IRENA REPORT

IRENA
International Renewable Energy Agency

Renewable Power Generation Costs in 2012: An Overview

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

Renewables account for almost half of new electricity capacity installed and costs are continuing to fall.

Renewable power generation technologies now account for around half of all new power generation capacity additions worldwide. IRENA's analysis of around 8 000 projects and range of literature sources shows that the rapid deployment of renewables, working in combination with the high learning rates[1] for some technologies, has produced a virtuous circle that is leading to significant cost declines and is helping fuel a renewable revolution.

In 2011 additions included 41 GW of new wind power capacity, 30 GW of solar photovoltaic (PV), 25 GW of hydropower, 6 GW of biomass, 0.5 GW of concentrated solar power (CSP) and 0.1 GW of geothermal power.

The levelised cost of electricity (LCOE)[2] is declining for wind, solar PV, CSP and some biomass technologies, while hydropower and geothermal electricity produced at good sites are still the cheapest way to generate electricity.

Renewable technologies are now the most economic solution for new capacity in an increasing number of countries and regions. Where oil-fired generation is the predominant power generation source (e.g. on islands, off-grid and in some countries) a lower-cost renewable solution almost always exists today. Renewables are also increasingly the most economic solution for new grid-connected capacity where good resources are available. As the cost of renewable power drops, the scope of economically viable applications will increase even further.

Crystalline silicon (c-Si) PV module prices are a good example. Average prices for Chinese modules have fallen by more than 65% over the last two years to below USD 0.75/watt (W) in September 2012. The increasing size of global renewable markets and the diversity of suppliers has produced more competitive markets for renewable technologies.

For those regions with significant remaining small hydropower[3] potential, the weighted average LCOE for new small hydropower projects is between USD 0.032 and USD 0.07/kWh depending on the region, while for large hydropower the weighted average for a region is between USD 0.03 and USD 0.06/kWh (Figure ES.1) assuming a 10% cost of capital. For biomass, the weighted average LCOE for non-OECD regions varies between USD 0.05 and USD 0.06/kWh. For geothermal, the weighted average LCOE by region is between USD 0.05 and USD 0.09/kWh, while for onshore wind the range is between USD 0.08 and USD 0.12/kWh. CSP and utility-scale solar PV are more expensive, with the weighted average LCOE for utility-scale solar PV varying between USD 0.15 and USD 0.31/kWh. The weighted average LCOE for CSP for a region varies between USD 0.22 and USD 0.25/kWh.

The importance of the level of existing good quality resources that are available or remain to be exploited is also highlighted in Figure ES.1. Europe has higher LCOEs for hydropower and biomass-fired electricity because, in the former case, most of the economic potential has already been exploited, while in the latter case feedstock costs are typically high. Similarly, with the exception of Italy and Iceland, the geothermal resources in Europe are generally poor in quality and require expensive investment to exploit.

It is important to note that distributed renewable technologies, such as rooftop solar PV and small wind, can't be directly compared to large utility-scale solutions where transmission and distribution costs of USD 0.05 to USD 0.15/kWh must be added to the total costs.

1 The learning rate is the percentage reduction in costs for a technology that occurs with every doubling of cumulative installed capacity.

2 The LCOE of a given technology is the ratio of lifetime costs to lifetime electricity generation, both of which are discounted back to a common year using a discount rate that reflects the average cost of capital. In this report all LCOE results are calculated using a fixed assumption of a 10% cost of capital to facilitate comparison unless an alternative is explicitly mentioned.

3 Small hydropower is defined in this report as projects with installed capacity of up to 20 MW.

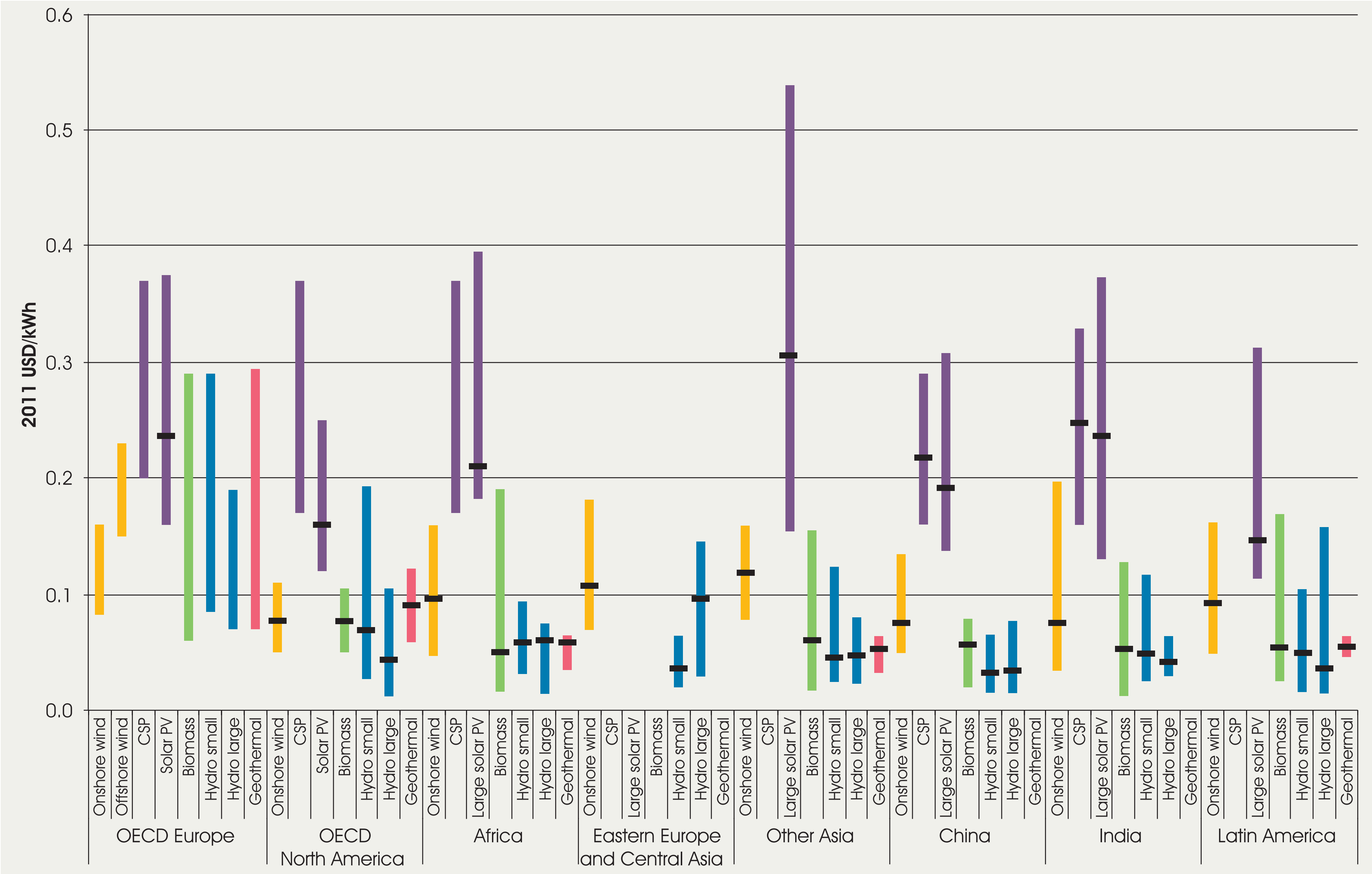

FIGURE ES.1: TYPICAL LCOE RANGES AND WEIGHTED AVERAGES FOR RENEWABLE POWER GENERATION TECHNOLOGIES BY REGION, 2012

Note: *The bars represent the typical LCOE range and the black horizontal bars the weighted average LCOE if enough individual project data are available. Figures assume a 10% cost of capital and biomass costs of between USD 1.3 and USD 2.5/GJ in non-OECD countries and between USD 1.3 and USD 9/GJ in OECD countries.*

The rapid growth in the deployment of solar and wind is driving a convergence in electricity generation costs for renewable power generation technologies at low levels.

It is not possible to identify a clear cost hierarchy for renewable technologies, as each technology has its own supply curve that can vary significantly by country, or even region within a country, depending on the resource availability and the local cost structure. However, an important observation is that there is a general hierarchy for renewable power generation in terms of costs and the scale of available resources. When excellent local resources are available, mature technologies, such as biomass, geothermal and hydropower, can all produce electricity at very competitive costs, although in limited quantities. Onshore wind is typically the next most economic, followed by solar PV and CSP, but the resource availability of these technologies globally is many times that of the mature technologies. In the past, renewable technologies with the largest resource potential therefore also had high costs.

The much larger wind and solar resources and their cost reduction potentials have helped spur support for wind and solar technologies in order to provide a larger share of power generation from renewables. As a result, as the deployment of wind and solar has increased, we are seeing a reduction in the costs of wind and solar technologies and a convergence in the LCOE of renewable technologies at low levels. How far this convergence will go remains to be seen, but it will continue in the short- to medium-term given the current manufacturing overcapacity for wind and solar PV.

The costs of renewables are very site specific, and resources are distributed unevenly across regions, countries and within a country. There is therefore no single "true" LCOE value for each renewable power generation technology. It is thus vital to collect national data to analyse renewable power generation costs and potentials.

This analysis is further complicated by the impact of variable renewables, which need to be analysed with a system-based approach. However, although a change in thinking is required in network operation, electricity storage or increased system flexibility with incremental system costs will typically only be needed when variable renewables reach 20-50% of total system capacity. Systems integration costs will vary widely and can be significantly reduced through proper system design.

As equipment costs decline, the share of balance of project costs and operations and maintenance costs in the LCOE will increase unless increased efforts are made to accelerate their decline as well.

Seven major components largely determine the LCOE for renewable power generation technologies – resource quality, equipment cost and performance (including capacity factor), the balance of project[4] costs, fuel (if any), operations and maintenance costs (and reliability), economic life of the project and the cost of capital. As equipment costs drop, the importance of the balance of project, or balance of system (BoS), and operations and maintenance (O&M) costs, and the cost of capital increases. For instance, BoS costs in the United States have not declined as fast as in more competitive markets, meaning that the average installed price for residential PV systems were more than twice as expensive as in Germany in the second quarter of 2012. In contrast, O&M costs for wind in most major European markets are typically twice as high as in the United States. These issues merit much more analysis and policy attention than they receive today in order to prevent a slowing in the rate of reduction in the LCOE of renewables.

This is particularly true for smaller systems. For residential PV systems, BoS costs (including installation) can account for 60% to 80% of the total project cost. Non-equipment costs are also higher in developing countries where transmission lines and roads must be built as part of the project. The share of the BoS or balance of project costs and the importance of O&M costs, indicate the order of magnitude of the opportunities for local content and value added, that may help meet local social and economic development goals.

For renewables, access to affordable financing and capital is often not the norm globally, yet it is critical to the ability to develop a renewable project and the LCOE generated. In new markets for renewables, special attention needs to be paid to ensure the regulatory and investment framework is favourable and that projects can access funds in the initial growth phase of the market. Once banks and other local financing sources

4 Sometimes referred to as "balance of system costs" for when small-scale applications of technologies like solar PV and wind are being discussed.

have experience with new technologies in their markets, financing should, but may not necessarily always, then be easier to access on favourable terms.

Further equipment cost reductions can be expected to 2020, which will lower the weighted average LCOE of renewables. The rate of decline to 2020 for solar PV is likely to be slower than in recent years, but wind and CSP may see an acceleration.

The technologies with the largest remaining cost reduction potential are CSP, solar PV and wind. Hydropower, geothermal and most biomass combustion technologies are mature and their cost reduction potentials are not large (Figure ES.2).

The range for LCOE of solar PV systems will decline more slowly in absolute terms than in the past, given that module prices have fallen so far. However markets which have higher than average cost structures for BoS today could see dramatic cost reductions in installed prices by 2020, lowering the weighted average costs significantly. Solar tower CSP plants costs could come down significantly by 2020 if deployment accelerates, given the potential of the technology and the current very low level of deployment. Wind turbine prices are falling after a period of high prices and increasing LCOEs, despite turbine improvements that increased capacity factors. If the wind turbine market follows a similar dynamic to the solar PV market, where overcapacity has led to large price reductions, some degree of convergence with Chinese and Indian turbine prices might occur. This would see LCOE cost reductions accelerating compared to in 2011 and 2012.

Although this is the likely outcome, risks remain to the outlook for the competitiveness of renewables that are beyond the scope of their control, such as commodity price increases (e.g. cement and steel) or falls in the price of fossil fuels.

In 2020 the LCOE ranges for the other technologies are not likely to be significantly lower than at present. Also, since today's best practice projects in China and India in particular are unlikely to be beaten, the main shift for wind and biomass will be in a convergence of equipment costs towards Chinese and Indian levels as their suppliers start to compete more actively internationally and improve the quality of their overall offer (e.g. warranties, O&M contracts and reliability guarantees). The cost range therefore masks the projected decline in the weighted average costs that are likely to occur in OECD countries till 2020.

There are significant differences in installed capital costs between technologies and regions. This highlights the need to collect comprehensive real world project data in order to properly evaluate the costs and potential of renewables.

With the exception of hydro upgrades and biomass co-firing, where the existing investment in dams or coal-fired power plants respectively have already been made, the lowest capital costs for renewable technologies are for wind and biomass in non-OECD countries (Figure ES.3). What is notable about this picture, compared to the analysis of two years ago, is that today the costs of utility-scale solar PV rival those of wind in some regions and have not yet finished their downward trajectory.

The installed cost range for wind in the major markets[5] is relatively narrow compared to those for other renewable technologies. This reflects not only the large share of wind turbine costs in the total, but also the more homogenous nature of wind farm developments.

For solar PV the installed cost range is very wide. For instance the total installed costs for residential PV systems in the second quarter of 2012 in Germany were as low as USD 1 600/kW for the cheapest systems (with an average of USD 2 200/kW), but rise to USD 8 000/kW for the most expensive systems in the United States (with an average of USD 5 500/kW). Some of this difference can be attributed to structural factors, the competitiveness of the local market, or the impact of policy support, but many factors remain unexplained.

Typical capacity factors[6] vary by technology and region. For instance, capacity factors for wind in Latin America range from 22% to 52%, with similar wide variations in North America. The importance of obtaining real project data to analyse the LCOE range for a given technology in a region cannot therefore be underestimated, since assumptions made on typical values can lead to misleading conclusions.

5 If smaller markets were included, this range would widen to a maximum of around USD 3 000/kW due to the less mature market infrastructure for wind, as well as higher infrastructure and commodity costs in many developing countries.

6 The ratio of the number of hours an electricity plant generates to the total number of hours in a year.

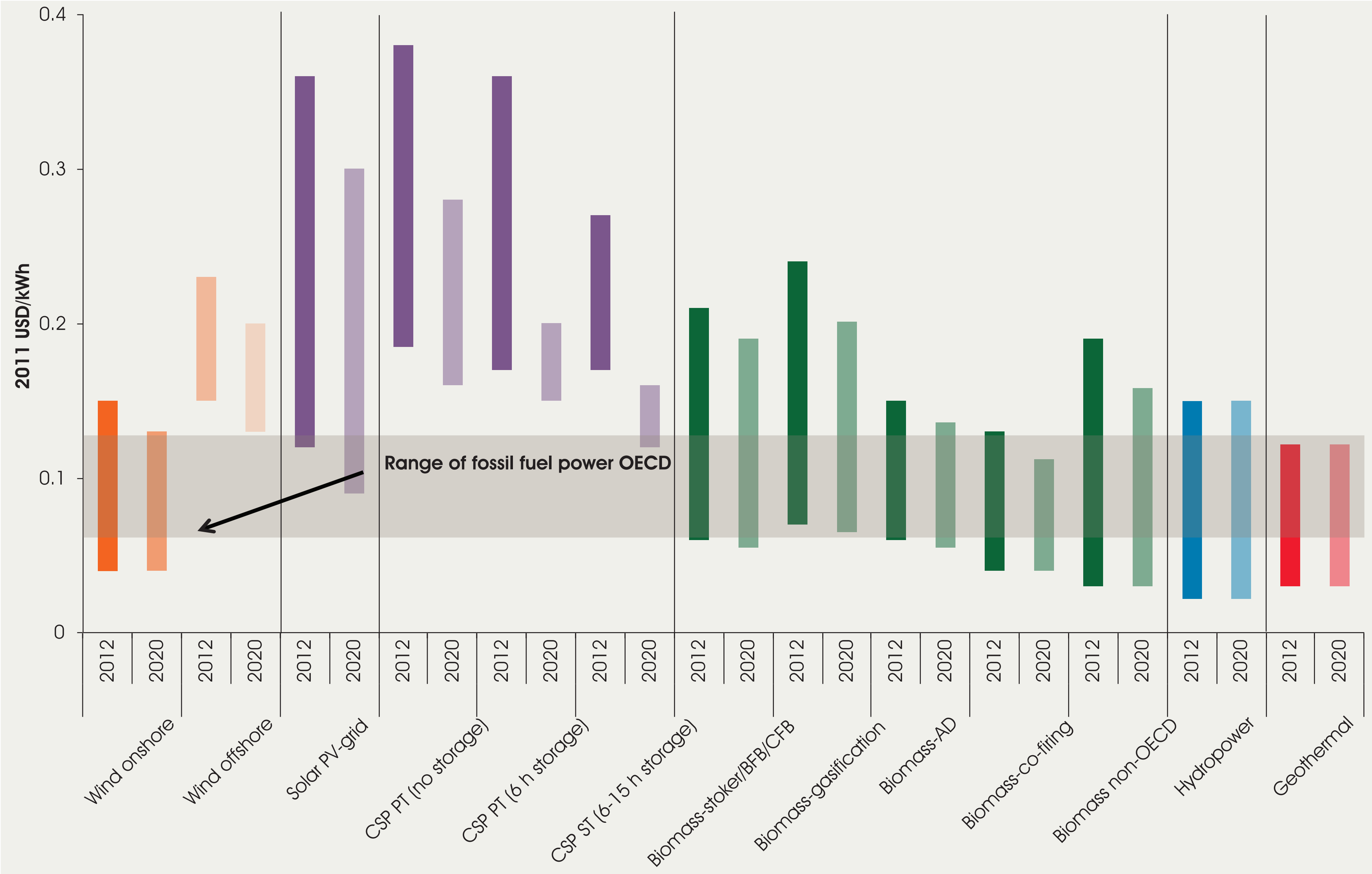

FIGURE ES.2: TYPICAL LCOE COST RANGES FOR RENEWABLE POWER GENERATION TECHNOLOGIES, 2012 AND 2020

Note: *PT = parabolic trough, ST = solar tower, BFB/CFB = bubbling fluidised bed/circulating fluidised bed, AD = anaerobic digestion.*

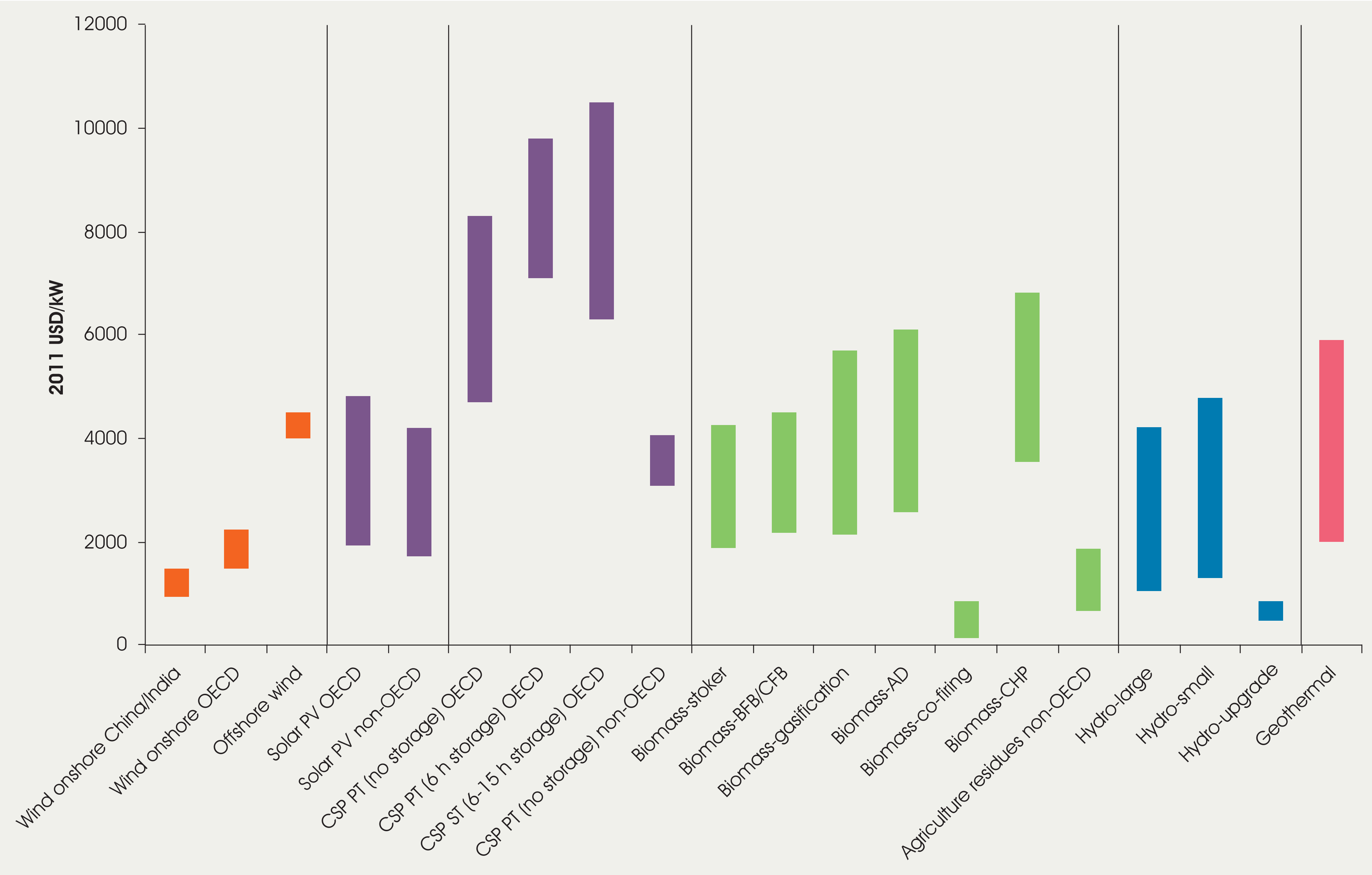

FIGURE ES.3: TYPICAL CAPITAL COST RANGES FOR RENEWABLE POWER GENERATION TECHNOLOGIES, 2012

Note: *PT = parabolic trough, ST = solar tower, BFB/CFB = bubbling fluidised bed/circulating fluidised bed, AD = anaerobic digestion.*

The rapid cost reductions in some renewable power generation technologies means that up-to-date data are required to evaluate support policies for renewables, while a dynamic analysis of the costs of renewables is needed to decide on the level of support.

Comparable, verified data on the costs and performance of renewable energy technologies are often not in the public domain, but need to be made available. It is clear that there is insufficient publicly available data to allow policy makers to make robust decisions about the role of renewable power generation. IRENA's cost analysis programme and this report are designed to help reduce this barrier to the accelerated deployment of renewables. Although the IRENA Renewable Cost Database contains close to 8 000 projects, this is a small proportion of the total number of projects installed or in development. Much more work therefore needs to be done to collect real project data in order to analyse emerging trends and the challenges facing renewables.

The rapid growth in installed capacity of renewable energy technologies and the associated cost reductions mean that even data one or two years old can significantly overestimate the cost of electricity from renewable energy technologies. In the case of solar PV, even data six months old can significantly overstate costs. In addition, there is also a significant amount of perceived knowledge about the cost and performance of renewable power generation that is not accurate or is even misleading. Conventions on how to calculate costs can influence the outcome significantly and it is imperative that these are well-documented.

An integrated power generation approach that considers all renewable energy technologies is required, as renewables will need to increasingly work more closely together to unlock synergies and ensure there is sufficient flexibility in the electricity system to achieve least-cost integration of high levels of variable renewables. The lock-in of infrastructure that comes with current investment in long-lived renewable and conventional energy assets means that sooner, rather than later, policy makers will need to move away from technology-specific support packages, to ones designed to minimise overall electricity system costs with higher levels of variable renewables, given that this is the trend in new capacity additions.

About IRENA

The International Renewable Energy Agency (IRENA) promotes the accelerated adoption and sustainable use of all forms of renewable energy. IRENA's founding members were inspired by the opportunities offered by renewable energy to enable sustainable development while addressing issues of energy access, security and volatility. Established in 2009, the intergovernmental organisation provides a global networking hub, advisory resource and unified voice for renewable energy. www.irena.org

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