



RDFZ ICC - The Disruptor's Challenge

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Levelized Cost of Electricity (LCOE) Comparison: Renewables vs Fossil Fuels

Extended Reference — AI-Generated Document

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1. Executive Summary

The levelized cost of electricity (LCOE) landscape has undergone a dramatic transformation in 2024–2025, with renewable energy technologies achieving unprecedented cost competitiveness against fossil fuels. According to IRENA, 91% of newly commissioned renewable energy projects in 2024 delivered power at a lower cost than the cheapest newly installed fossil fuel alternatives (IRENA, 2025). This represents a historic inflection point in the global energy transition.

The most recent data shows that onshore wind emerged as the most economical source of new electricity generation globally in 2024, with a weighted-average LCOE of \$0.034/kWh, followed by solar photovoltaic at \$0.043/kWh (IEA, 2025). These costs represent reductions of 70% and 90%, respectively, compared to 2010 levels. In contrast, fossil fuel technologies have experienced cost increases, with new combined-cycle gas turbine (CCGT) plants reaching a 10-year high LCOE of \$102/MWh in 2025, a 16% increase from the previous year (BloombergNEF, 2025).

China leads globally in the most competitive LCOE values, with onshore wind at \$0.029/kWh and solar PV at \$0.033/kWh. This reflects vertically integrated supply chains, abundant domestic manufacturing capacity, and streamlined project execution. The financing cost differential between regions is particularly striking, with capital costs ranging from 3.8% in Europe to 12% in Africa (PMC, 2024).

2. Current LCOE Landscape (2024–2025)

2.1 Overall Comparison: Renewables vs Fossil Fuels

The year 2024 marked a watershed moment in the global energy economy. The global weighted-average LCOE for utility-scale solar PV stabilized at \$0.043/kWh, making it 41% cheaper than the least-cost fossil-fuel-fired alternative. This cost advantage was even more pronounced for onshore wind, which achieved a global average LCOE of \$0.034/kWh, representing a 53% reduction compared to fossil-fuel-based generation (IRENA, 2025).

Global renewable power capacity additions reached an unprecedented 582 GW in 2024, a 19.8% increase compared to 2023. Among these additions, 91% were more cost-effective than any fossil-fuel-fired alternative (IRENA, 2025), with solar photovoltaics leading at 452.1 GW and wind at 114.3 GW.

IRENA estimates that in 2024, renewables helped avoid \$467 billion in fossil fuel costs, reinforcing their role as both the lowest-cost source of new power and a key driver of energy security.



Fossil fuel technologies have experienced significant cost increases. The LCOE for new CCGT plants jumped 16% to \$102/MWh in 2025, the highest level recorded (BloombergNEF, 2025). Coal maintains a relatively stable but high LCOE in the range of \$71–173/MWh (Lazard, 2025).

2.2 Renewable Energy Technologies

2.2.1 Solar Photovoltaics

Solar PV has experienced the most dramatic cost transformation of any energy generation technology in history. The global weighted-average LCOE for utility-scale solar PV has declined by 90% since 2010, from \$0.417/kWh to \$0.043/kWh in 2024. Total installed costs fell to \$691/kW in 2024, an 87% reduction from \$5,283/kW in 2010 (IRENA, 2025). The compound annual rate of LCOE decline has been approximately 24% (Lazard, 2020; Barbose et al., 2022).

China achieved the lowest solar LCOE at \$0.033/kWh, benefiting from vertically integrated supply chains. India followed at \$0.038/kWh. The United States and European Union face higher costs due to permitting delays and higher balance-of-system costs. Looking forward, global total installed costs are projected to reach approximately \$388/kW by 2029 (IRENA, 2025).

2.2.2 Wind Energy (Onshore and Offshore)

The global weighted average LCOE for onshore wind fell to \$0.034/kWh in 2024, a 70% reduction from \$0.113/kWh in 2010. Capacity factors increased from 27% in 2010 to 34% in 2024, and total installed costs fell from \$2,324/kW to \$1,041/kW (IRENA, 2025). China and Brazil achieved the lowest onshore wind LCOEs at \$0.029/kWh and \$0.030/kWh, respectively.

Offshore wind achieved a global weighted average LCOE of \$0.079/kWh in 2024, a 62% reduction from \$0.208/kWh in 2010. However, offshore wind costs increased slightly in 2024 due to a greater presence of projects in emerging markets. China achieved \$0.056/kWh for offshore wind; the US exceeded \$0.123/kWh (IRENA, 2025).

2.2.3 Other Renewables (Hydropower, Geothermal, CSP)

Hydropower maintained a global weighted average LCOE of \$0.057/kWh in 2024, a 2% decline from 2023. Geothermal achieved \$0.060/kWh, with a 16% reduction driven by improved drilling techniques. Concentrated solar power (CSP) achieved a dramatic 46% LCOE reduction in 2024, reaching \$0.092/kWh — a 77% reduction since 2010. Its thermal storage capability provides dispatchable renewable electricity, a key advantage. Bioenergy rose to \$0.087/kWh due to volatile feedstock costs (IRENA, 2025).

2.3 Fossil Fuel Technologies

2.3.1 Coal

New coal plants have an LCOE range of \$71–173/MWh with a midpoint of \$122/MWh (Lazard, 2025). Coal LCOE declined 7% in 2024 due to falling coal prices, with Australian coal dropping from \$172/ton to \$135/ton. However, increasing environmental compliance costs offset these gains. China and India can achieve coal LCOEs below \$0.05/kWh domestically; plants in the EU or US face costs exceeding \$0.10/kWh when carbon pricing is included.

2.3.2 Natural Gas

New CCGT plants reached a 10-year high LCOE of \$102/MWh in 2025, a 16% increase from the prior year, reflecting turbine shortages and rising costs (BloombergNEF, 2025). Combined-cycle gas plants have an LCOE range of \$48–109/MWh, with a midpoint of \$78/MWh. Gas peaking plants trade at \$149–251/MWh due to low capacity factors. In 2022, European gas prices peaked at \$339/MWh before stabilizing around \$130/MWh in 2025 (Construction Durable, 2025).



3. Regional and Geographic Variations

3.1 Global Regional Comparisons

China is the global leader in cost competitiveness in renewable energy. Its dominance in solar and wind manufacturing enables costs that are 20–30% lower than in European and North American markets. The US and EU face higher renewable costs due to permitting delays, interconnection bottlenecks, and higher balance-of-system costs. India achieved a competitive solar LCOE of \$0.038/kWh; Brazil recorded an onshore wind LCOE of \$0.030/kWh.

The financing cost differential between regions is particularly striking. Capital costs range from 3.8% in Europe to 12% in Africa, adding 50–100% to the LCOE of renewable projects in high-risk regions (PMC, 2024).

3.2 Impact of Resource Availability

Solar capacity factors range significantly by region. In China and India, capacity factors can exceed 20%; the global average capacity factor for solar PV increased from 15% in 2010 to 17% in 2024 (IRENA, 2025). Onshore wind capacity factors range from 21% to 41% globally. A 10% increase in capacity factor can reduce LCOE by approximately 7–10%.

Geothermal resources are limited to tectonic plate boundaries and volcanic regions, with global average capacity factors of approximately 88%. Hydropower requires a reliable water flow and an appropriate elevation difference. Geographic constraints explain why LCOE data alone cannot determine the best energy system for a given location.

4. Scale and Technology Effects

4.1 Economy of Scale

Global solar panel manufacturing capacity expanded from 27 GW in 2010 to over 500 GW in 2024, driving module prices down 36% in 2024 alone. The learning rate for solar PV has been approximately 24% per doubling of cumulative production (Lazard, 2020; Barbose et al., 2022). Wind turbine manufacturing exhibits a more moderate learning rate of approximately 15%, while average turbine size increased from under 2 MW in 2010 to over 5 MW in 2024.

4.2 Technology Learning Curves

Solar PV has exhibited the steepest learning curve, with an LCOE-based learning rate of 24%. Global onshore wind LCOE fell 56% between 2010 and 2020. Battery storage costs declined 93% from 2010 to 2024, falling from \$2,571/kWh to \$192/kWh, with lithium iron phosphate (LFP) batteries reaching \$115/MWh in 2024 (BloombergNEF, 2025).

Projections suggest solar PV LCOE could decline a further 31% by 2035 to \$25/MWh, while onshore wind could see a 22% reduction to \$28/MWh. Battery storage is expected to fall 50% to \$53/MWh by 2050 (Lazard, 2025).

5. Comparative Analysis

5.1 LCOE Comparison Table

Technology	Capacity Factor	LCOE Range (\$/MWh)	Midpoint	Trend
RENEWABLE TECHNOLOGIES				
Onshore Wind	25–55%	27–73	\$70	▼ -3%
Offshore Wind	45–55%	74–139	\$190 (US)	▲ +4%
Solar PV (Utility-scale)	20–30%	38–78	\$74	▲ +0.6%
Hydropower	40–60%	30–100	\$57	▼ -2%



Technology	Capacity Factor	LCOE Range (\$/MWh)	Midpoint	Trend
Geothermal	80–90%	50–100	\$60	▼ -16%
CSP with Storage	30–50%	70–150	\$92	▼ -46%
FOSSIL FUEL TECHNOLOGIES				
Coal (New Plant)	65–85%	71–173	\$122	▼ -7%
Natural Gas (CCGT)	30–90%	48–109	\$78	▲ +8%
Natural Gas (Peaker)	10–20%	149–251	\$200	—

Sources: Lazard LCOE+ (June 2025); IRENA Renewable Power Generation Costs in 2024; IEA Breakthrough Agenda Report 2025.

6. Future Cost Projections

6.1 Short-term (2025–2030)

Solar PV global total installed costs are projected to reach approximately \$388/kW by 2029, a 44% reduction from 2024. LCOE is expected to decline a further 2% in 2025 to \$35/MWh, with projections below \$25–30/MWh in high-volume markets by 2030 (IRENA, 2025). Onshore wind costs are projected to decline 4% in 2025 to \$37/MWh, with total installed costs stabilizing at \$850–1,000/kW by 2026. Battery storage LCOE is projected to fall 11% in 2025 to \$93/MWh, reaching \$50–60/MWh by 2030.

6.2 Long-term (2030–2050)

Solar PV LCOE is projected to fall a further 31% from 2025 levels to \$25/MWh by 2035 (Lazard, 2025). Onshore wind is projected to see a 22% reduction to \$28/MWh. Offshore wind LCOE is expected to fall 26% to \$67/MWh by 2050. Battery storage costs are projected to fall 50% to \$53/MWh by 2050. Hybrid systems combining solar, wind, and storage are projected to achieve LCOE below \$50/MWh by 2030 and below \$30/MWh by 2050 in many markets.

7. Conclusions

The year 2024 marked a historic milestone: 91% of new renewable projects delivered electricity at a lower cost than any fossil fuel alternative (IRENA, 2025). Solar PV achieved a 90% cost reduction since 2010; onshore wind achieved 70%. These trends are structurally driven by learning curves, manufacturing scale, and the absence of fuel price risk. Fossil fuel technologies are on an opposite trajectory, with natural gas reaching a 10-year high in 2025.

China leads global cost competitiveness for both solar and wind, with structural advantages in manufacturing and project execution. Regional financing cost differentials — from 3.8% (Europe) to 12% (Africa) — significantly impact global deployment economics. The energy transition is economically inevitable; the remaining questions concern pace and the specific technologies that will dominate in each region.

The policy environment, storage cost trajectory, and critical material availability will shape whether projections for 2030–2050 are met. AI and digitalization are expected to reduce O&M costs by 20–30% and improve grid integration. Small modular reactors (SMRs) may enter commercial deployment in the 2030s with a projected LCOE of \$100–140/MWh with tax credits.



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