

# Renewable Power Generation Costs in 2020: Cost Declines and Record Capacity Additions

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# Renewable Power Generation Costs in 2020

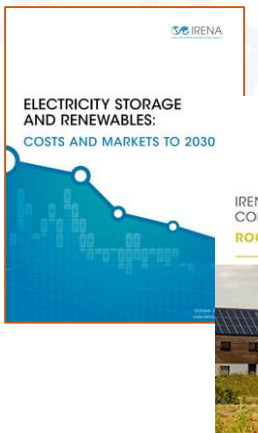
Michael Taylor, Pablo Ralon and Sonia Al-Zoghoul

# IRENA Costing Analysis Products



**Michael Taylor**  
Senior Analyst,  
Renewable  
Cost Status and  
Outlook

2017



2017



**Pablo Ralon**  
Associate  
Programme  
Officer,  
Renewable  
Energy Cost  
Status and  
Outlook

2018



**Sonia Al-Zoghoul**  
Associate  
Professional,  
Renewable Cost  
Status and  
Outlook

2019

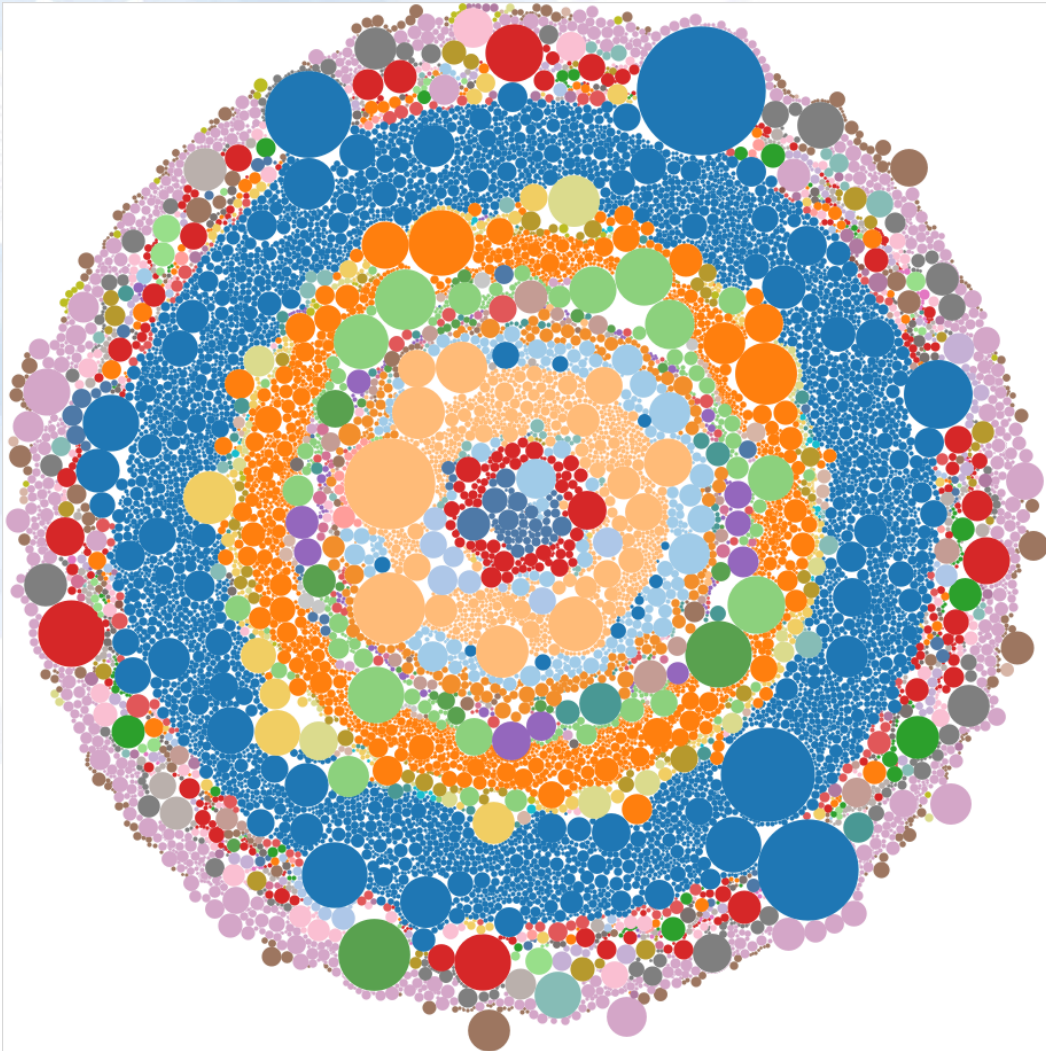


2016

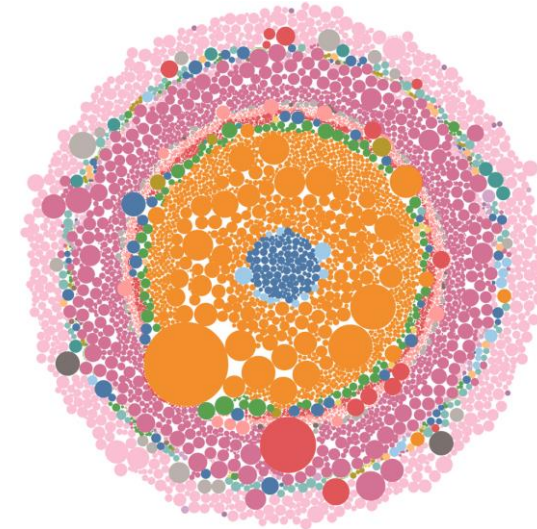


2020

# Power generation and PPA/tender databases



Project cost database  
~20k projects  
1982 GW



PPA/Auction database  
~13k projects  
583 GW



# What's new in the 2020 report

New WACC assumptions

Solar thermal heat for commercial/industrial use

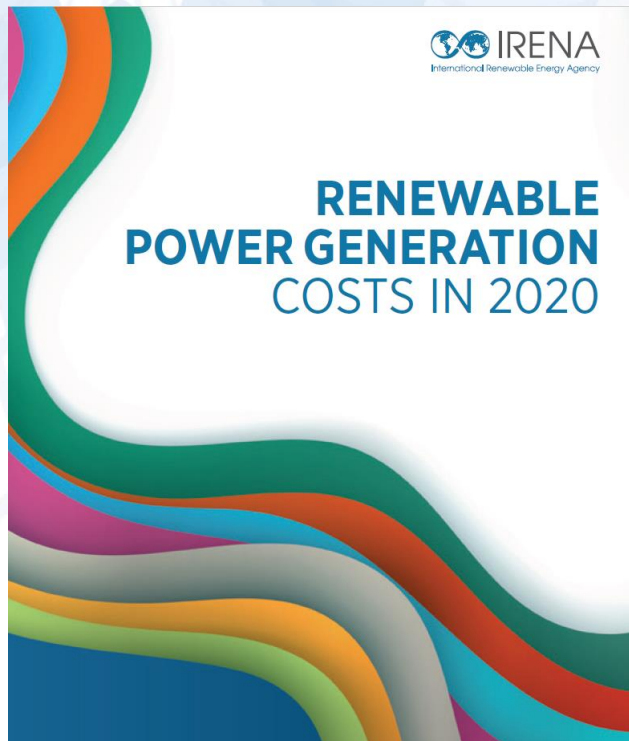
Some new cost/performance metrics for power gen

Behind-the-meter battery storage costs

Hybrid solar PV/storage pricing vs CSP

Snapshot: Low-cost renewable hydrogen today?

# RE power: A decade of declining



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

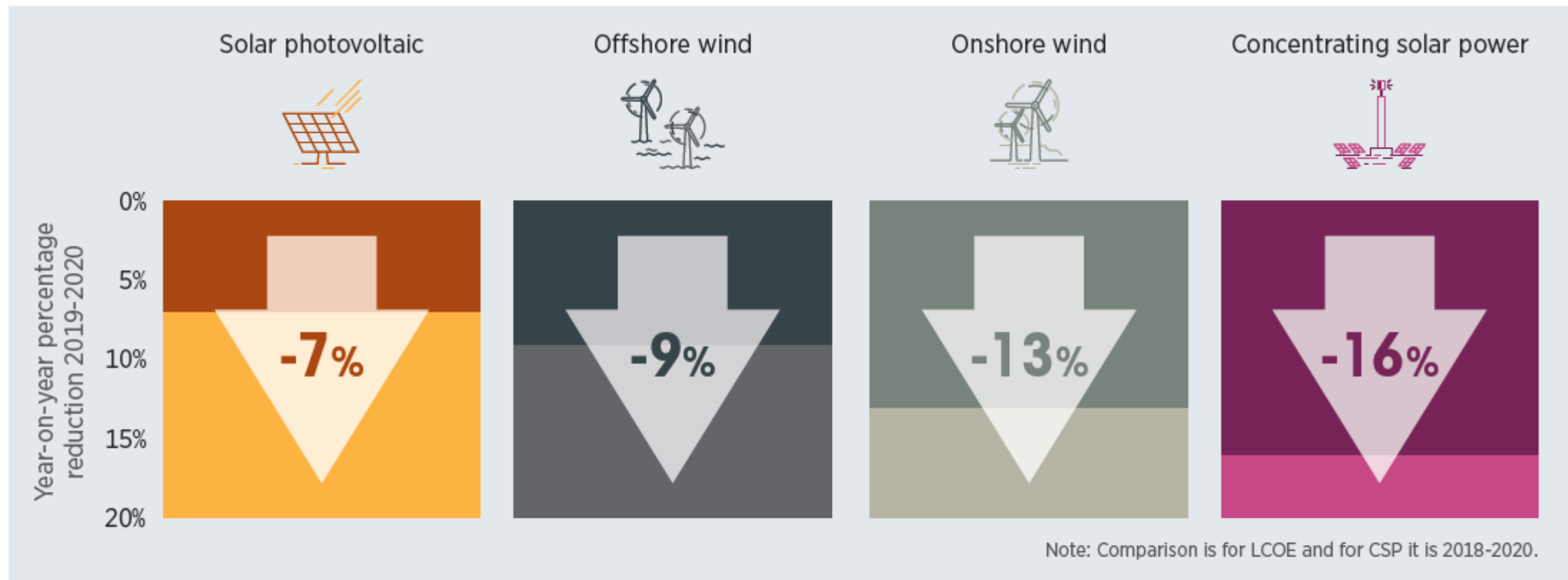
- ▶ 62% of utility-scale capacity added in 2020 cost less than cheapest new coal option

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

# Recent cost evolution

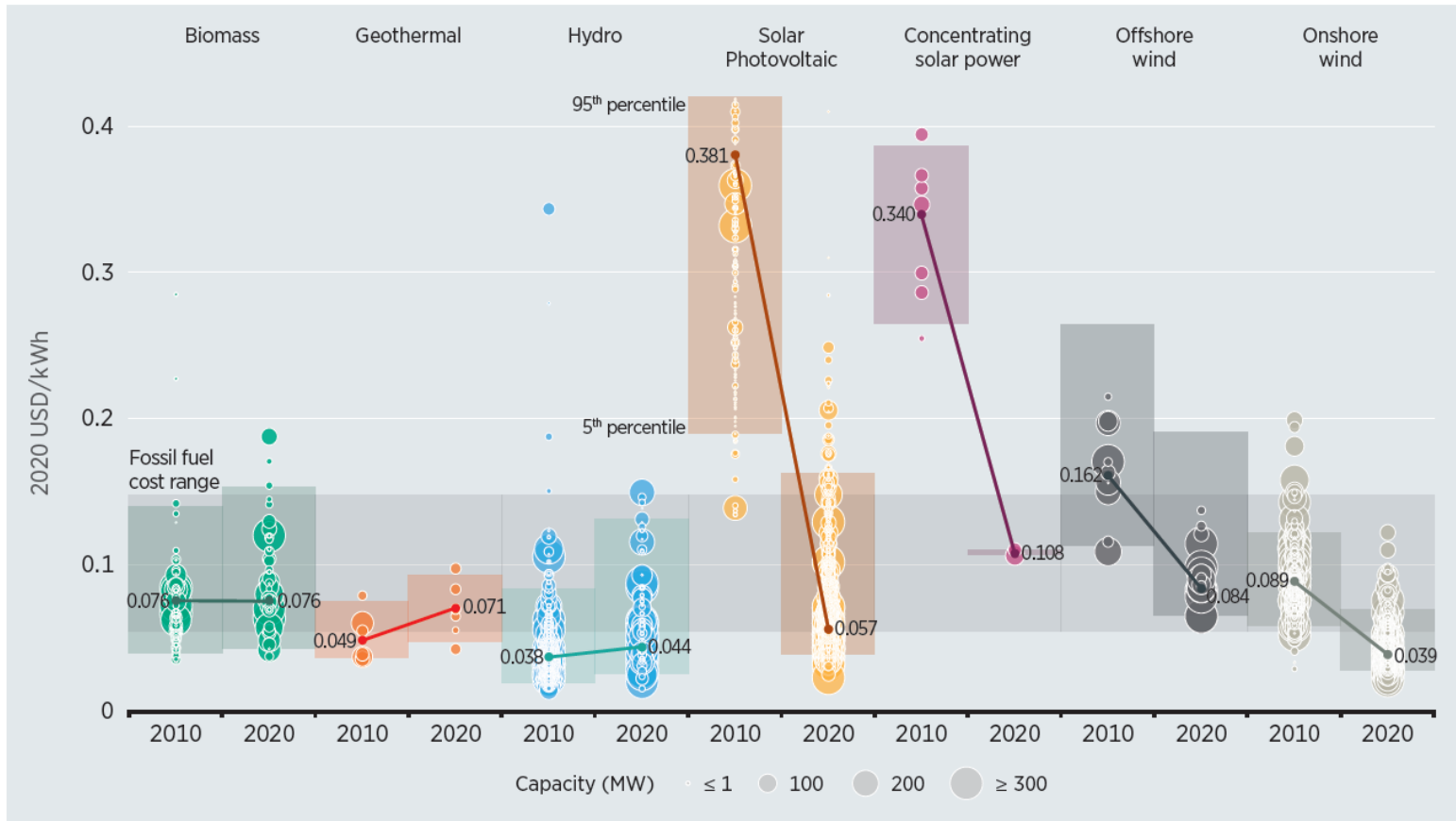


Source: IRENA Renewable Cost Database

Note: The comparison for CSP is the annual compound percentage reduction for 2018-2020, given that the 2019 value was something of an anomaly. Comparing against 2019 would see the year-on-year reduction rise to 49%.



# Recent cost evolution

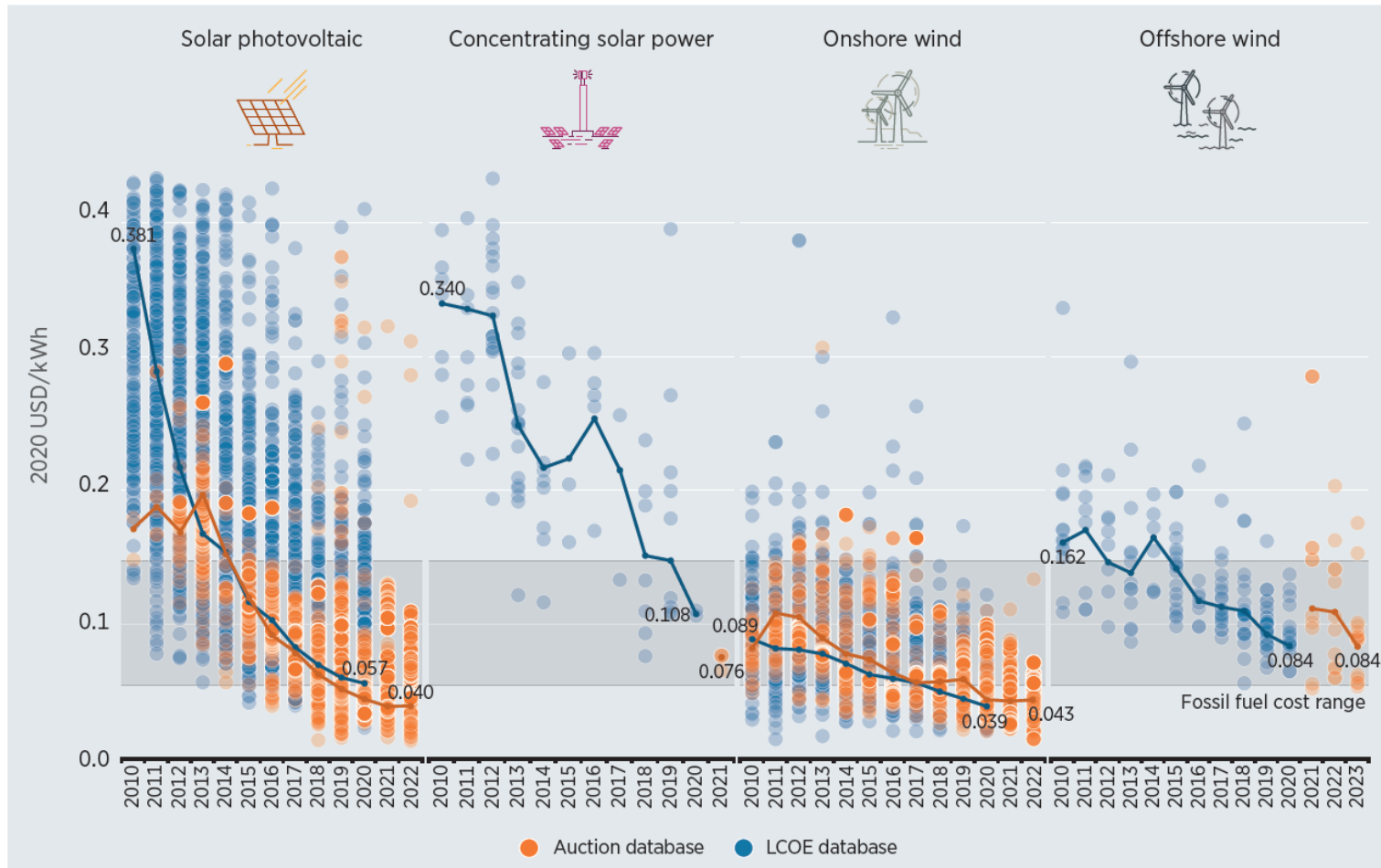


Source: IRENA Renewable Cost Database

Note: This data is for the year of commissioning. The diameter of the circle represents the size of the project, with its centre the value for the cost of each project on the Y-axis. The thick lines are the global weighted-average LCOE values for plants commissioned in each year. Real WACC was 7.5% in 2010 and 5% in 2020 for OECD countries and China, and 10% in 2010 and 7.5% in 2020 for the rest of the world. The single band represents the fossil-fuel fired power generation cost range, while the bands for each technology and year represent the 5<sup>th</sup> and 95<sup>th</sup> percentile bands for renewable projects.

- Average LCOE of all renewable power generation technologies fall in fossil fuel cost range in 2020.
- Bioenergy, geothermal, hydro, solar PV and onshore wind all at lower end or undercutting. CSP midway

# Recent cost evolution



- The PPA data available to IRENA is becoming smaller proportion of total installed capacity
- Useful insights particularly for identifying where market is heading and what is possible in best possible conditions

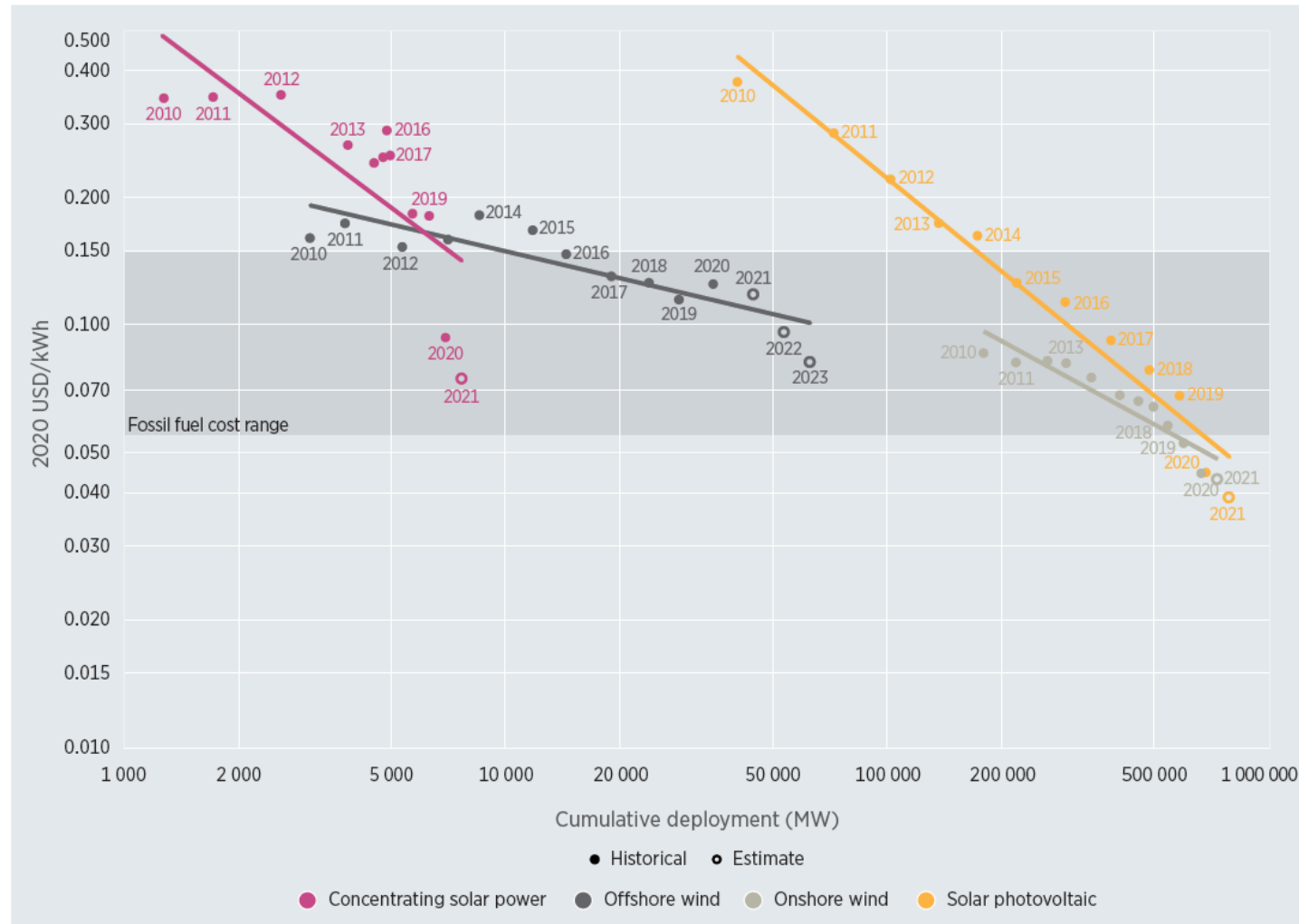
Source: IRENA Renewable Cost and Auction and PPA Databases

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

	2018 - 2020	2010 - 2020
<b>Solar PV</b>	<b>-7%</b>	<b>-85%</b>
<b>CSP*</b>	<b>-16%</b>	<b>-68%</b>
<b>Offshore wind</b>	<b>-9%</b>	<b>-48%</b>
<b>Onshore wind</b>	<b>-13%</b>	<b>-56%</b>

# Learning rates

Quite remarkable rates of deflation for wind and, in particular, solar power technologies.



Source: IRENA Renewable Cost Database

Quite remarkable rates of deflation for wind and, in particular, solar power technologies.

**Table ES2** Learning rates for solar PV, CSP, onshore and offshore wind, 2010-2020 and 2010 to 2021/3

	Learning rates	
	Total installed cost 2010-2020	LCOE 2010-2021/23
	(%)	(%)
Utility-scale solar PV	34	39
CSP	22	36
Onshore wind	17	32
Offshore	9	15

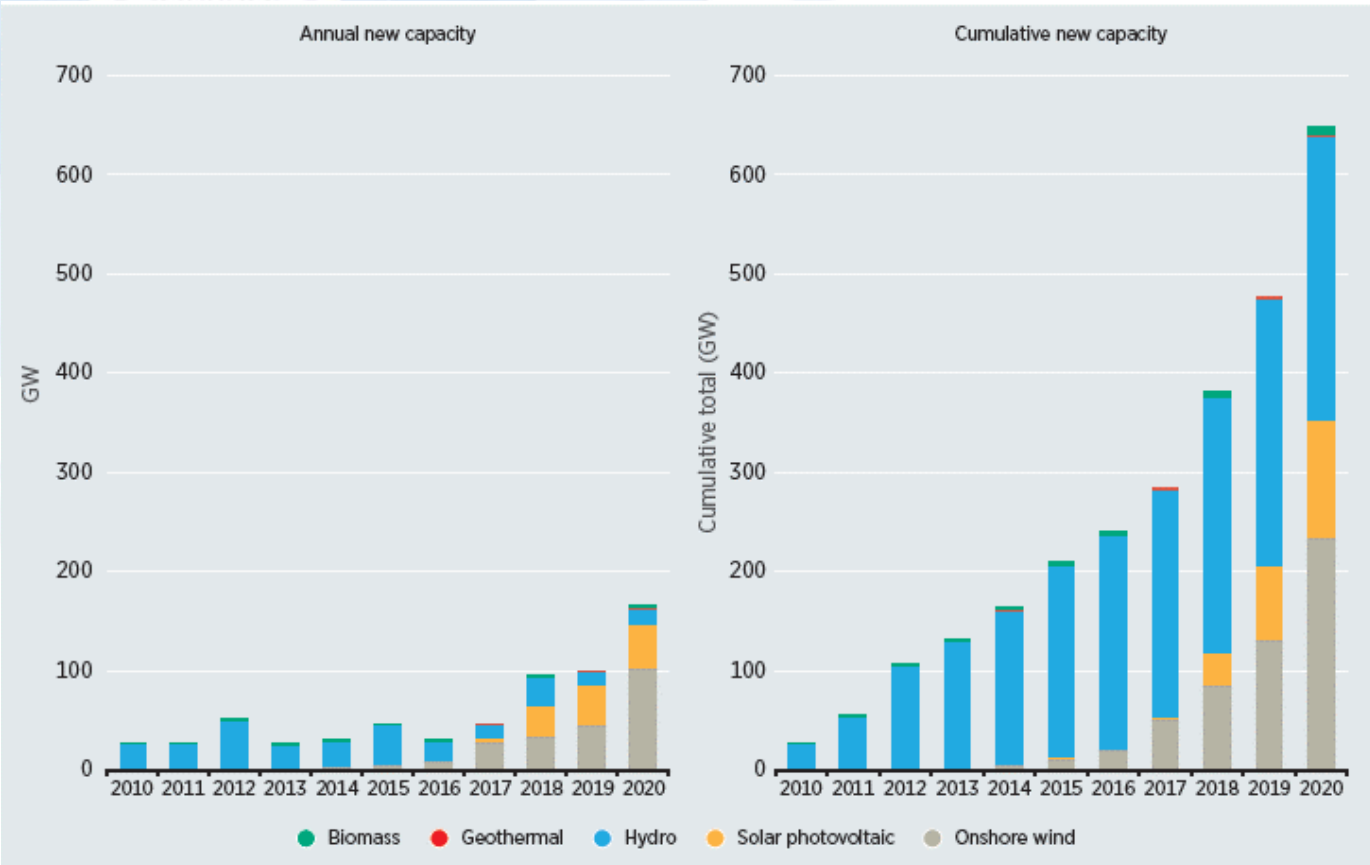
6 The learning rate is the percentage reduction in the price/cost for every doubling of cumulative installed capacity.



# **NOT JUST FALLING COSTS, BUT ABSOLUTELY LOW COSTS**

# Competitive costs

New renewable capacity added with costs lower than cheapest fossil fuel option



- 644 GW over 10 years has costs lower than cheapest fossil fuel option.
- 534 GW in emerging economies likely to save USD 32 billion this year....
- 62% of capacity (~160 GW) added in 2020 was lower-cost than new fossil fuel option

Source: IRENA Renewable Cost Database

# Falling costs increase stranded asset risks

**Figure 1.10** Operating costs only of existing coal-fired power plants in Bulgaria, Germany, India and the United States by installed capacity and capacity factor in 2020

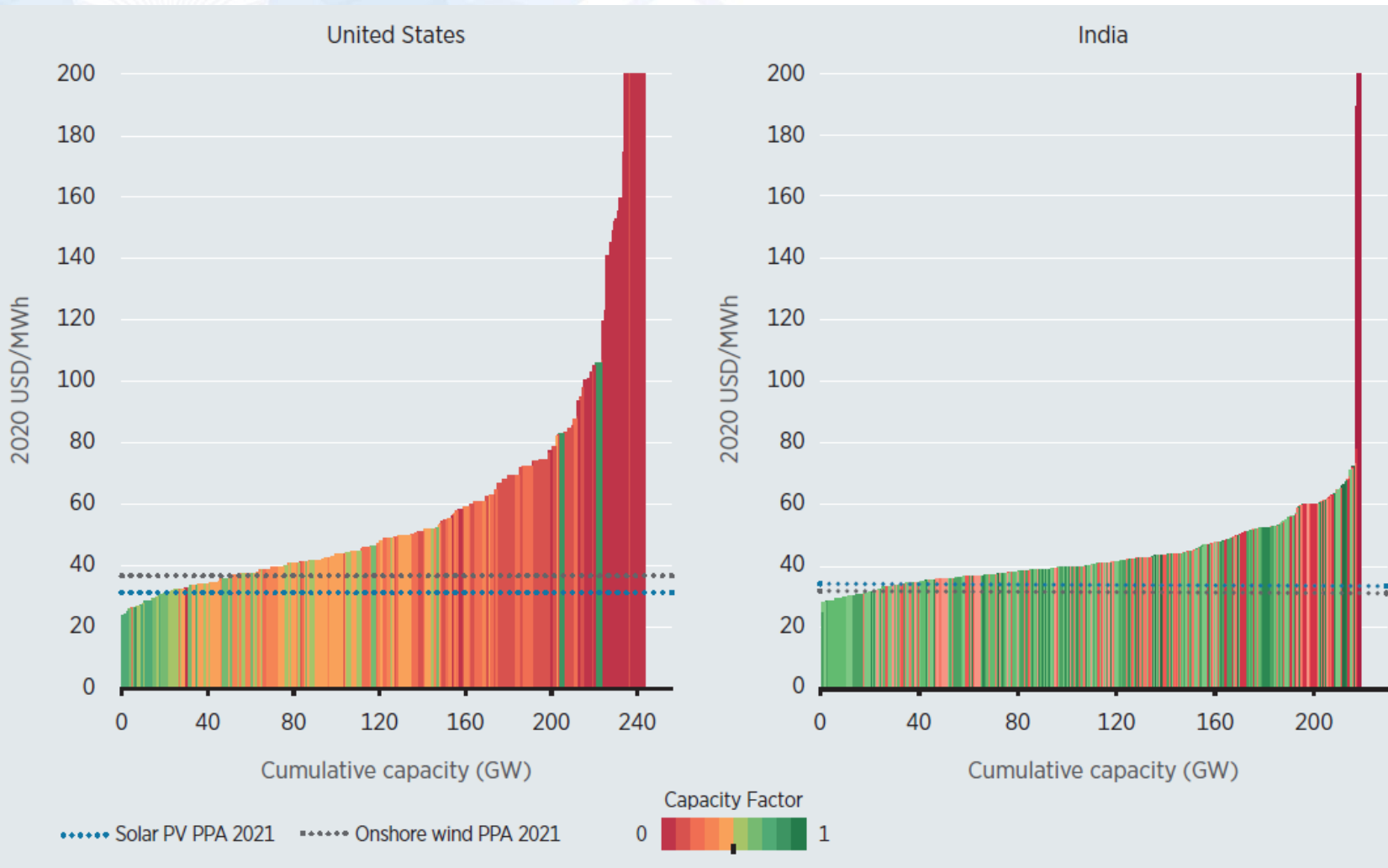


- Falling capacity factors, high fixed costs and CO2 prices spell trouble for Europe's coal generators

- Cost ≠ Capture price/value

But: Gap is looking very large in Europe

# Falling costs increase stranded asset risks

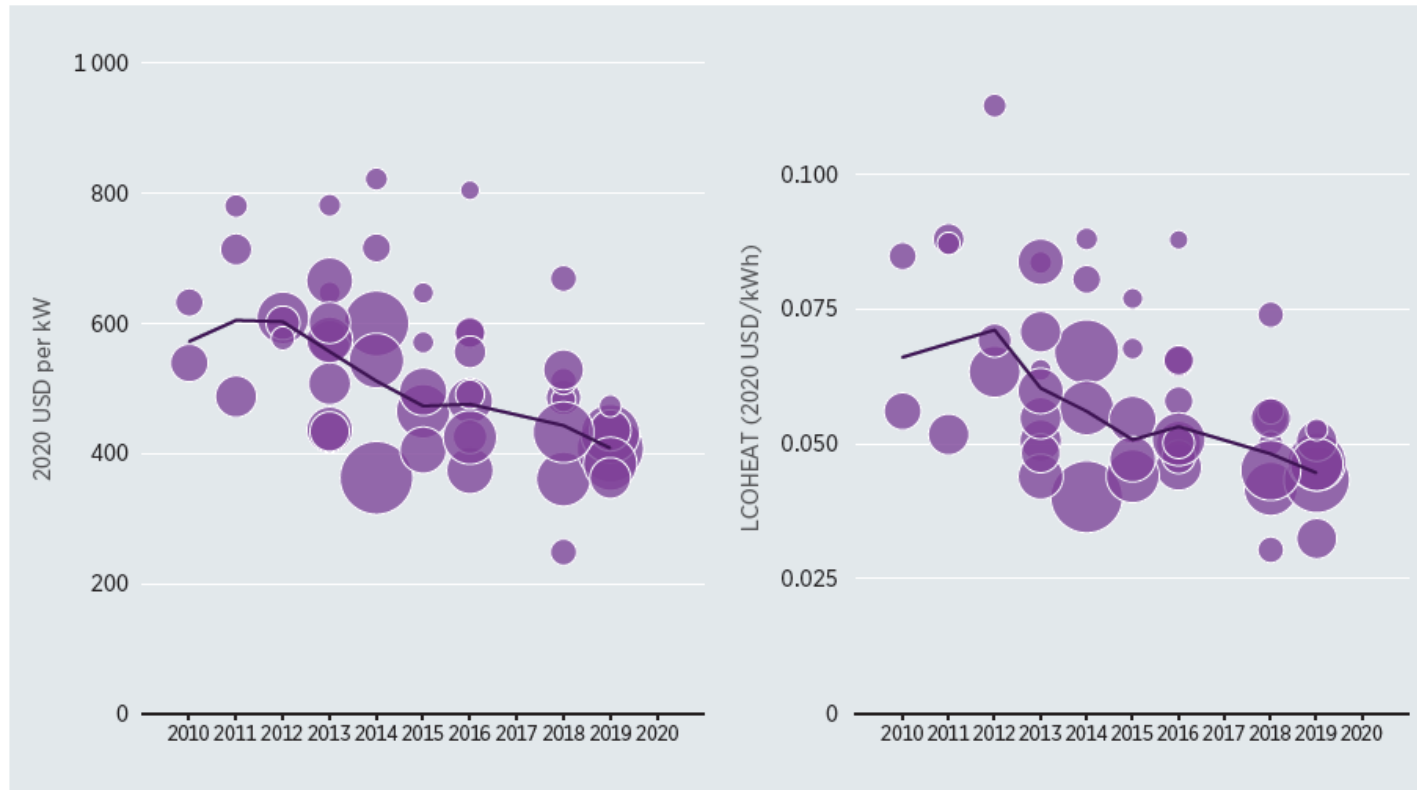


- US and India have lower coal operating costs, but...
- But same challenge, as very competitive RE costs...and...
- falling capacity factors and high fixed costs
- Cost  $\neq$  Capture price/value

But: Gap is looking very large particularly in US, even with dual-firing

# Solar thermal heat: Commercial & Industrial sectors

**Figure 9.1** Total installed costs and LCOHEAT for solar thermal district heating plants in Denmark, 2010-2019



Source: IRENA and Solar Payback, 2021.

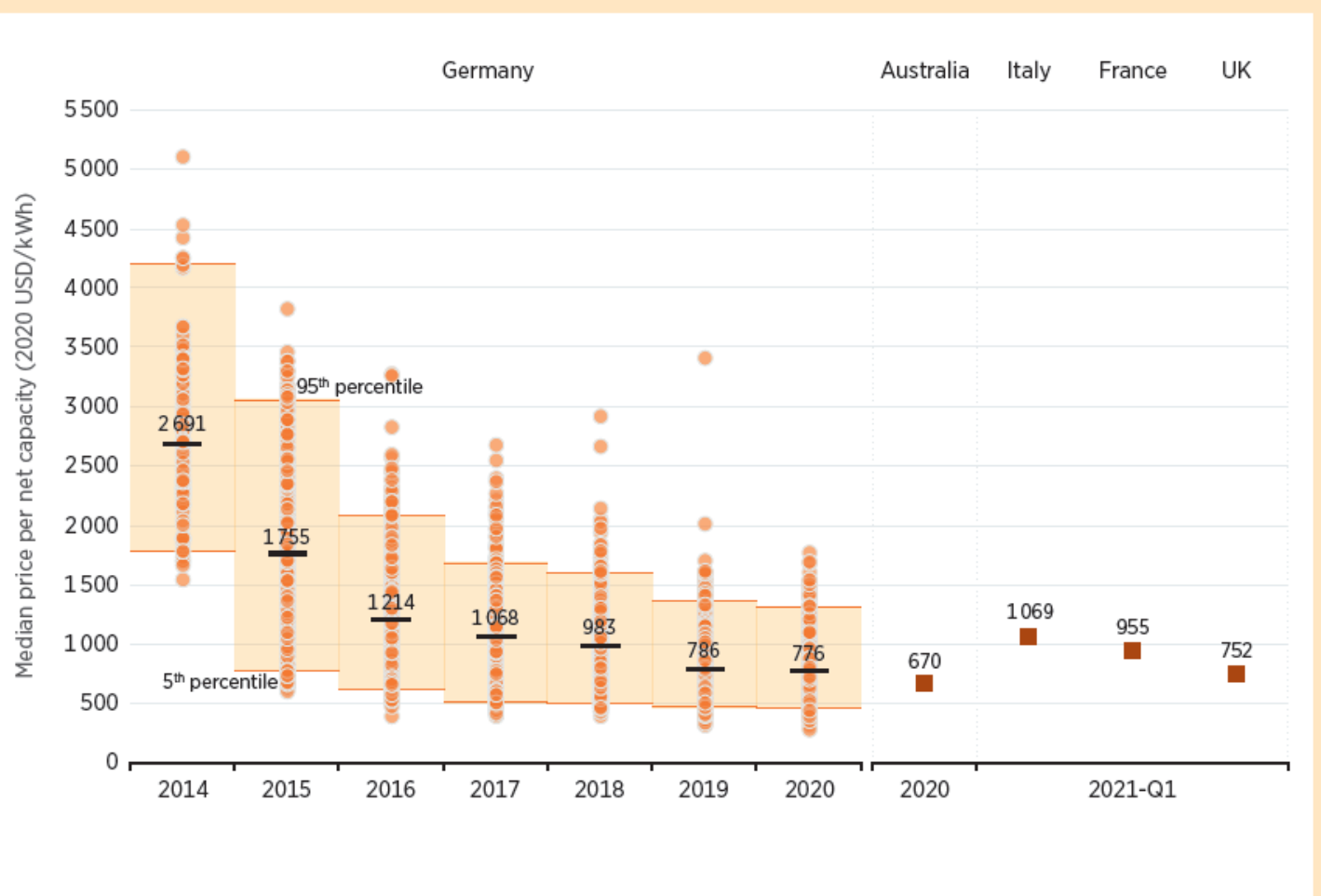
Note: Data is for 50 projects commissioned between 2010 and 2019 ranging in size from 1.8 MW<sub>th</sub> to 26 MW<sub>th</sub>.

- In total:  
~1750 projects ~935 MW<sub>th</sub>  
Data for 24 countries
- Denmark has competitive market and falling costs
- District heating installed cost learning rate is 17-19% in Denmark
- RPGC in 2020 also includes data for Austria, Germany and Mexico
- Larger report to come Q3



# Battery storage cost trends

Behind-the-meter battery storage cost trends 2014-2020/21



Source: IRENA and EUPD Research GmbH, 2021; and Solar Choice, 2021

- US utility-scale battery costs fell 71% between 2015 and 2018, to USD 635/kWh

## Behind-the-meter

- Battery storage system prices fell 71% between 2014 and 2020
- Australia somewhat more competitive, Italy and France more expensive

# Beyond 4 hours storage....

Figure B5.1 Results of recent auction and PPA results for utility scale solar PV and CSP



Source: Based on LBNL, 2020; RenewPower, 2020; and Antuoko, 2020

- Mainland and island Solar+storage is already competitive
- But limited to four hours storage
- CSP is somewhat more expensive, but bridges the gap to daily storage, and with 6 GW deployed, as lots of potential for cost reductions



**HYDROPOWER**

**BIOENERGY**

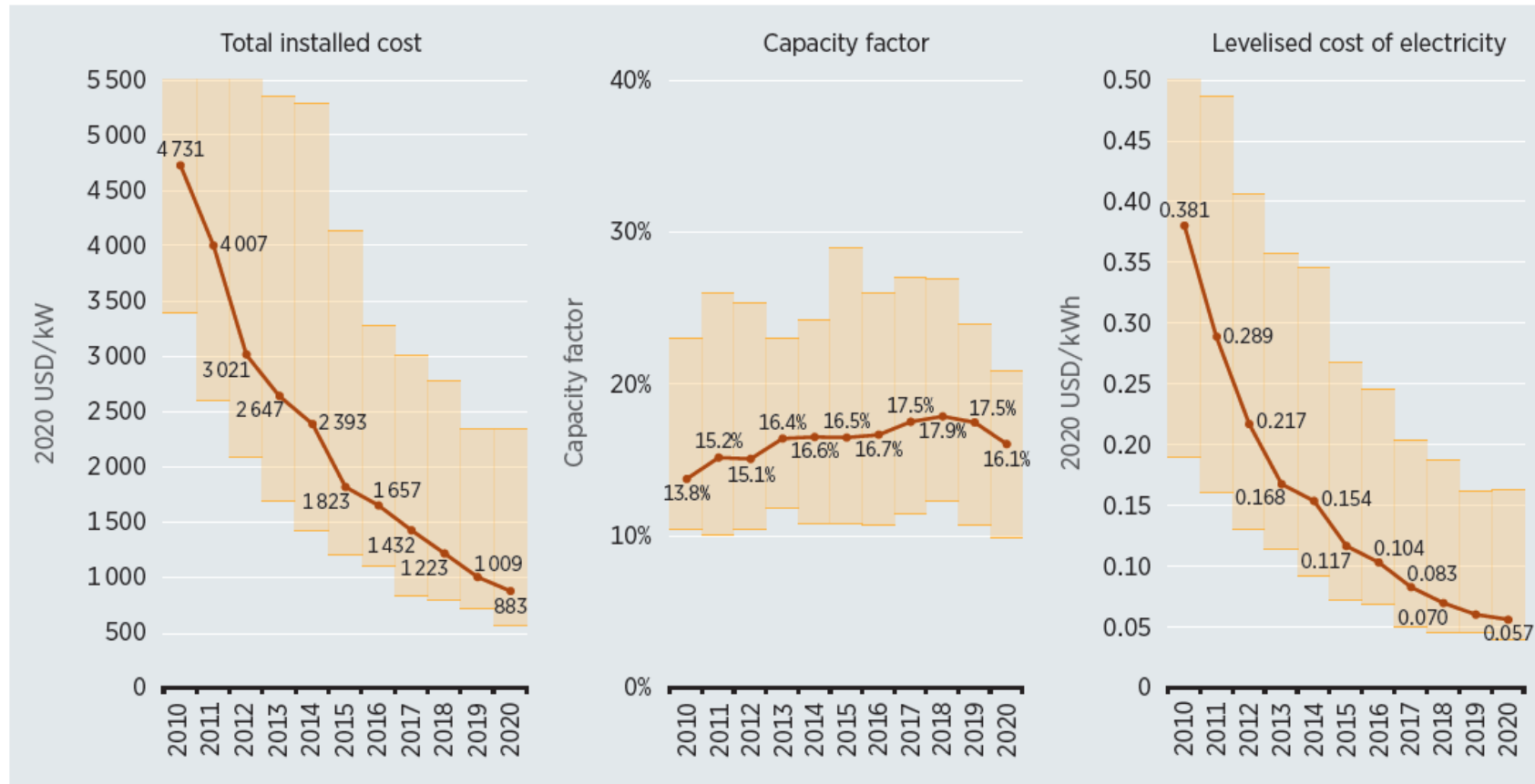
**GEOHERMAL**

# DEEP DIVE: SOLAR PV



# Solar PV cost trends

The LCOE of utility-scale PV has declined 7% YoY in 2019-2020 to USD 0.057/kWh



Source: IRENA Renewable Cost Database

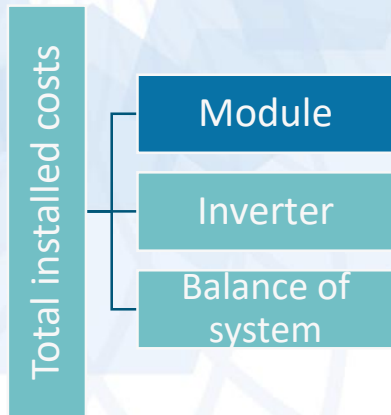
- Total installed costs w. avg. declined 13% from 2019 and 81% from 2010.
- Record new capacity added: 127 GW
- Cost reduction drivers
  - lower module costs
  - sustained BoS decline
- Capacity factor drop: Shift in share of deployment, but some uncertainty.

Note: costs for PV expressed per kilowatt direct current (DC); capacity factor expressed as an AC-to-DC value.

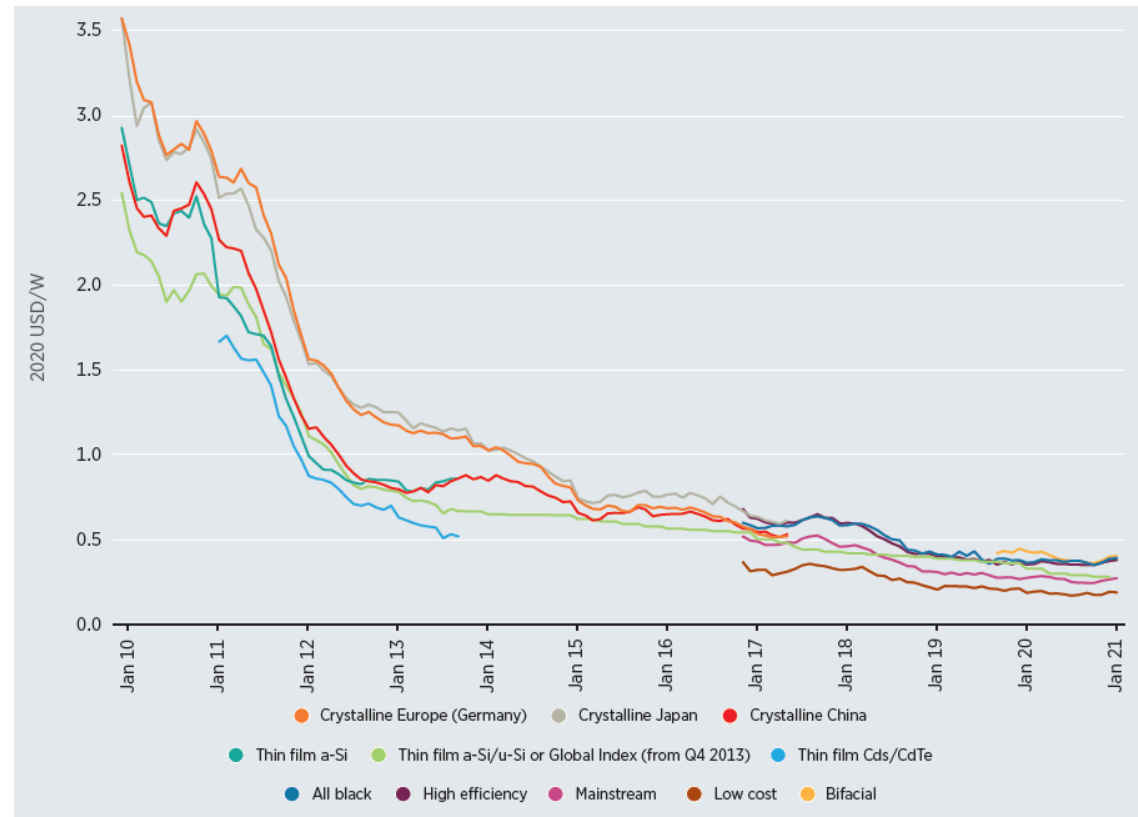


## Module costs continue its decline, driven by manufacturing optimization and efficiency gains

- Crystalline PV module costs decline around 89-95% (Dec 2009-Dec 2020)



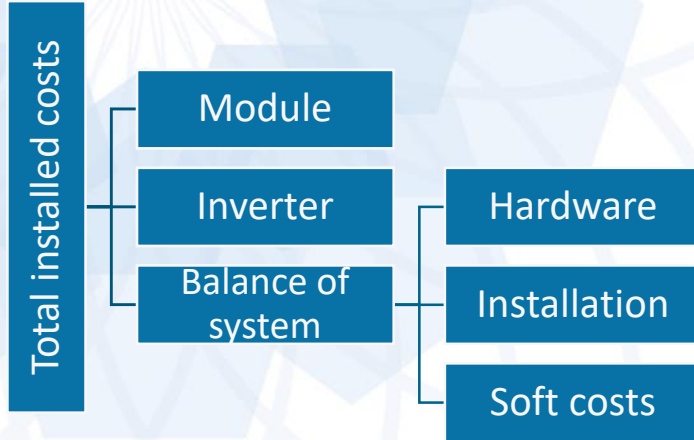
- Costs range in Dec 2020 from USD 0.19/W to USD 0.38-0.40/W
- Recently upward blip due to supply chain tightness



Source: GlobalData (2019); pvXchange (2020); Photon Consulting (2017).

# Solar PV cost trends

As balance of system costs fell, so did total installed costs

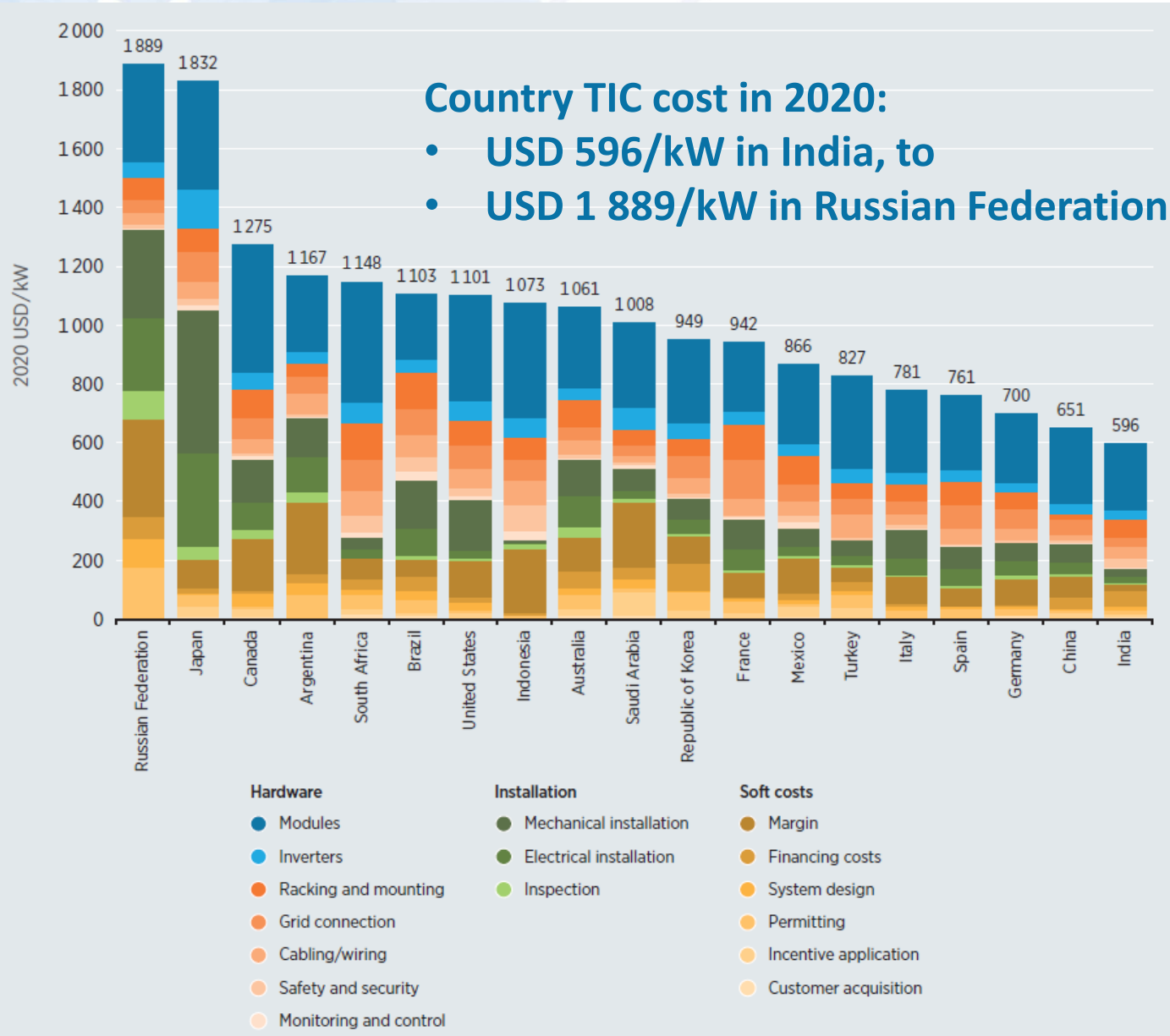


- Total installed costs fell 77% - 90% by country
- Narrowing of country cost differential, but differences remain



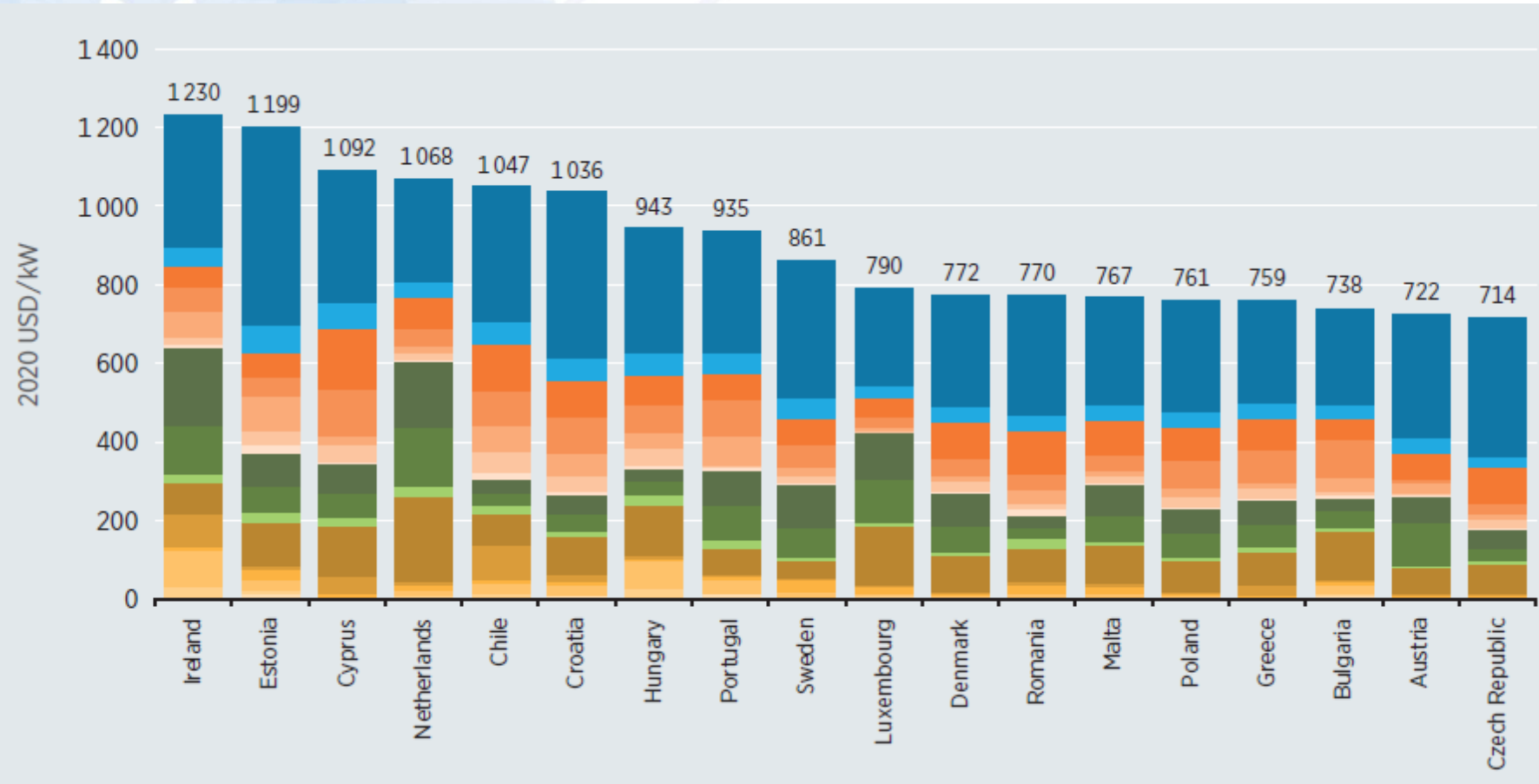
Source: IRENA Renewable Cost Database.

# Solar PV cost trends



- 61% of global global weighted-average TIC decline due to modules. 39% BoS
- The highest cost average was 3x more than the lowest
- Despite convergence of installed costs in major markets in last 5 years, differences persist.

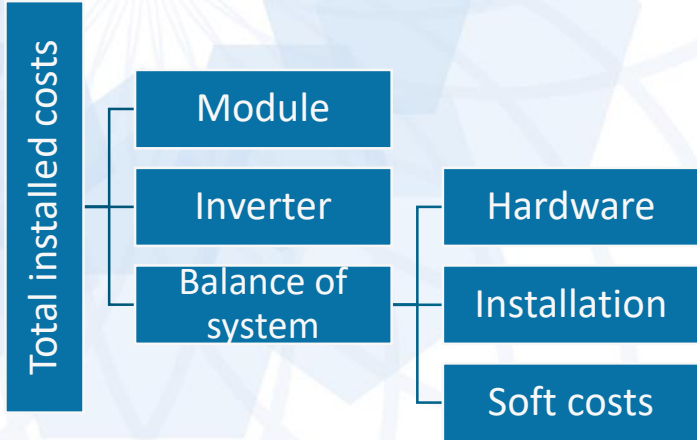
# Solar PV cost trends



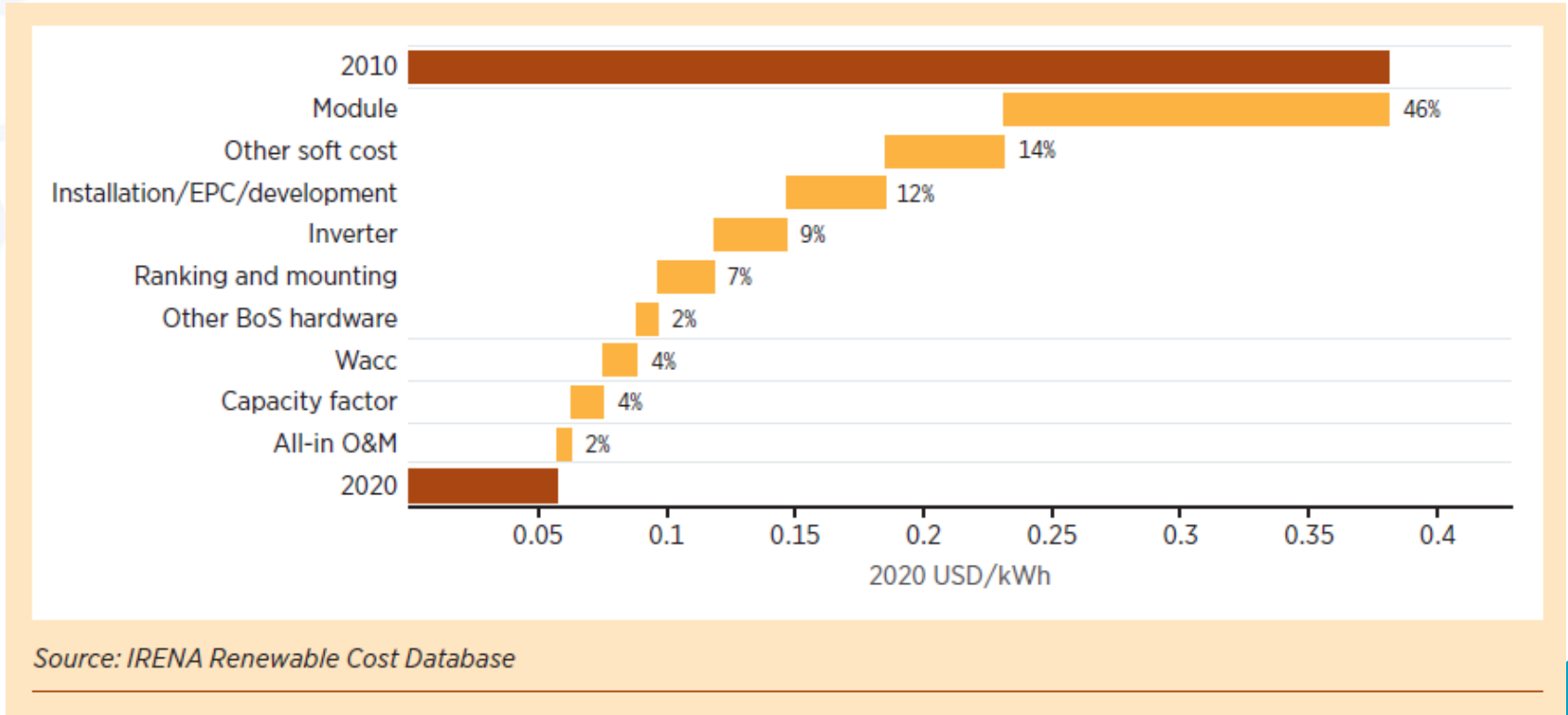
- Hardware**
- Modules
- Inverters
- Racking and mounting
- Grid connection
- Cabling/wiring
- Safety and security
- Monitoring and control
  
- Installation**
- Mechanical installation
- Electrical installation
- Inspection
  
- Soft costs**
- Margin
- Financing costs
- System design
- Permitting
- Incentive application
- Customer acquisition

Source: IRENA Renewable Cost Database.

# LCOE cost reduction drivers: Utility-scale solar PV

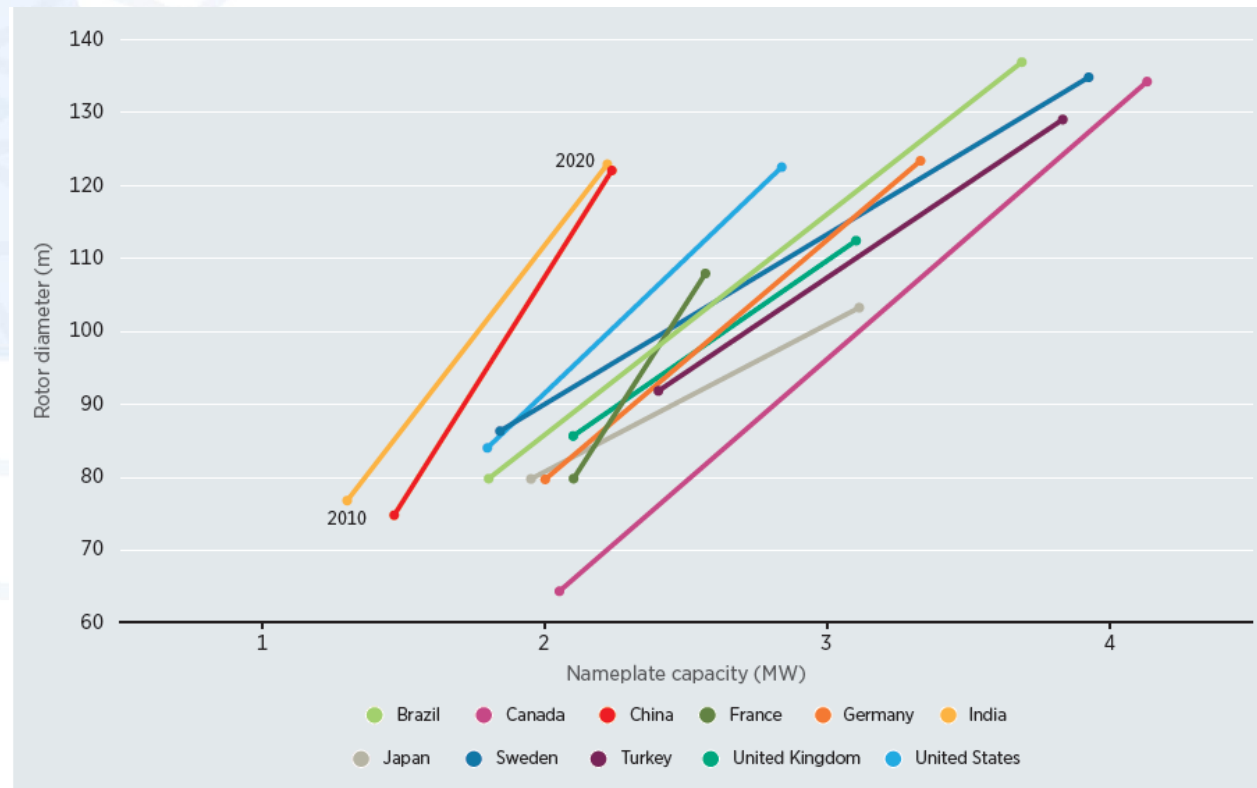


- Modules and inverters accounted for 55% of the global weighted-average LCOE decline
- BoS costs are also an important contributor



# DEEP DIVE: ONSHORE WIND

# Wind turbine cost and performance trends



Source: Based on CanWEA, 2016; GlobalData, 2021; IEA Wind, 2020; Danish Energy Agency, 2020; Wood Mackenzie, 2020a and IRENA Renewable Cost Database.

The more competitive, established markets show larger reductions in total installed costs over longer time periods than newer markets.

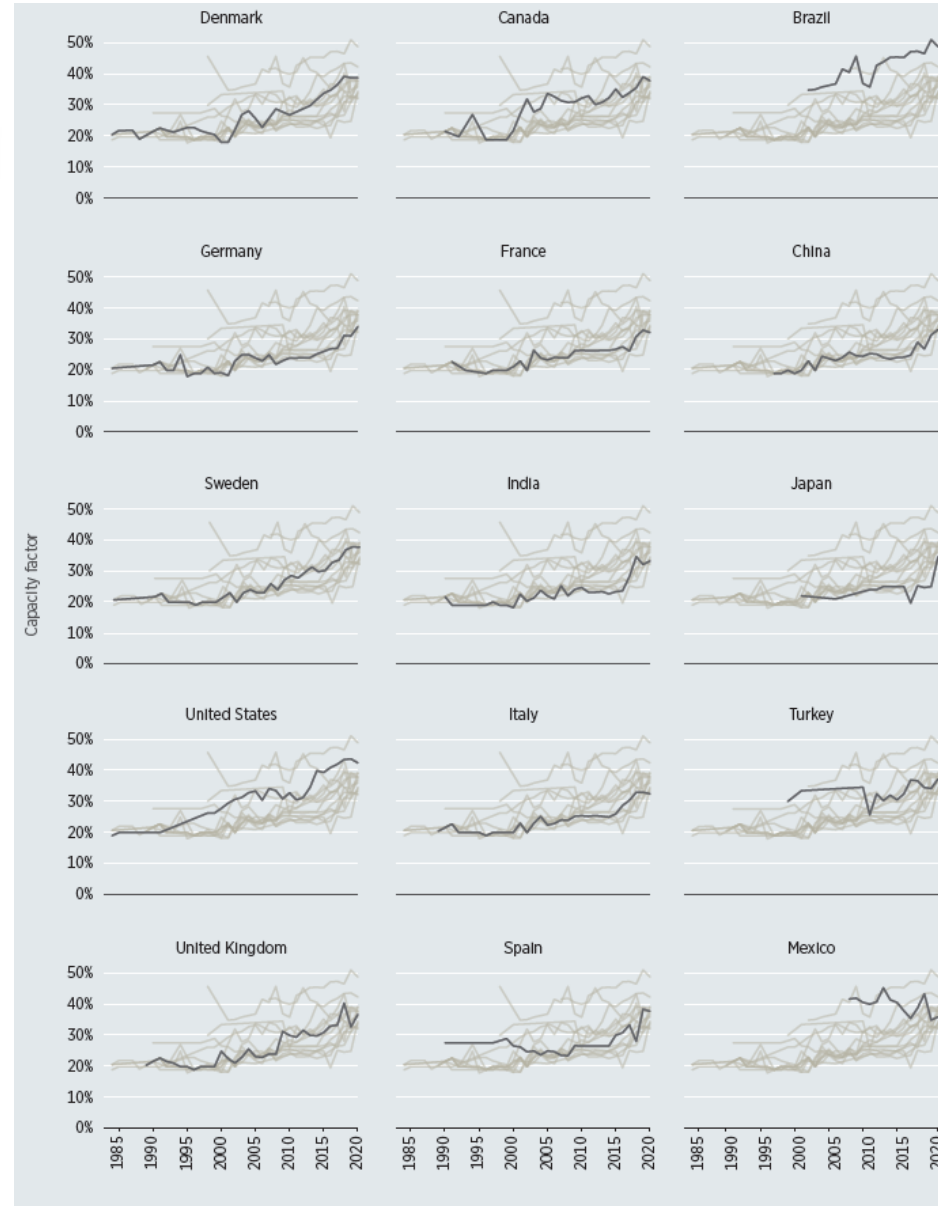
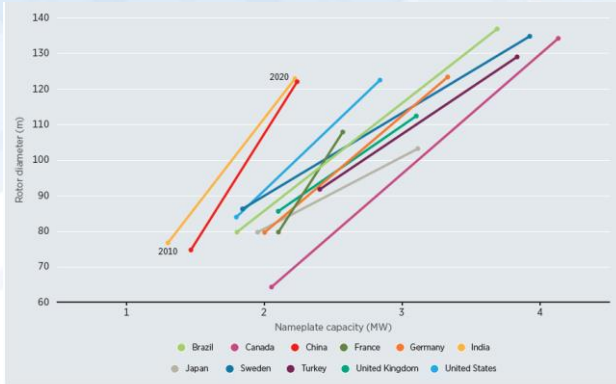
Country and site specific requirements influences the wide range in installed costs and O&M cost reductions.

Average capacity factors have increased from improved turbine technology, siting and operations.



# Wind turbine cost and performance trends

## Turbine capacity and rotor diameter



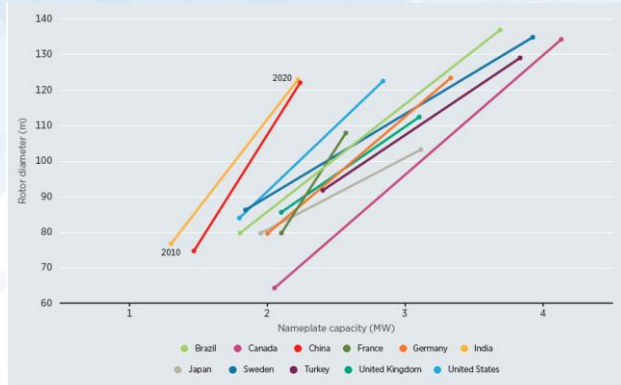
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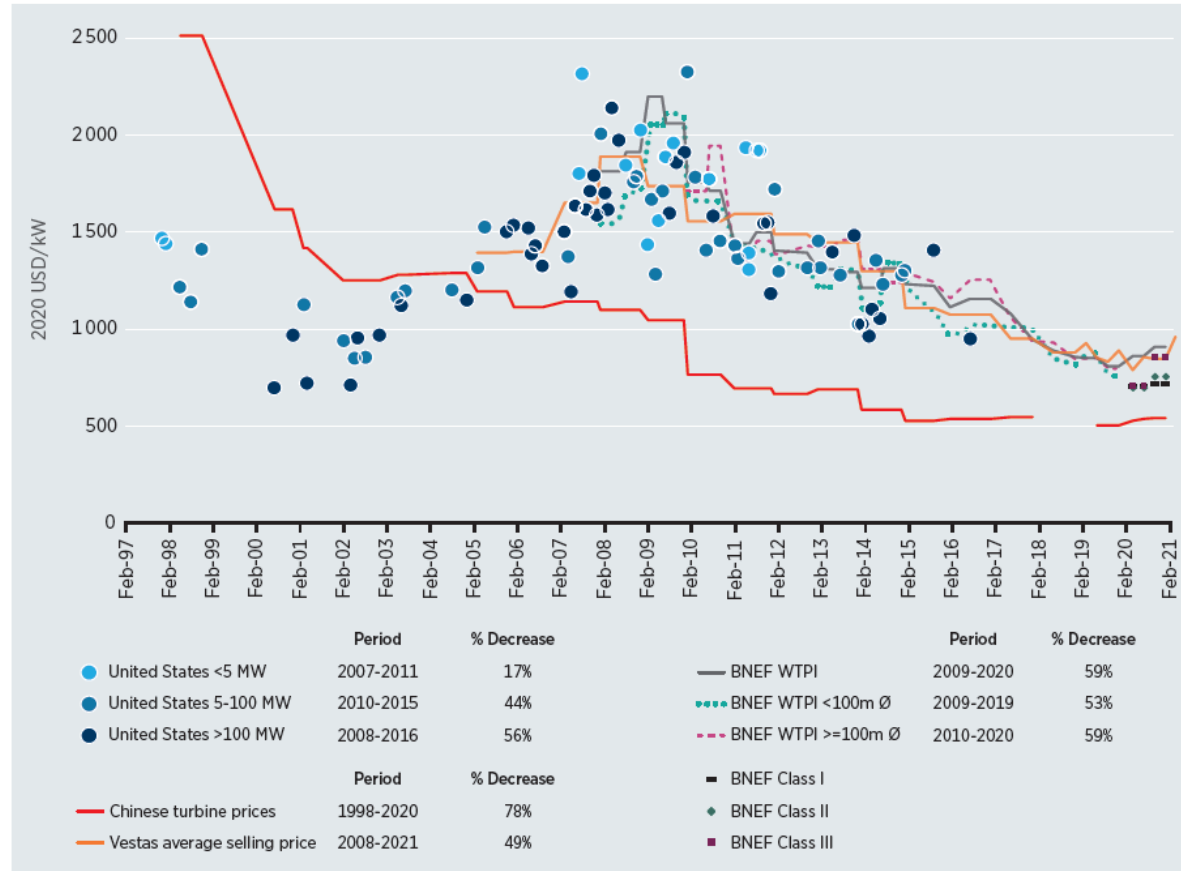
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# Wind turbine cost and performance trends

## Turbine capacity and rotor diameter



Source: Based on CanWEA, 2016; GlobalData, 2021; IEA Wind, 2020; Danish Energy Agency, 2020; Wood Mackenzie, 2020a and IRENA Renewable Cost Database.



Source: BNEF 2020b; Wiser, et al., 2020; Vestas Wind Systems, 2005-2021 and the IRENA Renewable Cost Database.

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

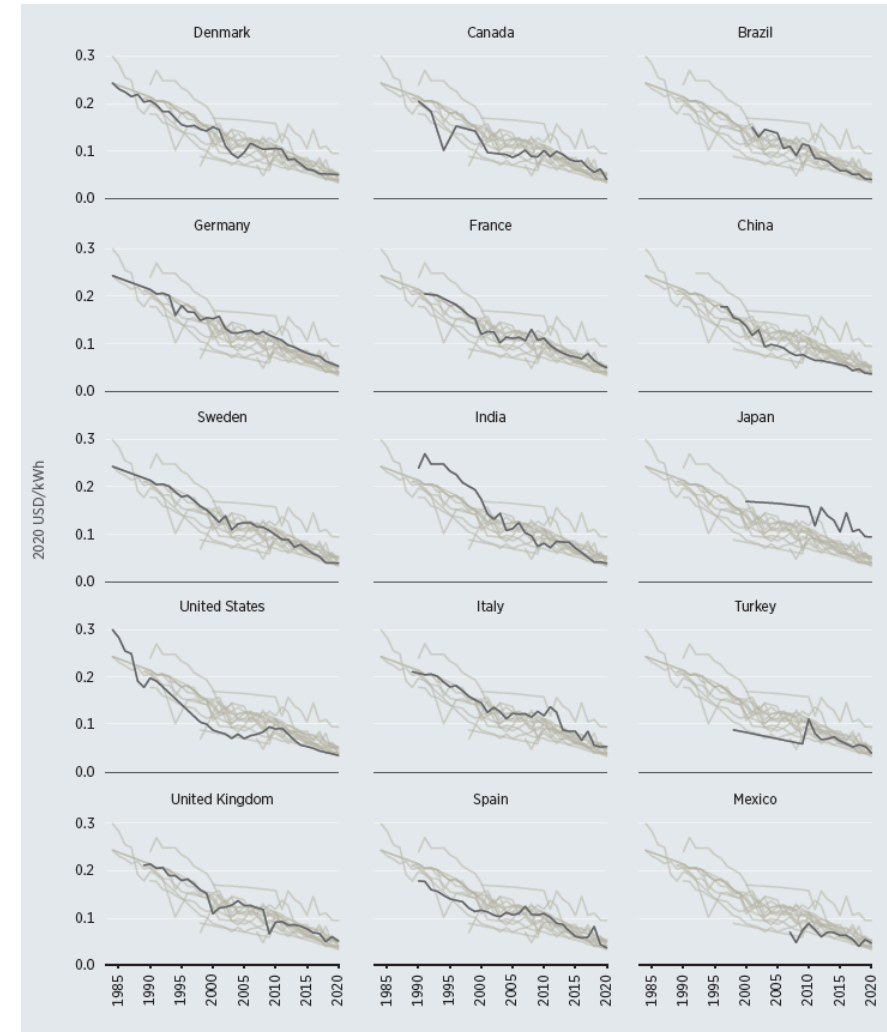
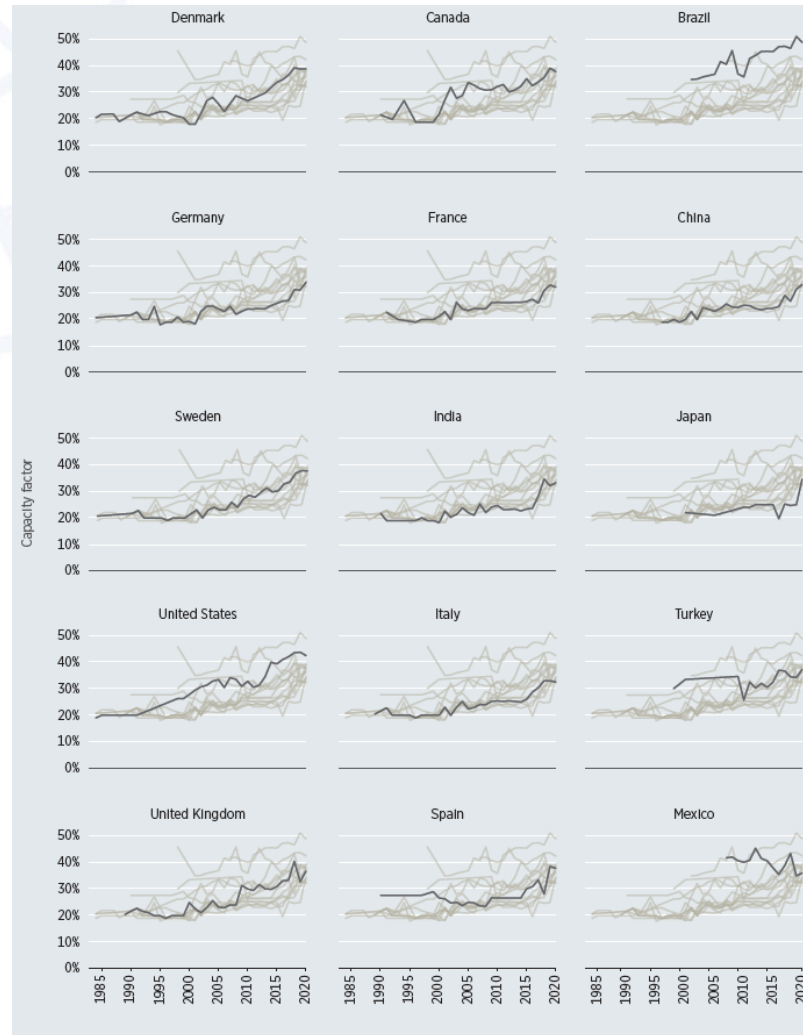
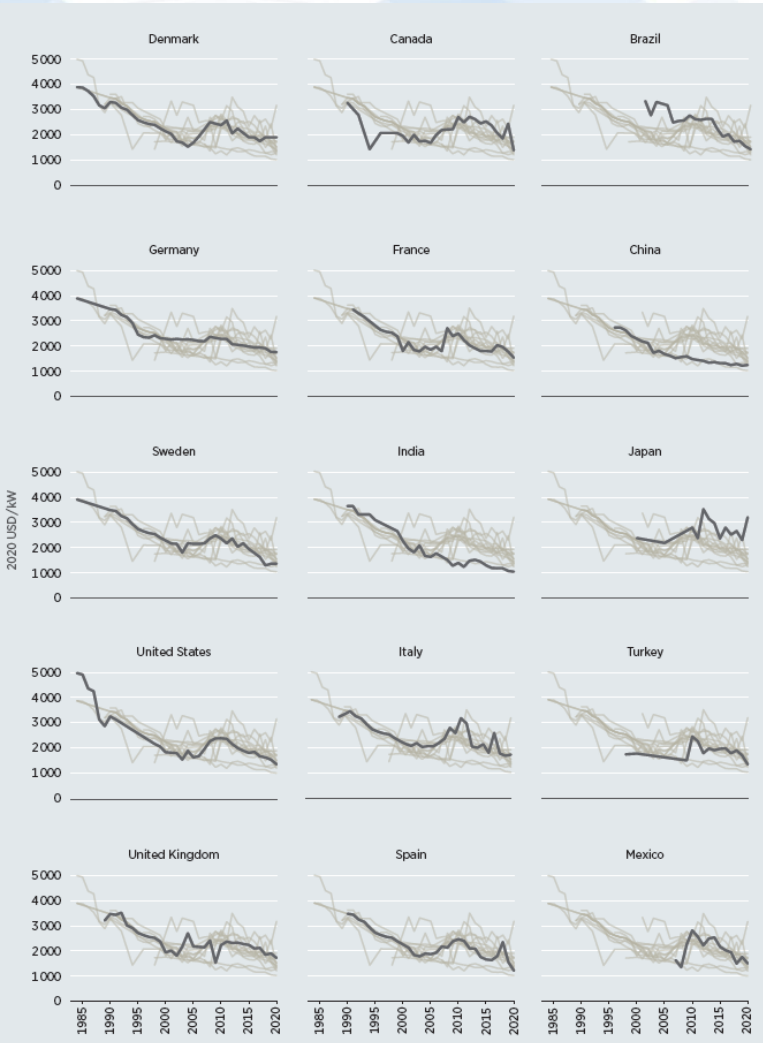
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# Levelised cost of electricity

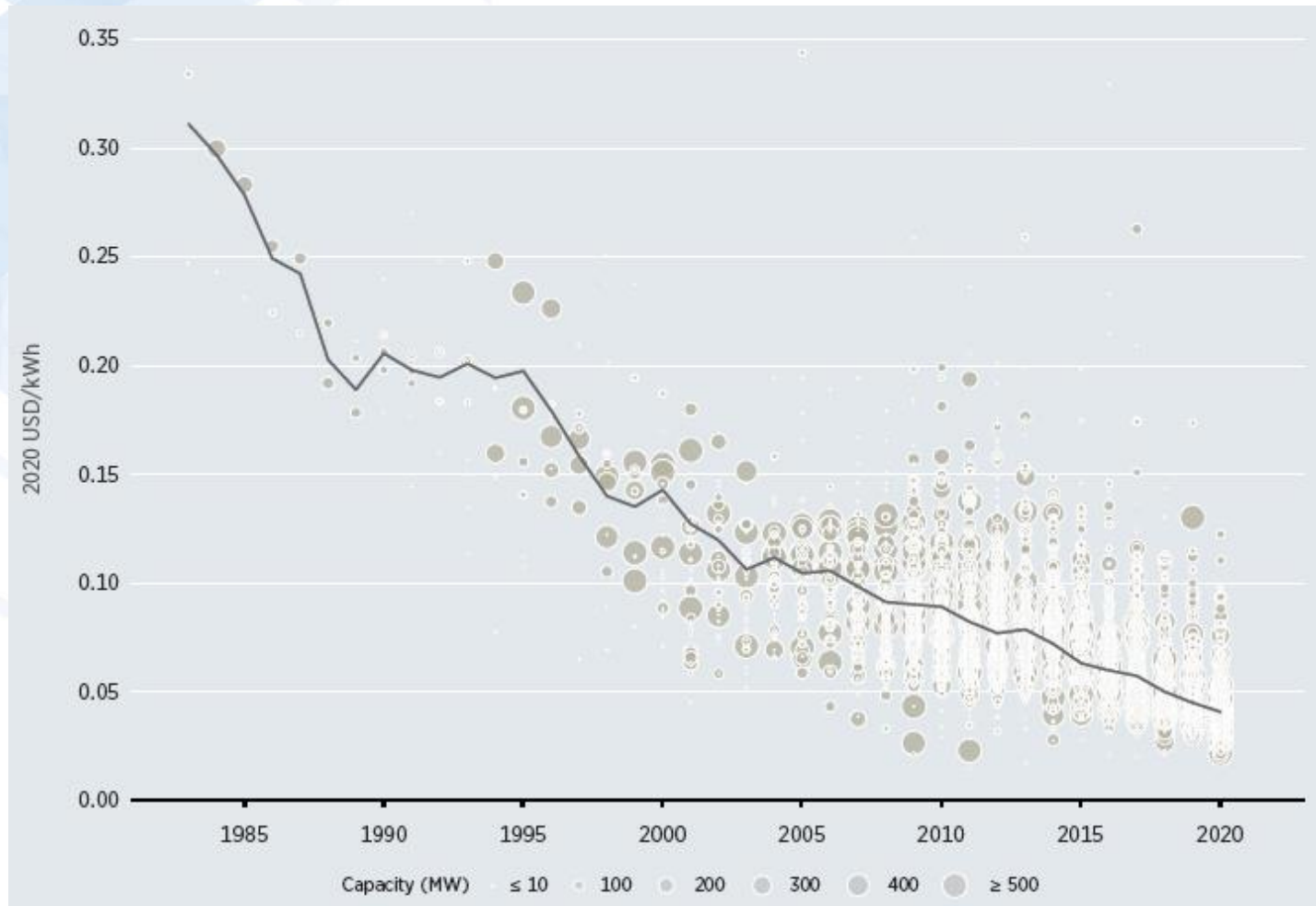
## Total installed costs

## Capacity factors

## LCOE



# Levelised cost of electricity



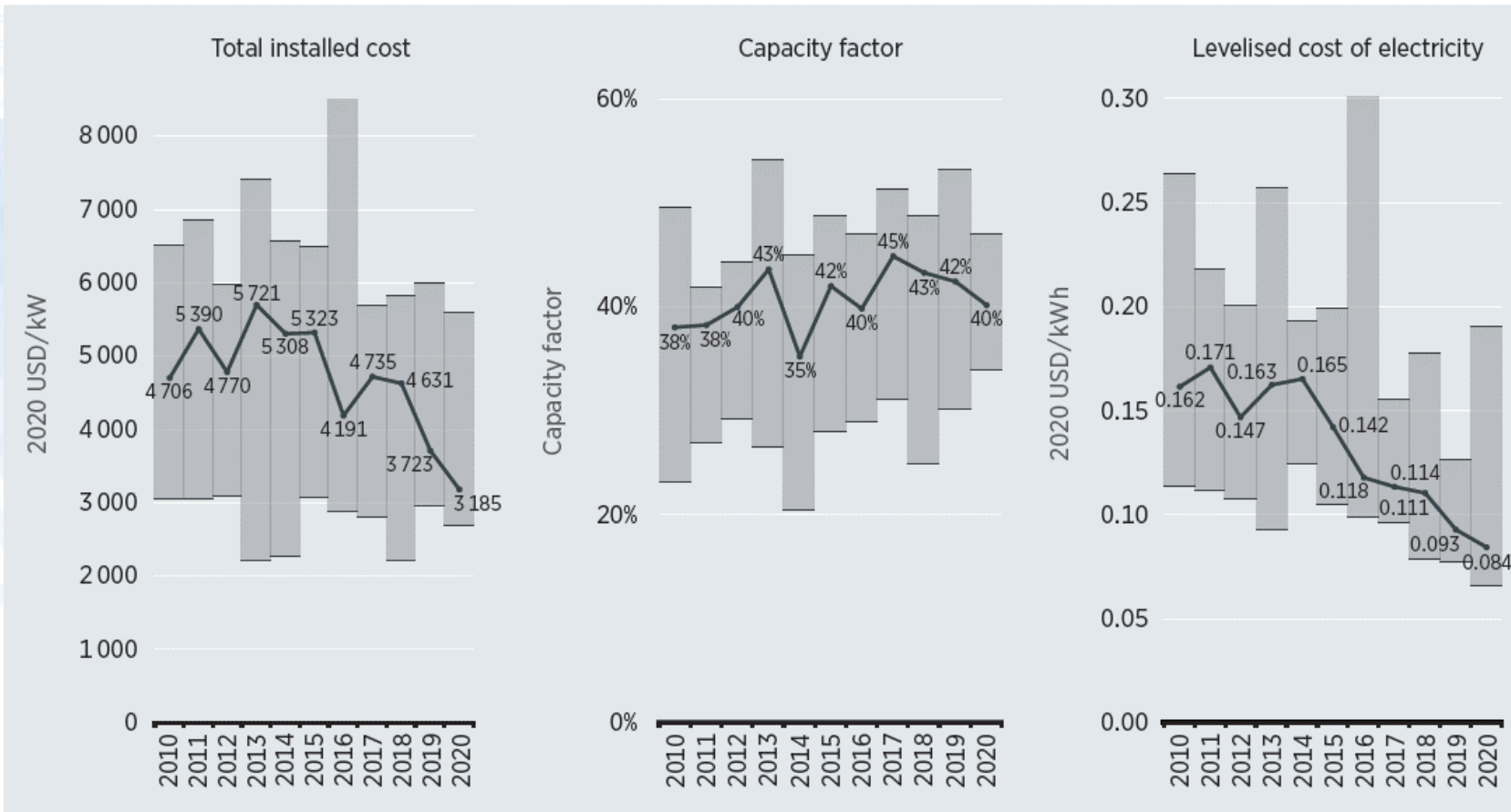
Global LCOE of onshore wind has declined by **87%** between 1983-2020:

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

# OFFSHORE WIND



# Offshore wind cost and performance trends

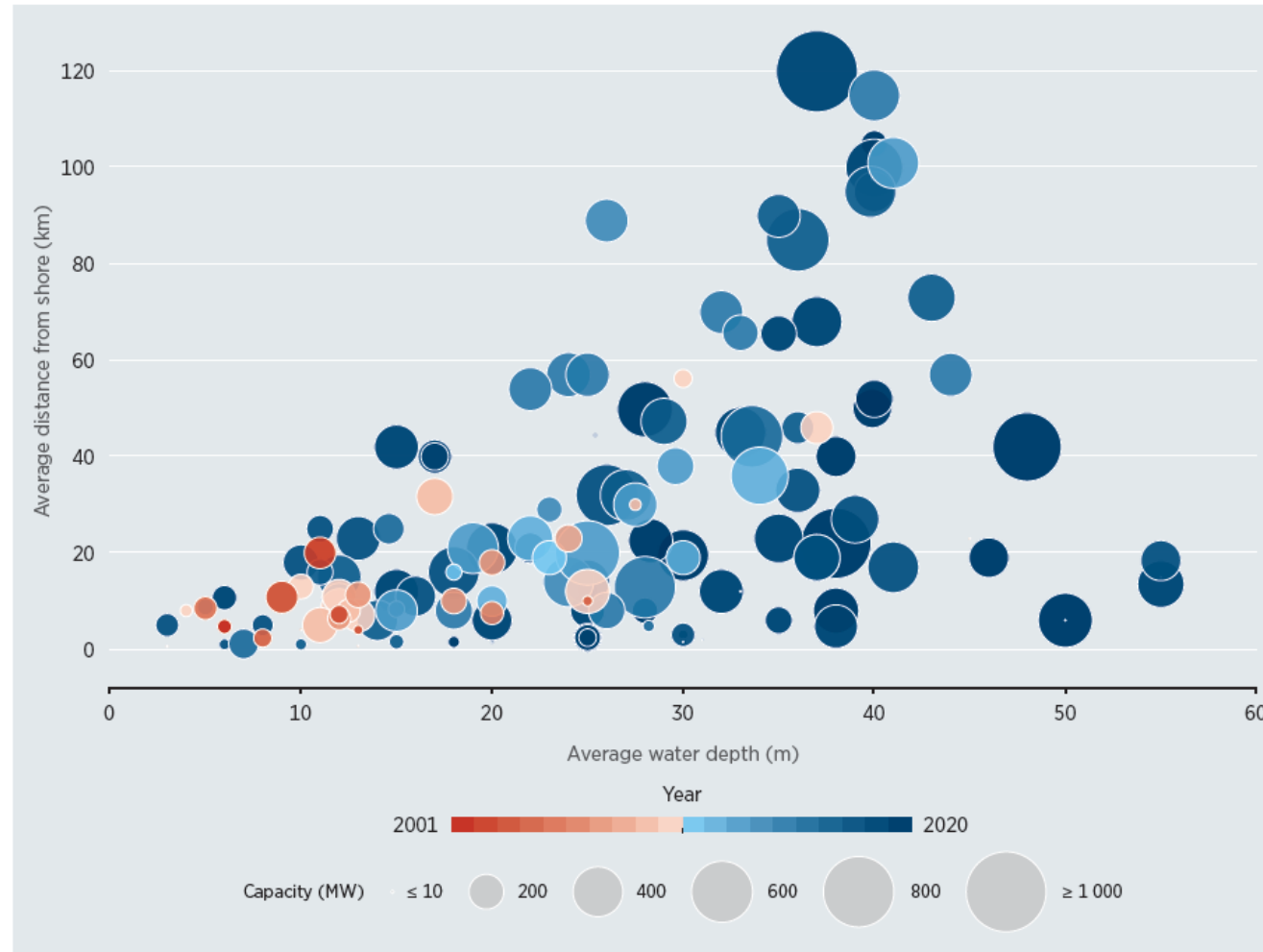


Source: IRENA Renewable Cost Database.

Between 2010-2020, the global weighted average:

- Total installed cost reduced by **32% from USD 4 706 to USD 3 185/kW**
- Capacity factor increased **from 37% to 40%**
- LCOE reduced **by 48% from USD 0.162/kWh to USD 0.084/kWh**
- **China accounted for half of new capacity in 2020**

# Offshore wind - industry trends



Source: IRENA Renewable Cost Database.

Trend towards deployments farther offshore in deeper waters, with larger turbines and installations growing in new and established market.

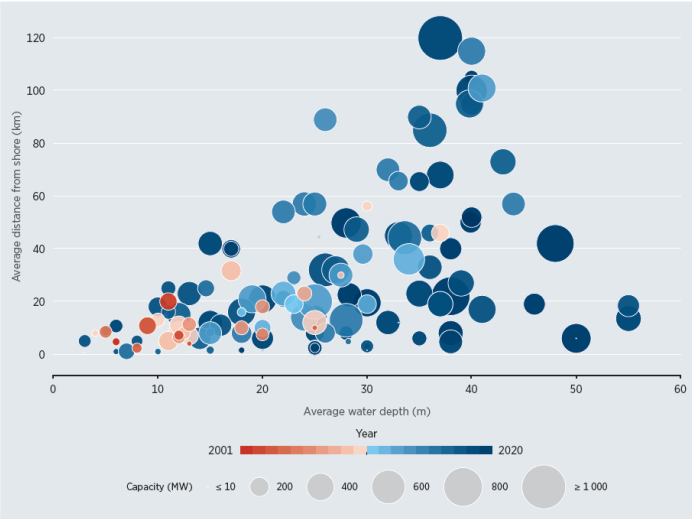
Total installed costs peaked in 2008 ~USD 5 500/kW but has since fallen to USD 3 185/kW in 2019.

LCOE is now in range USD 0.05-0.10/kWh

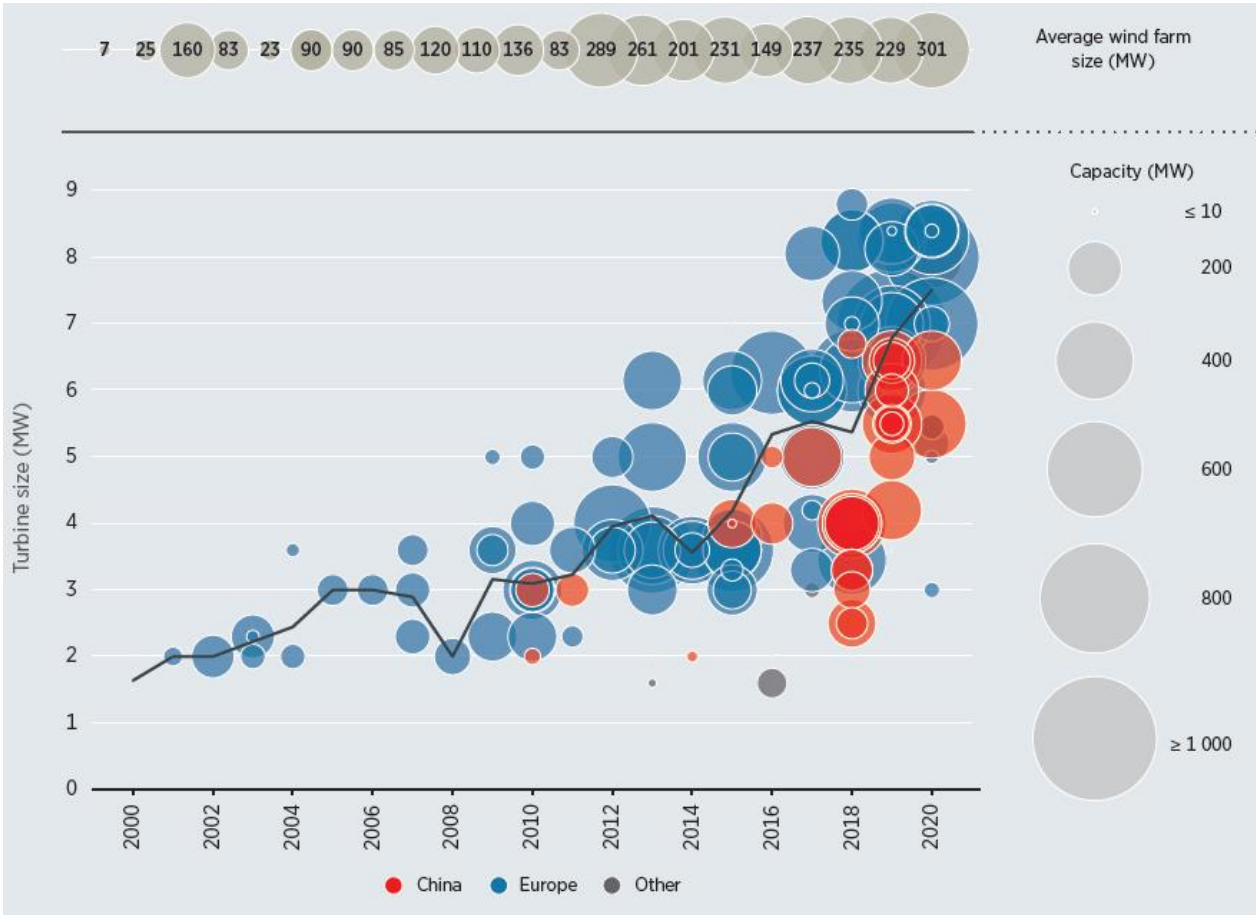


# Offshore wind - industry trends

## Distance from shore & water depth



Source: IRENA Renewable Cost Database.



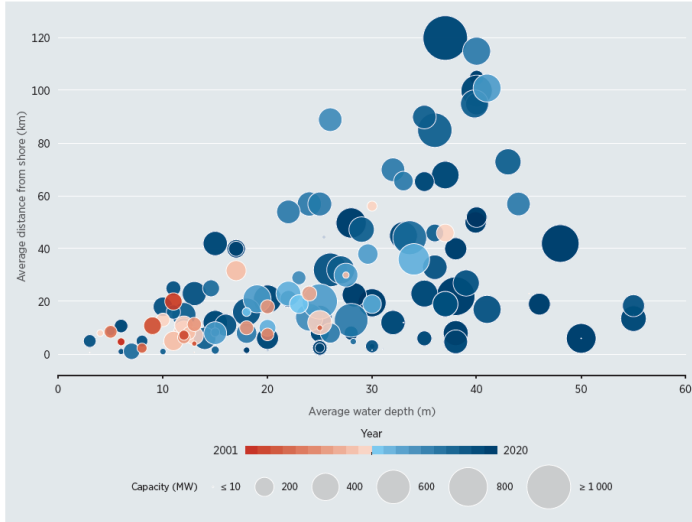
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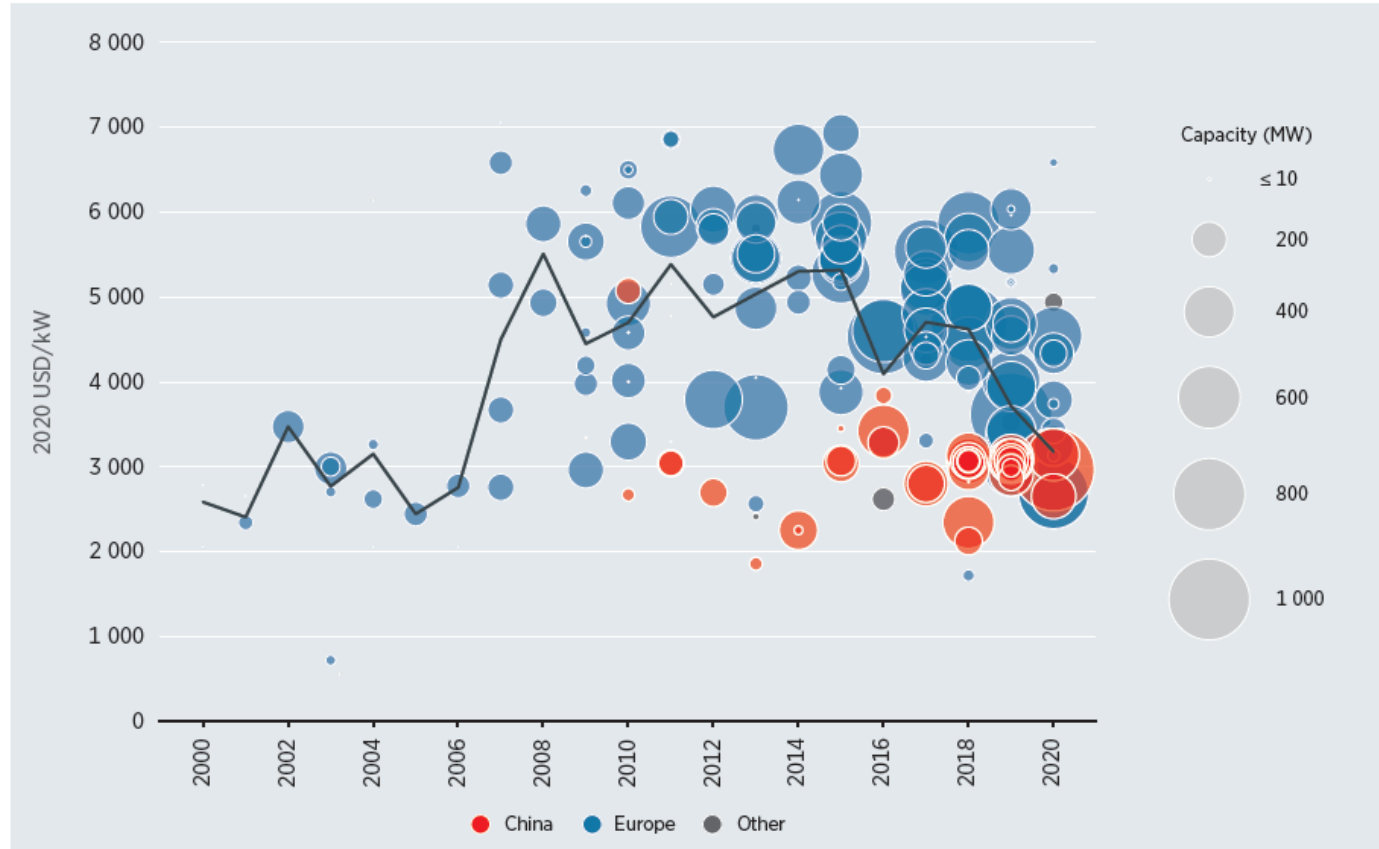
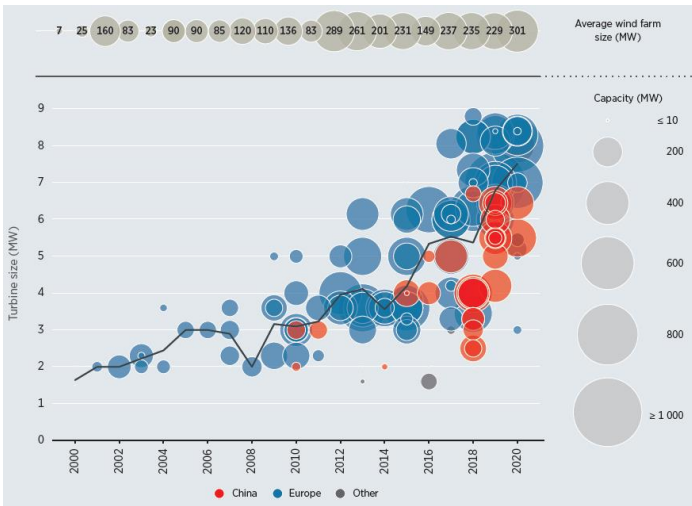
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# Offshore wind - industry trends

## Distance from shore & water depth



## Turbine size and windfarm capacity



Trend towards deployments farther offshore in deeper waters, with larger turbines and installations growing in new and established market.

Total installed costs peaked in 2008 ~**USD 5 500/kW** but has since fallen to **USD 3 185/kW** in 2019.

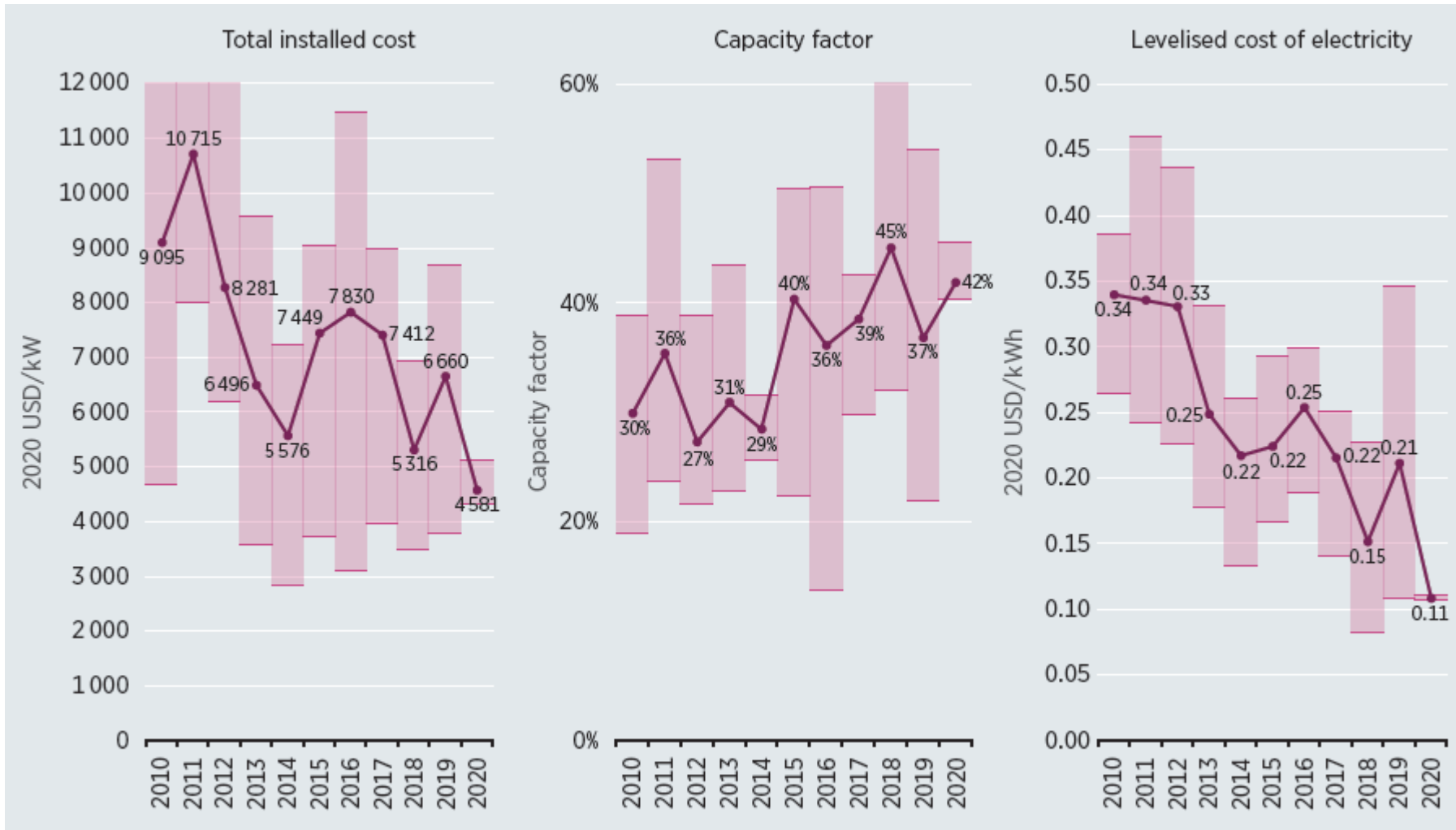
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# DEEP DIVE: CONCENTRATING SOLAR POWER



# Concentrating solar power cost trends

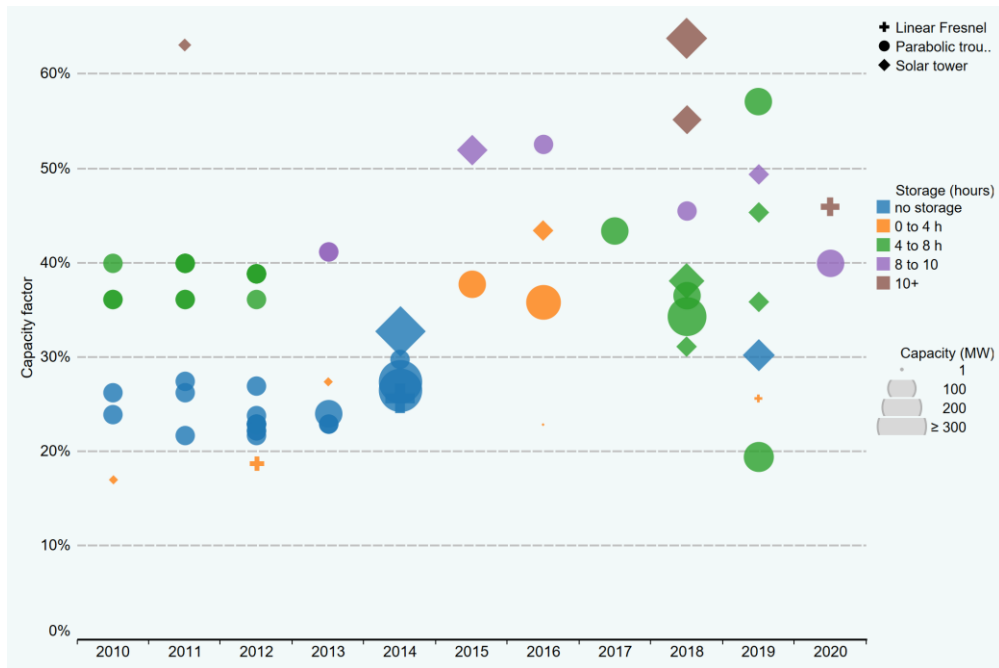
## The LCOE of CSP LCOE of CSP plants fell by 68% between 2010 and 2020



- Global w.avg. total installed costs of CSP plants in 2020 at USD 4581/kW – (36% lower than in 2010).
- Capacity factor increased from 30% in 2010 to 45% in 2019
  - Better technology
  - Shift to higher DNI areas
  - Higher storage hours
- Between 2010 and 2019, LCOE cost declined from USD 0.346/kWh to USD 0.182/kWh

# Concentrating solar power cost trends

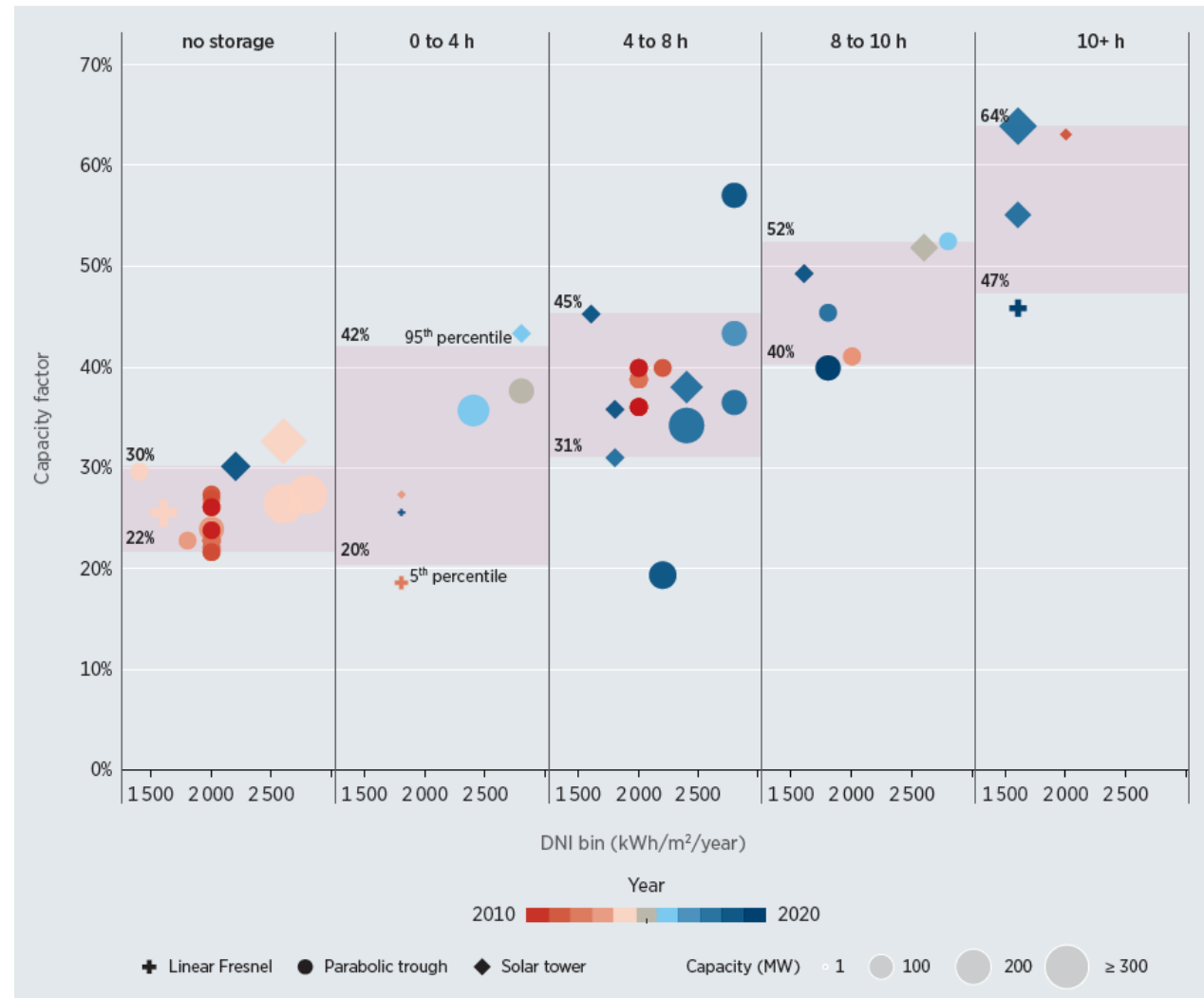
## Shift to areas with higher DNI and more storage



- Costs for thermal energy storage have fallen
- Operating temperatures have increased
- This has led to storage capacity (hours) optimal now higher when before when seeking lowest LCOE

Source: IRENA Renewable Cost Database.

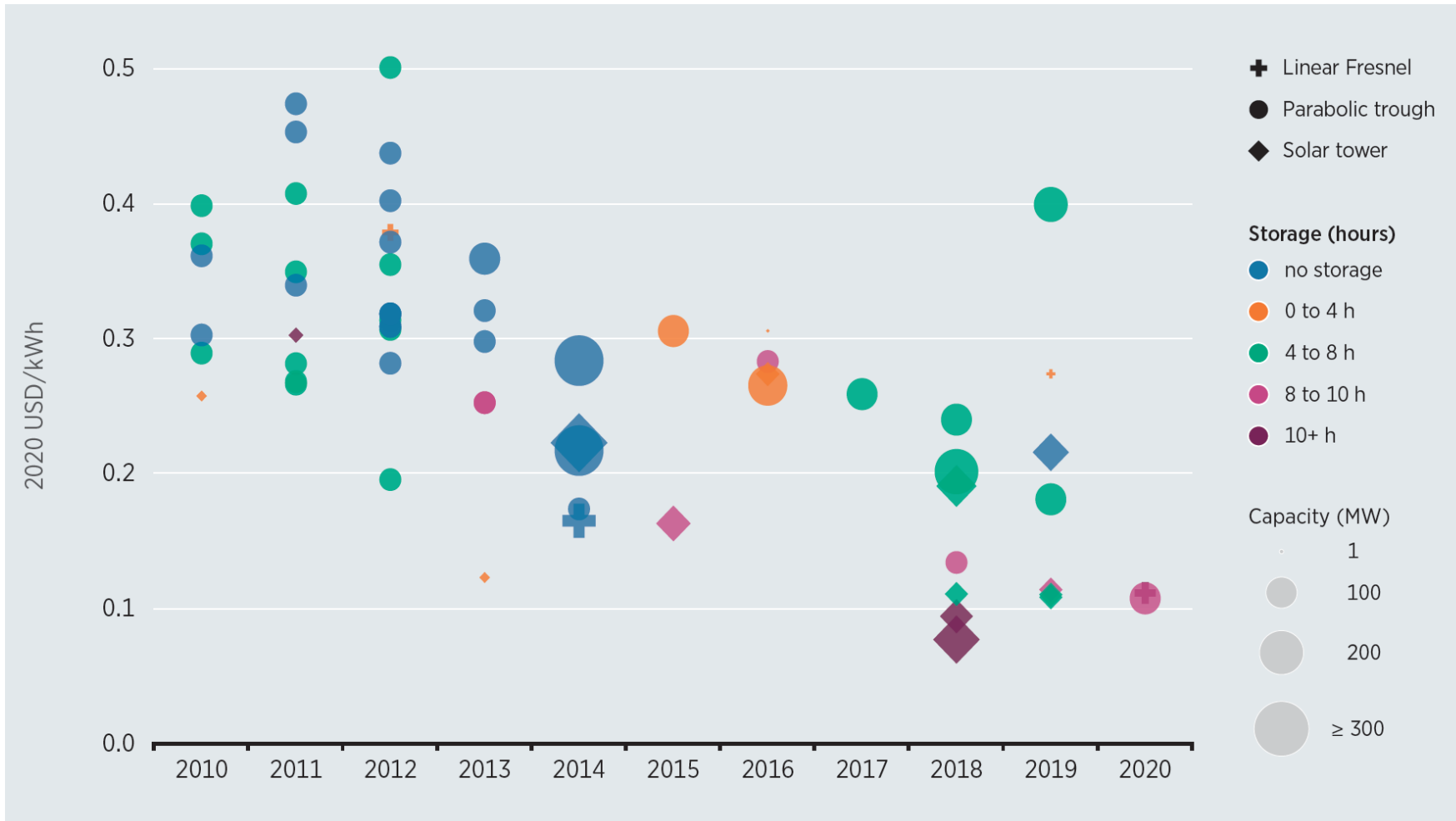
## ► higher capacity factors





# Concentrating solar power cost trends

## PPA announcements point to a declining trend in costs of electricity



- LCOE fell 68% between 2010 and 2020.
- CSP can play an important role in the energy transition
  - Low-cost
  - long-duration thermal energy storage
  - ability to be dispatched

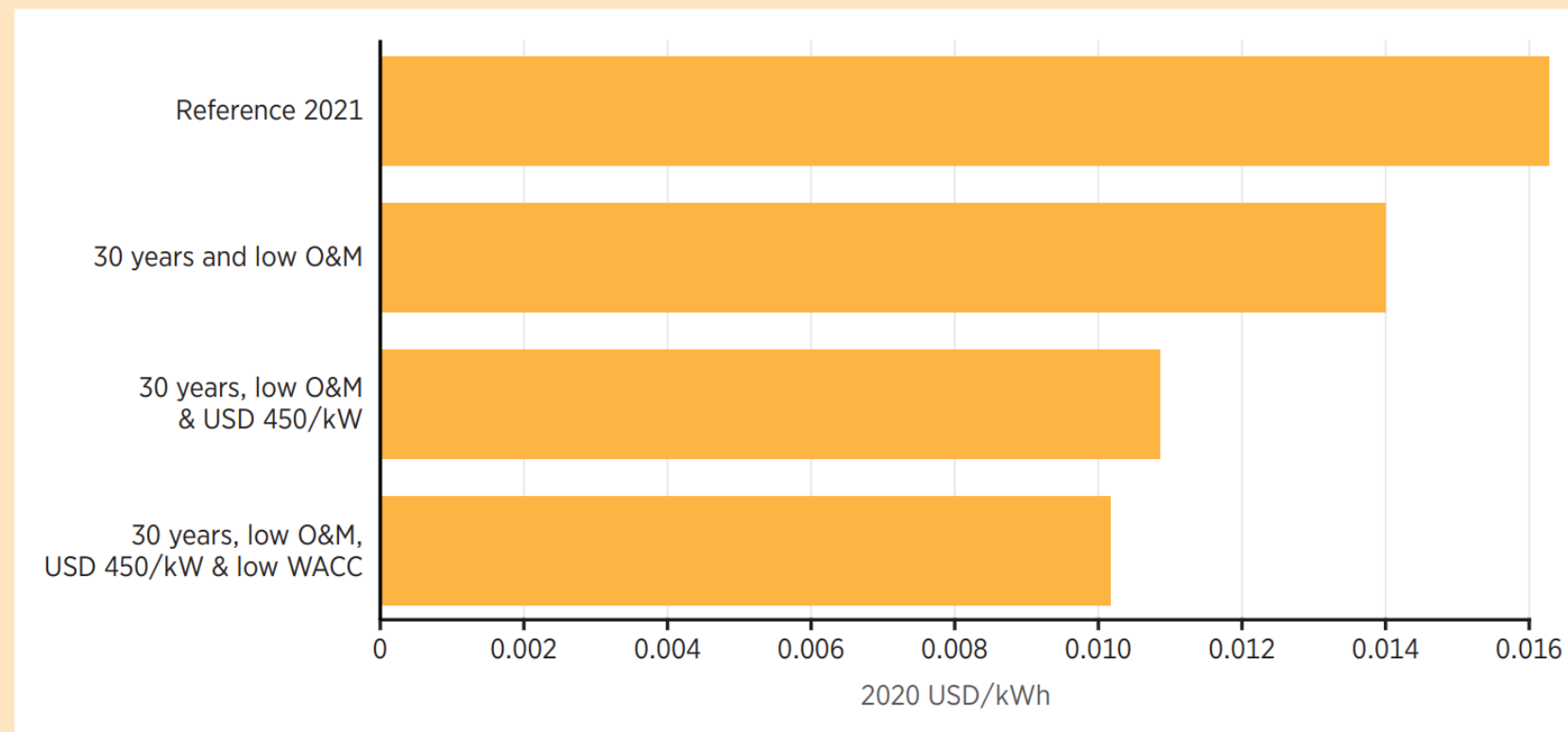
# VERY LOW COST RENEWABLE ELECTRICITY



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

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

**Figure B3.3** Scenarios for utility-scale solar PV LCOE under different input assumptions in Saudi Arabia

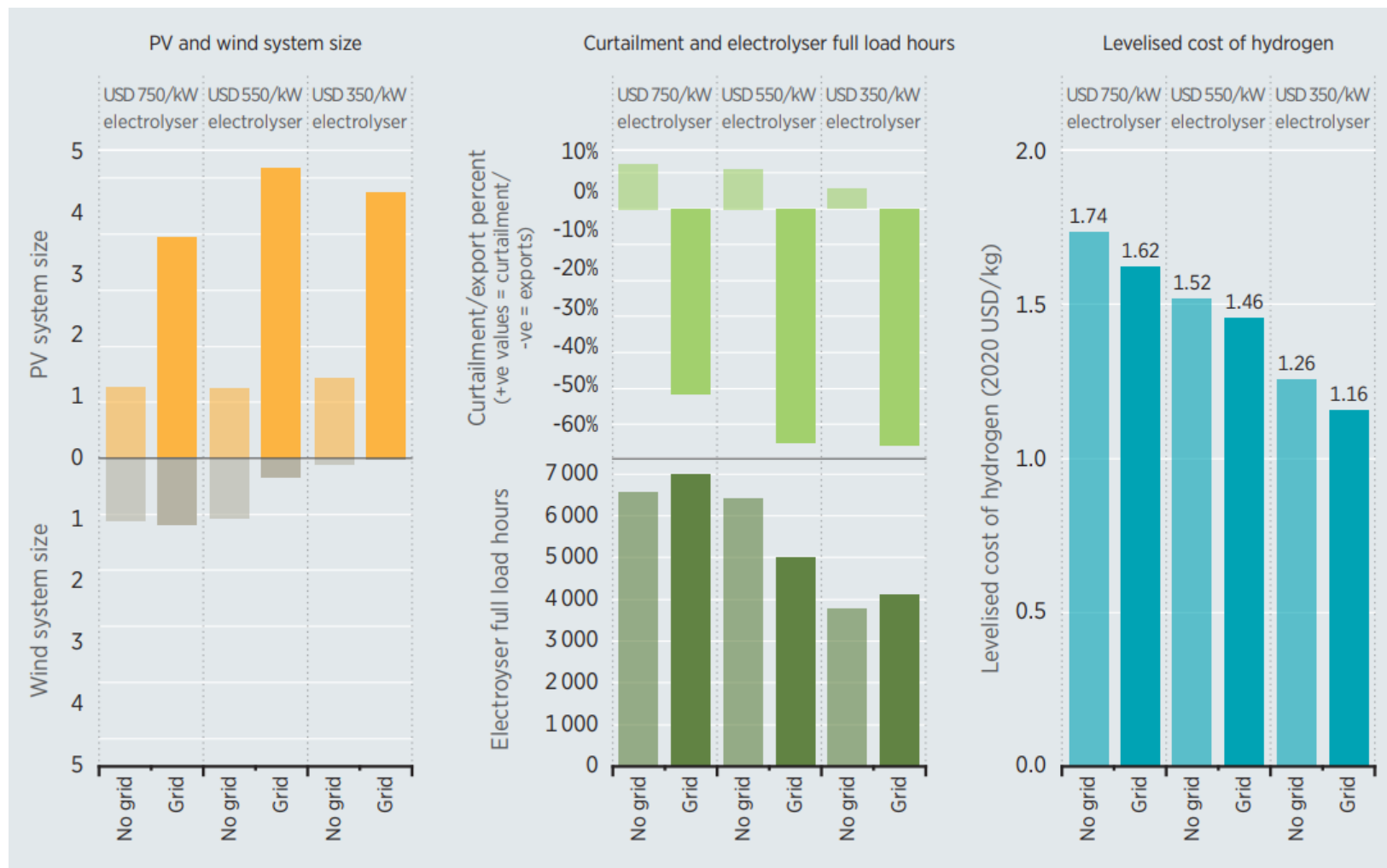


Source: IRENA Renewable Cost Database

- In Saudi Arabia in 2022 there will be low-cost PV and onshore wind
- 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%

# 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 H<sub>2</sub> in 2022

# Renewables are increasingly competitive



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

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[mtaylor@irena.org](mailto:mtaylor@irena.org)

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