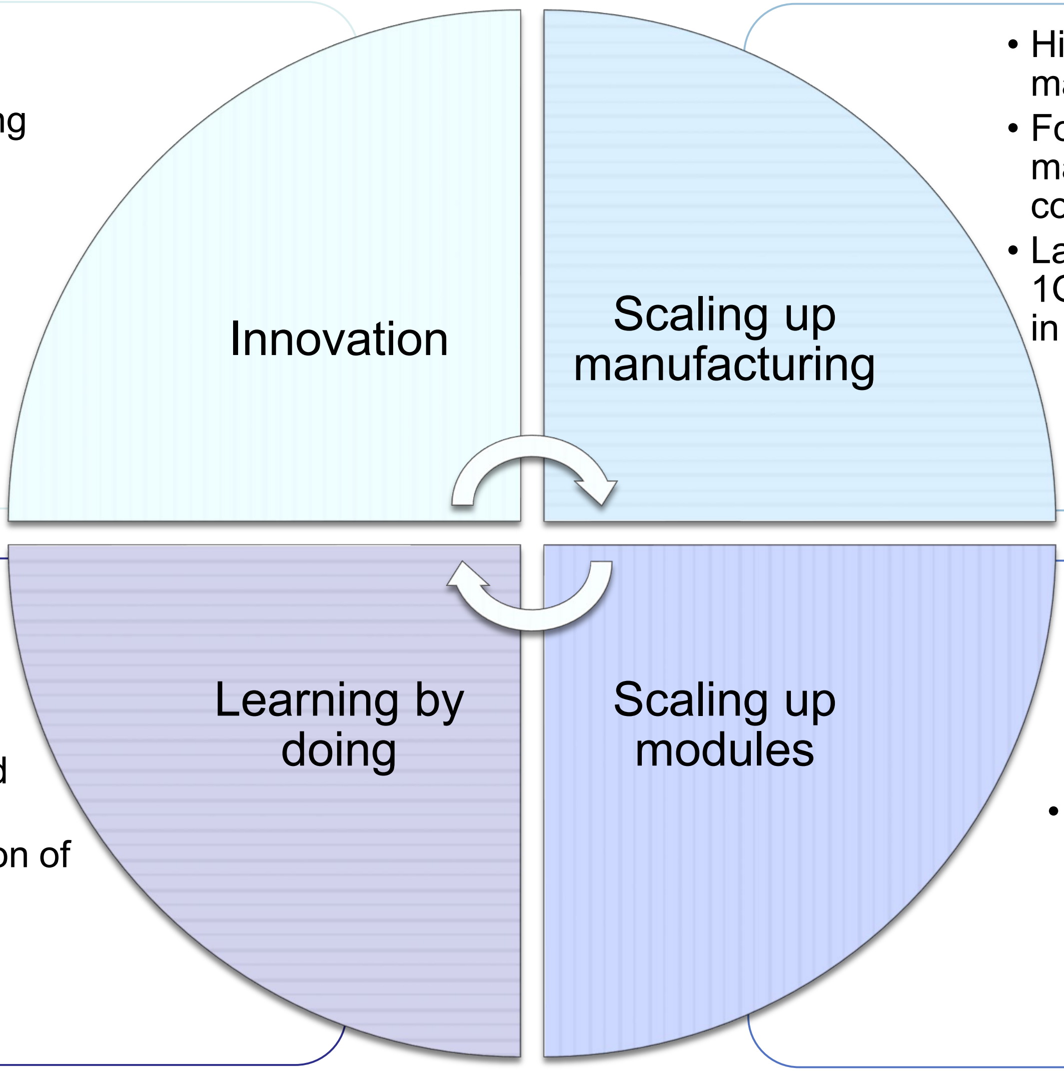
- Reduce cost with standardization and simplifying manufacturing and design
- Improve efficiency
- Increase durability



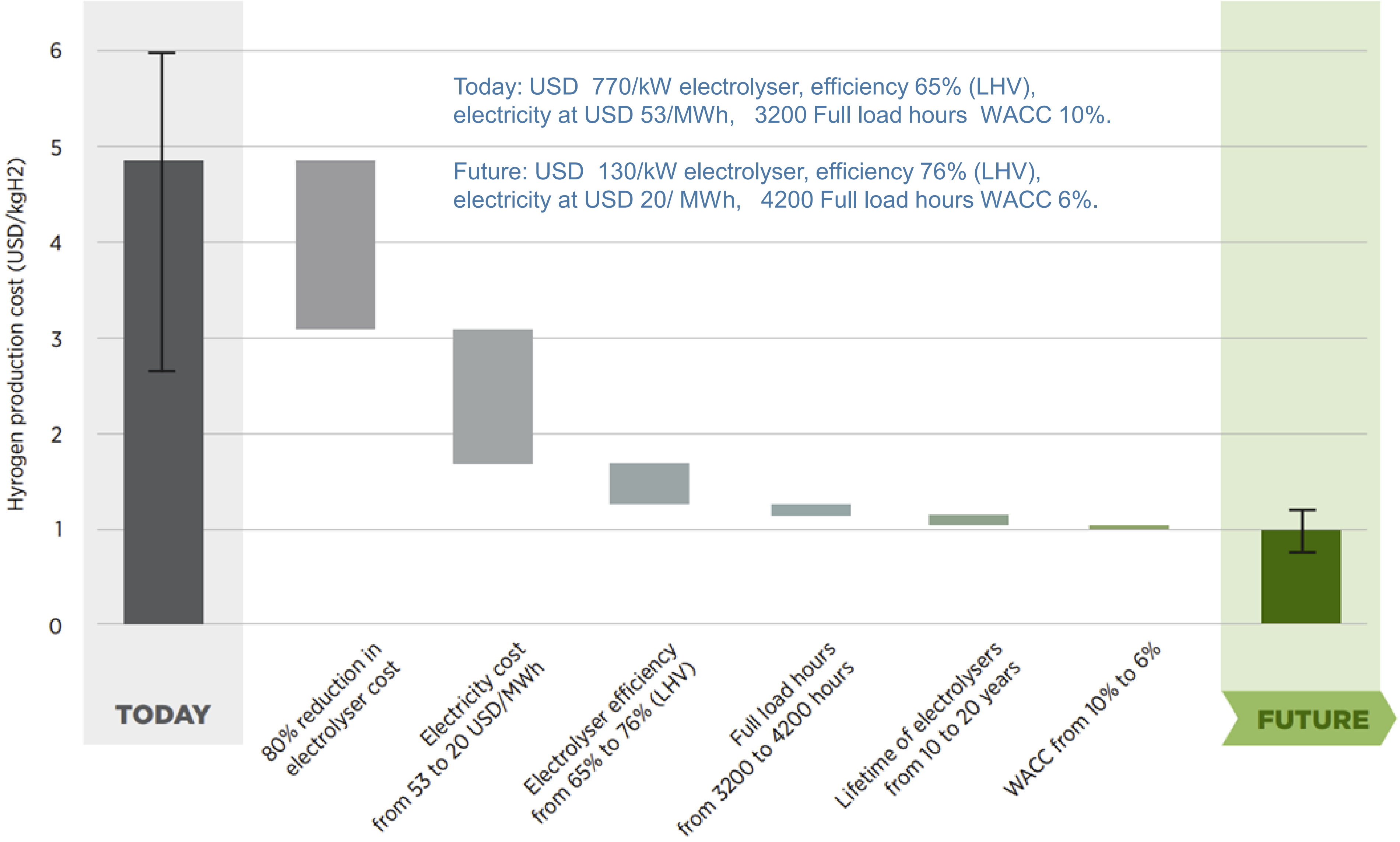

- High throughput, automated manufacturing operation
- For PEM roll-to-roll manufacturing of catalyst coated membrane
- Large players reaching 1GW/yr + (60-70% reduction in stack costs…)

- Standardisation
- Applying lessons learned from deployment
- Optimization of installation of equipment (execution of multiple projects)

- Large manufacturing volumes improve utilization
- Unlock automatic assembly
- Advanced coating technologies (PEM), roll-to-roll
- Faster higher throughput

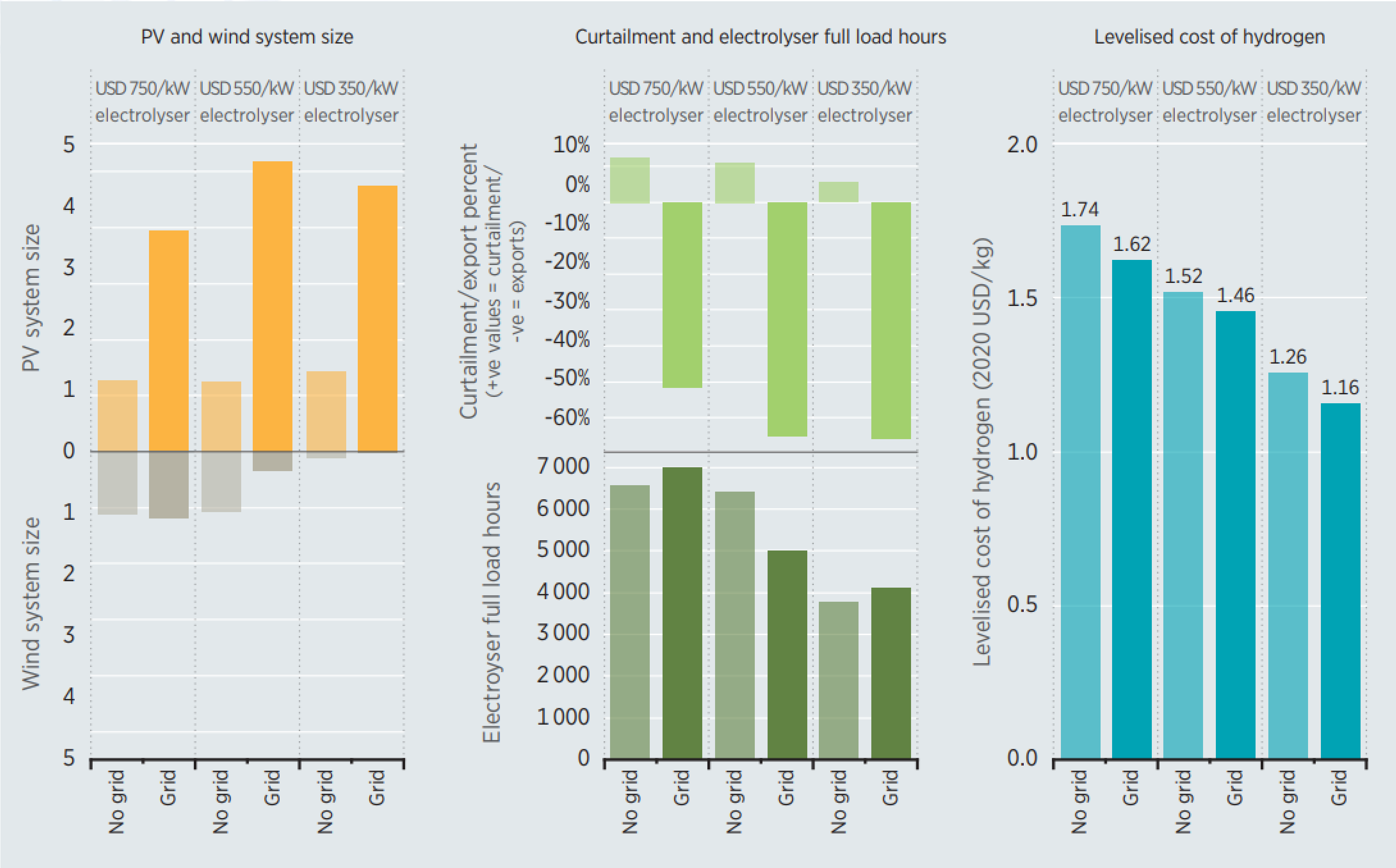
# Hydrogen electrolysers: strategies for cost reduction

- Reduction in **electrolyzer cost** and **lower electricity price** represents the bulk of total cost reduction to reach the 2 USD/kg mark



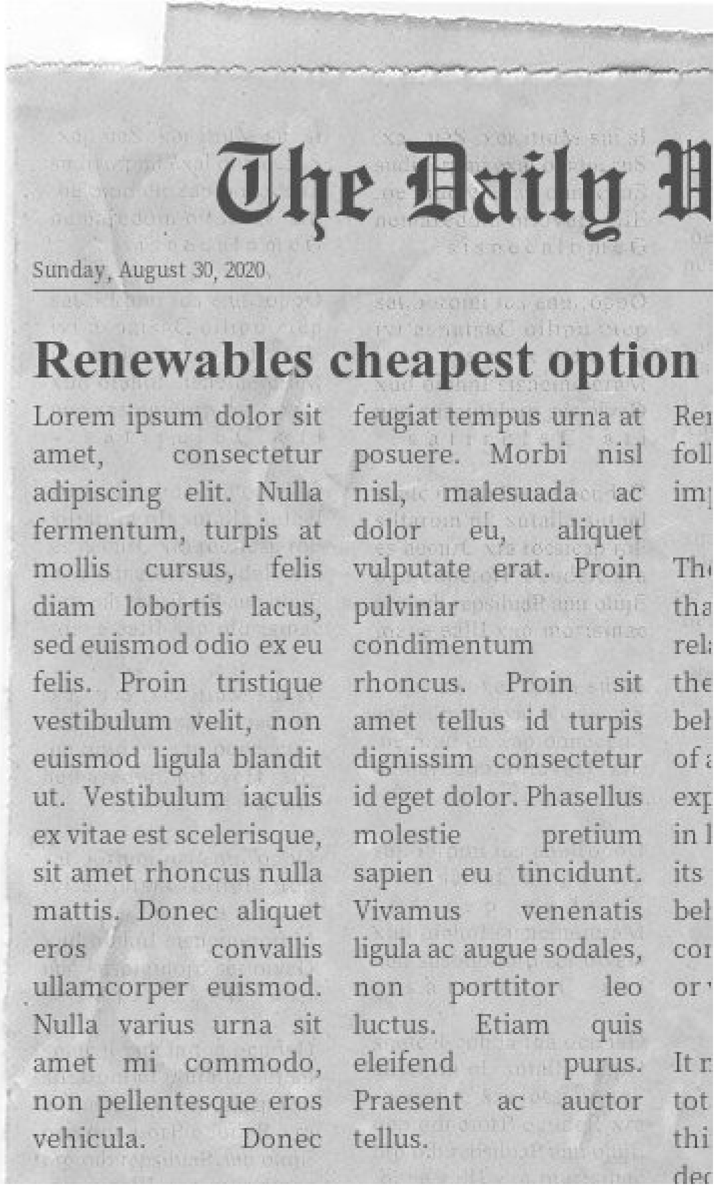
# Is low-cost renewable hydrogen possible today?

## Very low-cost electricity makes a lot of things possible….




- In Saudi Arabia in 2022 there will be low-cost PV and onshore wind
- USD 750/kW for alkaline electrolyser,15 year or 80k hours stack life, 3% OPEX and same WACC as the PV
- USD ~1.62-1.74/kg H2 in 2022

## Good news!



The Daily

Sunday, August 30, 2020

Renewables cheapest option

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# Key messages

- Low-cost renewable electricity to be backbone of electricity system
- Low cost renewable electricity is a prerequisite to produce competitive green hydrogen but not enough
- Reductions in the cost of electrolysis facilities are also needed.
- They will decline from 40% in the short term to 80% in the long term.
- They will mainly come from:
  - Innovation leading to improved electrolyser design and construction
  - Economies of scale
  - Learning by doing (project experience).
- Governments can support innovation in electrolysers by issuing clear long-term signals

# Renewables are increasingly competitive

## The winners are customers, the environment and our future

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