IRENA
International Renewable Energy Agency

RENEWABLE POWER GENERATION COSTS IN 2022

EXECUTIVE SUMMARY

Citation: IRENA (2022), *Renewable power generation costs in 2022*, International Renewable Energy Agency, Abu Dhabi.

ISBN 978-92-9260-544-5

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Acknowledgements

This report was developed under the guidance of Roland Roesch (Director, IRENA Innovation and Technology Center) and Michael Taylor (IRENA).

The report was authored by Michael Taylor, Sonia Al-Zoghoul and Pablo Ralon (IRENA), with assistance from Olga Sorokina (European Energy Link Group).

The authors are grateful for the valuable contributions from Erick Ruiz Araya, Francis De Jaeger, Juan Pablo Jimenez Navarro, Binu Parthan and Ludovico Del Vecchio (IRENA) in the preparation of this study.

This report benefited from the reviews and comments of numerous experts, including Ana Andrade (Direção Geral de Energia e Geologia [DGEG]), Alex Campbell and Rebecca Ellis (IHA), Manuel Quero (Sunntics), Alexander Hogeveen Rutter (ISA), Christoph Walter (DEA), Yuetao Xi (CREEI) and Feng Zhao (GWEC). All opinions and errors remain those of the authors.

Publications, editorial and communications support were provided by Francis Field, Stephanie Clarke, Nicole Bockstaller and Daria Gazzola.

The report was copy-edited by Jonathan Gorvett and Stefanie Durbin, and a technical review was provided by Paul Komor. The graphic design was provided by Ignacio de la Concepción Sanz.

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The growing competitiveness of renewable power continues to provide the most compelling pathway to the decarbonisation of the global energy system

HIGHLIGHTS

In 2022, the global weighted average cost of electricity from newly commissioned utility-scale solar photovoltaics (PV), onshore wind, concentrating solar power (CSP), bioenergy and geothermal all fell. This was despite rising materials and equipment costs.

China was the key driver of the global decline in costs for solar PV and onshore wind, with other markets experiencing a much more heterogeneous set of outcomes that saw costs increase in many major markets.

For newly commissioned onshore wind projects, the global weighted-average levelised cost of electricity (LCOE) fell by 5% between 2021 and 2022, from USD 0.035/kWh to USD 0.033/kWh. For utility-scale solar PV projects, the global weighted-average LCOE decreased by 3% year-on-year in 2022, to USD 0.049/kWh. For offshore wind, the cost of electricity of new projects increased by 2%, in comparison to 2021, rising from USD 0.079/kWh to USD 0.081/kWh in 2022.

The fossil fuel price crisis of 2022 was a telling reminder of the powerful economic benefits that renewable power can provide in terms of energy security. In 2022, the renewable power deployed globally since 2000 saved an estimated USD 521 billion in fuel costs in the electricity sector.

Due to soaring fossil fuel prices, the 2021-2022 period saw one of the largest improvements in the competitiveness of renewable power in the last two decades. Looking at the trend since 2010:

- In 2010, the global weighted-average LCOE of onshore wind was 95% higher than the lowest fossil fuel-fired cost; in 2022, the global weighted-average LCOE of new onshore wind projects was 52% lower than the cheapest fossil fuel-fired solutions.
- Even this improvement was surpassed by that of solar PV, however. This renewable power source was 710% more expensive than the cheapest fossil fuel-fired solution in 2010; however, driven by a spectacular decline in costs, it cost 29% less than the cheapest fossil fuel-fired solution in 2022.

Table H.1 Total installed cost, capacity factor and LCOE trends by technology, 2010 and 2022

	Total installed costs (2022 USD/kW)			Capacity factor (%)			Levelised cost of electricity (2022 USD/kWh)		
	2010	2022	Percent change	2010	2022	Percent change	2010	2022	Percent change
Bioenergy	2 904	2 162	-26%	72	72	1%	0.082	0.061	-25%
Geothermal	2 904	3 478	20%	87	85	-2%	0.053	0.056	6%
Hydropower	1 407	2 881	105%	44	46	4%	0.042	0.061	47%
Solar PV	5 124	876	-83%	14	17	23%	0.445	0.049	-89%
CSP	10 082	4 274	-58%	30	36	19%	0.380	0.118	-69%
Onshore wind	2 179	1 274	-42%	27	37	35%	0.107	0.033	-69%
Offshore wind	5 217	3 461	-34%	38	42	10%	0.197	0.081	-59%

EXECUTIVE SUMMARY

THE COMPETITIVENESS OF RENEWABLE POWER IMPROVED DRAMATICALLY IN 2022, DESPITE COST INFLATION.

After decades of falling costs and improving performance in solar and wind technologies, the economic benefits of renewable power generation – in addition to its environmental benefits – are now compelling.

Indeed, due to soaring fossil fuel prices, the 2021 to 2022 period saw one of the largest improvements in the competitiveness of renewable power in the last two decades.

This was despite most markets, excluding China, seeing equipment price increases for solar photovoltaic (PV) modules and wind turbines. It was also despite the fact that many markets experienced overall solar wind power cost inflation.

In 2021, of the 20 countries for which IRENA has detailed data, nine saw the competitiveness[1] of their utility-scale solar PV improve by *more* than the global weighted-average levelised cost of electricity (LCOE) for that year. In 2022, eight countries saw such an improvement.

For onshore wind, the situation was even starker. In the 2021-2022 period, of the 20 countries examined for onshore wind, 15 saw their largest absolute improvement in competitiveness since detailed data became available. This included markets which saw total installed costs increase, with fossil fuel prices rising far more than the prices of their renewable alternatives.

The rate at which the competitiveness of solar and wind power has improved as the cost of electricity from solar and wind power has fallen is also quite remarkable.

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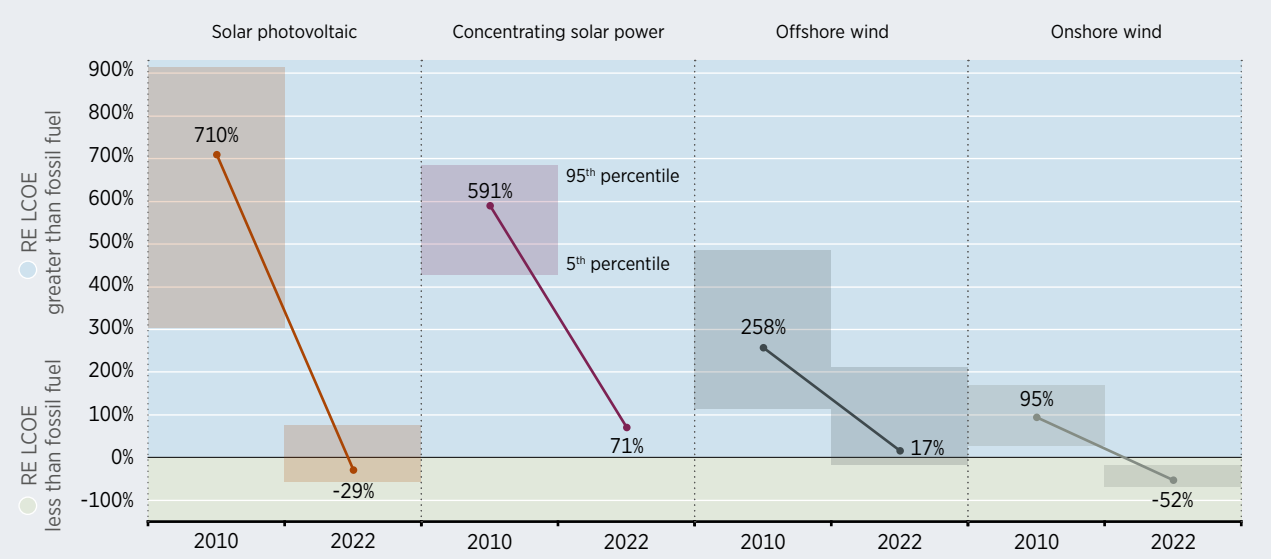
[1] *IRENA has calculated a competitiveness metric for 20 countries. This is based on a weighted average cost of new fossil fuels calculated from project-level capital cost data and country-specific fossil gas and coal fuel marker prices to electricity generators. The competitiveness metric subtracts the country weighted average fossil fuel levelised cost of electricity (LCOE) from the renewable power LCOE, so negative values represent renewable power LCOEs lower than those of fossil fuels.*

In 2010, the global weighted-average LCOE of onshore wind was USD 0.107/kilowatt hour (kWh). This was 95% higher than the lowest fossil fuel cost of USD 0.056/kWh. By 2022, the global weighted-average LCOE of new onshore wind projects was USD 0.033/kWh, 52% lower than the cheapest fossil fuel-fired option, which had risen to USD 0.069/kWh (Figure S.1).

Over the same period, the global weighted-average LCOE of offshore wind went from being 258% more expensive than the cheapest fossil fuel option to being just 17% more expensive, as the cost fell from USD 0.197/kWh to USD 0.081/kWh.

Figure S.1 Change in competitiveness of solar and wind by country based on global weighted average LCOE, 2010-2022



Note: The global weighted average LCOE data by technology and the fossil fuel LCOE data used to derive this chart is presented in detail in Chapter 1; RE = renewable energy.

Concentrating solar power (CSP) saw its global weighted-average LCOE fall from 591% higher than the cheapest fossil fuel option in 2010 to 71% higher in 2022.

Even this improvement was surpassed by that of solar PV, however. This renewable power source had a global weighted-average LCOE of USD 0.445/kWh in 2010 – 710% more expensive than the cheapest fossil fuel-fired option. Yet, by 2022, a spectacular decline in costs – to USD 0.049/kWh – made solar PV's global weighted-average LCOE 29% lower than the cheapest fossil fuel-fired option.

Indeed, with fossil fuel-fired power generation costs rising in 2021-2022, primarily because of fossil fuel price increases, around 86%, or 187 gigawatts (GW), of newly commissioned, utility-scale renewable power generation projects commissioned in 2022 had costs of electricity lower than the weighted-average fossil fuel-fired cost by country/region. This figure was 8% higher than the 174 GW estimated for 2021.

Overall, between 2010 and 2022, 1120 GW of renewable power generation with a lower LCOE than that of the weighted-average fossil fuel-fired LCOE by country/region was deployed.

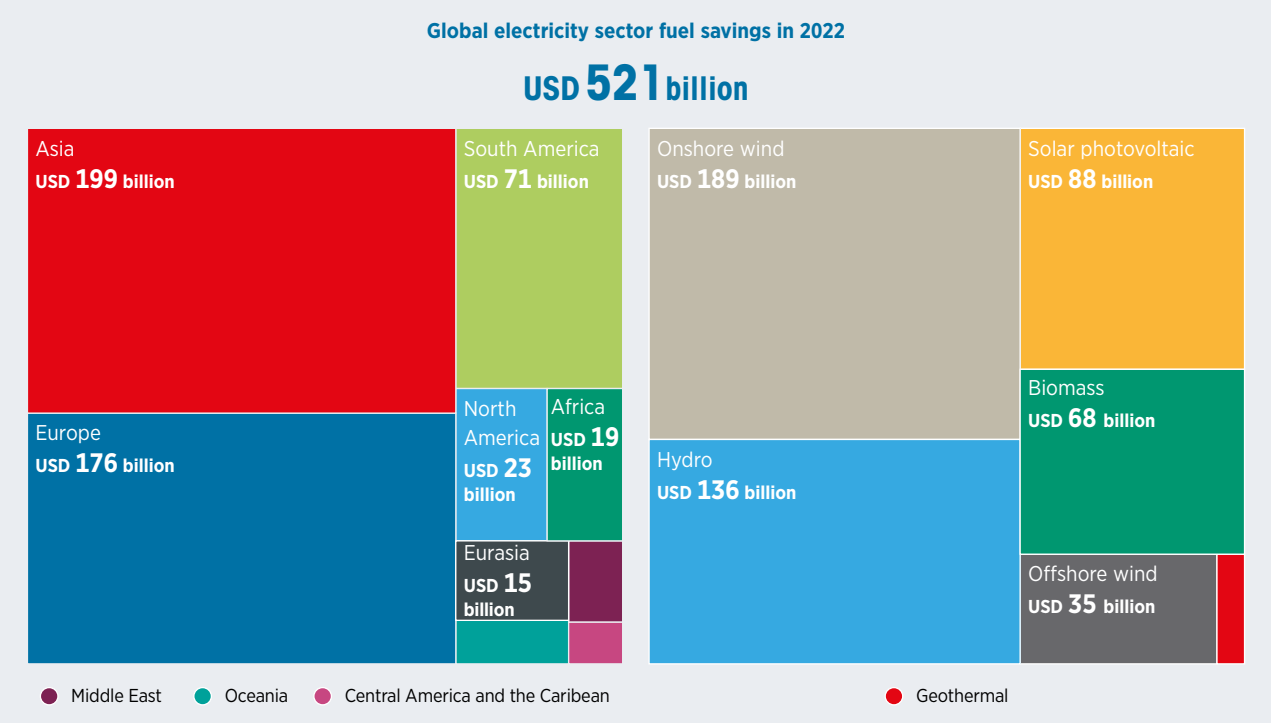
RENEWABLE POWER PROVIDES MAJOR ENERGY SECURITY BENEFITS.

The fossil fuel price crisis of 2022 was a telling reminder of the powerful economic benefits that renewable power can provide, in terms of energy security. Indeed, 2022 was the year that the energy security benefits of renewables were widely 'rediscovered'.

Unlike energy security policies that focus on the physical supply of fossil fuels, renewable power reduces the economic costs of exposure to inherently volatile fossil fuel prices by reducing the need for fossil fuels and their import. In short, substitutes to fossil fuels that have stable costs over their lifetime, such as renewable power and energy efficiency, and can be deployed rapidly, provide by far the largest energy security benefits. This may seem obvious, but in the scramble to secure additional fossil fuel supplies in 2022, this was often a secondary priority among policy makers.[2]

In 2022, the renewable power deployed globally since 2000 saved an estimated USD 521 billion[3] in fuel costs in the electricity sector alone (Figure S.2). In Europe, that figure was USD 176 billion. In addition, it is possible that the build-out of renewables since 2010 probably saved the continent from a full-blown economic crisis, as in the absence of renewable power generation,[4] the direct economic costs of the fossil fuel price hikes would have been much higher.

Figure S.2 Global fossil fuel cost savings in the electricity sector in 2022 from renewable power added since 2000



[2] *It is worth noting that policy makers were overwhelmed by the impact of the fossil fuel price crisis in 2022. It is therefore not surprising that, given limited institutional resources and the wide-ranging call on policy makers, different areas were prioritised. It does represent something of a missed opportunity, however.*

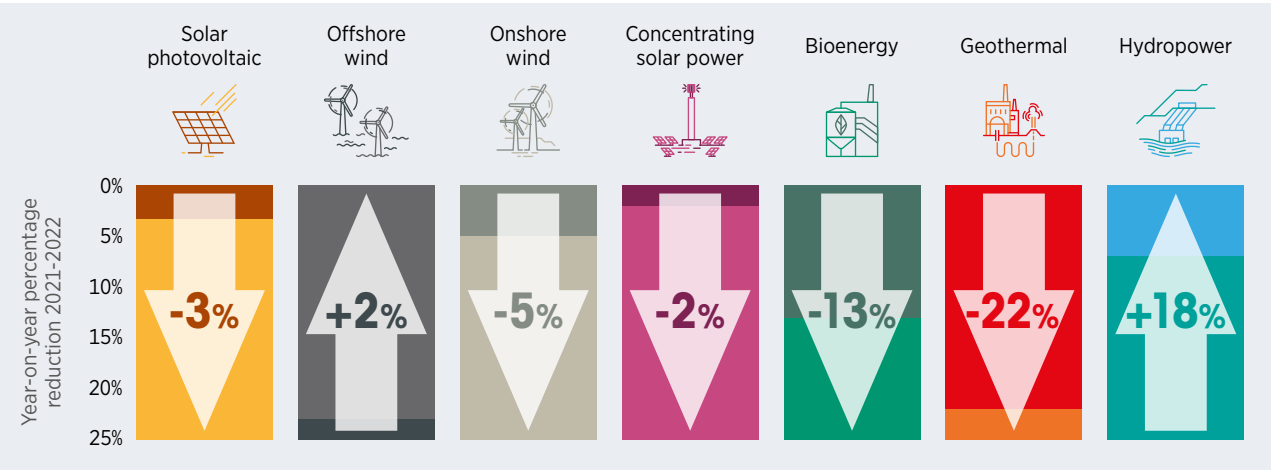
[3] *This is could be a low estimate. It is probable that the higher fossil fuel demand in 2022 – as a result of the hypothetical lower renewables deployment – would have raised prices even higher and made the supply shock even more damaging.*

[4] *This is before counting the impact of the use of heat pumps, solar thermal water heaters and energy efficiency measures.*

IN 2022, THE GLOBAL WEIGHTED AVERAGE COST OF ELECTRICITY FROM SOLAR PV, ONSHORE WIND, CSP, BIOENERGY AND GEOTHERMAL ALL FELL.

For newly commissioned onshore wind projects, the global weighted-average LCOE fell by 5% between 2021 and 2022, from USD 0.035/kWh to USD 0.033/kWh (Figure S.3). In 2022, China was once again the largest market for new onshore wind capacity additions, with its share of global new deployment rising from 41% to 50% between 2021 and 2022. This resulted in markets with higher installed costs decreasing their share relative to 2021. If China had been excluded, the global weighted-average LCOE curve for onshore wind for the period would have remained flat.

Figure S.3 Global LCOE from newly commissioned, utility-scale renewable power technologies, 2021-2022



For newly commissioned, utility-scale solar PV projects, from 2021 to 2022, the global weighted-average LCOE decreased by 3%, to USD 0.049/kWh. This was driven by a 4% decline in the global weighted-average total installed cost for this technology, from USD 917/kilowatt (kW) in 2021 to USD 876/kW for the projects commissioned in 2022.

Overall, the solar PV experience in 2022 was mixed, with different markets moving in different directions. The decline in LCOE in 2022 was less than the 13% year-on-year decline experienced in 2021, as 11 of the top 20 utility-scale solar PV markets for which IRENA has detailed data saw their total installed cost increase in real terms, with 12 seeing an increase in nominal terms. Some of these increases were substantial – there was a 34% hike in France and Germany, for example, while Greece saw an estimated 51% cost increase driven by rising PV module and commodity prices at the end of 2021 and into 2022. Some of this variability represents the normal variation in individual project costs, but it is clear commodity and labour cost inflation had a significant impact on some markets.

That the global weighted average cost of electricity from newly commissioned utility-scale solar PV fell in 2022, however, was due to the fact that China had lower costs than most markets and its share of global utility-scale solar PV deployment increased from 38% in 2021 to an estimated 45% in 2022.

The offshore wind market added 8.9 GW of new capacity in 2022. This would have been a new record, if not for the unprecedented expansion seen in 2021, when 21 GW was added globally, driven by a surge in China. Indeed, in 2022, the fall in China's share in new capacity additions and the commissioning of projects in new markets saw the global weighted-average cost of electricity of new projects increase by 2%, in comparison to 2021, from USD 0.079/kWh to USD 0.081/kWh. The increase in global weighted-average total installed costs (from USD 3 052/kW in 2021 to USD 3 461/kW in 2022) was partially offset by the increase in capacity factors for newly commissioned projects from 39% in 2021 to 42% in 2022.

For newly commissioned bioenergy for power projects, the global weighted-average LCOE fell by 13% between 2021 and 2022, from USD 0.071/kWh to USD 0.061/kWh. This occurred as the share of new, low-cost, projects commissioned in China and Brazil increased in 2022.

For geothermal power projects, between 2021 and 2022 the global weighted-average LCOE of the ten projects commissioned fell by 22%, to USD 0.056/kWh.

Newly commissioned hydropower projects, in contrast, saw their global weighted-average LCOE increase by 18% between 2021 and 2022, from USD 0.052/kWh to USD 0.061/kWh. In 2022, a number of projects that experienced significant delays and large cost overruns were commissioned partially, or in full. As a result, the global weighted average total installed cost of new hydropower projects increased from USD 2 299/kW in 2021 to USD 2 881/kW in 2022, a rise of 25%.

BETWEEN 2010 AND 2022, SOLAR AND WIND POWER EXPERIENCED REMARKABLE COST DEFLATION.

The experience of the last two years has changed stakeholders' understanding of price expectations in fossil fuel markets, while also demonstrating the vulnerability of countries dependent on fossil fuels for power generation.

Even prior to the fossil fuel price crisis in 2022, however, renewables were out-competing fossil fuels. Indeed, when new electricity generation capacity was required in 2021, renewables significantly undercut new fossil fuel additions, while in many locations renewables even undercut existing plants, once the impact of financial support was factored out. The competitiveness of renewable power saw a significant leap in 2022 as fossil fuel prices spiked.

Since 2010, solar PV has experienced the most rapid cost reductions. The global weighted-average LCOE of newly commissioned utility-scale solar PV projects declined from USD 0.445/kWh to USD 0.049/kWh between 2010 and 2022 – a decrease of 89% (Figure S.4). This reduction in LCOE has been primarily driven by declines in module prices. These fell by around 90% between December 2009 and December 2022, despite an increase in 2022. Important reductions have also occurred in balance of plant costs, operations and maintenance (O&M) costs and the cost of capital.

For onshore wind projects, between 2010 and 2022, the global weighted-average cost of electricity fell by 69%, from USD 0.107/kWh to USD 0.033/kWh.

Cost reductions for onshore wind were driven by two key factors: wind turbine cost declines and capacity factor increases from turbine technology improvements. Wind turbine prices outside of China fell by 39-55% between 2010 and 2022, depending on the wind turbine price index, while the decline in China was almost two-thirds, at 64%. The global weighted-average capacity factor of newly commissioned projects increased from 27% in 2010 to 39% for those commissioned in 2021. This global weighted average then fell back to 37% in 2022, as the share of new deployment taken by China increased, owing to the country's generally poorer wind resource locations.

For newly commissioned offshore wind projects, between 2010 and 2022 the global weighted-average LCOE declined from USD 0.197/kWh to USD 0.081/kWh, a reduction of 59%.

In 2010, China and Europe saw newly commissioned offshore projects with weighted average LCOEs of USD 0.189/kWh and USD 0.198/kWh, respectively. In 2021, newly commissioned European projects had a weighted-average cost of USD 0.056/kWh, which was lower than the USD 0.083/kWh cost in China that year. In 2022, the weighted-average LCOE in Europe increased to USD 0.074/kWh as a range of more expensive projects were completed, including in new markets. Europe's LCOE, however, was still around 4% lower than Chinese projects completed in 2022, with these seeing a weighted average of USD 0.077/kWh.

CSP deployment remains disappointing, with less than 0.1 GW added in 2022 and global cumulative capacity standing at 6.5 GW at the end of 2022.

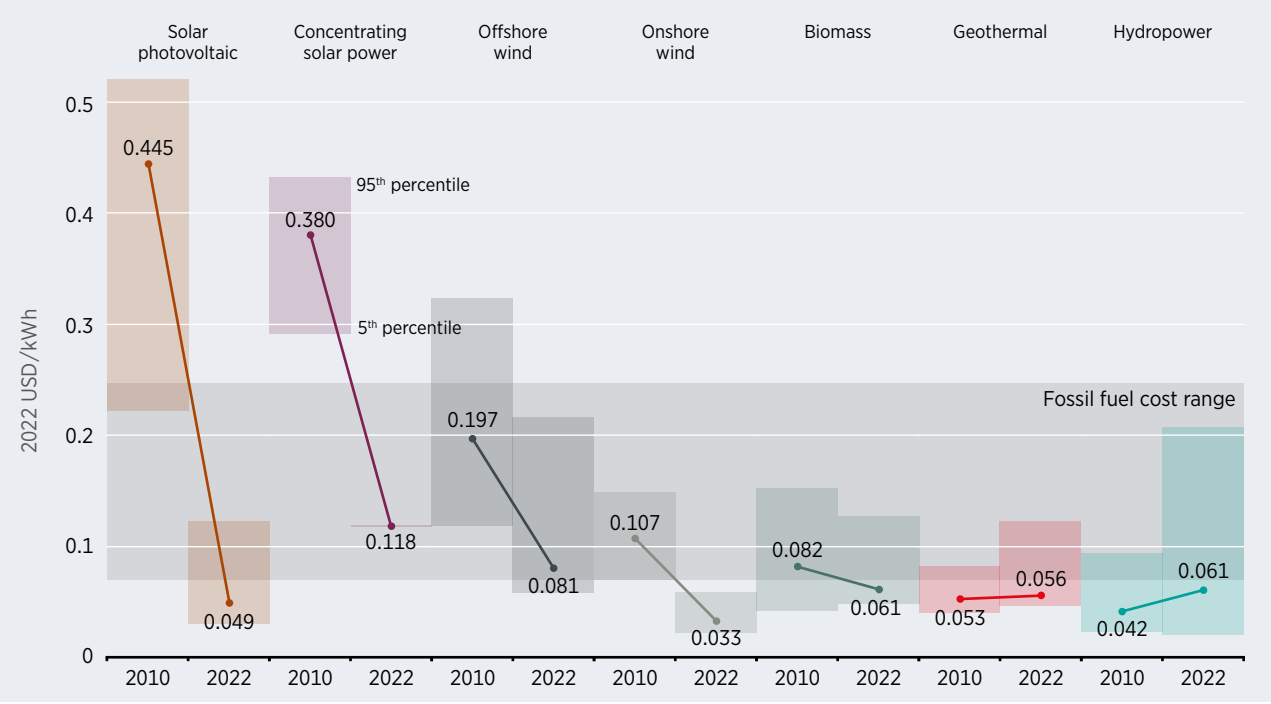
For the period 2010 to 2022, the global weighted-average cost of newly commissioned CSP projects fell from USD 0.38/kWh to USD 0.118/kWh – a decline of 69%. The LCOE of CSP fell rapidly between 2010 and 2020, despite annual volatility. Since 2020, however, the commissioning of projects that were either delayed or included novel designs has seen the global weighted-average cost of electricity from this technology stagnate. CSP would benefit from additional policy support, given the impressive cost reductions it has managed with just 6.5 GW of cumulative deployment.

Bioenergy for power projects saw its global weighted-average LCOE experience a certain degree of volatility during the 2010-2020 period, without a notable trend upwards or downwards. In 2022, however, bioenergy's global weighted-average LCOE of USD 0.061/kWh was 13% lower than the 2021 value and one-quarter lower than the value in 2010, which had been USD 0.082/kWh.

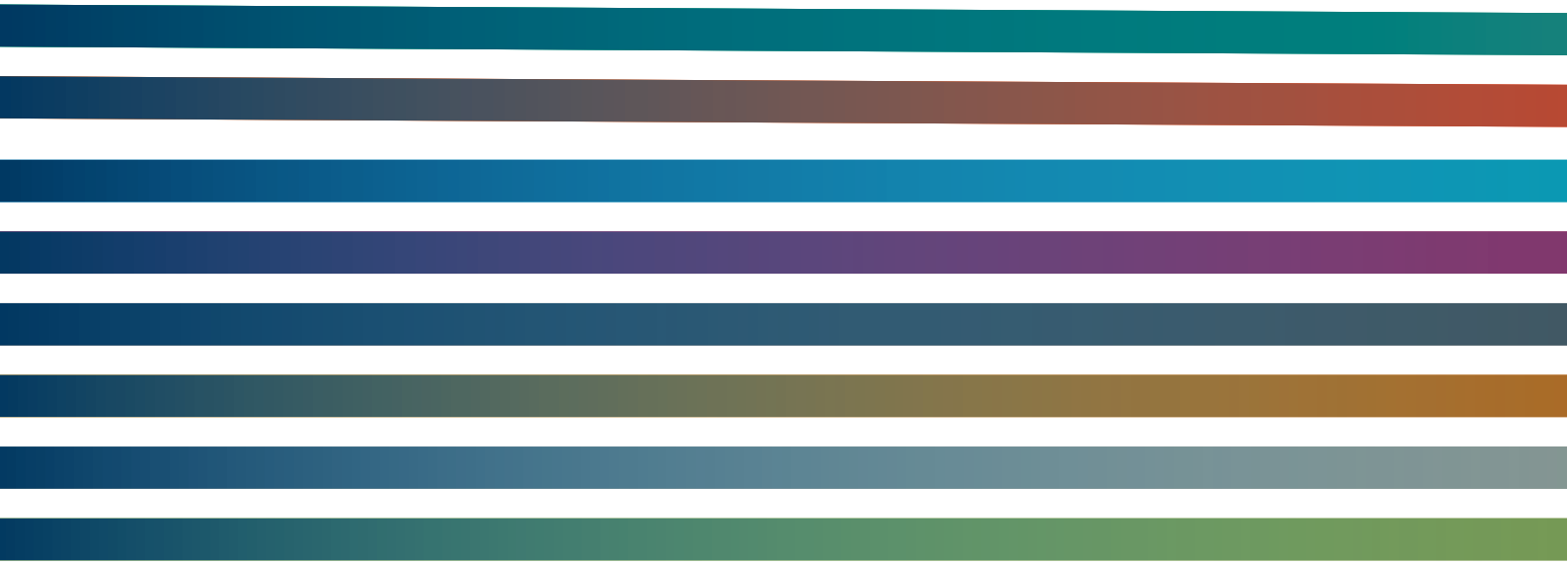
For geothermal projects, the global weighted-average LCOE fell 22% between 2021 and 2022, to USD 0.056/kWh. This was 6% higher than in 2010, but well within the USD 0.053/kWh to USD 0.091/kWh range seen between 2013 and 2021.

Newly commissioned hydropower projects saw their global weighted-average LCOE rise by 47% between 2010 and 2022, from USD 0.042/kWh to USD 0.061/kWh. This was still lower than the cheapest new fossil fuel-fired electricity option in 2022, despite the fact that global weighted average costs increased by 18% that year. The increase in 2022 over 2021 was driven by the commissioning of a number of projects that experienced very significant cost overruns, notably in Canada.

Figure S.4 Global LCOE from newly commissioned utility-scale renewable power technologies, 2010 and 2022



Note: These data are for the year of commissioning. The thick lines are the global weighted average LCOE value derived from the individual plants commissioned in each year. The LCOE is calculated with project-specific installed costs and capacity factors, while the other assumptions, including weighted average cost of capital (WACC), are detailed in Annex I. The grey band represents the fossil fuel-fired power generation cost in 2022, assuming that 2021 fossil gas prices were the correct lifetime benchmark rather than the crisis prices of 2022. While the bands for each technology and year represent the 5th and 95th percentile bands for renewable projects.



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