

# Renewable Power Generation Costs in 2019: Latest Trends and Drivers

- **Michael Taylor, Renewable Cost Status and Outlook team, IRENA**

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**TUESDAY, 9 JUNE 2020 • 15:00 – 15:30 CEST**

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# Renewable Power: The True Costs

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**RENEWABLE POWER GENERATION COSTS IN 2019**

# IRENA Costing Analysis Products



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2017

2018

2019

2020

# Costs continuing to fall for RE, solar & wind power in particular

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

- ▶ 56% of utility-scale capacity added in 2019 cost less than cheapest new coal option

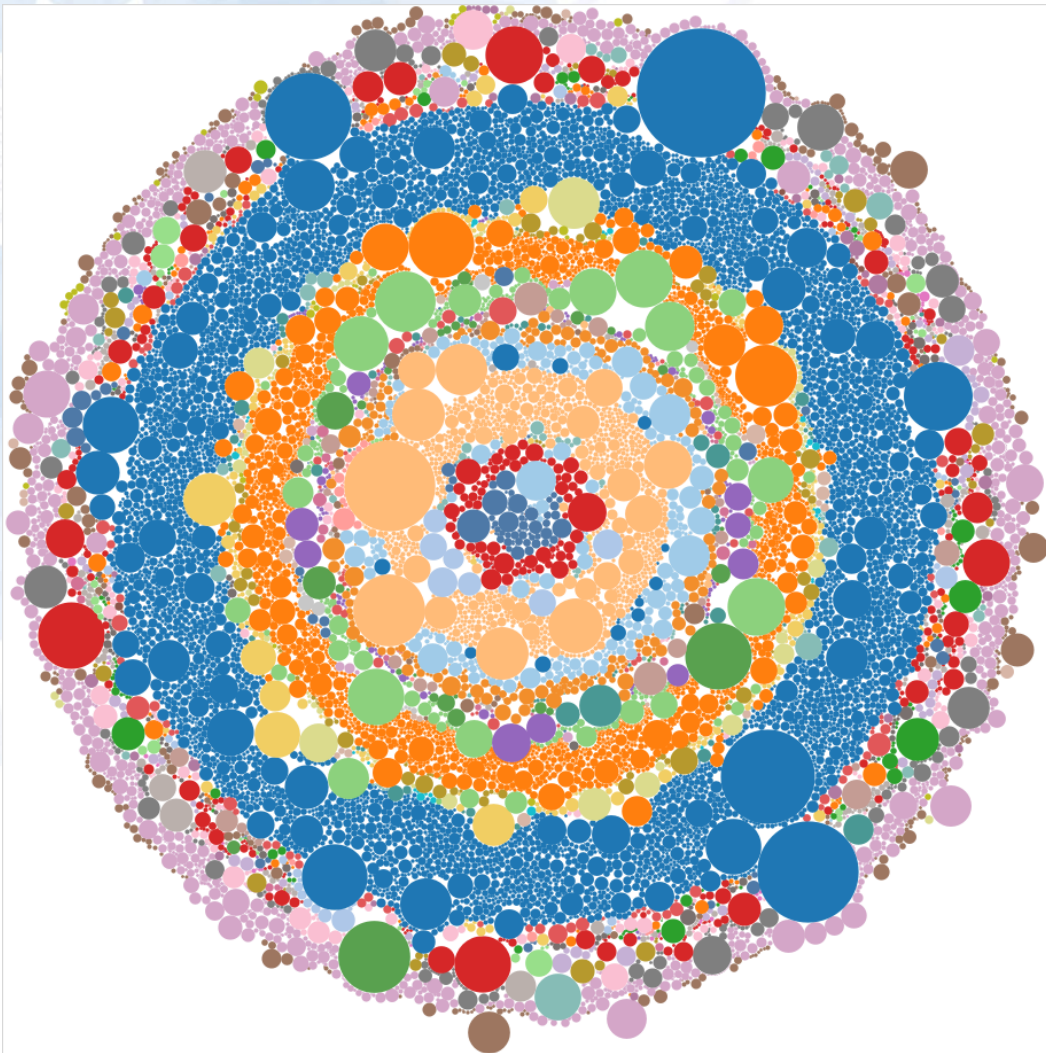
Will increasingly undercut even operating costs of existing coal

Cost reductions for solar wind are coming from:

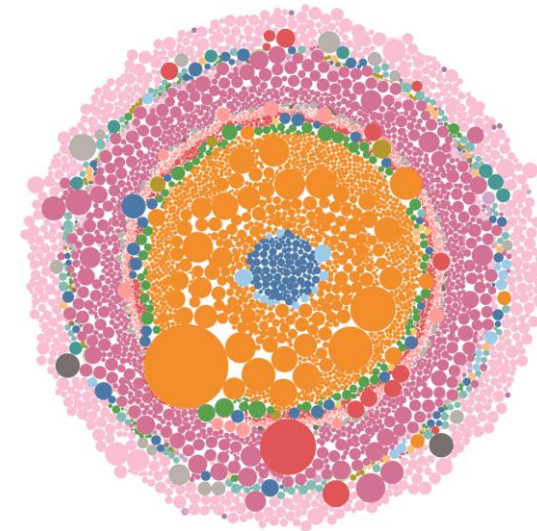
- ▶ improved technology, economies of scale, more competitive supply chains and developer experience



# Power generation and PPA/tender databases

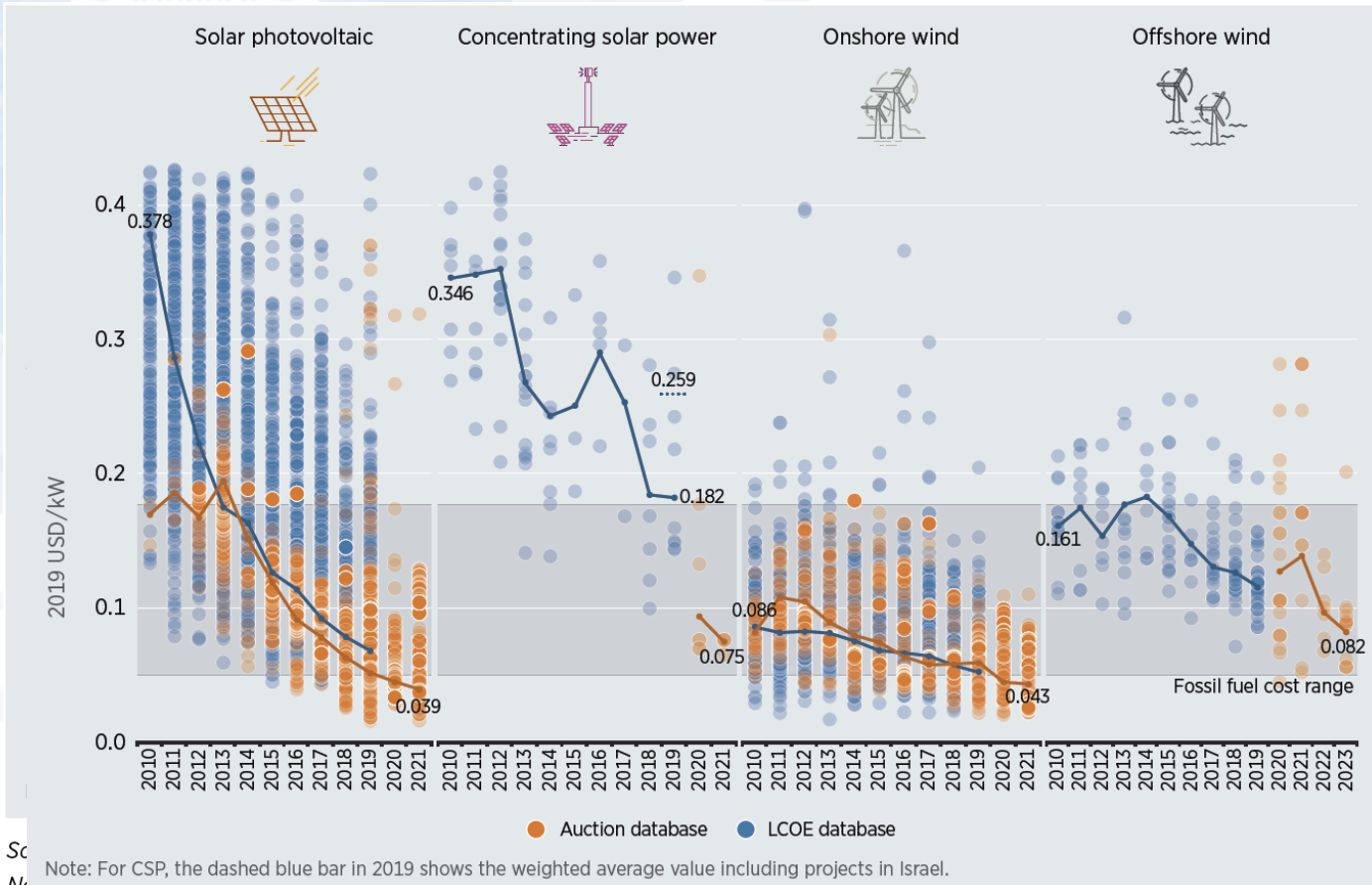


Project cost database  
~18k projects  
1775 GW



PPA/Auction database  
~11k projects  
496 GW

# Recent cost evolution



Sc  
Nc

Source: IRENA Renewable Cost Database.

Note: Each circle represents an individual project LCOE (blue dots), or an auction result (orange dots), where there was a single clearing price at auction, for the actual or estimated year of commissioning respectively. The centre of the circle is the value for the cost of each project on the Y axis. The thick lines are the global weighted average LCOE, or auction values, by year. For the LCOE data, the real WACC is 7.5% for OECD countries and China, and 10% for the rest of the world. The band represents the fossil fuel-fired power generation cost range.

- Cost reductions continue to 2021/23
- Average LCOE of all renewable power generation technologies, except CSP fall
- Utility scale solar average in 2019 undercut cheapest new fossil fuel
- Bioenergy, geothermal, hydro, solar PV and onshore wind all at lower end of fossil cost range
- Offshore wind and CSP see step change in costs
- Offshore wind to USD 50-100/MWh
- CSP, with an even lower deployment, could fall to USD 70-80/MWh



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

2018 - 2019

2010 - 2019

2010 - 2021/23

**Solar PV**

**-13%**

**-82%**

**-90%**

**CSP**

**-1%**

**-47%**

**-78%**

**Offshore wind**

**-9%**

**-29%**

**-49%**

**Onshore wind**

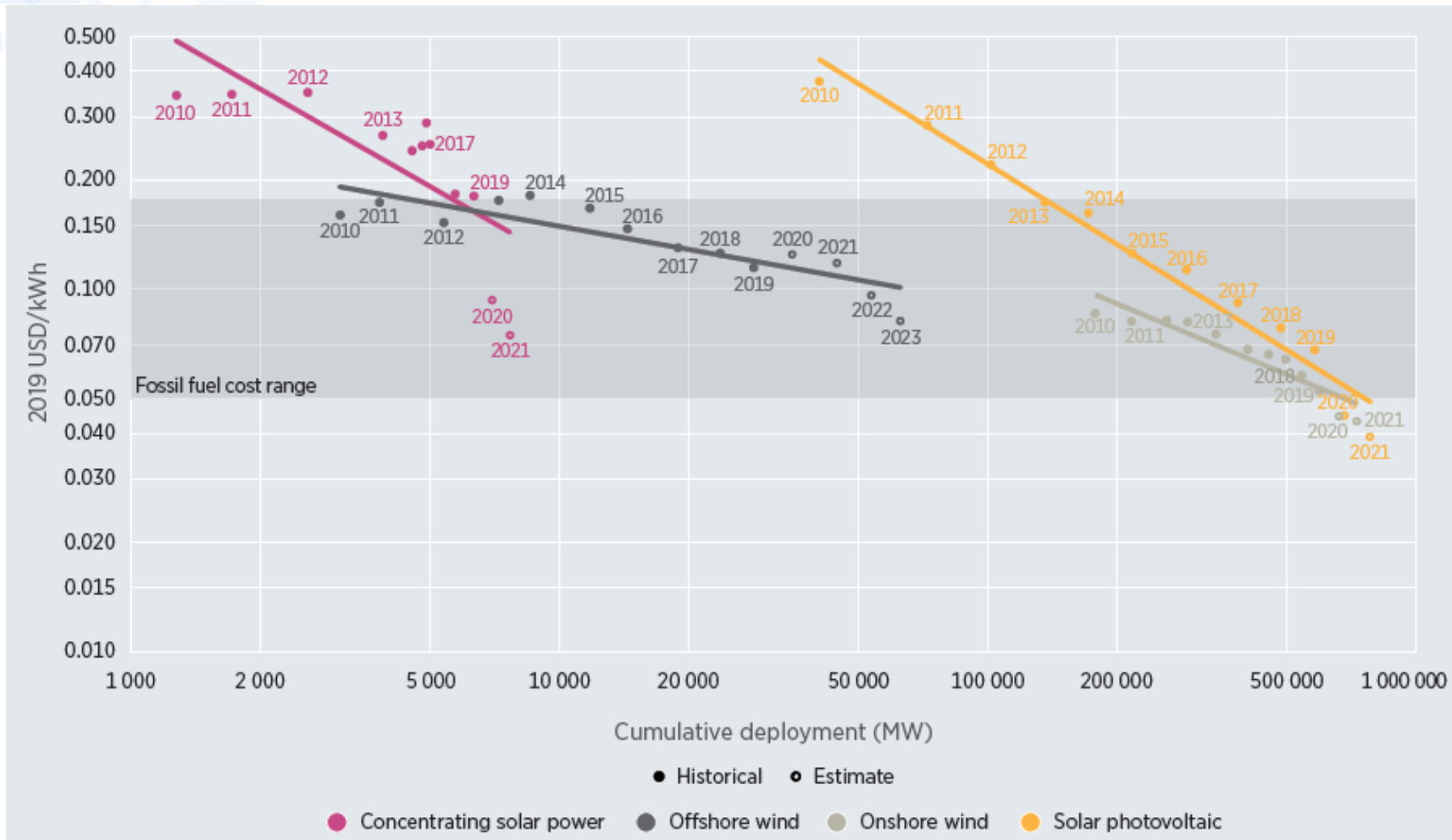
**-9%**

**-39%**

**-50%**

# Learning rates

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



Learning rates:

- Utility-scale solar PV:  
36% for 2010 – 2019  
**40% for 2010 - 2021**
- Concentrating solar power:  
23% for 2010 - 2019  
**38% for 2010 - 2021**
- Onshore wind:  
23% for 2010 - 2019  
**29% for 2010 - 2021**
- Offshore wind:  
10% for 2010 - 2023  
**10% for 2010 - 2023**

Note: The LCOE and auction price data are for utility-scale projects.

Source: IRENA.

# Less investment \$ = more capacity



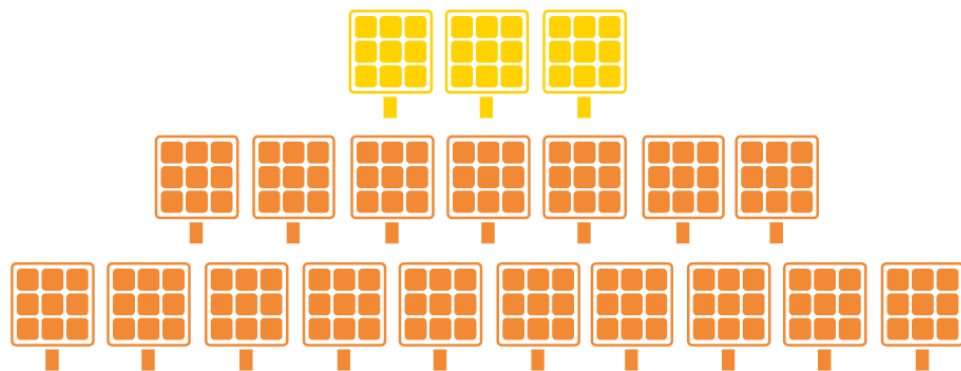
USD 1 million invested

Solar PV



● 2010 ● 2019

213 kW → 1 005 kW

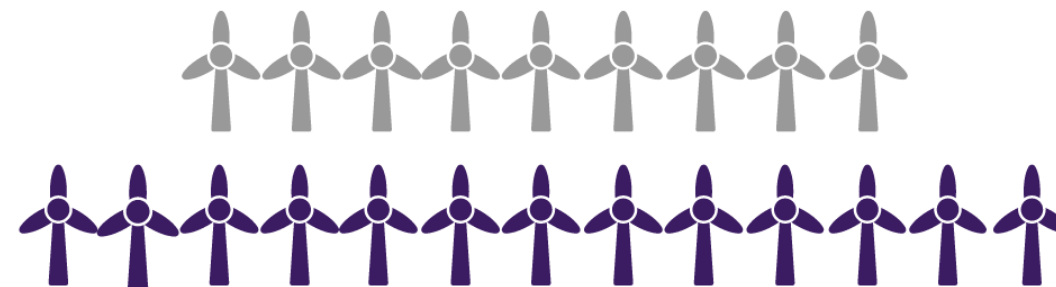


Onshore Wind



● 2010 ● 2019

514 kW → 679 kW





# **DEEP DIVE: ONSHORE WIND**

# Wind power costs are falling....

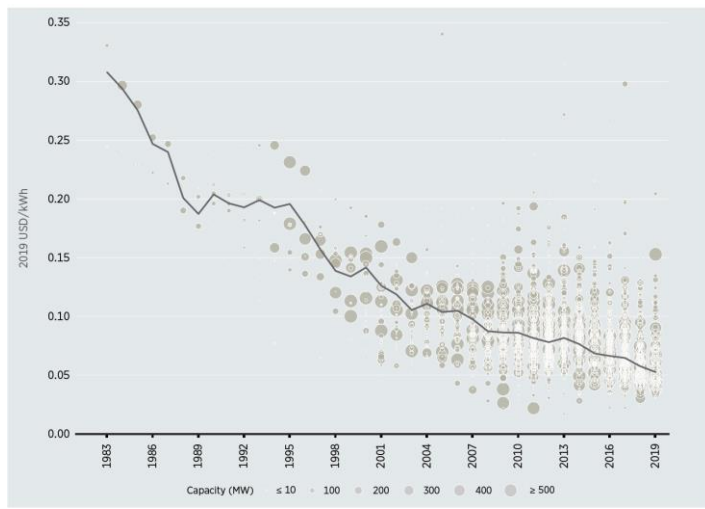
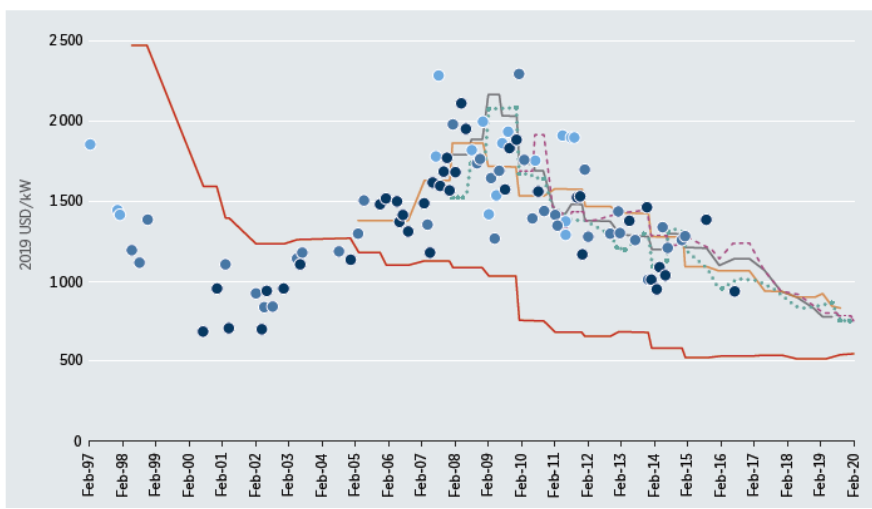
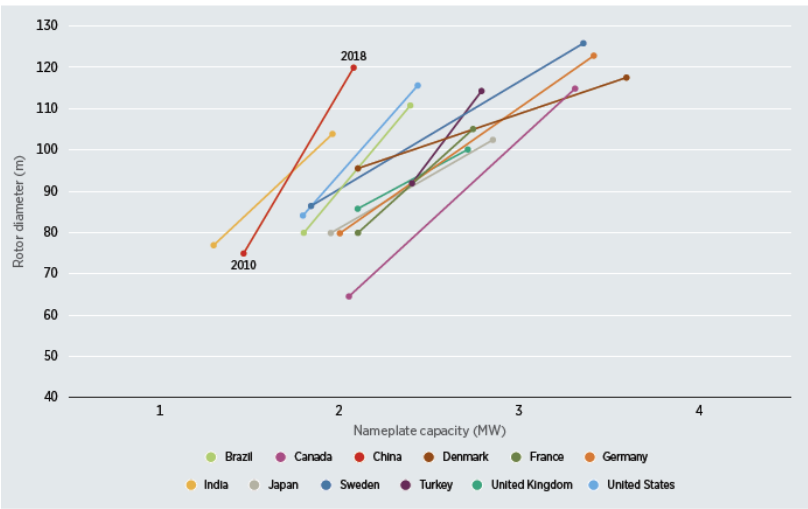
Higher capacity factors from improved technology



Total installed cost declines: lower wind turbine costs

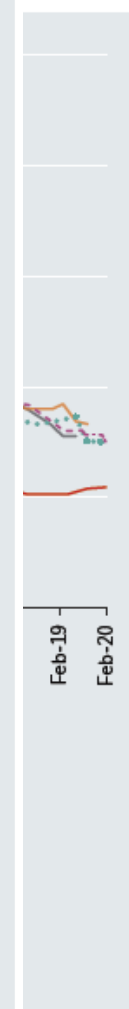
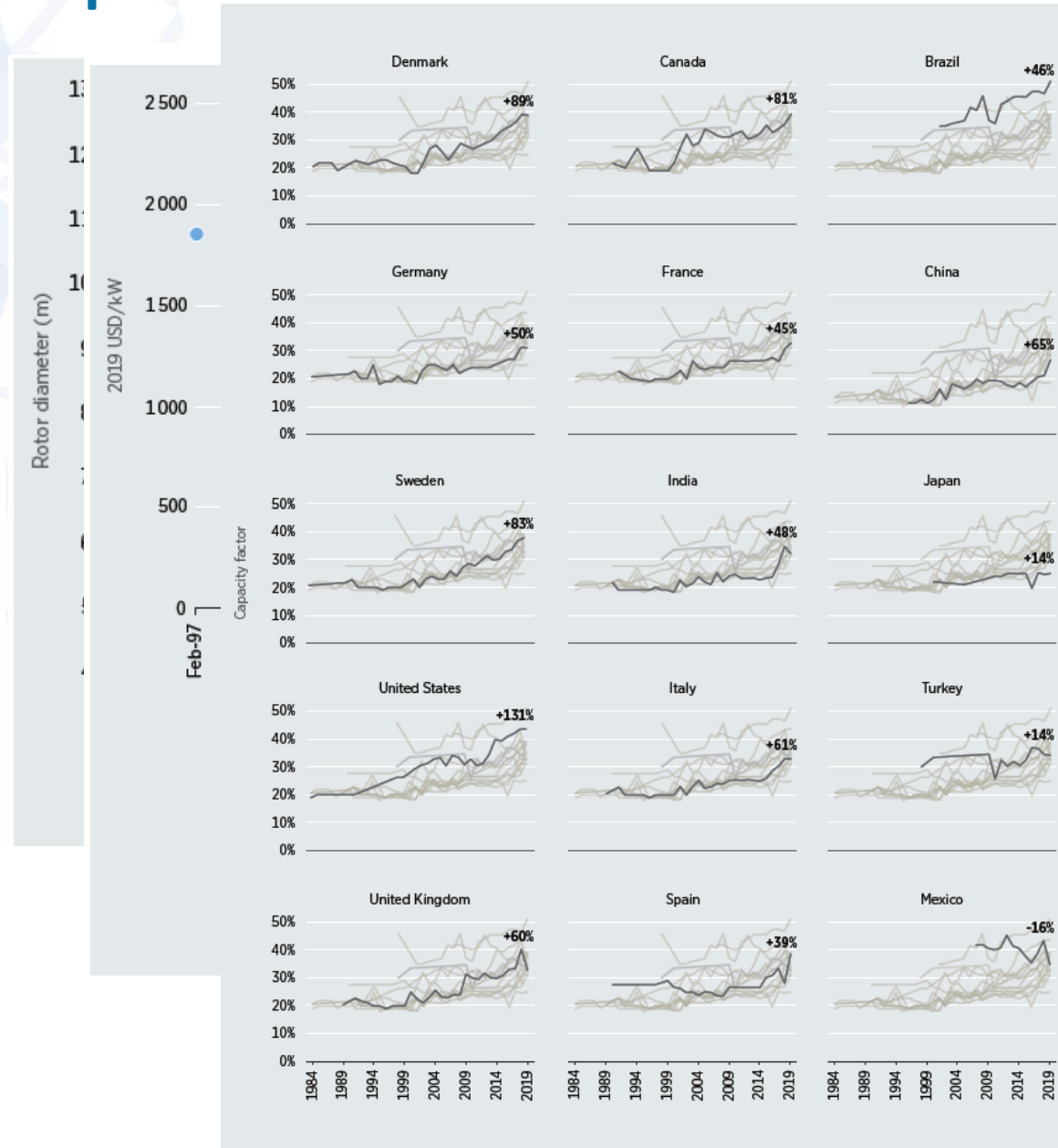
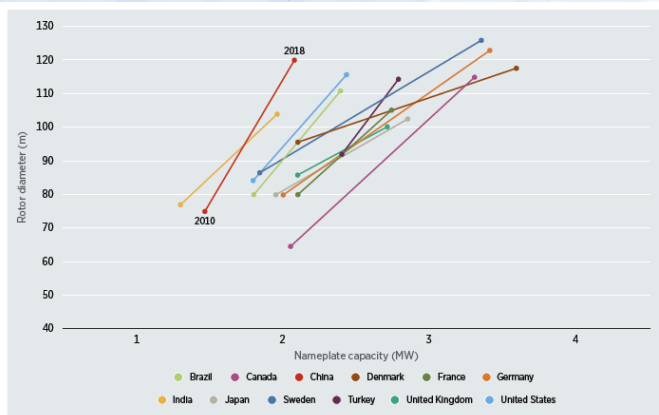


LCOEs are falling



# Wind turbine cost and performance trends

Turbine capacity and rotor diameter



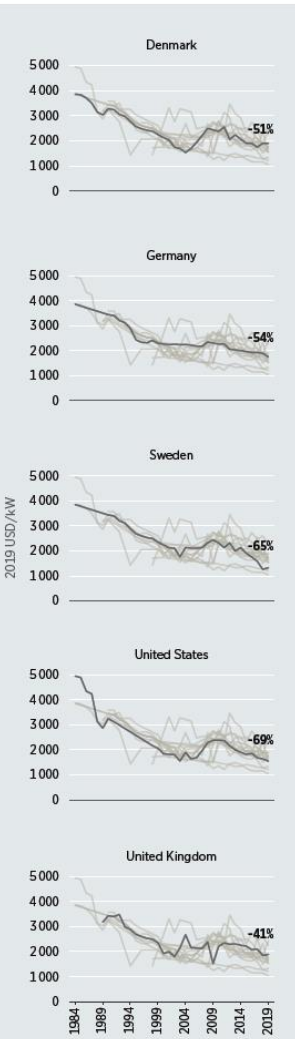
The more competitive, established markets show larger reductions in total installed costs over longer time periods than newer markets.

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

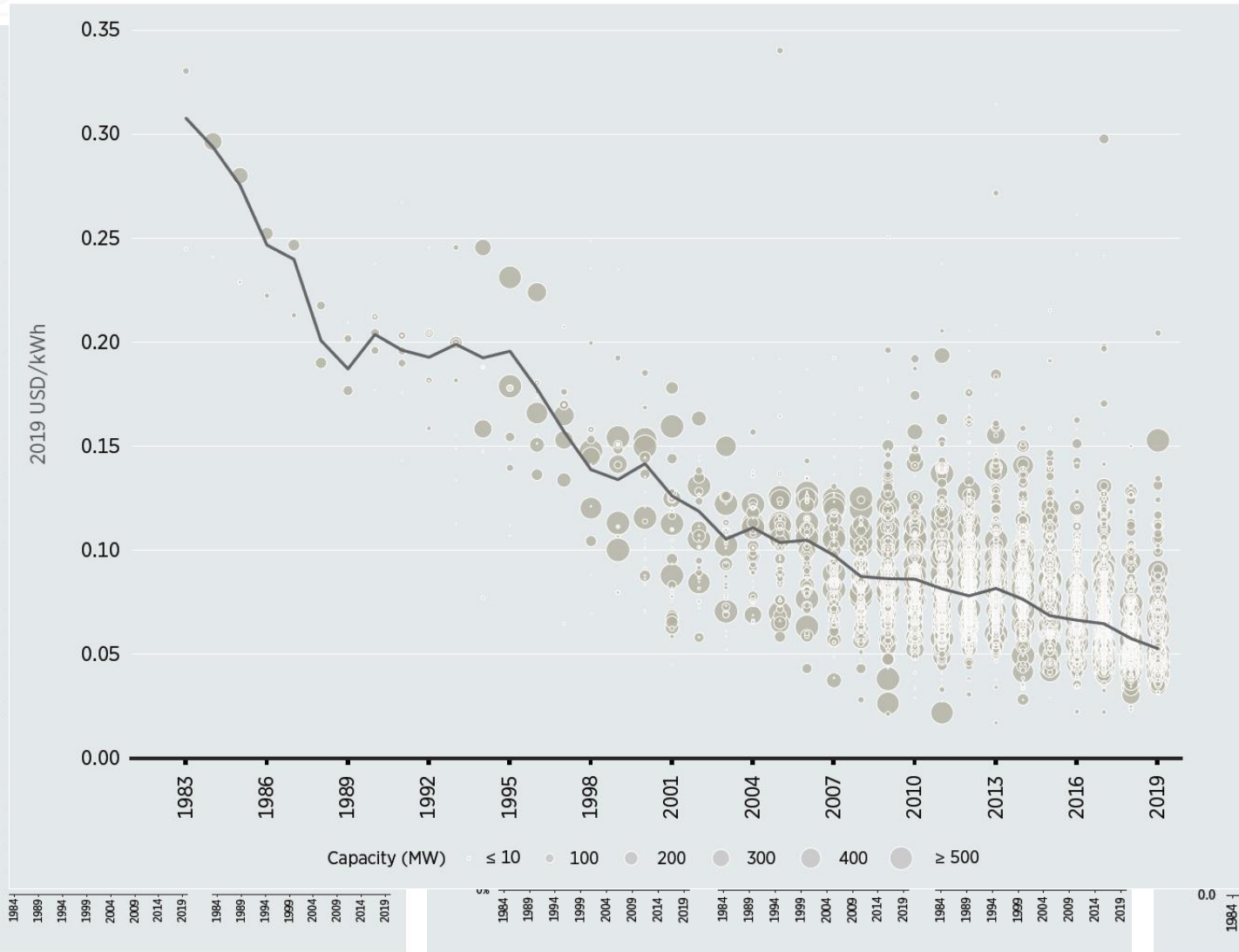
Average capacity factors have increased from improved turbine technology, siting and operations.

# Levelised cost of electricity

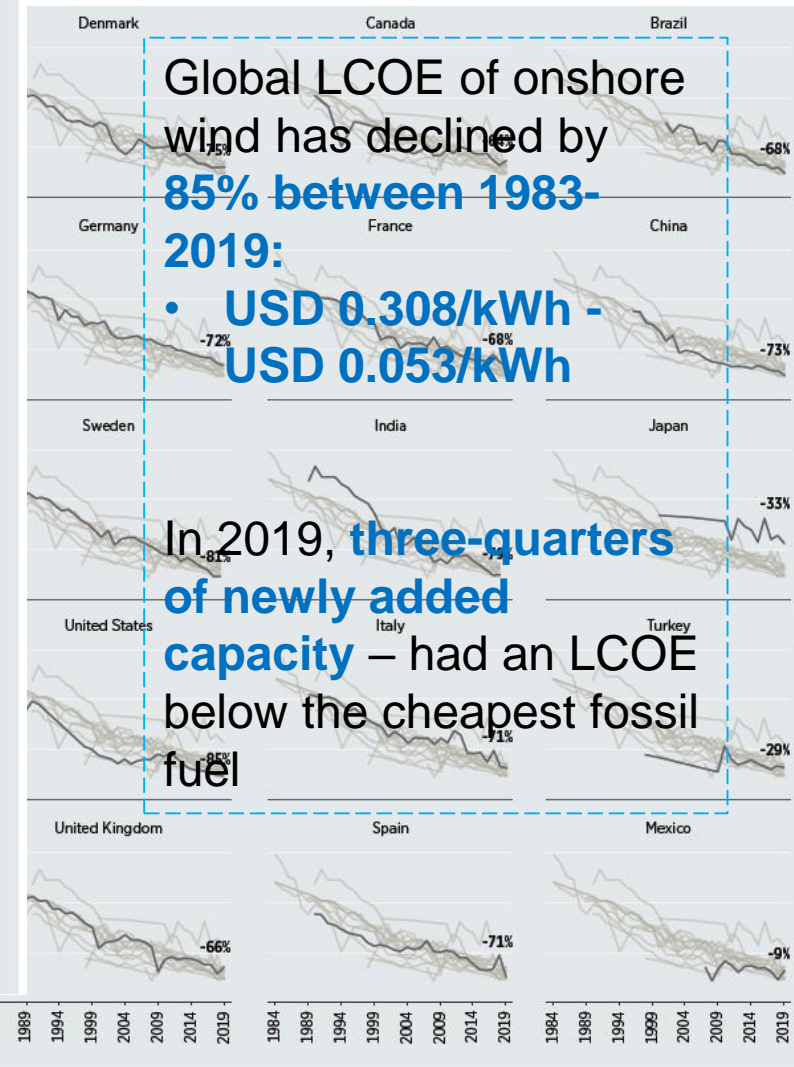
## Total installed costs



## Capacity factors



## LCOE



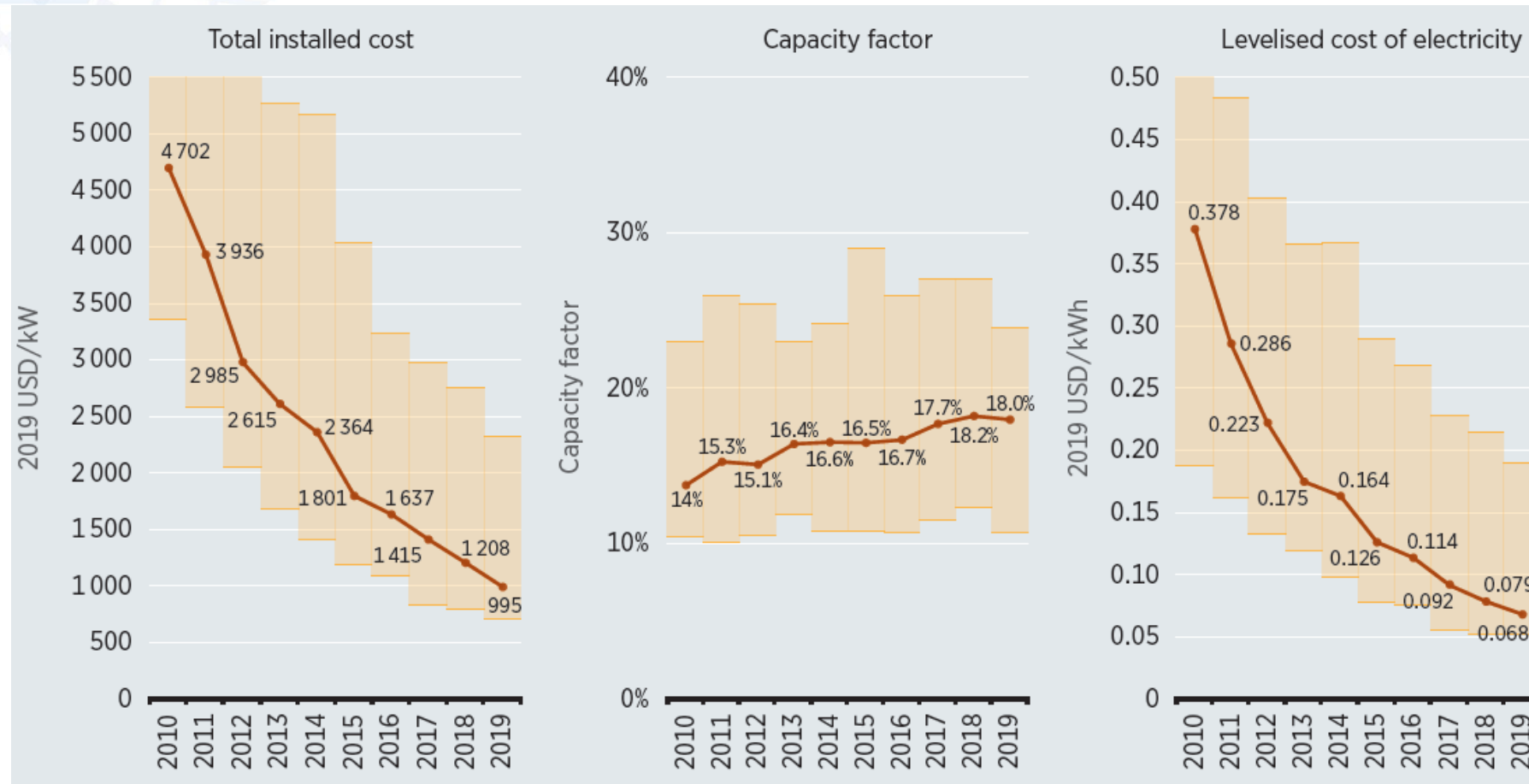
# DEEP DIVE: SOLAR PV





# Solar PV cost trends

The LCOE of utility-scale PV has declined 13% YoY in 2018-2019 to USD 0.068/kWh



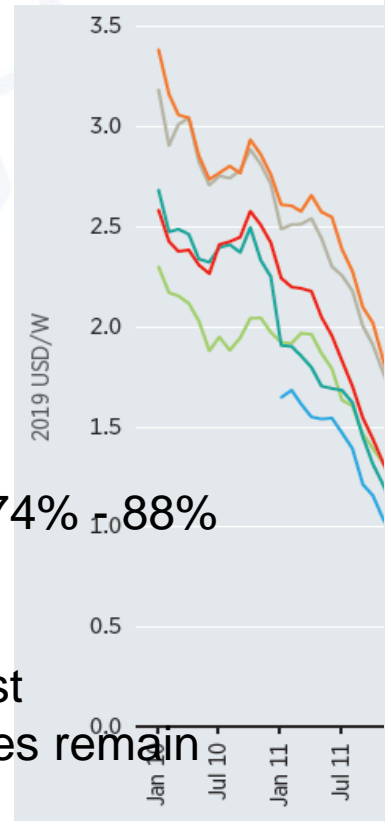
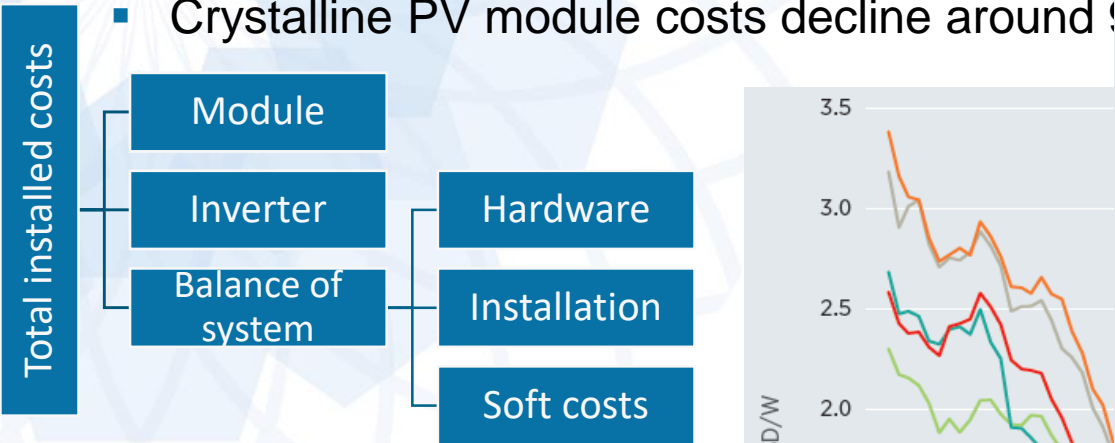
Source: IRENA Renewable Cost Database.

- Total installed costs w. avg. declined 13% from 2018 and 79% from 2010.
- Shift of w. avg. to lower end of the 5th and 95th percentile ranges
- Cost reduction drivers
  - lower module costs
  - sustained BoS decline
- Capacity factor stable around 18%

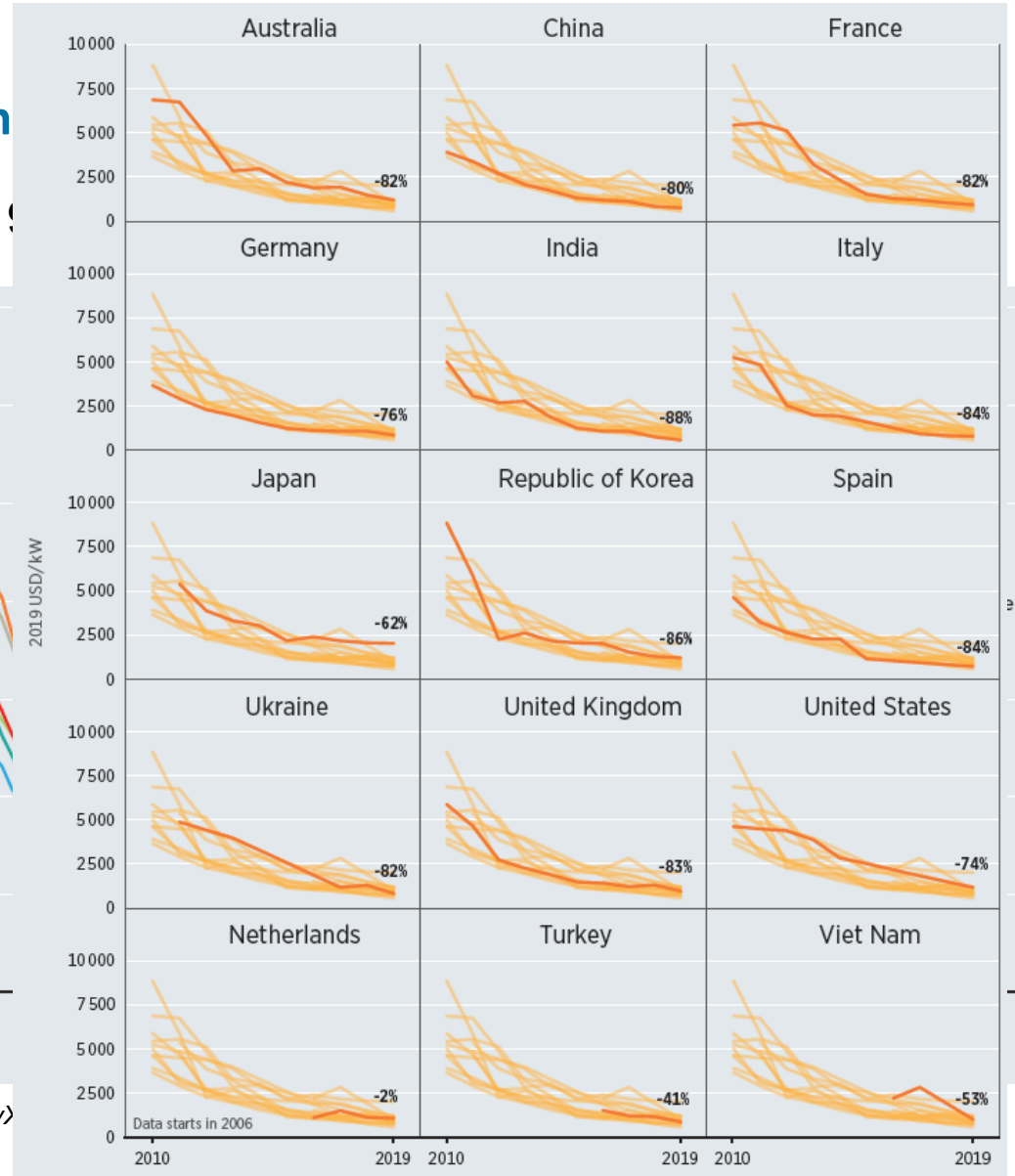
Note: costs for PV expressed per kilowatt direct current (DC); capacity factor expressed as an AC-to-DC value.

# Solar PV cost trends

As balance of system costs fell, so did module costs continue its decline, driven by manufacturing scale and total installed costs



Source: GlobalData (2019); pv

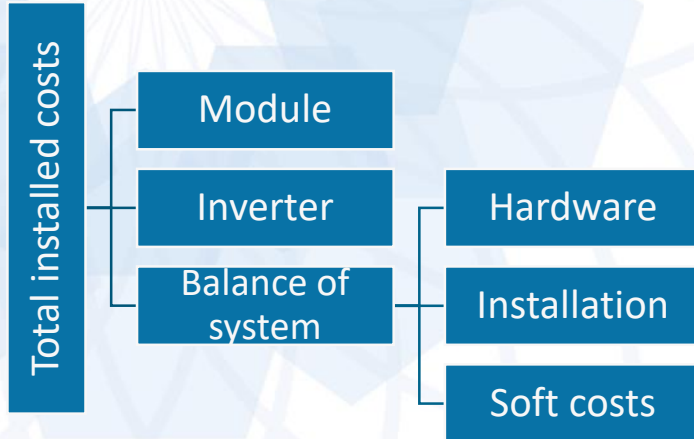


Source: IRENA Renewable Cost Database.

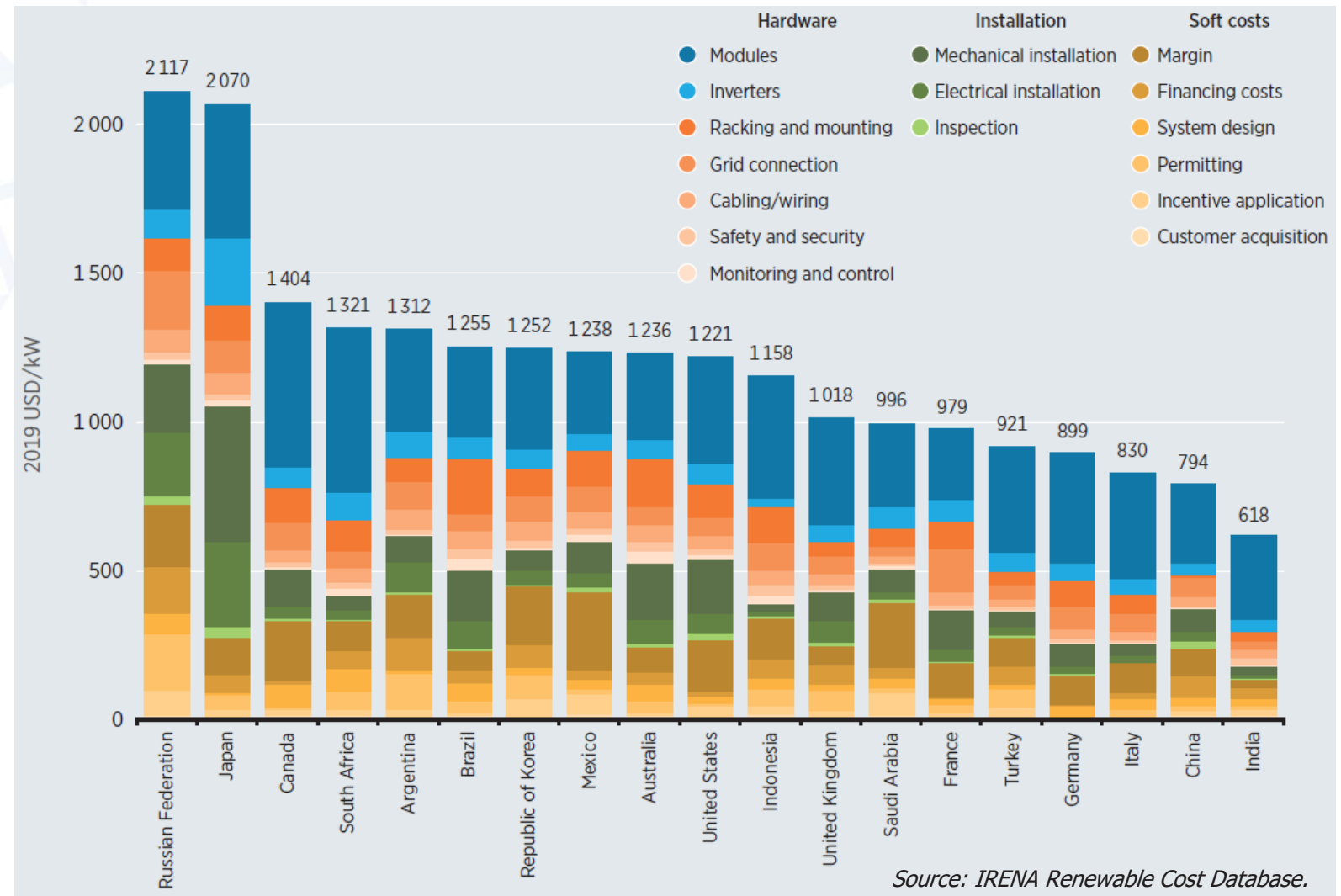
- Costs range in Dec 2019 from USD 0.21/W to USD 0.38/W
- High efficiency crystalline silicon fell 74% at USD 0.36/W
- Recently bifacial module costs within a close range of higher performing mono-facial options
- Narrowing of country cost differential, but differences remain

# Solar PV cost trends

## Country TIC cost in 2019 from USD 618/kW in India to of USD 2 117/kW in Russian Federation

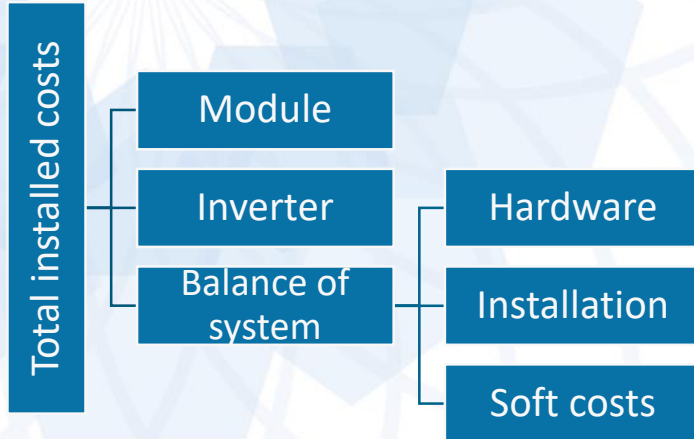


- In 2019 BoS (excl. inverter) made up 64% of TIC (up from about half of TIC in 2016).
- The highest cost average was 3.5x more than the lowest
- Despite convergence of installed costs in major markets in last 4 years, differences persist.

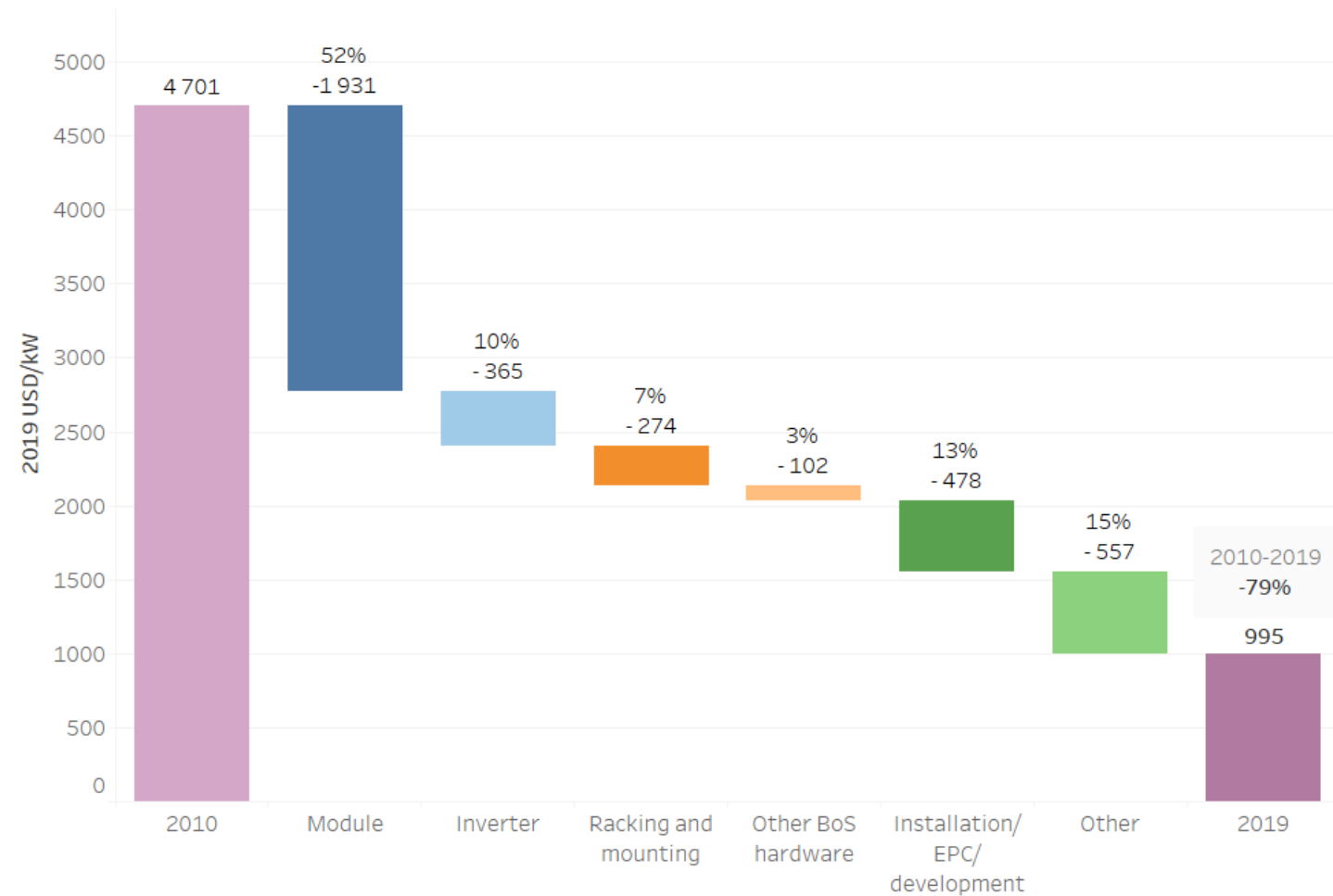


Source: IRENA Renewable Cost Database.

# Total installed cost reduction drivers



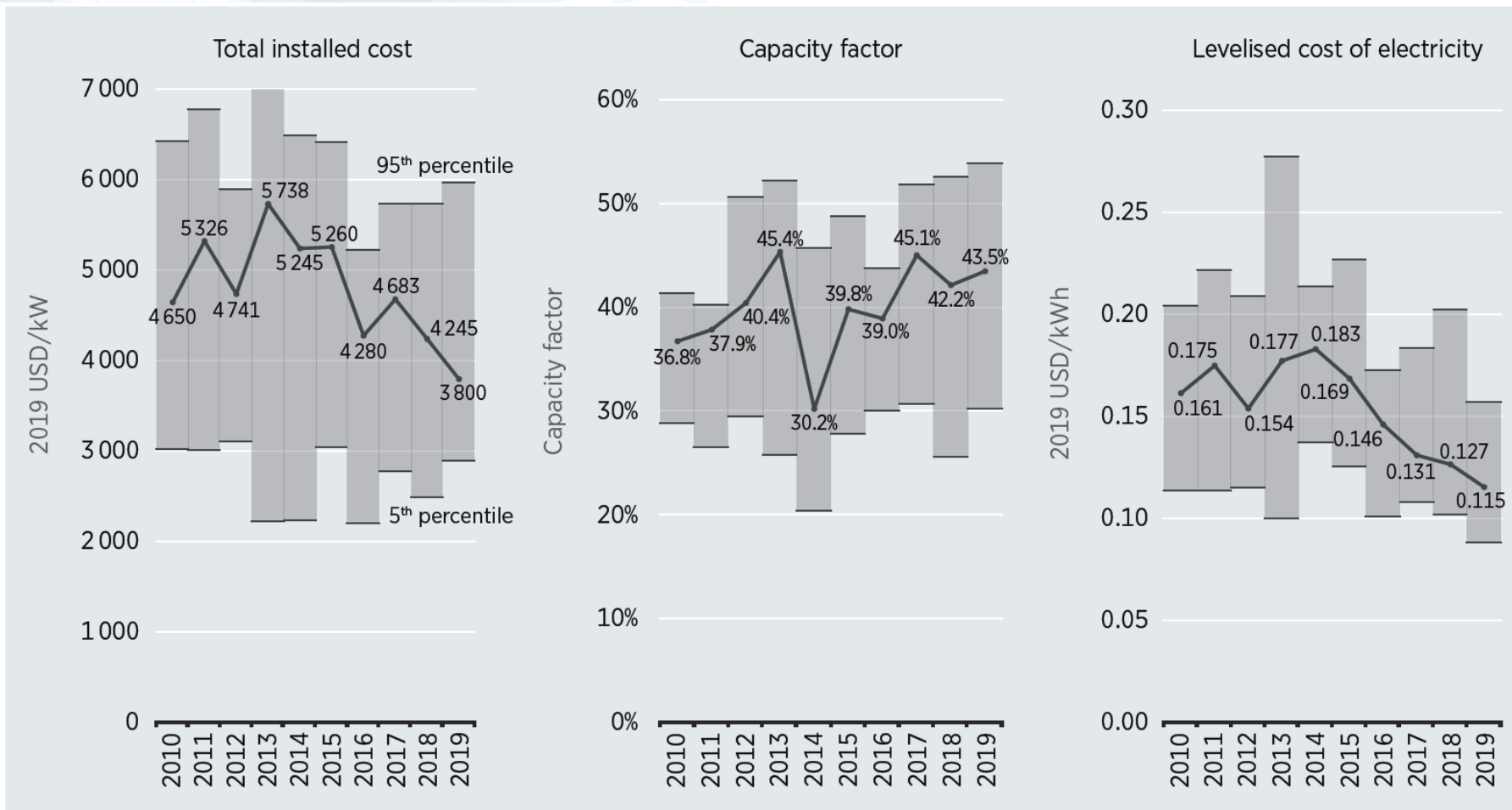
- Modules and inverters accounted for 62% of the global weighted-average total installed cost decline
- BoS costs are also an important contributor





# OFFSHORE WIND

# Offshore wind cost and performance trends



Between 2010-2019, the global weighted average:

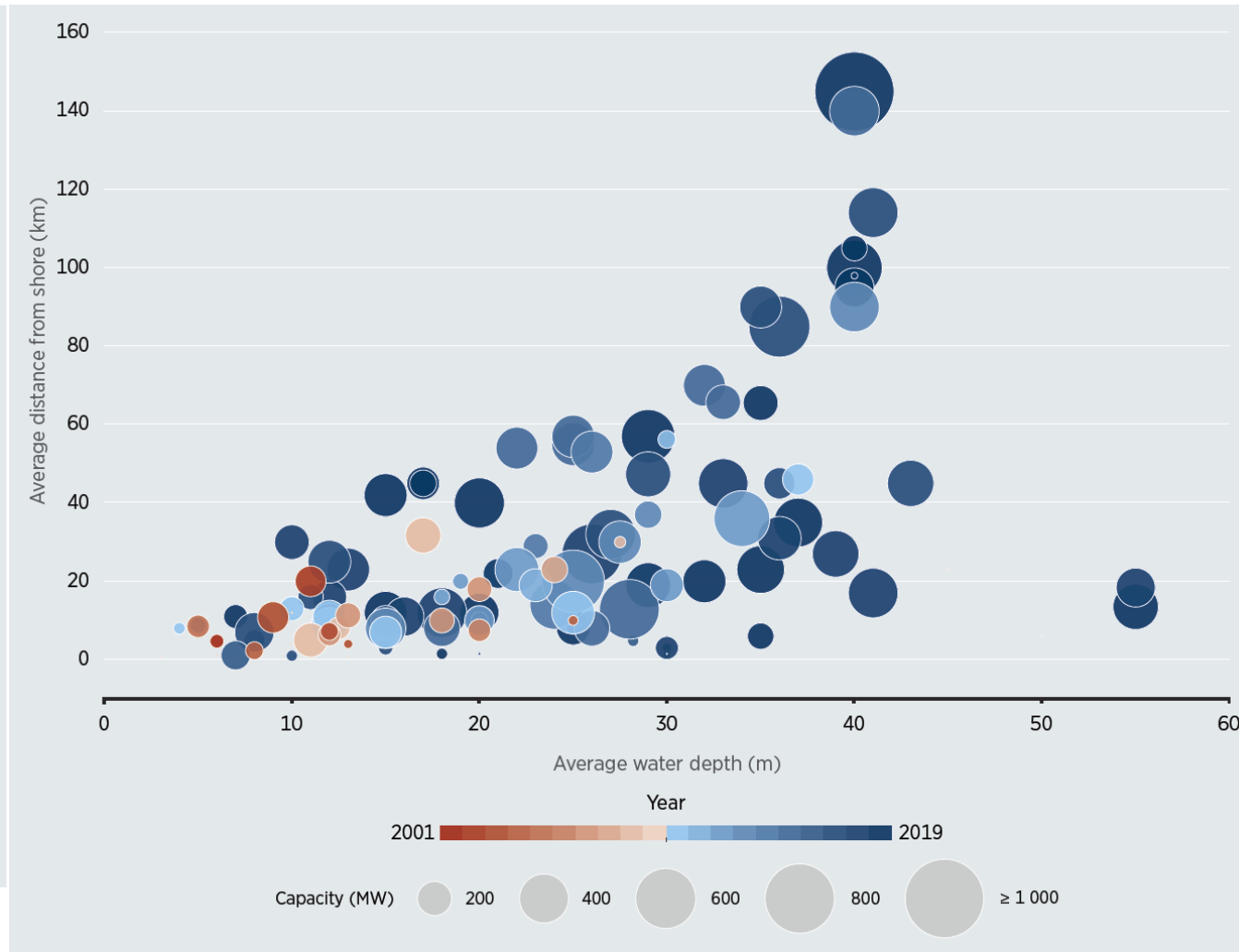
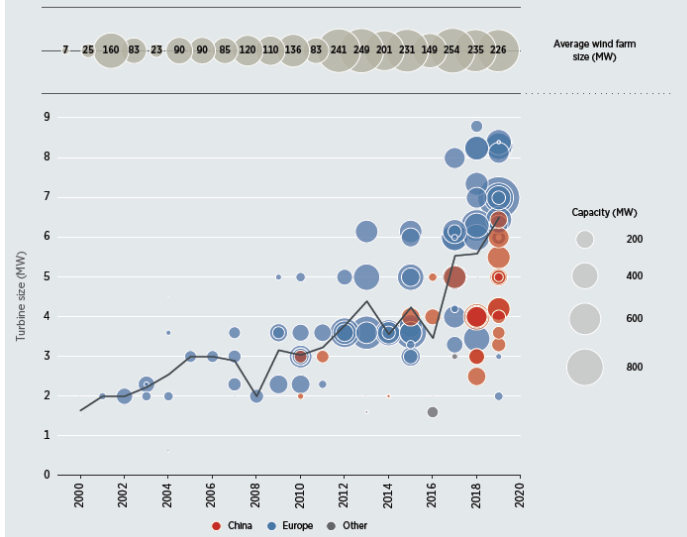
- Total installed cost reduced by **29% from USD 4 650 to USD 3 800/kW**
- Capacity factor increased by **7 percentage points from 37% to 44% in 2019**
- LCOE reduced by **29% from USD 0.161/kWh to USD 0.115/kWh**

# 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 2013 **USD 5 740/kW** but has since fallen to **USD 3 800/kW** in 2019.

Average lifetime capacity factors increased with improved turbine technology and operations from growing experience.

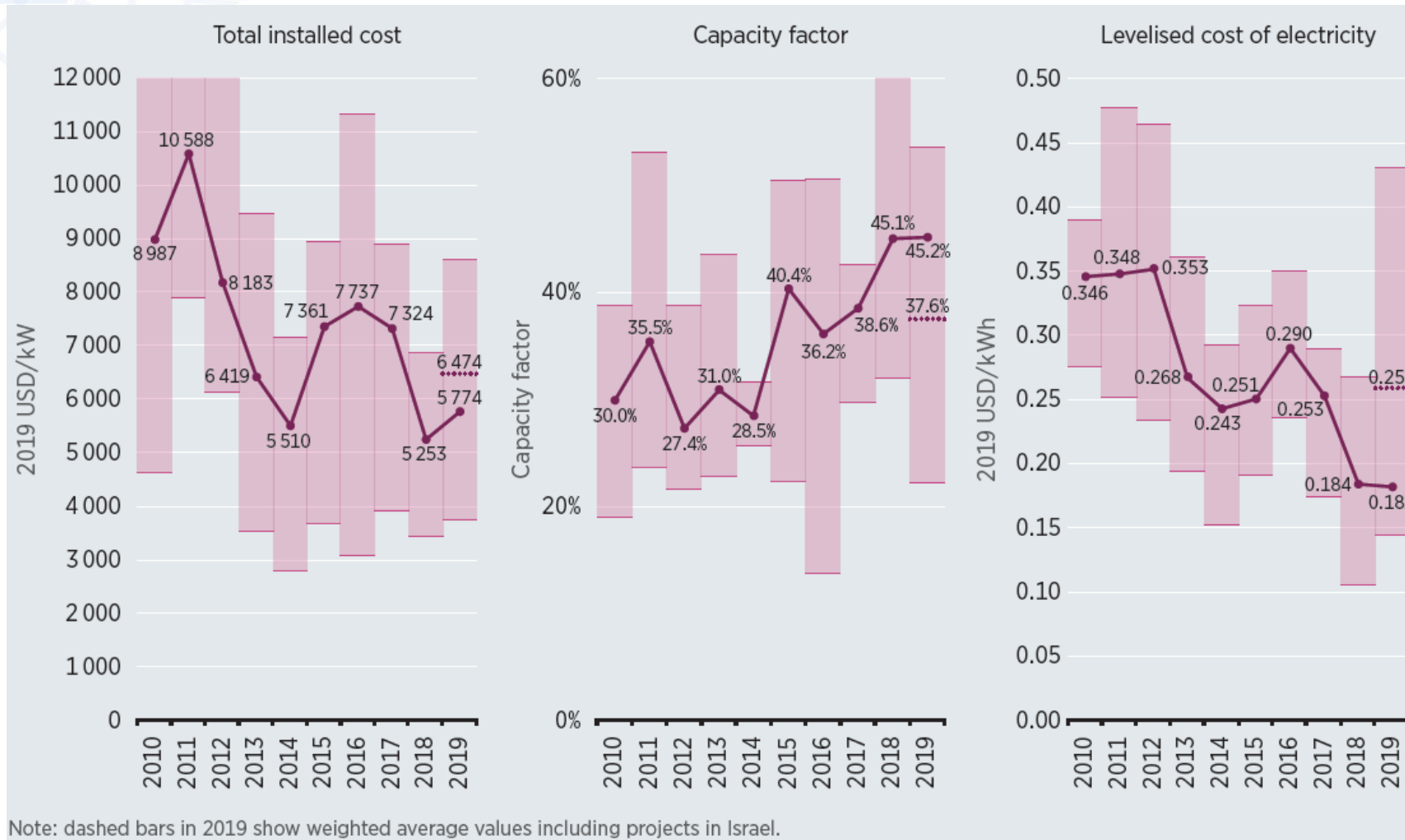
# DEEP DIVE: CONCENTRATING SOLAR POWER





# Concentrating solar power cost trends

## The LCOE of CSP LCOE of CSP plants fell by 47% between 2010 and 2019

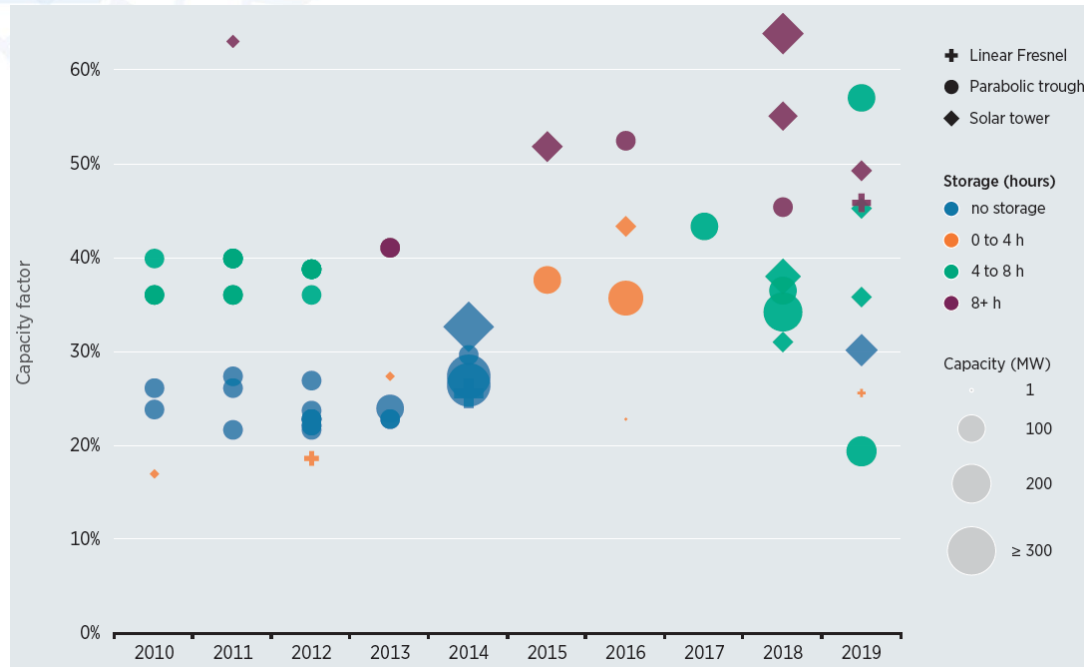


Source: IRENA Renewable Cost Database.

- Global w.avg. total installed costs of CSP plants in 2019 at USD 5774/kW – one-tenth higher than in 2018 (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

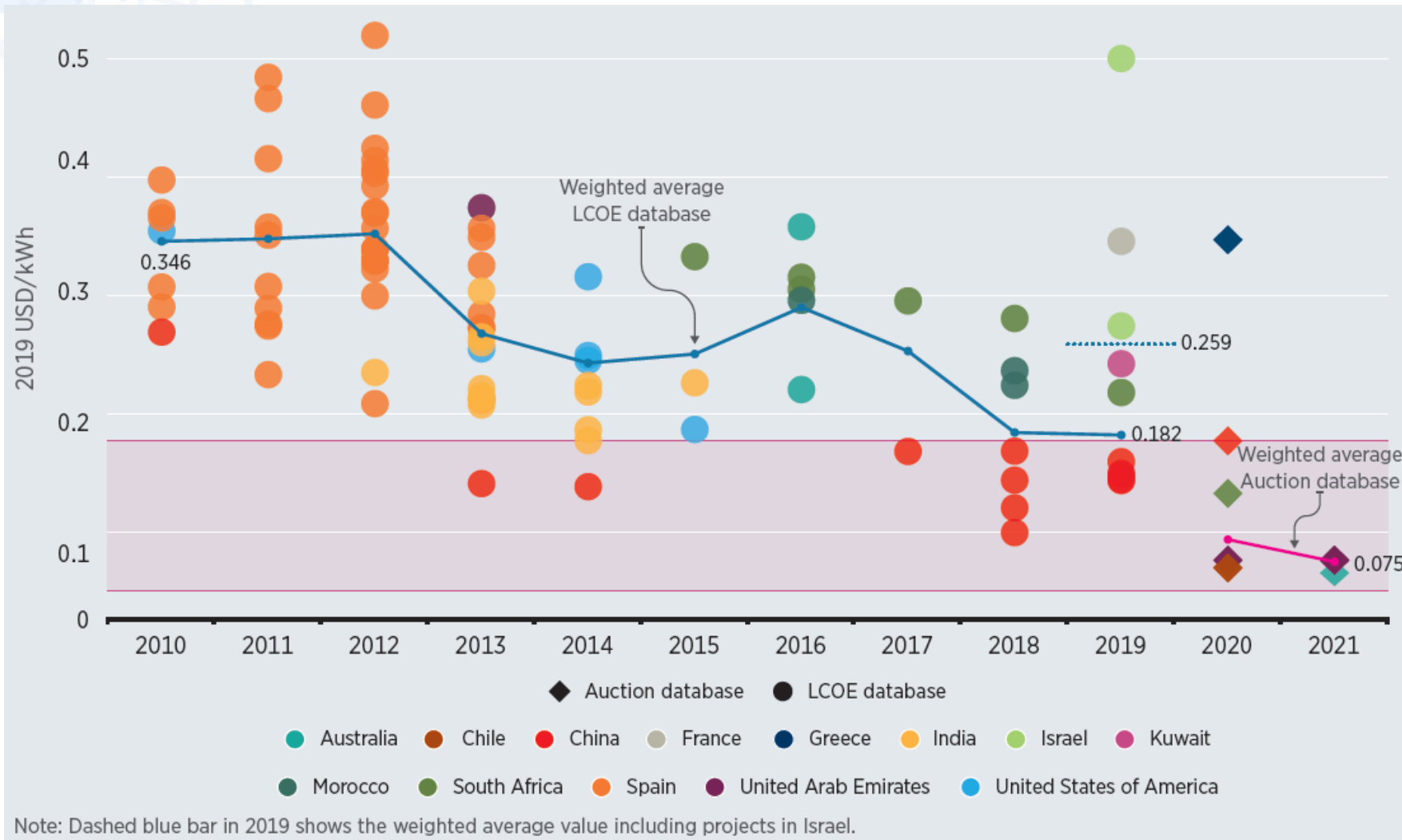
Source: IRENA Renewable Cost Database.

## ► higher capacity factors



# Concentrating solar power cost trends

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



- Weighted-average price of electricity of USD 0.075/kWh for CSP commissioned in 2021
- This represents a reduction of 59% when compared to the global weighted-average project LCOE in 2019
- CSP can play an important role in the energy transition
  - Low-cost
  - long-duration thermal energy storage
  - ability to be dispatched



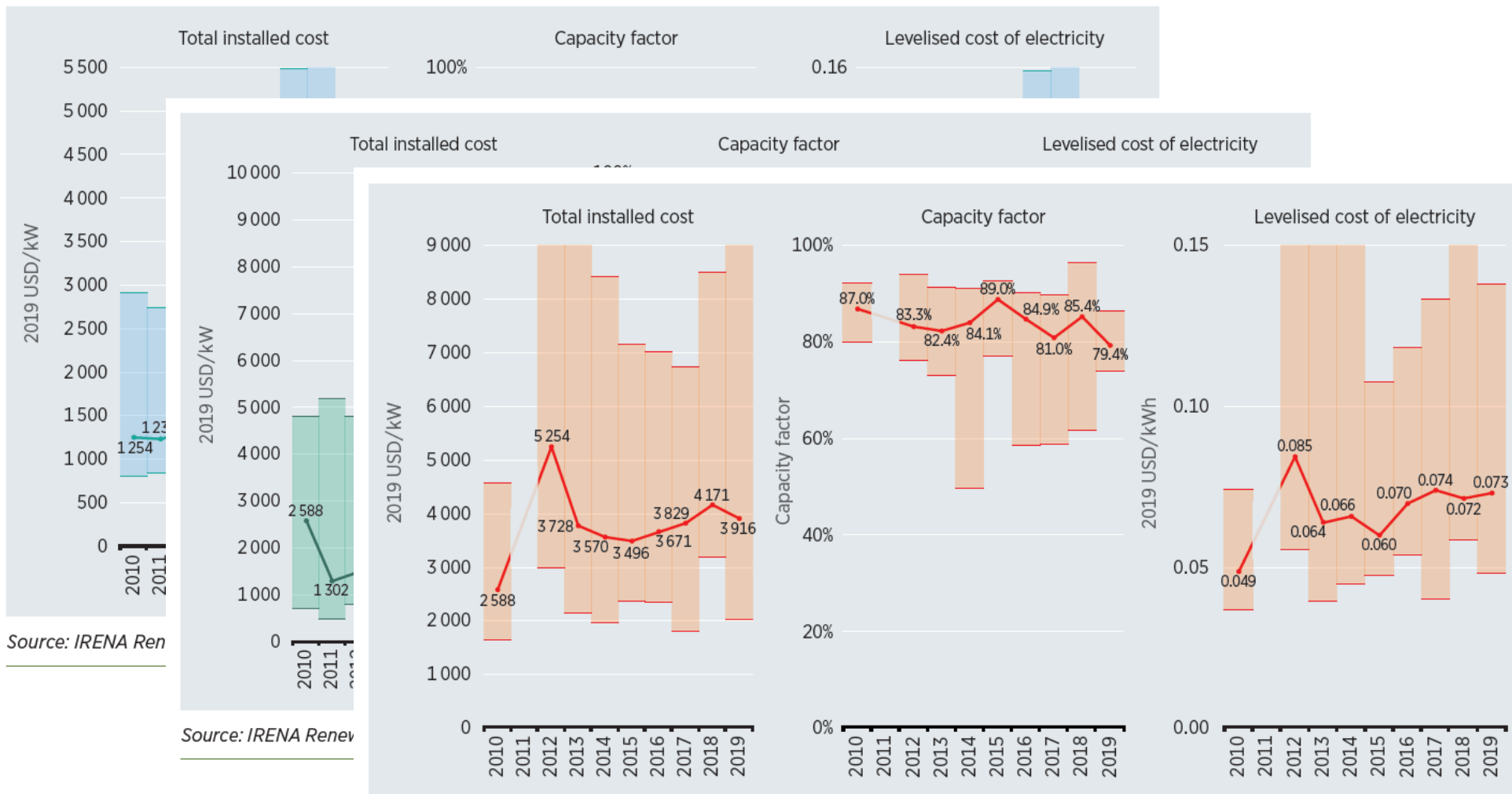
**HYDROPOWER**

**BIOENERGY**

**GEO THERMAL**

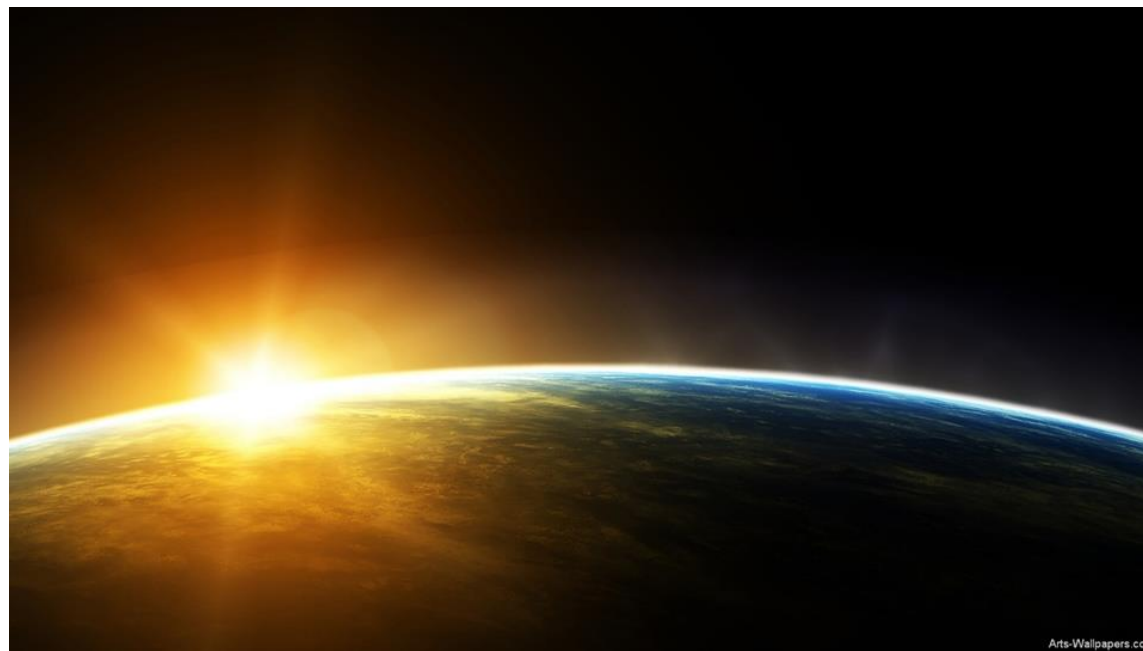
# Don't forget about the mature technologies!

Dispatchable, flexible, low-cost....



Source: IRENA Renewable Cost Database.

# Renewables are increasingly competitive



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

[www.irena.org](http://www.irena.org)  
[mtaylor@irena.org](mailto:mtaylor@irena.org)

# Upcoming cost analysis at IRENA

**G20 cost reduction potential for solar and wind to 2030**

**PV cost differentials in Japan**

**Solar and Wind in harsh operating conditions**

**Learning curves and technology policy**

# Recent cost evolution

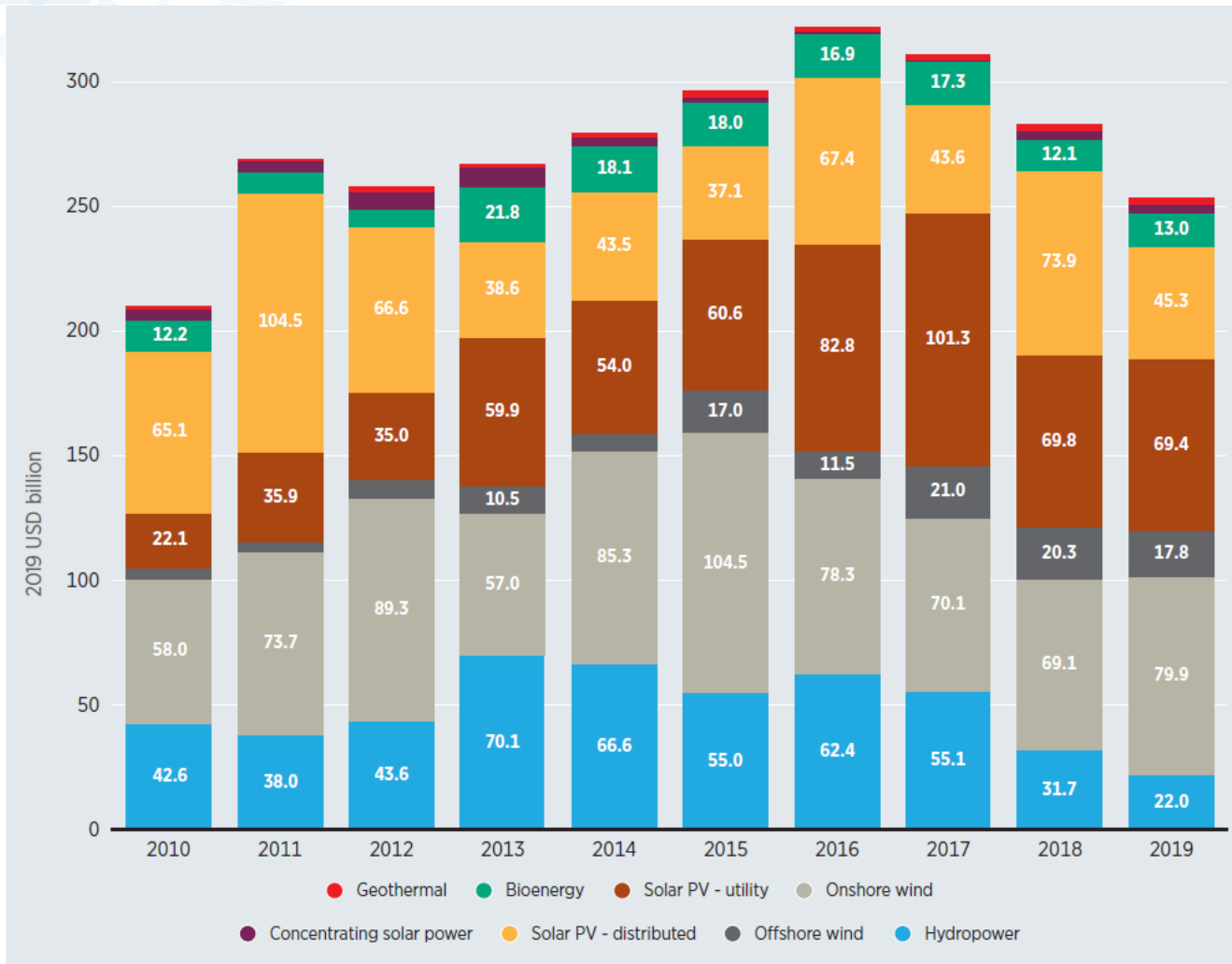


- Latest trends in the cost and performance of renewable power generation technologies
- Global and country data to 2019
- Detailed analysis of equipment costs and LCOE drivers
- Integration of project LCOE and Auction results:
  - ▶ Insights into cost of electricity to 2021-23



# Investment trends

## Falling costs make renewables a cost-effective investment



- In 2010 new RE capacity additions were 88 GW for an investment value of USD 210 billion
- In 2019, twice that level of new RE capacity was commissioned, but only one-fifth higher – USD 253 billion

Source: This report for total installed costs and IRENA, 2020a for deployment statistics.

# Less investment \$ = more capacity

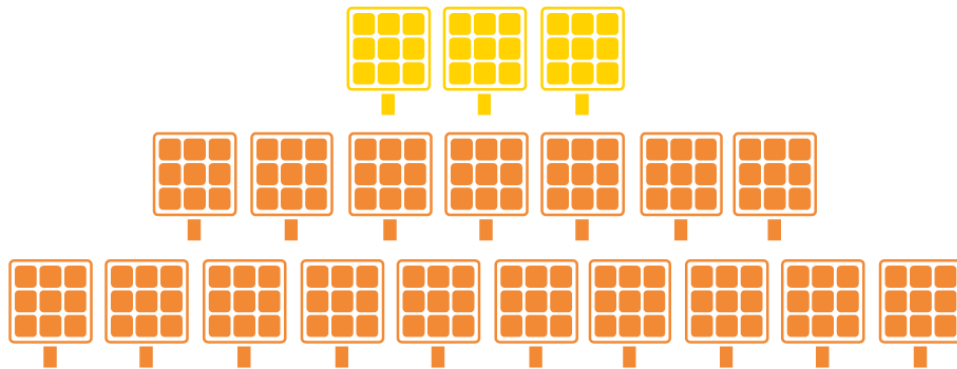


USD 1 million invested

Solar PV

● 2010 ● 2019

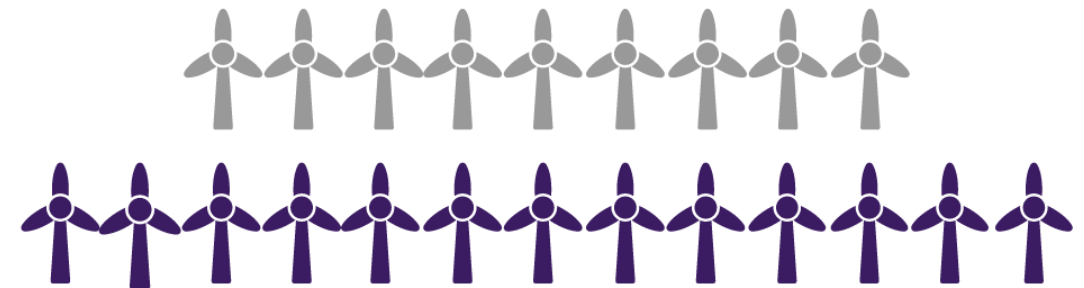
213 kW → 1 005 kW



Onshore Wind

● 2010 ● 2019

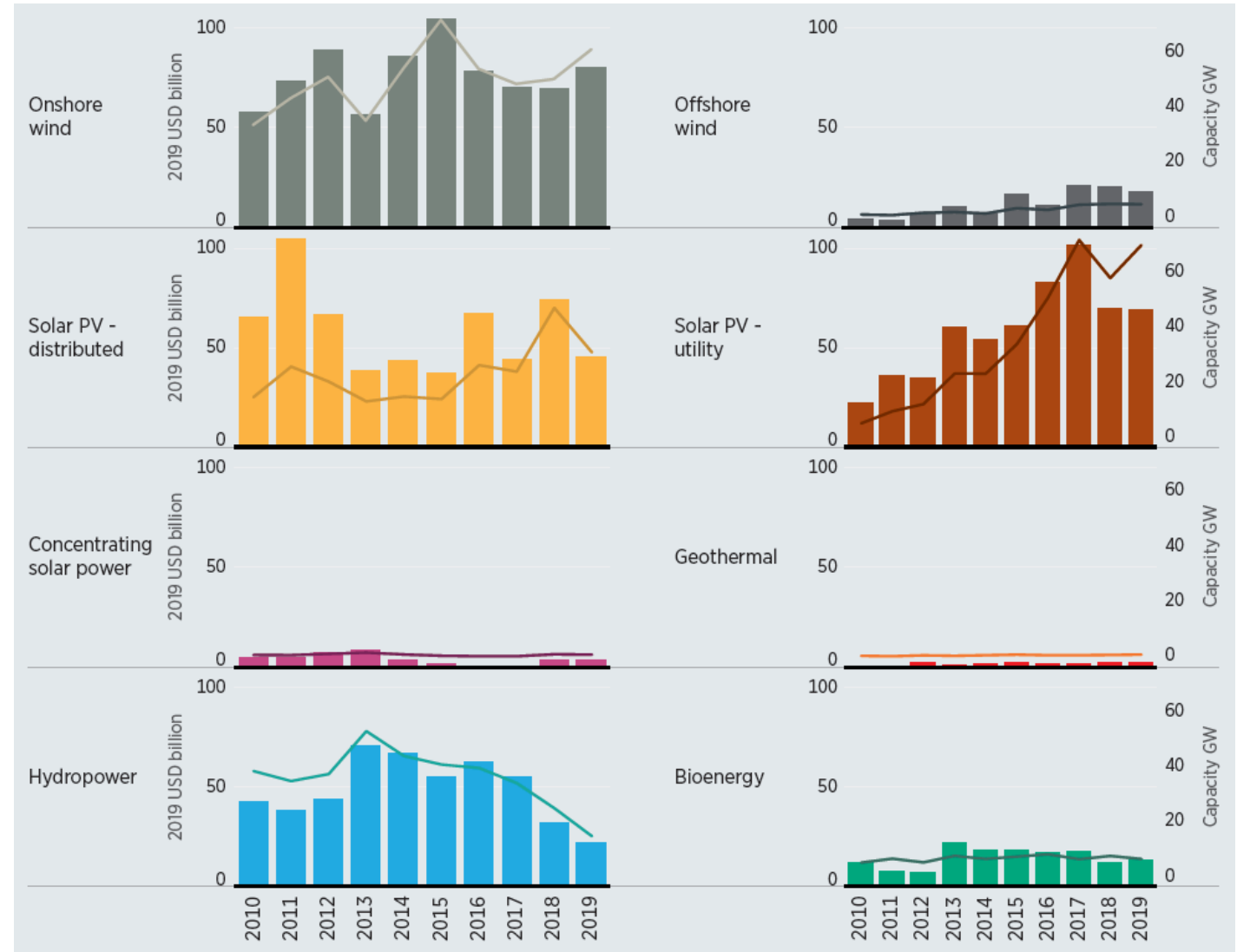
514 kW → 679 kW



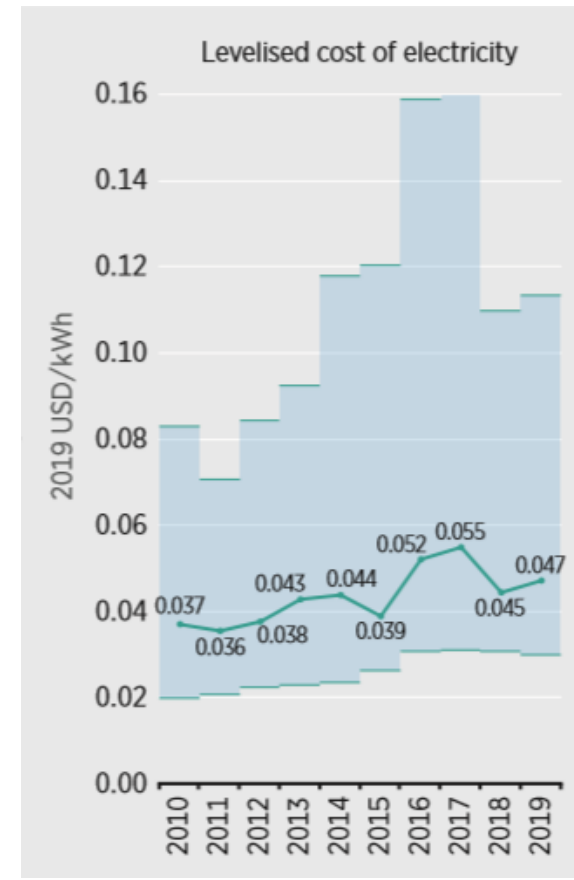
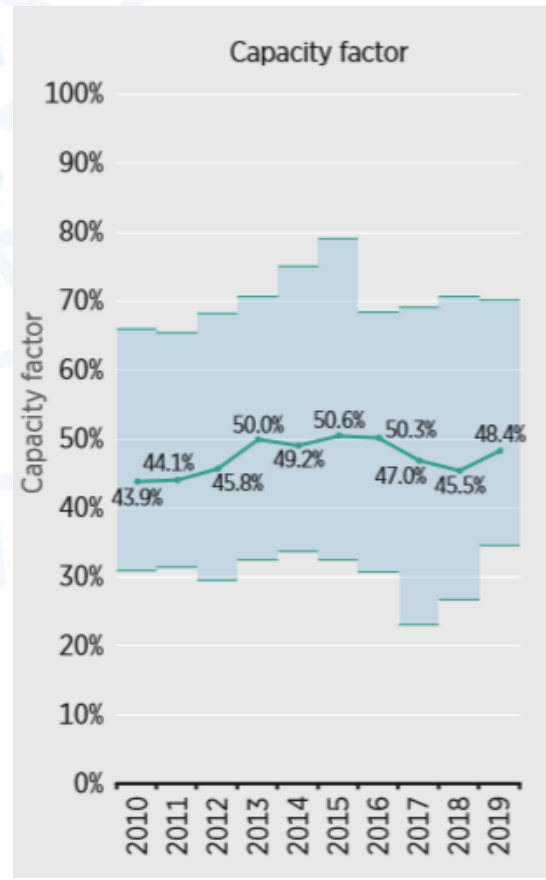
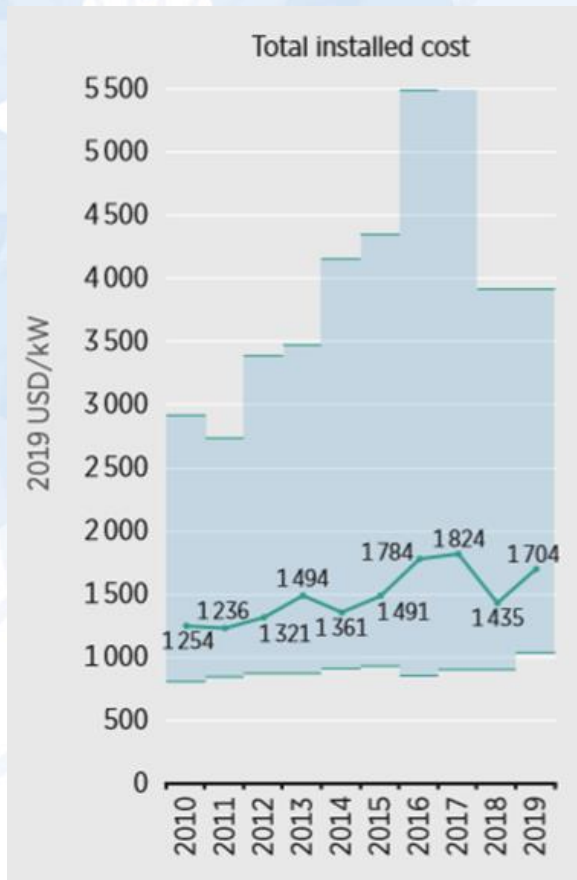
# Investment trends

## Falling costs make renewables a cost-effective investment

- Important to look at investment trends by technology to understand how investment needs shifted over time
- Dramatic increase in utility-scale solar PV deployment relative to the total investment needed
- A significant trend in this respect also in the distributed solar PV sector
- A bit more modest trend for wind technologies



# Hydropower cost and performance trends



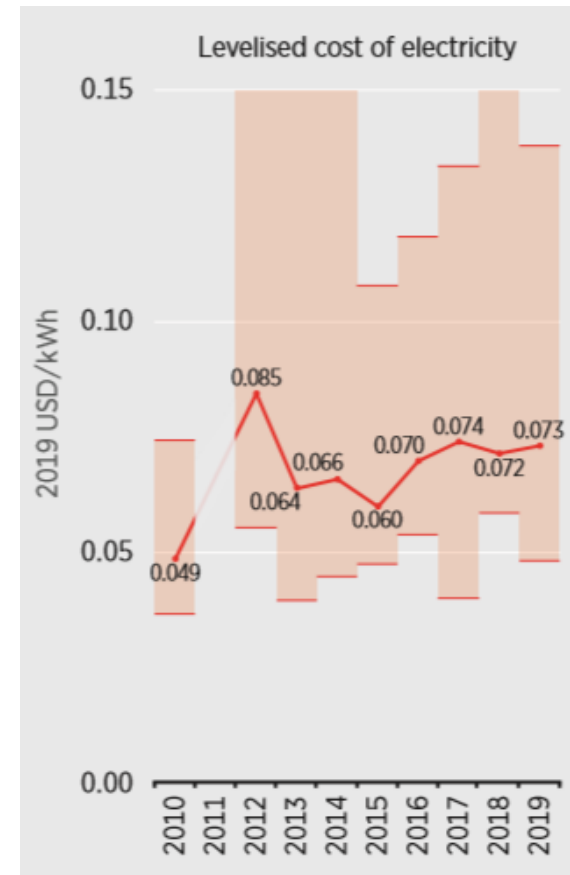
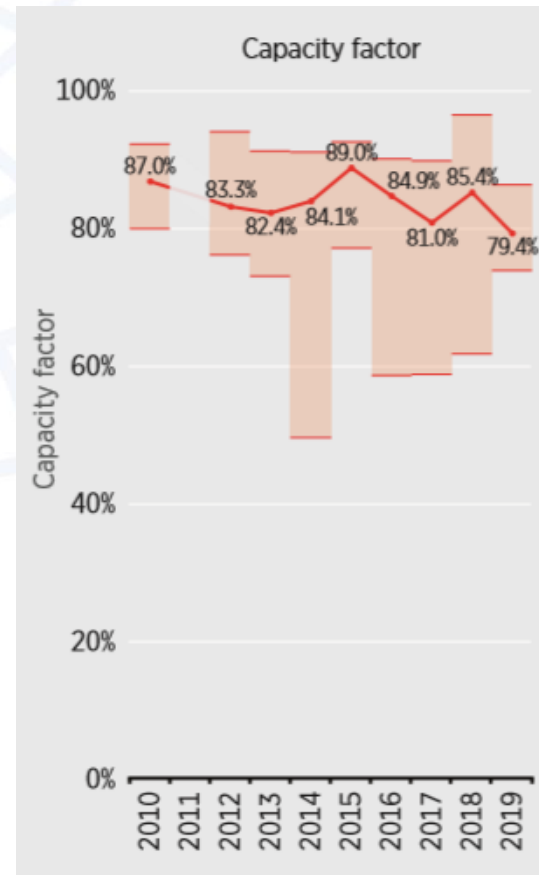
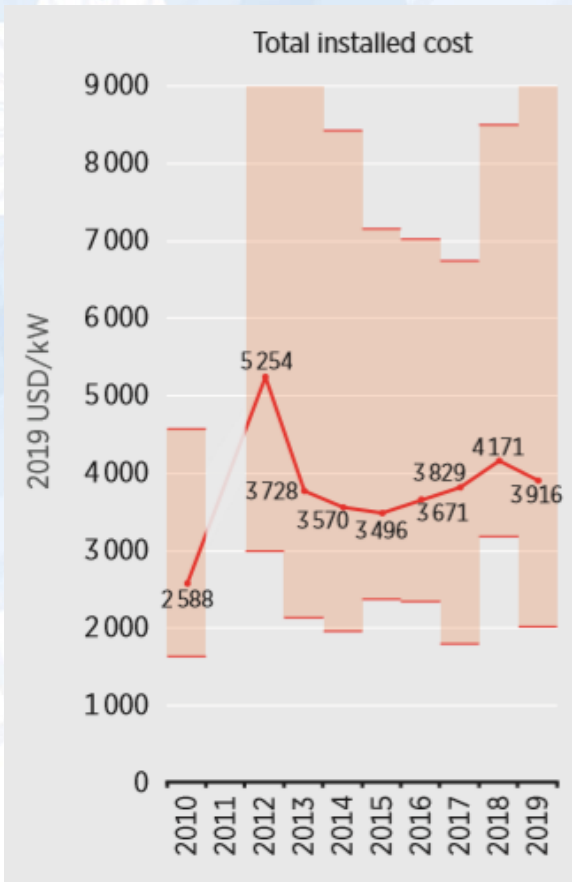
In 2019, total installed cost of newly commissioned hydropower projects increased to USD 1704/kW, 17% higher than in 2018.

Between 2010 and 2019, the capacity factor for hydropower projects commissioned varied between 44% – in 2010 – and a high of 51% in 2015. For projects commissioned in 2019, it was 48%.

2019 was USD 0.047/kWh, 6% higher than 2018 and 27% higher 2010

Despite these increases through time, however, 89% of the capacity added in 2019 had costs lower than the cheapest new source of fossil fuel-fired electricity generation.

# Geothermal cost and performance trends



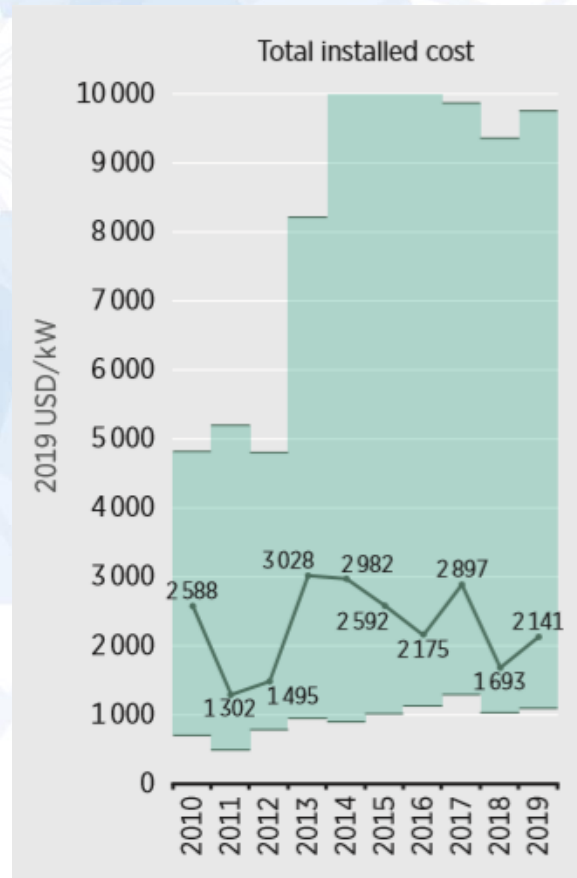
The deployment of geothermal power plants remains modest, with the **682 MW** added in **2019** – a **new record**.

Between 2014 and 2019, total installed costs increased from **USD 3570/kW** to **USD 3916/kW**. In 2019, the total installed costs of the majority of newly commissioned plants spanned the range **USD 2000** to **USD 5000/kW**.

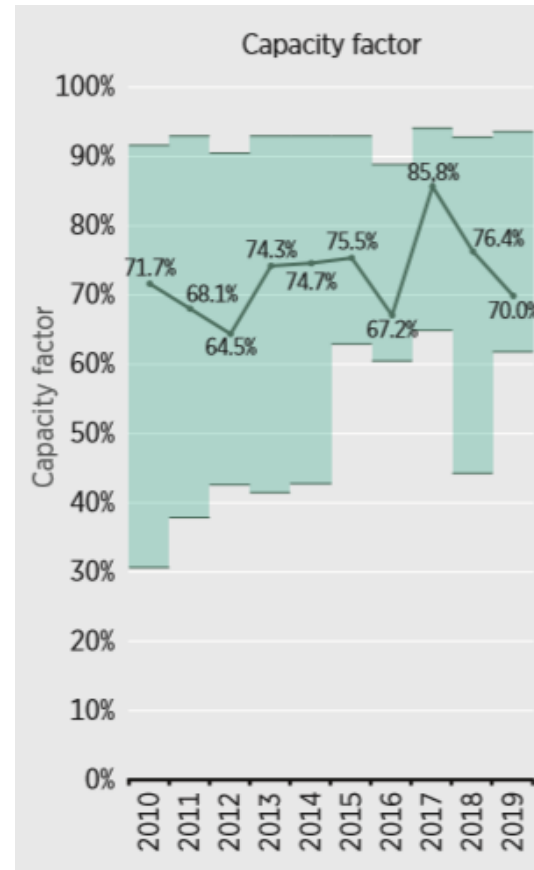
In 2019, the global weighted-average capacity factor for newly commissioned plants was **79%**.

The global weighted-average LCOE of the projects commissioned in 2019 was **USD 0.073/kWh**, broadly in line with values seen over the last four years.

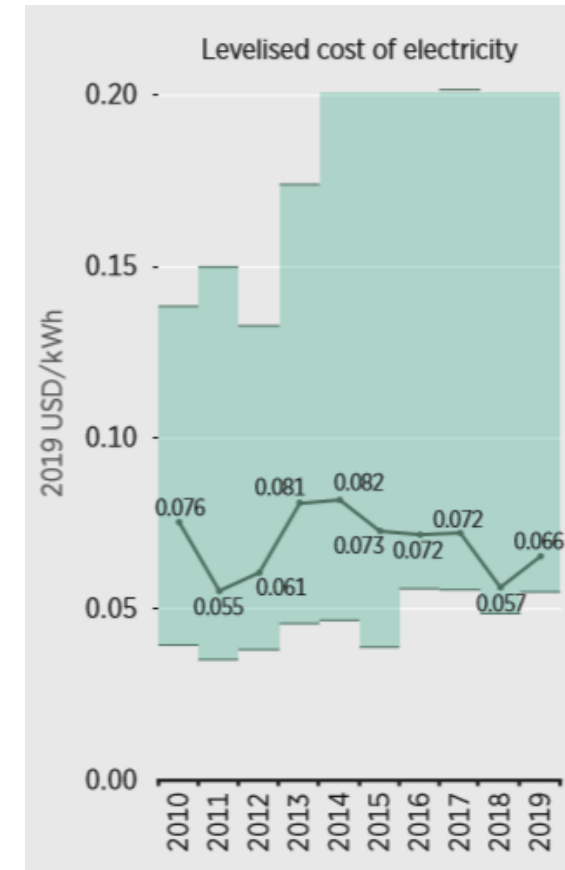
# Bioenergy cost and performance trends



For bioenergy projects newly commissioned in 2019, the global weighted-average total installed cost was **USD 2141/kW**. This represented an increase on the 2018 weighted-average of **USD 1693/kW**

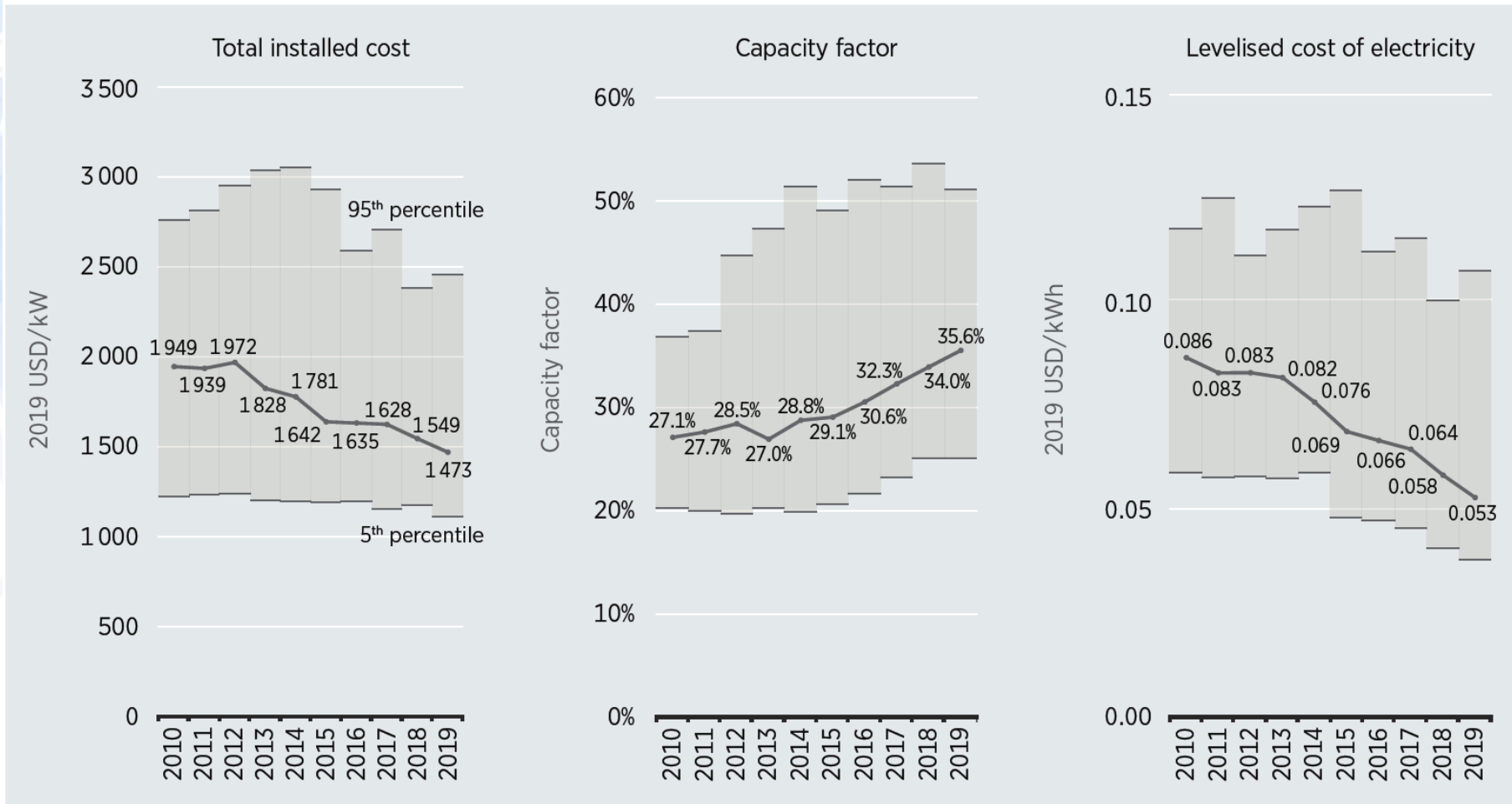


Between 2010 and 2019, the global weighted-average capacity factor for bioenergy projects varied between a low of **65%** in 2012 to a high of **86%** in 2017



Between 2010 and 2019, the global weighted-average LCOE of bioenergy for power projects fell from **USD 0.076/kWh** to **USD 0.066/kWh** – a figure at the lower end of the cost of electricity from new fossil fuel-fired projects.

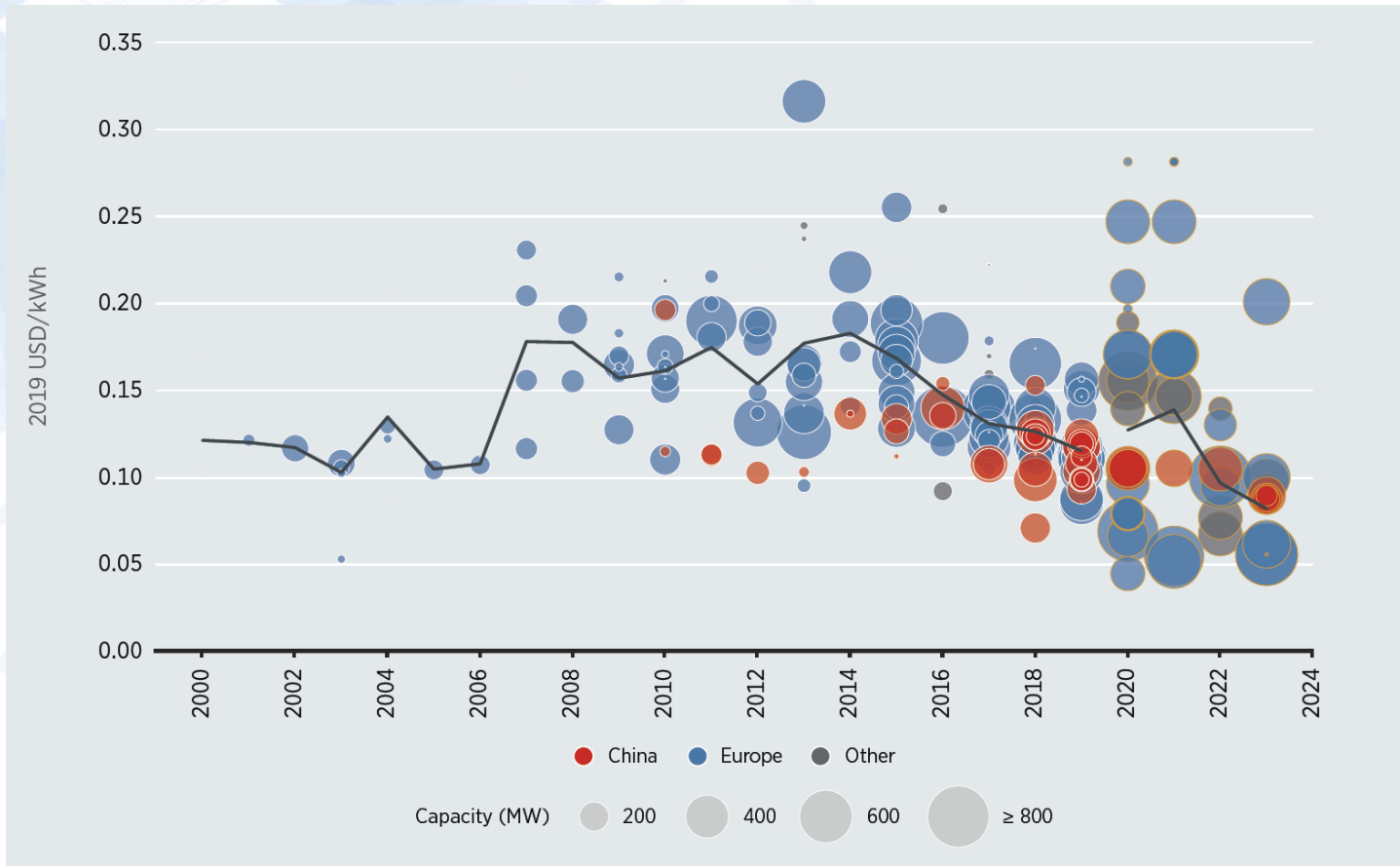
# Wind cost and performance trends



Between 2010-2019, the global weighted average:

- Total installed cost reduced by **24% from USD 1 949/kW to USD 1 473/kW**
- Capacity factor increased by **9 percentage points from 27% to 36%**
- LCOE reduced by **39% from USD 0.086/kWh to USD 0.053/kWh**

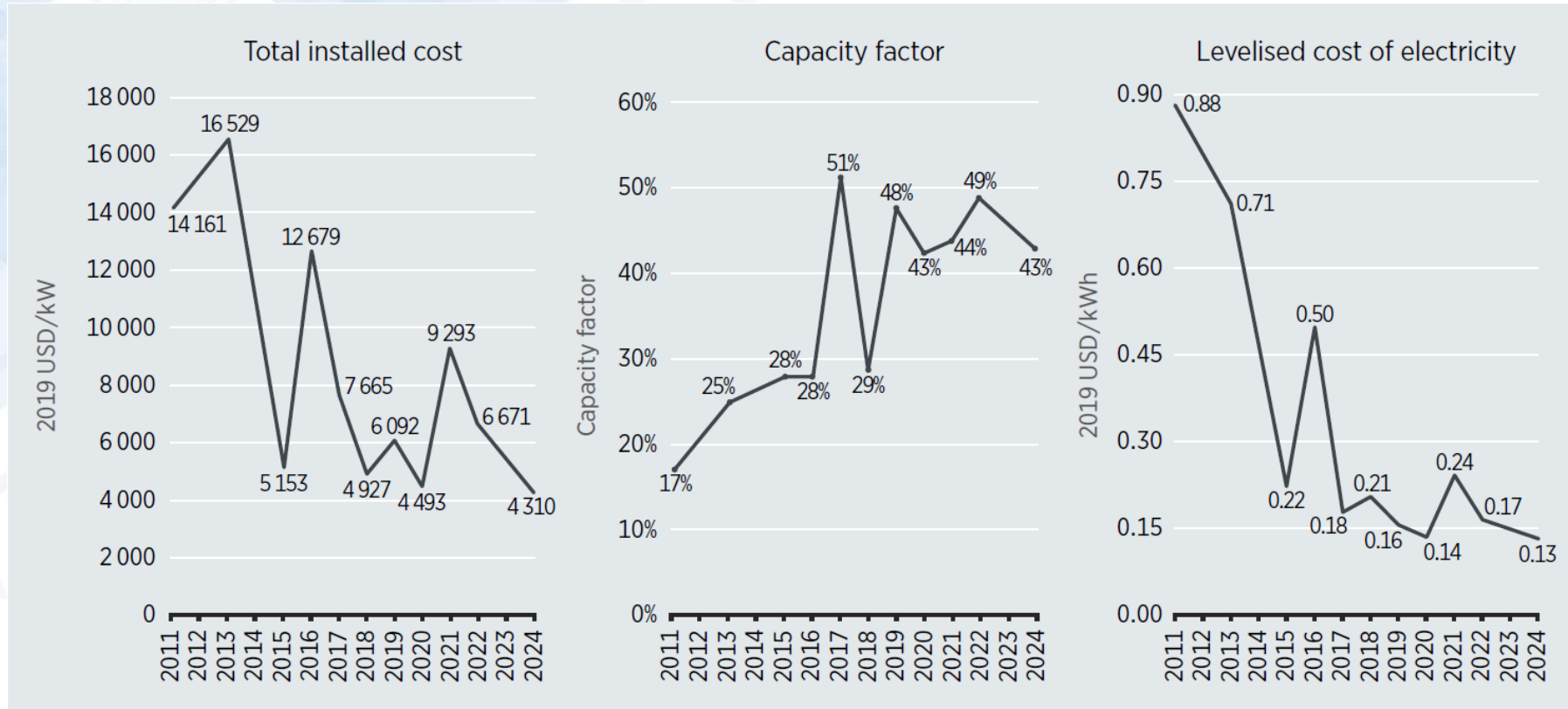
# Offshore wind - LCOE and PPA/Auction prices



- Country-level LCOEs influenced by local policies and maturity of market, for example with some level of grid connection support in China and Denmark, both countries had the lowest LCOEs of around **USD 3000/kW** in 2019
- Zero-subsidy projects in mature European markets since 2017 are driving efficiencies in development, construction, installation and O&M practices.
- Excluding a delayed project in the UK, expected to be deployed in 2019, the weighted average costs are trending towards **USD 0.072/kWh** by 2023, with costs as low as **USD 0.045/kWh**



# Floating offshore wind



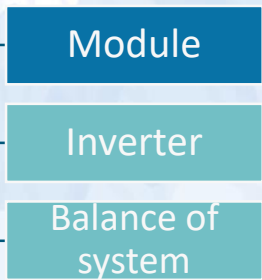
- Higher shares of potential offshore wind resources located in deeper waters (above 50 m) offshore; for example in the US, 60% (2.45 TW) of offshore wind resources are located farther offshore.
- Floating wind is still developing with several commercial projects expected to be deployed from 2024 onwards.
- The indicative LCOE in 2024 is **USD 0.133/kWh**, 85% below the average LCOE in 2011 of **USD 0.882/kWh**.

# Solar PV cost trends

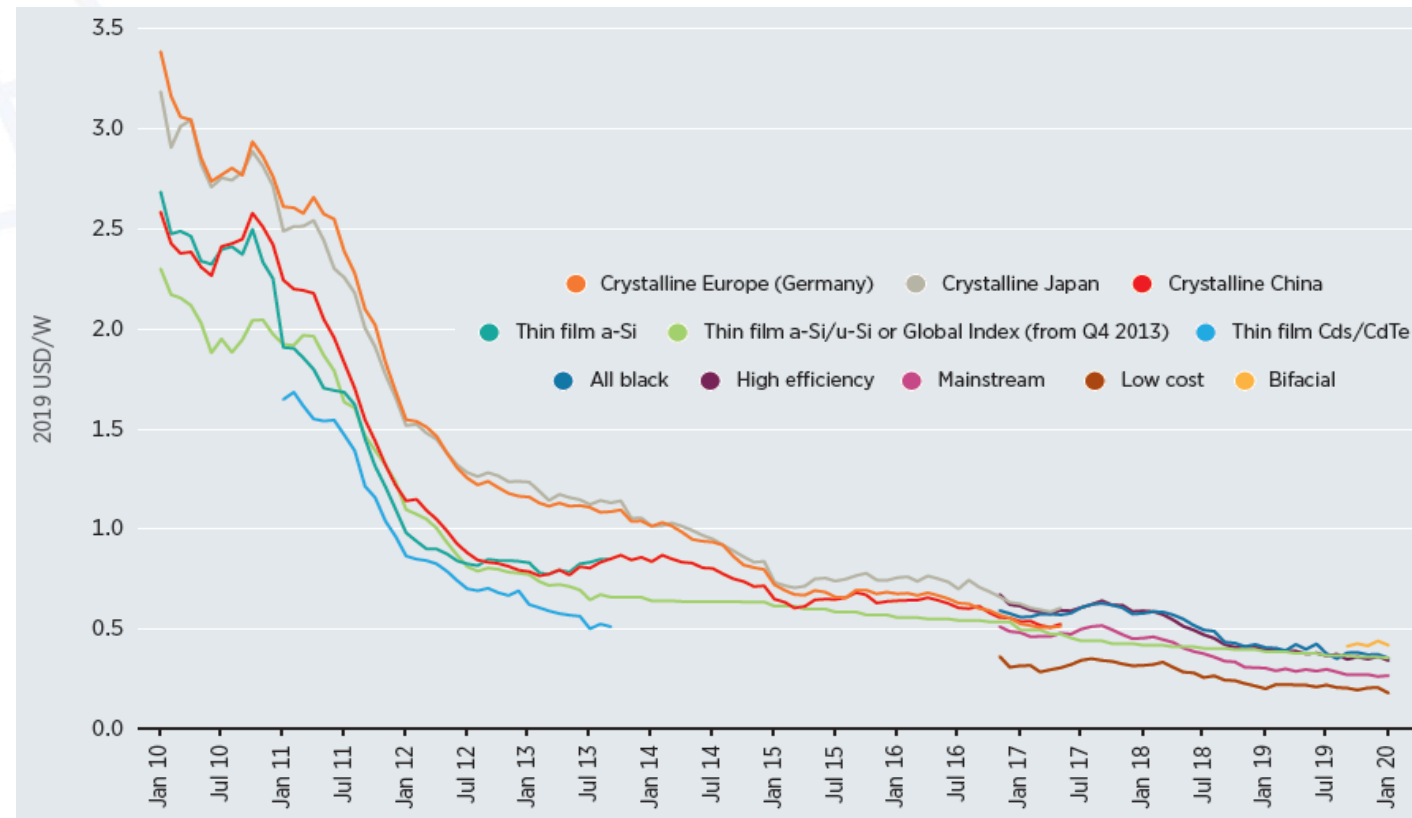
## Module costs continue its decline, driven by manufacturing optimization and efficiency gains

Total installed costs

- Crystalline PV module costs decline around 90% since 2010 (and 14% since 2018)



- Costs range in Dec 2019 from USD 0.21/W to USD 0.38/W
- High efficiency modules selling at USD 0.36/W
- Recently bifacial module costs within a close range of higher performing monofacial options



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

# Solar PV cost trends

## Average module prices by country continued falling between 2013 and 2019

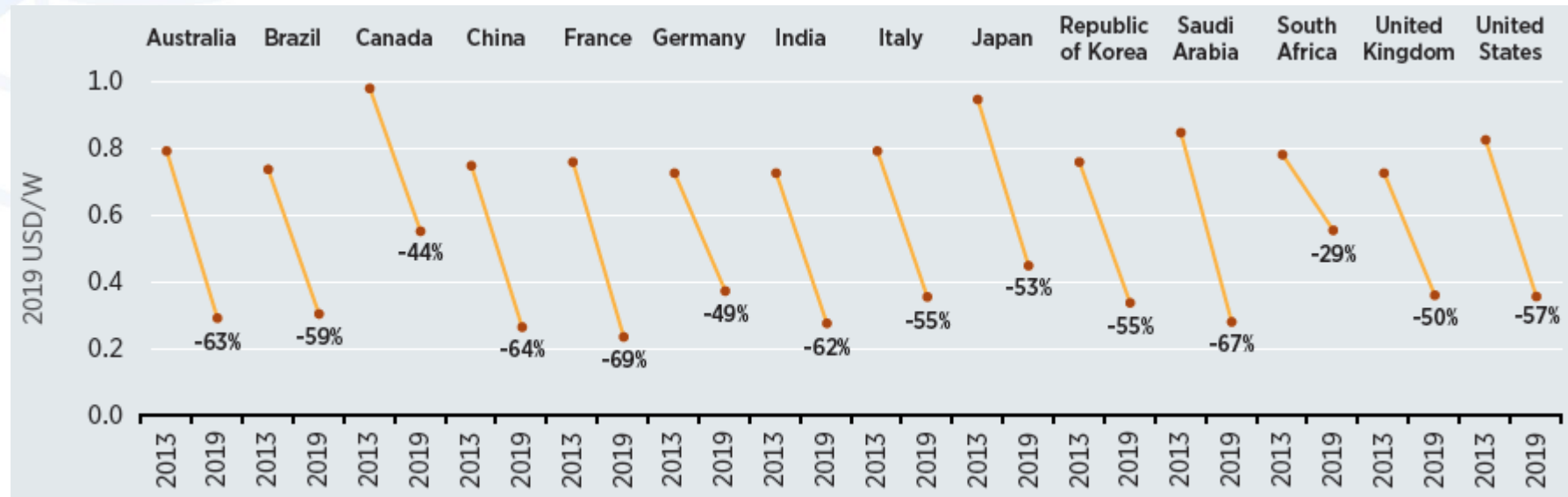
Total installed costs

Module

Inverter

Balance of system

- Market-level module costs declined between 29% (South Africa) and 69% (France) between 2013 and 2019.
- Compared to 2018, the highest-to-lowest cost range narrowed from USD 0.52/W to USD 0.32/W compared to 2018 (ratio declined from 2.9 to 2.4).
- Between 2018 and 2019, module costs declined between 4% and 30%.



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

# Solar PV cost trends

Total installed cost of utility-scale PV declined in all major markets from 2010-2019

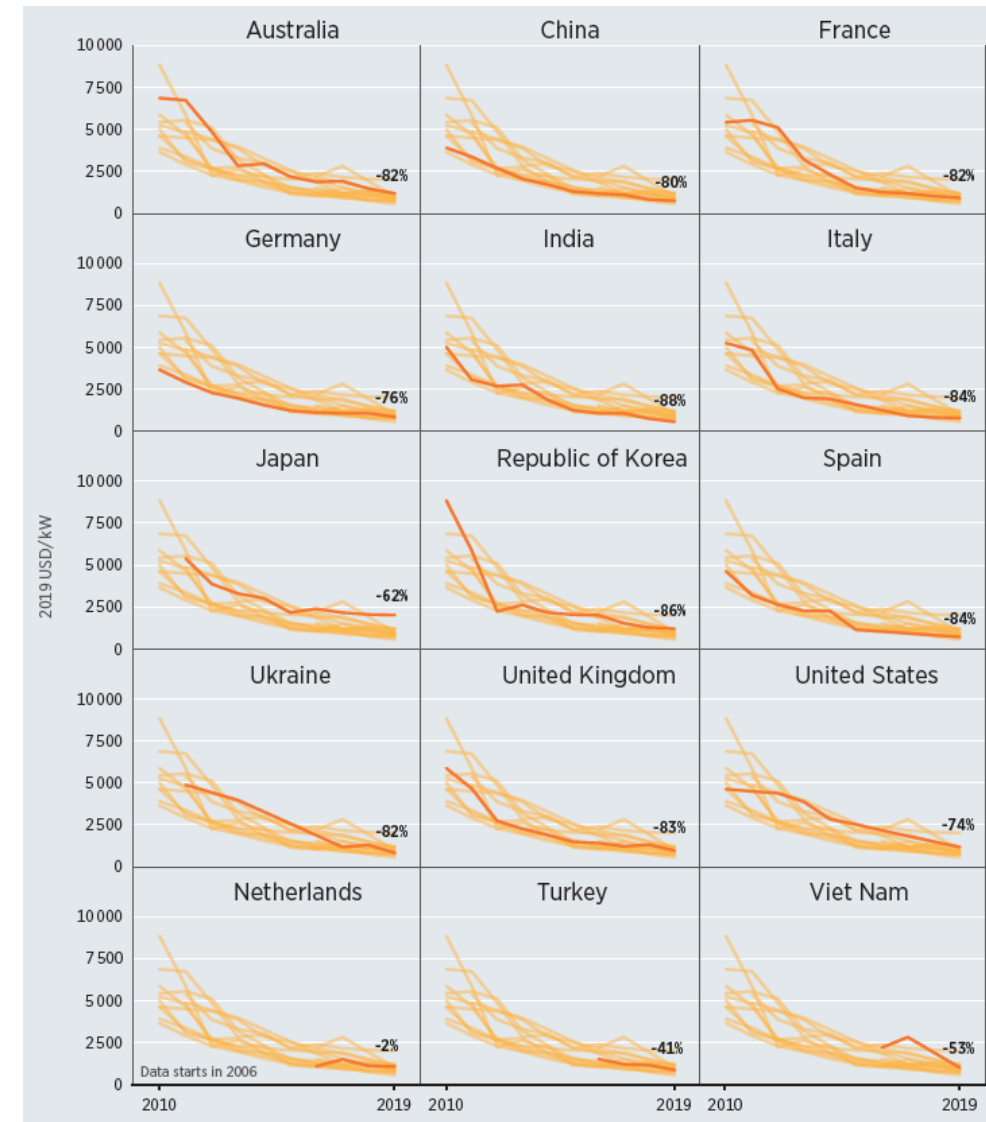
Total installed costs

Module

Inverter

Balance of system

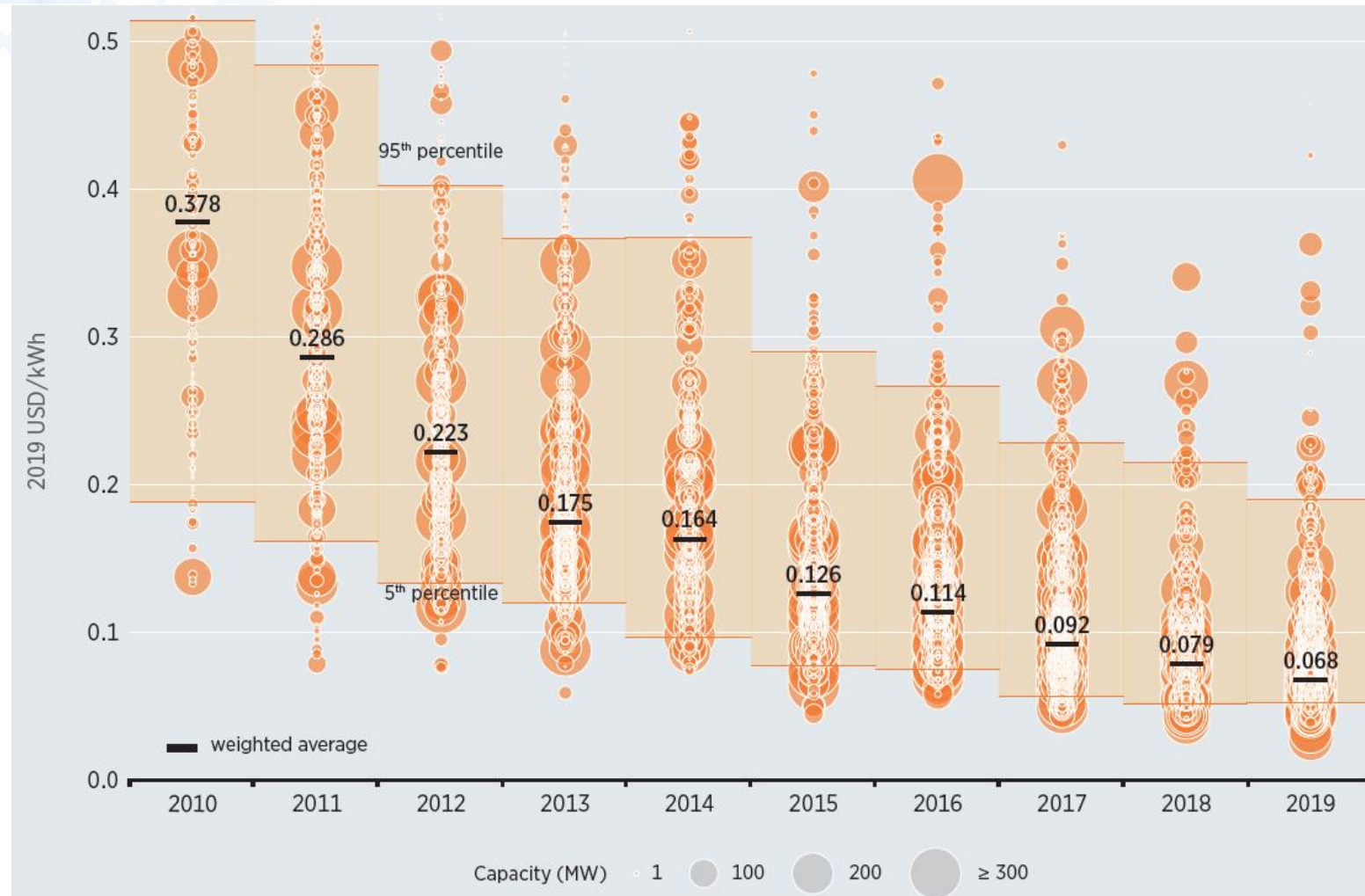
- Total installed costs fell 74% - 88% by country
  - Narrowing of country cost differential, but differences remain
- Driven by increasingly competitive local markets adopting best practice project development and cost structures
- YoY cost reduction 2018-2019 between 1.5% (Japan) and 35% (Ukraine)
- Eight out of 15 markets under USD 1000/kW in 2019



Source: IRENA Renewable Cost Database.

# Solar PV cost trends

The 82% decline in LCOE also saw the range of costs also decline steadily



- 2010-2019: LCOE of utility-scale PV decreased from USD 0.378 to USD 0.068/kWh
- The 5<sup>th</sup> and 95<sup>th</sup> percentile for projects in 2019 ranged from USD 0.052 to USD 0.190/kWh
- A 72% and 63% decline in the 5<sup>th</sup> and 95<sup>th</sup> percentile, respectively
- The LCOE declined 13% YoY from 2018

# Solar PV cost trends

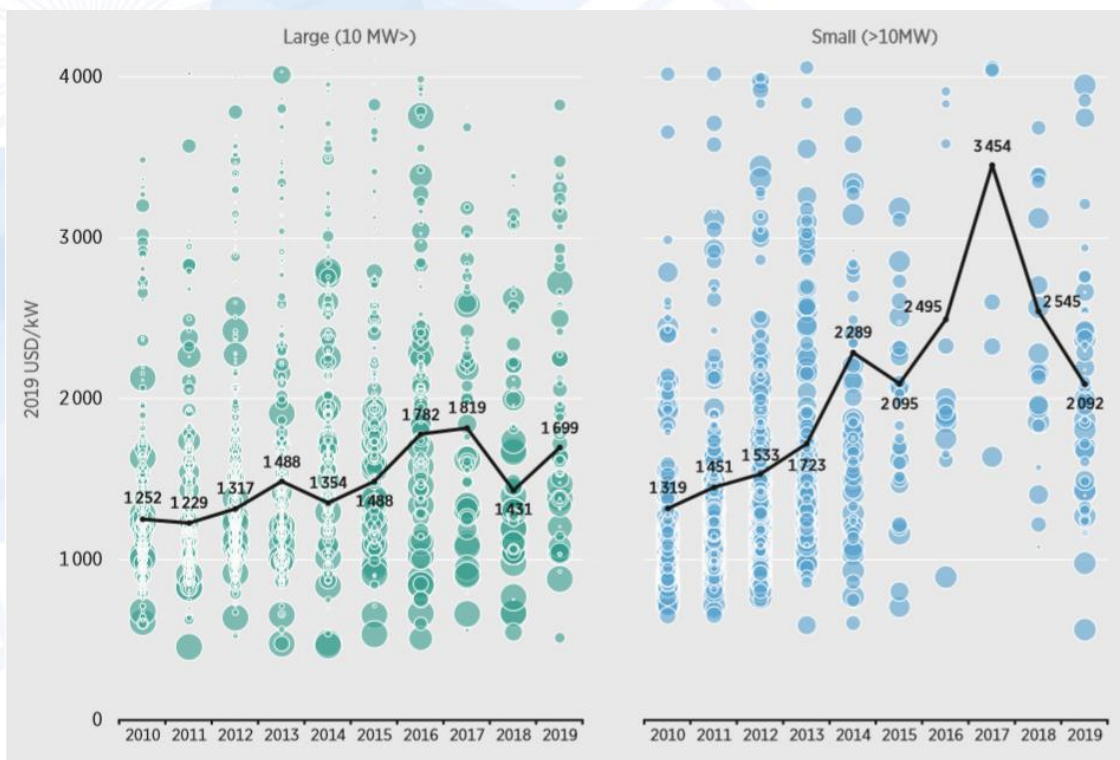
## Country-average LCOEs of utility-scale solar PV continue declining trend

- Projects LCOE decreased by 66% to as much as 85% depending on the country between 2010-2019
- Country-average ranged from USD 0.045/kWh in India to USD 0.144/kWh in Japan
- China and Spain also with very competitive LCOEs (USD 0.054/kWh and USD 0.056/kWh, respectively).
- US LCOE reduced 14% YoY to reach USD 0.068/kWh likely driven by BoS cost reductions



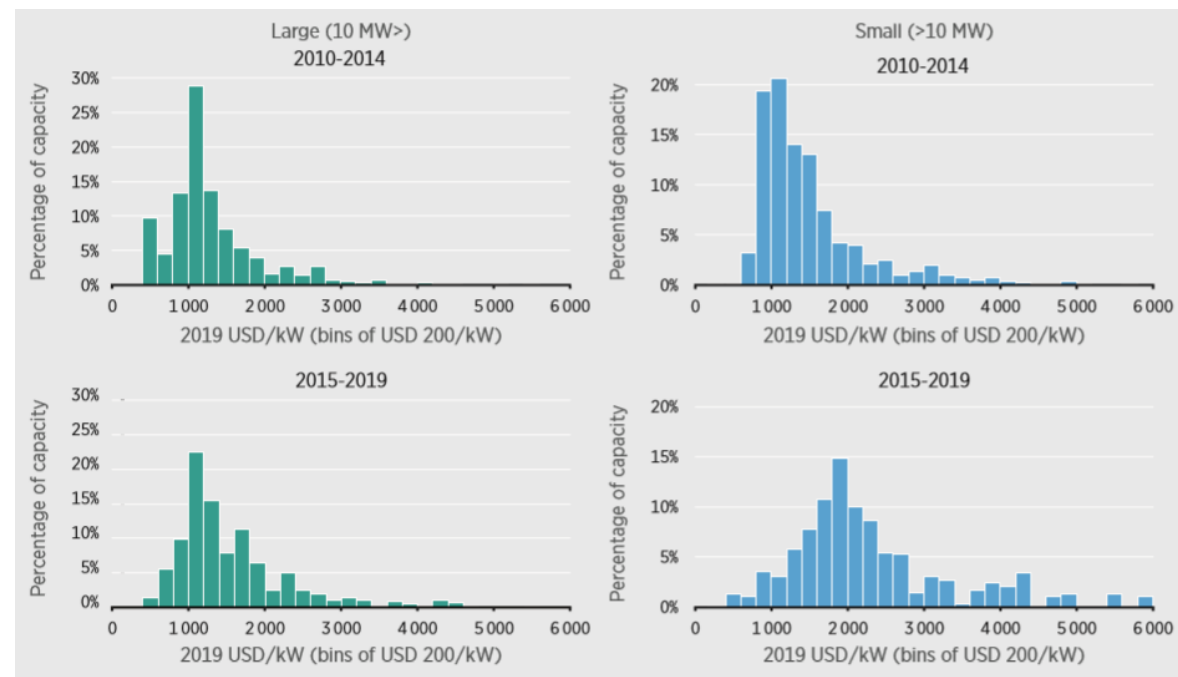
Source: IRENA Renewable Cost Database.

# Large Vs. Small Hydropower projects, total installed costs analysis



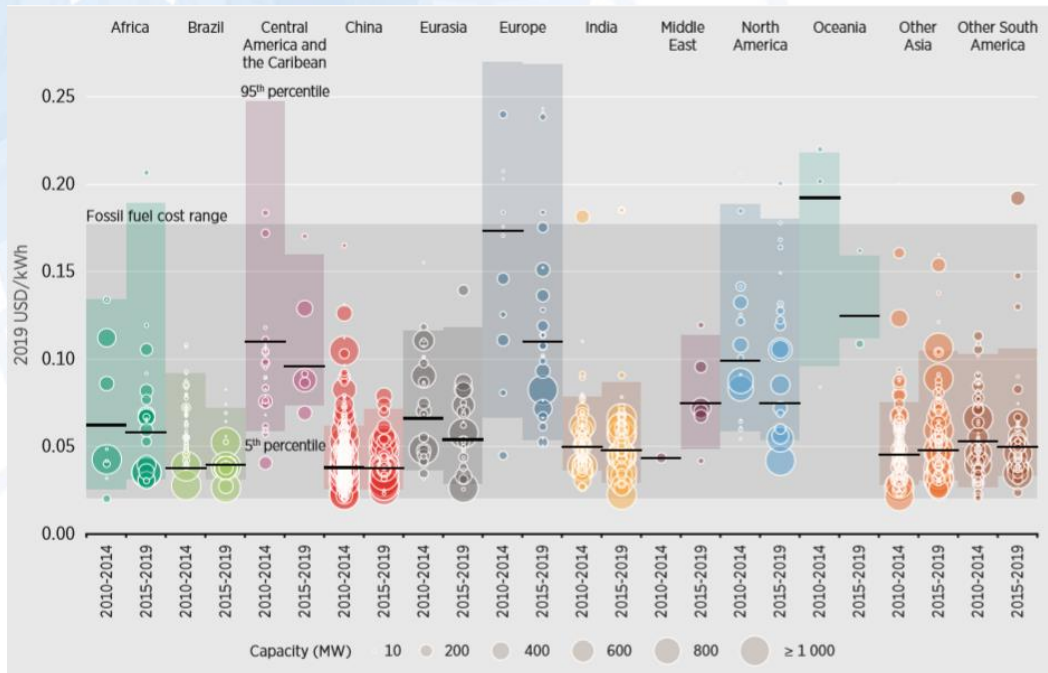
The global weighted-average total installed cost trends for **large** hydro (greater than 10 MW in capacity) and **small** hydro (10 MW or less) suggests that average installed costs for **small** hydro have increased at a faster rate than for **large** hydropower projects

Compared to the period **2010-2014**, the data for **2015-2019** shows a reduction in the share of newly commissioned projects in the **USD 600 to USD 1200/kW** range and an increase in the capacity of projects above that.

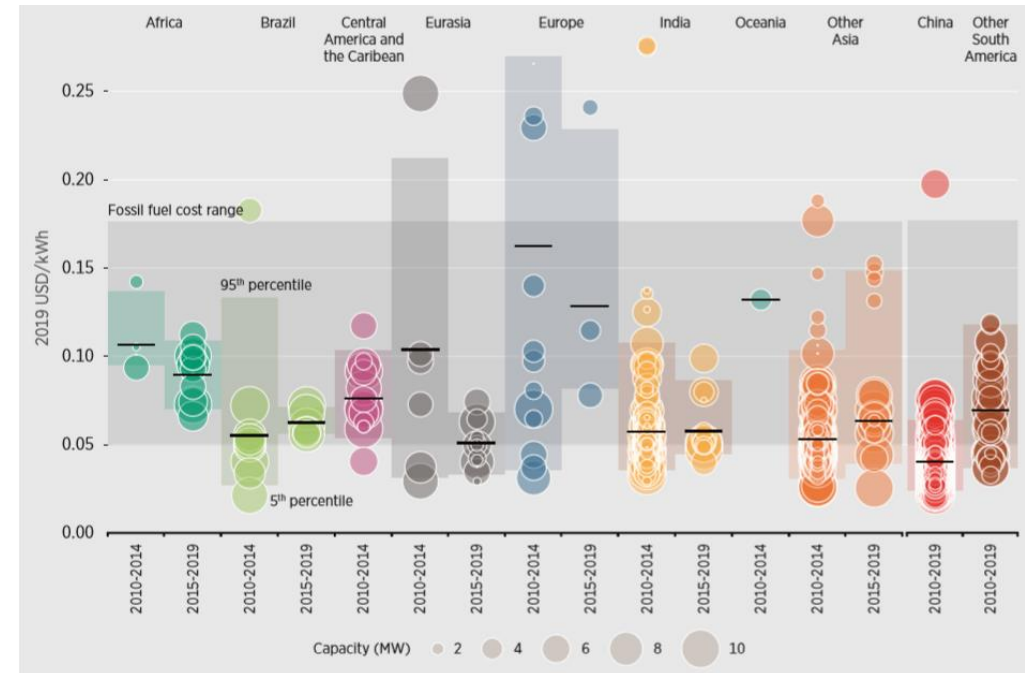


# LCOEs of large and small hydropower projects and the capacity weighted averages by country/region

## Large Hydropower



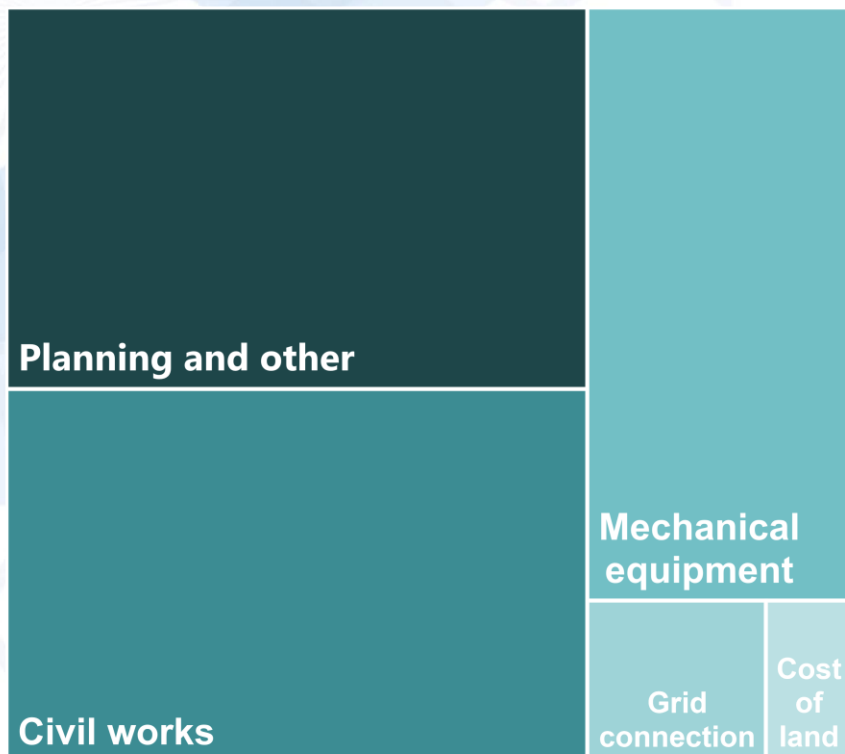
## Small Hydropower



In **2019**, the global weighted-average cost of electricity from hydropower was **USD 0.047/kWh**, **up 27%** from the **USD 0.037/kWh** recorded in **2010**. The global weighted-average cost of electricity from hydropower projects commissioned in years **2010 to 2014** averaged **USD 0.044/kWh**. This **increased** to an average of **USD 0.049/kWh** for projects commissioned over the years **2015 to 2019**.



# Total installed and O&M cost breakdown for hydro power projects

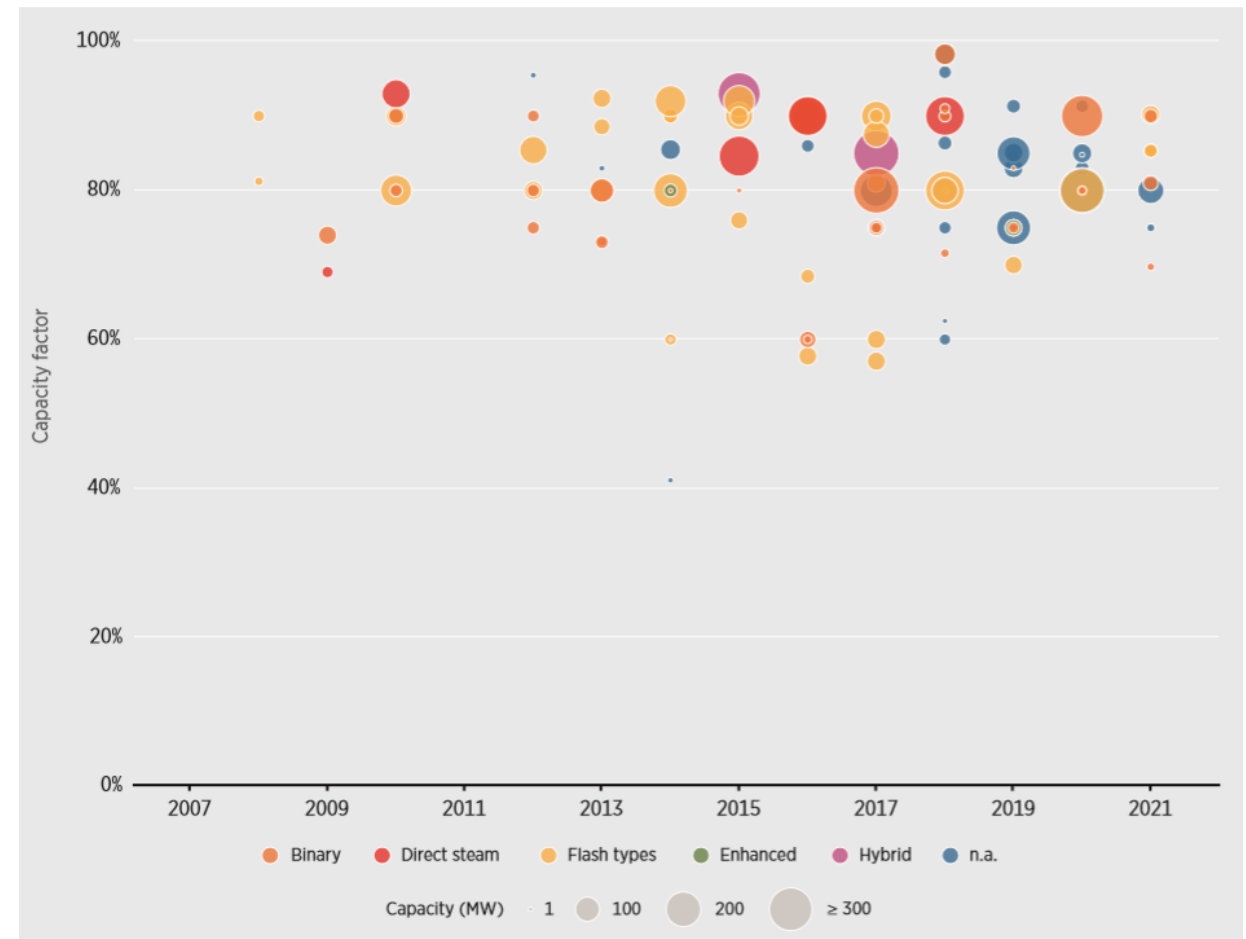




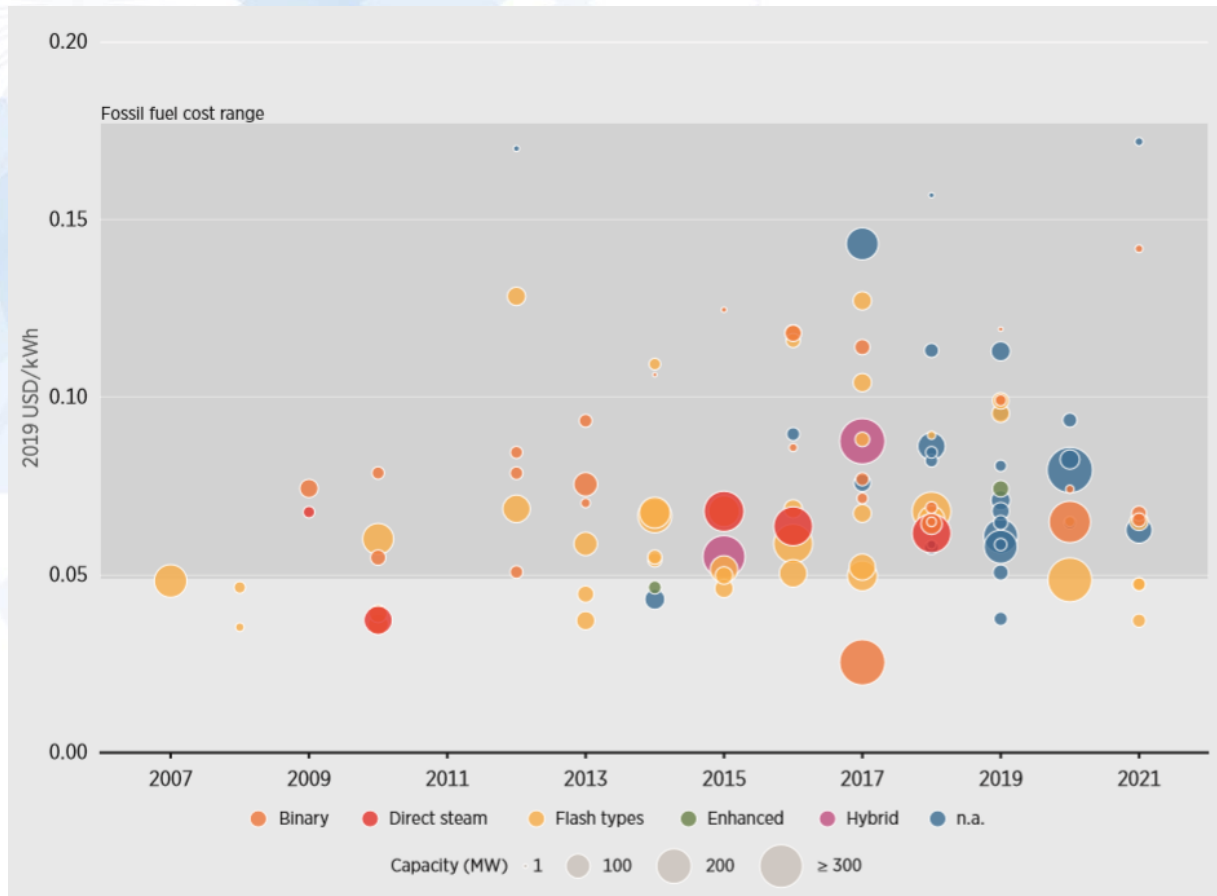
# **GEO THERMAL**

# Capacity factors of geothermal power plants by technology and project size, 2007-2021

Geothermal power plants provide firm, 'always on' power, with **capacity factors** typically ranging between **60%** to more than **90%** depending on site conditions and plant design.



# LCOE of geothermal power projects by technology and project size, 2007-2021



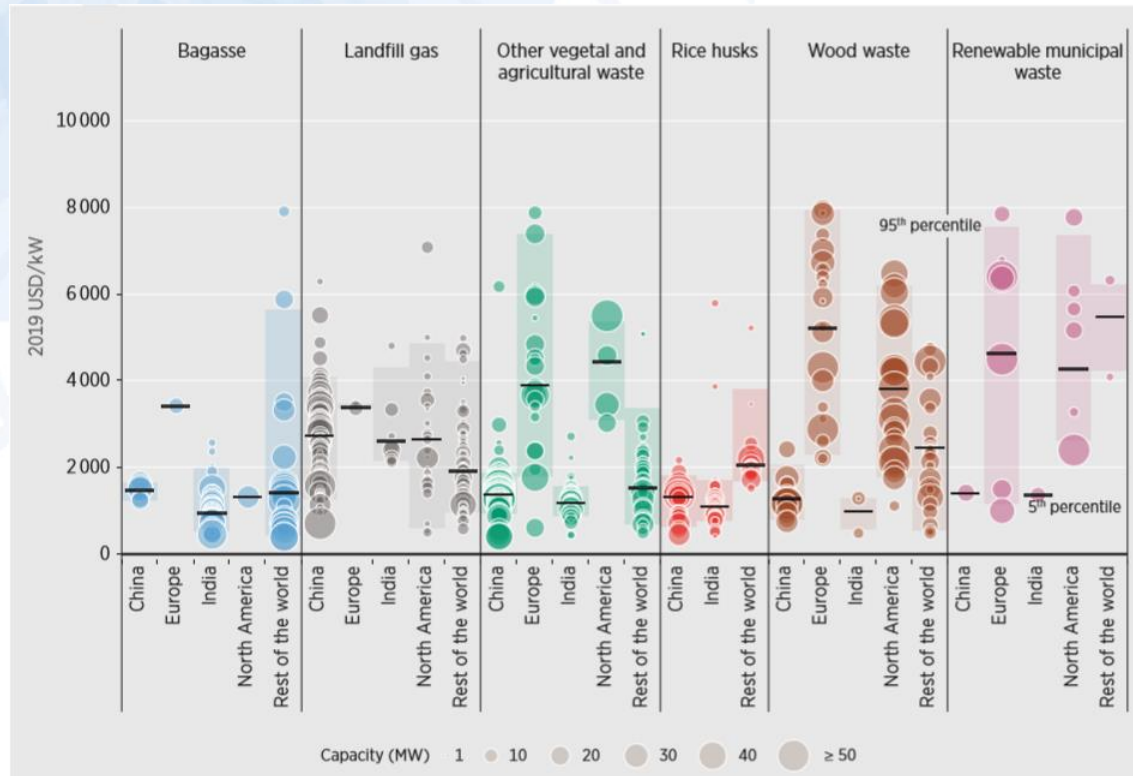
The global weighted-average LCOE increased from around **USD 0.05/kWh** for projects commissioned in 2010 to around **USD 0.07/kWh** in 2019.



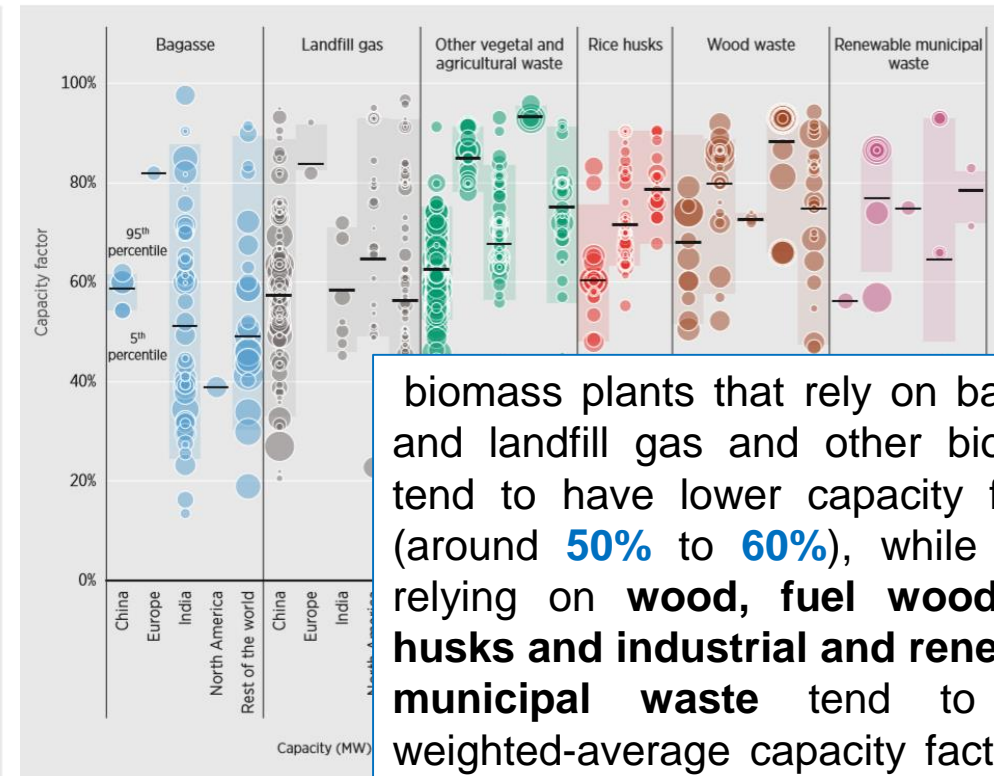
# BIOENERGY

# Total installed costs and project capacity factors of bioenergypower generation projects by selected feedstocks and country/region, 2000-2019

## Total installed costs

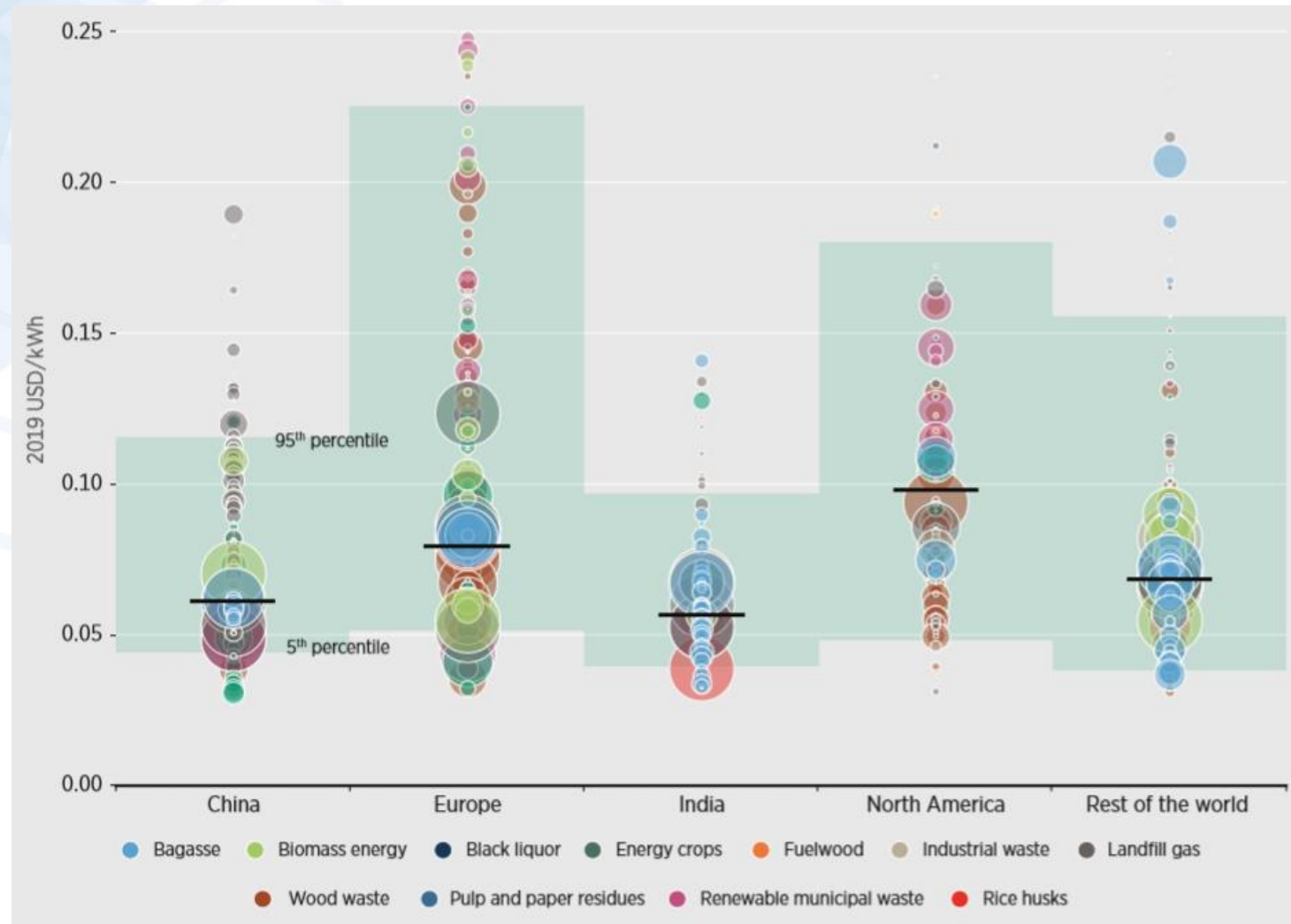


## Capacity Factors

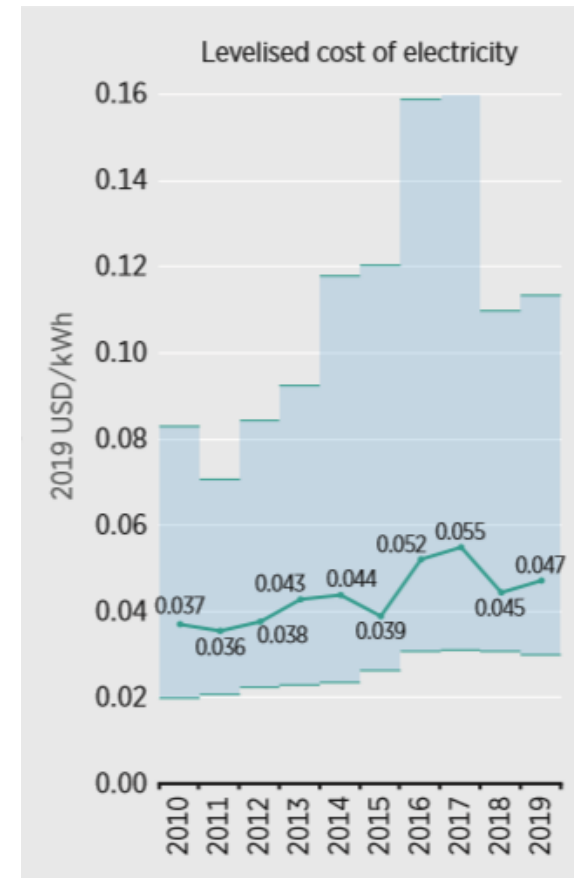
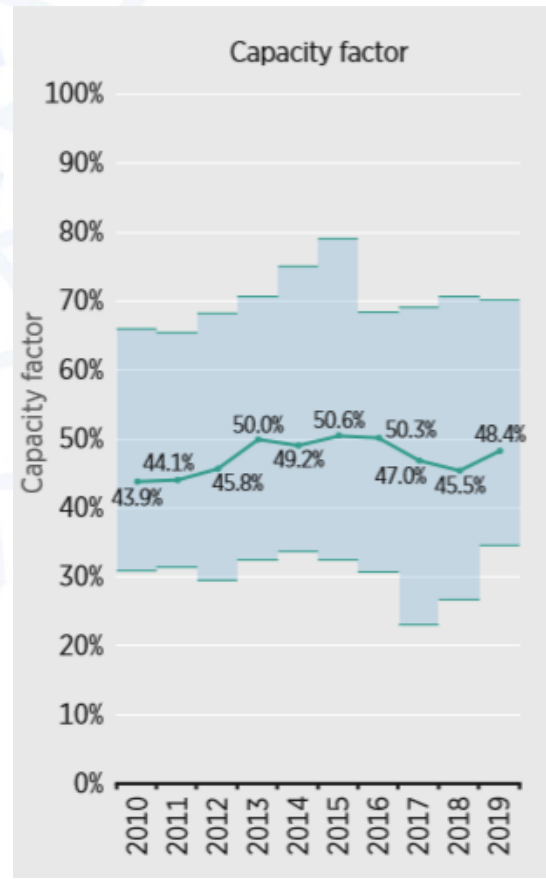
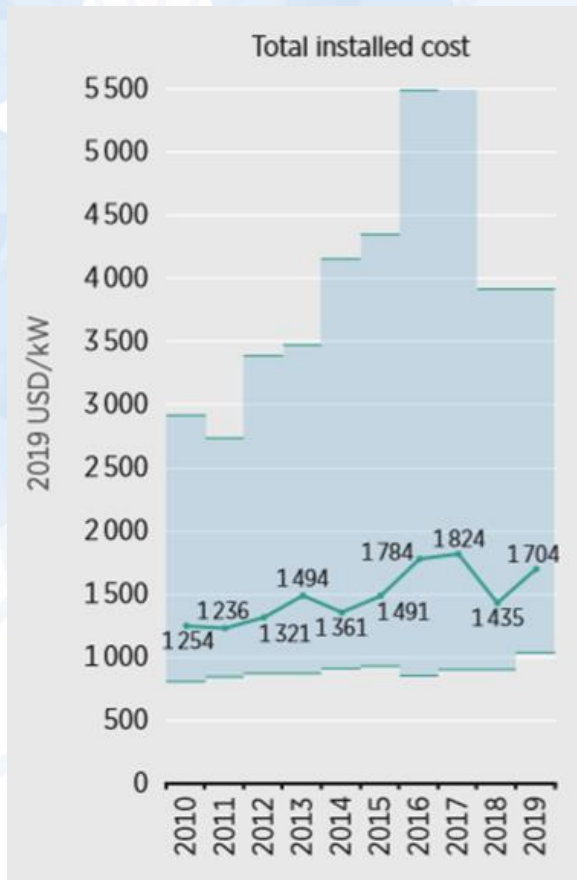


biomass plants that rely on bagasse and landfill gas and other biogases tend to have lower capacity factors (around **50%** to **60%**), while plants relying on **wood, fuel wood, rice husks and industrial and renewable municipal waste** tend to have weighted-average capacity factors by region in the range of **60%** to **85%**.

# LCOE by project and weighted averages of bioenergy power generation projects by feedstock and country/region, 2000-2019



# Hydropower cost and performance trends



In 2019, total installed cost of newly commissioned hydropower projects increased to **USD 1704/kW**, **17%** higher than in 2018.

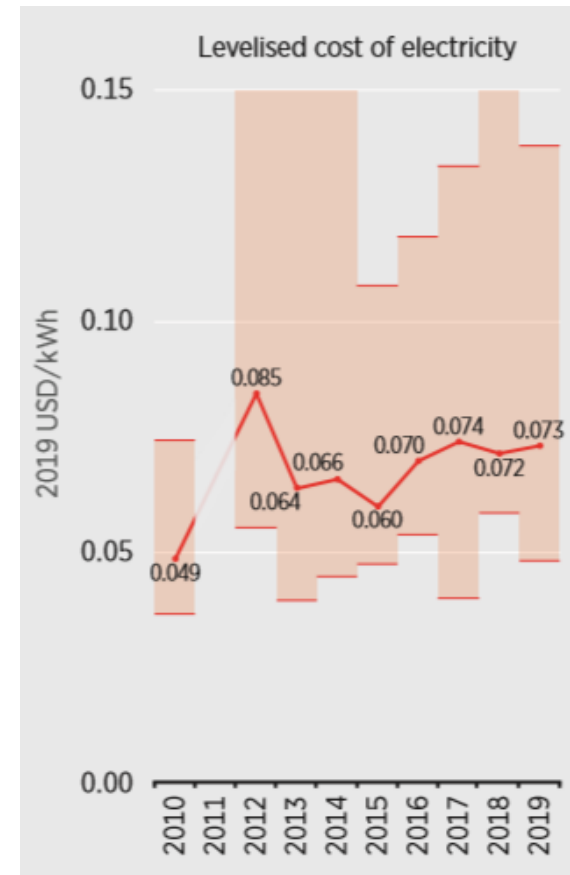
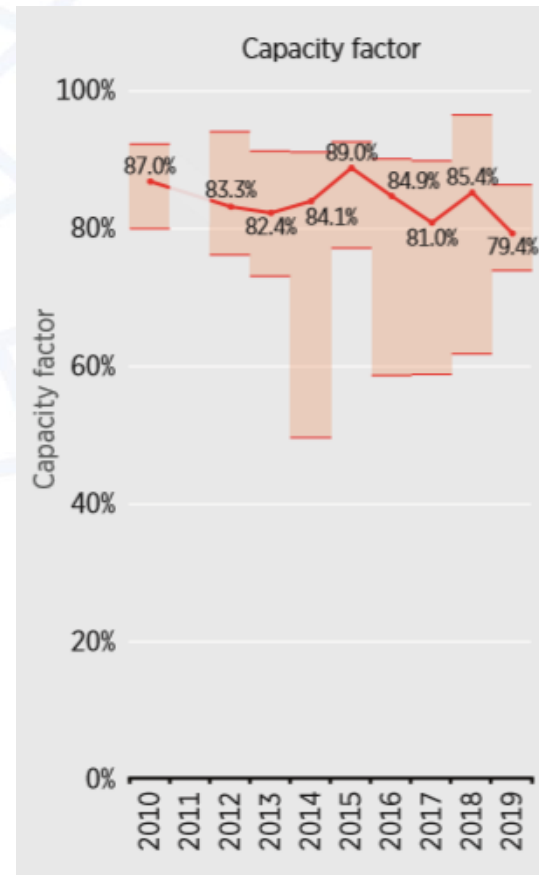
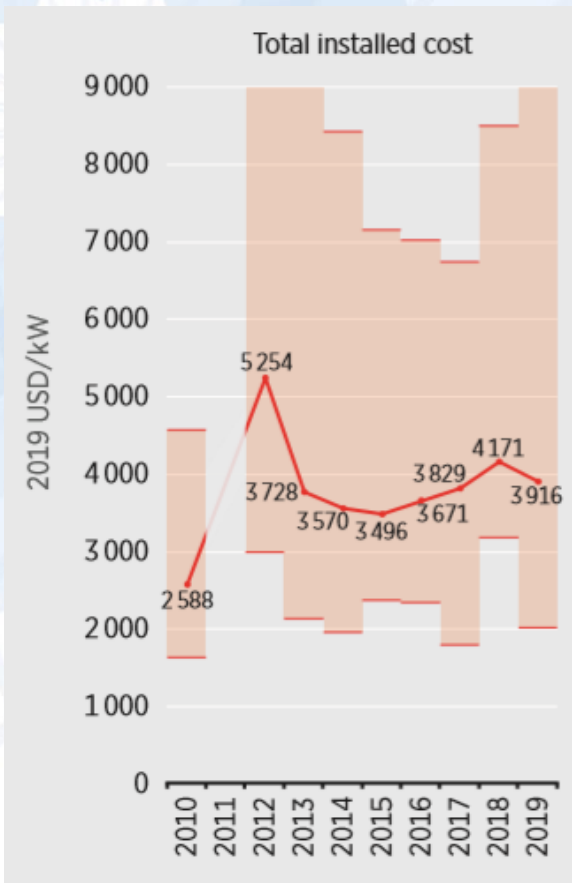
Between 2010 and 2019, the capacity factor for hydropower projects commissioned varied between **44%** – in 2010 – and a high of **51%** in 2015. For projects commissioned in 2019, it was 48%.

2019 was **USD 0.047/kWh**, **6%** higher than 2018 and **27%** higher 2010

Despite these increases through time, however, **89%** of the capacity added in 2019 had costs **lower** than the cheapest new source of fossil fuel-fired electricity generation.



# Geothermal cost and performance trends



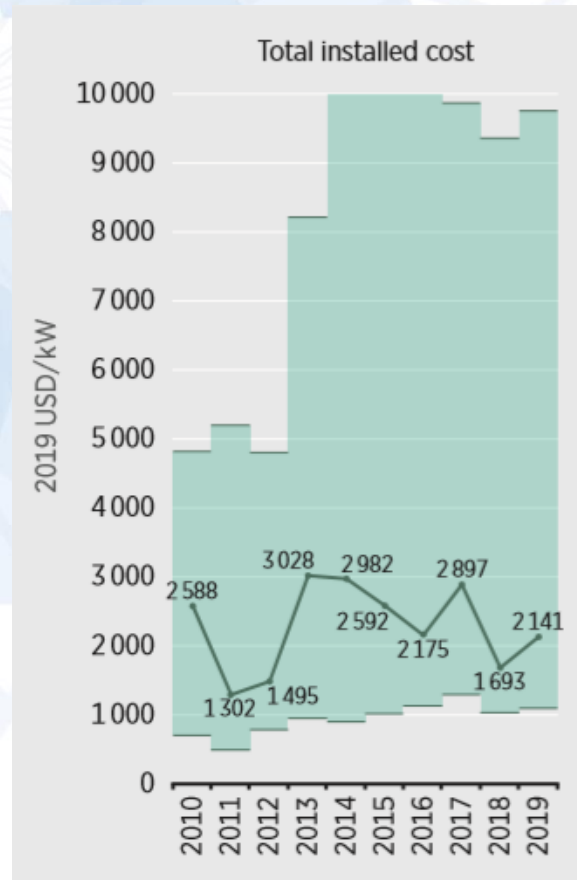
The deployment of geothermal power plants remains modest, with the **682 MW** added in **2019** – a **new record**.

Between 2014 and 2019, total installed costs increased from **USD 3570/kW** to **USD 3916/kW**. In 2019, the total installed costs of the majority of newly commissioned plants spanned the range **USD 2000** to **USD 5000/kW**.

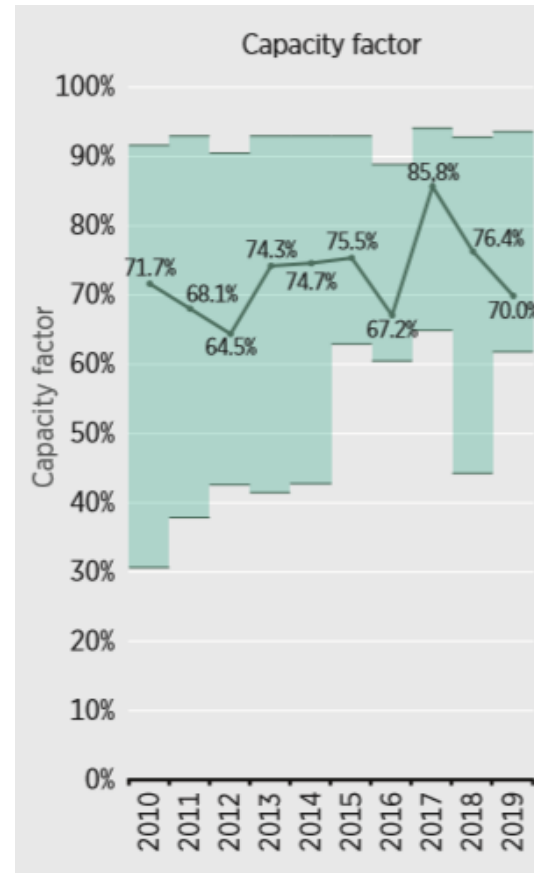
In 2019, the global weighted-average capacity factor for newly commissioned plants was **79%**.

The global weighted-average LCOE of the projects commissioned in 2019 was **USD 0.073/kWh**, broadly in line with values seen over the last four years.

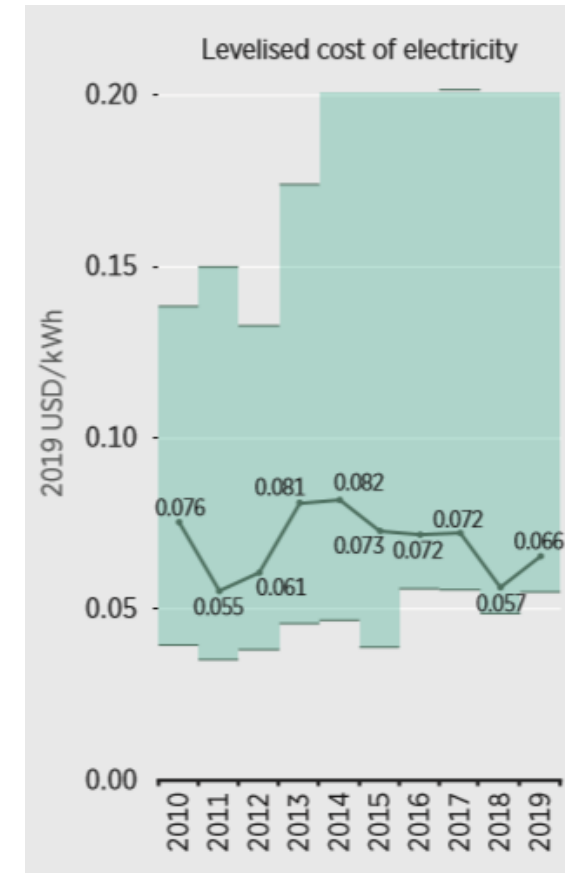
# Bioenergy cost and performance trends



For bioenergy projects newly commissioned in 2019, the global weighted-average total installed cost was **USD 2141/kW**. This represented an increase on the 2018 weighted-average of **USD 1693/kW**



Between 2010 and 2019, the global weighted-average capacity factor for bioenergy projects varied between a low of **65%** in 2012 to a high of **86%** in 2017



Between 2010 and 2019, the global weighted-average LCOE of bioenergy for power projects fell from **USD 0.076/kWh** to **USD 0.066/kWh** – a figure at the lower end of the cost of electricity from new fossil fuel-fired projects.

## Questions & Answers

Please use the 'Questions' feature on the webinar panel

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# Thank you very much for your attention!

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