KEY FINDINGS

ABOUT THE DECADE 2010-2019:

- The years 2010-2019 will have seen $2.6 trillion invested in renewable energy capacity (excluding large hydro), more than treble the amount invested in the previous decade. Solar is set to have attracted the most in 2010-2019, at $1.3 trillion, with wind securing $1 trillion and biomass and waste-to-energy $115 billion.

- China will be the top country by far in terms of the sums invested in renewables capacity during the current decade. It committed $758 billion between 2010 and the first half of 2019, with the U.S. second on $356 billion and Japan third on $202 billion.1

- Europe as a whole invested $698 billion in 2010 to first-half 2019, with Germany contributing the most, at $719 billion, and the U.K. $122 billion. India is an increasingly important investor in renewables, and had committed $90 billion by the end of the first half of this year.

- The decade has seen a spectacular improvement in the cost-competitiveness of renewables, with the levelized cost of electricity for solar photovoltaics 2 down 81%, for onshore wind down 46% and for offshore wind down 44%. One or other renewables technology is now the cheapest option for new generation in many countries around the world.

- Behind these cost reductions in solar and wind have been a combination of economies of scale in manufacturing, fierce competition along the supply chain – intensified by the introduction of auctions in many countries – record-low costs of finance, and improvements in the efficiency of generating equipment.

- There will have been more solar capacity installed during the decade than any other generating technology, fossil or renewable. Solar’s additions, of some 638GW during 2010-2019, is a remarkable figure given that there were only 25GW of solar power capacity worldwide at the end of 2009.

- The 2010-2019 period is set to have seen a net 2.4 terawatts of power capacity of all sorts installed, with solar first, coal second, and wind narrowly beating gas for third place. Nevertheless, the stock of fossil fuel power already installed, and those added this decade, has meant that global power sector emissions are likely to have risen by at least 10% between the end of 2009 and 2019.

ABOUT 2018:

- Global investment in renewable energy capacity in 2018 was $272.9 billion, the fifth successive year in which it has exceeded $250 billion, but down 12% compared to 2017 – due in large part to a policy change that hit the financing of Chinese solar in the second half of the year.

- The global investment figure for 2018 was achieved despite continuing falls in the capital cost of solar and wind projects. Solar kept its position as the technology attracting the most capacity investment, at $133.5 billion, although this was down 22% on 2017. Wind secured $129.7 billion, up 3%.

- Renewable energy capacity investment was more spread out across the globe than ever, with 29 countries each investing more than $1 billion in 2018, although this was down 22% on 2017. Wind secured $129.7 billion, down 6%.

- Spain, Vietnam, Ukraine and South Africa were among the countries in the “$1 billion-plus club” that saw capacity investment jump by more than fivefold in 2018. There were also increases of 100% or more in investment in the Netherlands, Sweden, Morocco, Russia and Taiwan.

- Investment in renewables capacity in 2018 was about three times global investment in coal and gas-fired generation capacity combined. This came despite further reductions last year in the average capital cost per MW of solar and wind projects.

- The world added a record 167GW of new capacity of renewables excluding large hydro in 2018, with solar additions hitting their own record of 108GW. This helped renewables excluding large hydro to raise its share of global electricity generation, from 11.6% in 2017 to 12.9% in 2018, helping the world to avoid an estimated 2 gigatonnes of carbon dioxide emissions.

- Other types of investment in renewables showed increases in 2018. Government and corporate research and development was up 10% at $13.1 billion, while equity raising by specialist companies on public markets was 6% higher at $6 billion, and venture capital and private equity investment was up 35% at $2 billion. Overall renewable energy investment, including these categories as well as capacity investment, was down 11% at $288.3 billion in 2018.

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1 Excluding large hydro. All renewable energy investment totals in this report also exclude large hydro.
2 Without a tracking system to follow the sun. Systems with tracking have seen similar-sized cost reductions.
FOCUS CHAPTER

A DECADE OF RENEWABLES INVESTMENT

- At the dawn of this decade, in January 2010, wind and solar were dots on the horizon of the world power system, accounting for only 4% of global generating capacity and much less of total electricity produced. They were also relatively expensive, and reliant on subsidies.

- A startling transformation has since taken place. By the end of the decade of 2010-2019, in a few short months’ time, the two leading renewable energy technologies are expected to account for some 18% of global generating capacity, after the investment of some $2.4 trillion in new projects over the 10 years.

- The cost comparison has also changed out of all recognition. Since the second half of 2009, the benchmark global levelized cost of electricity[^1] for solar photovoltaics without tracking systems has fallen by 81%, the equivalent for onshore wind by 46% and offshore wind by 44%. In many countries, the cheapest source of new generating capacity in 2019 is either solar or wind.

- Overall, including other renewable energy technologies but not large hydro, capacity investment over the 2010-2019 period is set to reach $2.6 trillion. The biggest investing country, by far, during the decade is set to be China, which committed $758 billion between the beginning of 2010 and mid-year 2019. Europe as a whole invested $698 billion in that time, and the U.S. $356 billion.

- Interest rates at record lows in major economies during the decade have been an important factor in making this possible. A much higher proportion of lifetime costs for wind and solar are incurred in advance rather than during the operating phase than for coal and gas. This upfront capital has to come from equity providers and lenders.

- Few would have dreamt at the start of 2010 that solar would see more capacity added during the decade ahead, at 638GW, than any other generating technology – renewable, fossil fuel or nuclear. However, the greening of the electricity system still has a very long way to go. The 2010-2019 period will have seen more than 500GW of new coal plants added worldwide, pushing up overall power system emissions.

DAWN OF THE DECADE

In the first decade of the Twenty-First Century, it was far from clear whether non-hydro renewables would ever be competitive with fossil fuel generation. New renewables were routinely called “alternative energy”, and regarded as a small niche. It was also uncertain which of the new technologies would be important in the decades ahead, or how difficult it might be for grids to absorb more than a tiny proportion of electricity from variable generation sources such as wind and solar. The electricity system was familiar with juggling large, centralized coal, gas, oil, nuclear and hydro generating units.

However, in that 2000-2009 period, at least there was a rise in interest in renewable energy technology on the part of governments, investors and the public. That, together with climate change

[^1]: Levelized cost of electricity, or LCOE, for any generating technology includes the cost of project development and construction, lifetime operating and maintenance expenses, feedstock costs and finance costs.
worries, was leading by the turn of the decade to sharp increases in the amount of investment going into sectors such as wind, solar and biofuels. In 2009, the world invested a record $147 billion in new renewable energy capacity (excluding large hydro-electric projects).

For a while, early in the current decade, it looked as if the rise of renewables might come to an end. Slow economic growth after the 2008-2009 financial crisis, particularly in developed countries, helped to limit demand for energy, and the shale gas boom in North America introduced a significant new source of both gas and oil into the markets. Energy prices fell, with for instance the Newcastle coal contract halving between a peak in early 2011 and its low in 2016, and the Henry Hub gas price in the U.S. averaging $3.30 per million British thermal units in the current decade compared to $5.85 during the 2000s. And in late 2014, the world oil price crashed.

There was also pressure on renewables from a political direction, as consumers protested about rising electricity bills. In most countries, subsidies for green power were only one of several reasons for higher charges per kilowatt-hour – but governments in many cases had under-estimated the take-up of wind and solar, and therefore the cost of their support. Some politicians argued for renewables-friendly policies to be abandoned. There were retroactive cuts in subsidies for existing projects in a number of European countries. Eventually and more positively, governments in Europe followed the example of developing countries such as Brazil and moved toward auctioning as a means of trying to ensure that additional capacity got built at the lowest practicable cost.

The renewable energy manufacturing sector, meanwhile, had its own problems. Over-expansion and cut-price competition led to falling share prices and – in the solar photovoltaic sector – to a stream of bankruptcies and closures, particularly in 2012-2014.

THE MONEY FLOWS

From the middle of this decade onward, the ongoing cost reductions in solar PV and both onshore and offshore wind have become more obvious to policy-makers, investors and incumbent energy companies, and this has engendered a new environment in which the growing importance of low-cost renewables is widely recognized. At the same time, wind and solar projects have sprung up in an increasing number of countries, notably in the developing world. New ways of integrating their variable generating output have emerged, including more flexible grids and the deployment of batteries and other forms of energy storage.

The current decade, if you define it as 2010 to 2019, is not quite over at the time of writing this report, but approximate figures for investment in 2019 can be estimated on the basis of published numbers for the first half of the year.4

In Figure 1, we estimate that the 2010s, when they end in December 2019, will have seen a total of $2.6 trillion of investment in renewable energy capacity, excluding large hydro. The chart also shows the extent to which investment will have been dominated by just two sectors – solar, with $1.3 trillion, or 52% of the total;

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We make an assumption that the eventual total for the year will be two times the originally published first-half figure – this is likely to be a conservative estimate, since in every one of the last five years, the eventual full-year total has been significantly more than double the originally published first-half figure. See the box at the end of Chapter 1 for more on the investment in 1H 2019.
and wind, with $1 trillion, or 41% (note that the sum of the two rounds up to $2.4 trillion). The only other sector to attract three figures of billions over the decade is set to be biomass and waste-to-energy, with $115 billion invested, or 4% of the total. Small hydro capacity got commitments of $43 billion, biofuels $27 billion, geothermal $20 billion and marine less than $500 million.

Figure 2 shows the amount invested in renewable energy capacity in the top 20 markets up to the end of the first half of 2019 (it does not include an estimate for the second half of this year). All of them have spent more than $14 billion on renewables excluding large hydro. The runaway leader in the 2010s has been China, with investment of $758 billion, nearly 31% of the global total, with the U.S. second on $356 billion, or 14%.

There are eight European countries in the top 20, headed by Germany with $179 billion and the U.K. with $122 billion, and Europe as a whole has accounted for investment over the period from 2010 to the first half of 2019 of about $698 billion, some 28% of the global total. Some
European nations have experienced booms and busts in capacity investment during the decade – Germany and Italy, for instance, seeing their annual total touch $30 billion or more in at least one year between 2009 and 2011 as developers rushed to build solar systems to take advantage of generous feed-in tariffs.

The top 20 includes a number of developing countries, led by India with $90 billion, with most of the others in the latter part of the list. However, in most cases, developing economies have only broken into their stride on renewables investment since solar and wind costs came down to competitive levels in mid-decade, so we could expect to see them taking up higher positions in a list for 2015-2025, for instance.

THE COST REVOLUTION

The decade opened with non-hydro renewables widely seen as expensive relative to conventional generation sources – unless you assumed a high carbon price to reflect the pollution and greenhouse gas effects of fossil fuel power. As recently as January 2014, the Economist published an article entitled “Why is Renewable Power So Expensive?”

Figure 3 shows the transformation in costs achieved over the decade by the three leading green power sources – solar photovoltaics, onshore wind and offshore wind. BNEF’s levelized cost of electricity (LCOE) model, which distills data on development, construction, operations and maintenance and finance costs from actual projects around the world, shows that the global benchmark for solar PV without tracking has tumbled by 81%, from $304 per megawatt-hour in the second half of 2009 to $57 per MWh in the first half of 2019. The equivalent figure for onshore wind has been a 46% fall, from $93 per MWh, to $50; and for offshore wind a 44% drop, from $160 per MWh, to $89.

These moves have been the result of several factors: fierce competition among manufacturers and developers to cut overheads, the influence of renewable energy auctions in driving that competition, improving technology that has added incrementally to efficiency (the number of megawatt-hours of energy coming from the same number of megawatts of capacity), and a strong downward trend in finance costs.

This last factor is often overlooked. Renewable energy technologies all involve significant upfront capital expenditure and, in the cases of wind and solar, ongoing running costs are very low by comparison. That makes the cost of the equity and debt used to finance new capacity highly influential in calculating the total LCOE of new green power projects. Record-low official interest rates in many countries during the 2010s, and increasing competition among investors and banks to participate in renewable energy deals, has driven down the cost of both equity and debt. To take one example, the all-in cost of debt for a German onshore wind farm dropped from 6% at the end of 2009, to 2.2% in the first half of 2018.

The result is that, as the decade draws to a close, either wind or solar (or both) find themselves to be cheaper options for new generating capacity than fossil fuel sources in an increasing number of countries.

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A DECADE’S ADDITIONS

Figure 4 highlights the estimated gigawatt capacity added for the different renewable power technologies over 2010-2019. It breaks down solar into its two main varieties, PV and solar thermal, and wind into onshore and offshore, to provide further insight. The greatest amount of new capacity added over the decade by far will have been in PV, at 633GW, multiplying the amount installed at the end of 2009 by 27 times.

Onshore wind was more established than PV at the turn of the decade, so its addition of 458GW since the end of 2009 is “only” a fourfold increase. Offshore wind, however, which was more expensive and relatively immature when the decade dawned, will have added 29GW over the period, multiplying its installed capacity by 15.5 times. Biomass and waste will have nearly doubled its fleet, by adding 62GW. The other technologies have managed more modest increments.

A regional analysis of the capacity additions (Figure 5) shows that China will have installed by far the highest amount of new capacity of renewables excluding large hydro over the 10 years, at about 451GW, or 36% of the world total. Europe is set to come second, with 267GW added, and the U.S. third with 151GW. The steepest expansion in capacity in proportionate terms will have come in Middle East and Africa, with a 15-fold rise from 3GW to 45GW.

Figure 6 is thought-provoking in both a positive and a negative way. It shows the global capacity added not just in renewables but in fossil fuel and nuclear also. Solar is set to have been the most heavily installed generation technology in the 2010s, with some 638GW added worldwide (including solar thermal as well as PV) – an astonishing result for a power source that could boast only 25GW of global capacity at the end of 2009.

7 These totals are made up of estimates of BNEF’s sector analysts for 2010 to 2018, based on hard data from its project database, plus its forecasts for 2019 based on expected progress on project pipelines.
Solar is on course to have a significant lead, of more than 100GW, over the next-most installed technology. But, worryingly, that is set to be coal, with some 529GW added – despite all the global concerns about climate change and the earnest declarations made at international conferences such as COP-21 in Paris in December 2015.

China has seen by far the largest participant in the build-out of both solar and coal, adding more than 200GW of each during the 2010s. Otherwise, solar's growth has been well spread through much of the globe. By contrast, coal has seen strong expansion in emerging markets far more than offsetting nearly 100GW of closures in the U.S. and Europe.

Third place among the most installed power sources is relatively close between wind and gas, but BNEF's figures suggest that wind will have the edge once a full tally is done at the end of 2019, with 487GW added during the 2010s compared to 438GW for gas-fired generation. Wind will have seen China and Europe add nearly 300GW between them. Gas will have seen significant expansion in the U.S., on the back of the shale gas boom, but also elsewhere, partly due to rising international trade in liquefied natural gas, or LNG.

Fifth place looks set to be taken by hydro-electric (large and small), with 283GW added, helped by
the commissioning of a number of megaprojects such as the 13.9GW Xiluodo dam in 2014. Two other technologies, oil-fired generation and nuclear, look likely to see a small net shrinkage in their global gigawatt capacity as closures more than offset openings.

One other point is crucial when it comes to the sustainability of the addition of different power sources cited above. Although solar is set to have beaten coal in the 2010s in terms of new capacity, it will not have done so in terms of new electricity generation. This is because the capacity factor of solar globally is in the 11-35% range, reflecting the availability of sunlight, whereas coal-fired power stations have the potential to generate electricity round the clock and throughout the year. In practice, coal’s capacity factor around the world is often much lower than this because of operating problems or electricity prices at times too low to justify generation. But the point is that even though there was a lot of solar and wind capacity installed in the latest decade, its impact on the electricity mix has been gradual, not dramatic.

The result is that power sector greenhouse-gas emissions have continued to rise despite the impressive growth of renewables, and despite international climate commitments. And this will continue to be the case until the growth of renewable electricity generation can outpace the growth in demand for power.

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8 See Figure 25 in Chapter 2 for the size of large hydro investment relative to other renewables, and the box at the end of Chapter 3 for discussion of large hydro activity in 2018.
9 This is shown in Figure 15 in Chapter 1.
10 See Figure 17 in Chapter 1.
The chapter so far has focused on capacity investment in renewables and other generation technologies. However, as discussed in Chapter 2, capacity investment is only part of the picture in terms of the new money coming into the renewable energy sector. Also important are research and development, and equity raising by specialist renewable energy companies on public markets and from venture capital and private equity investors.

These other areas of investment were particularly vital to the emergence of the sector in the first decade of this century. They remain important – but not to the same degree as a decade ago. The mix between these different sources of finance for technologies and companies has also evolved. Venture capital funding has become less significant than it was in 2010, for instance, while annual corporate R&D (taking place in large companies, both specialist and diversified) has almost doubled since then.

Overall, corporate R&D will have amounted to about $51 billion during the decade as a whole, with government-funded R&D very close to that, as Figure 7 shows. Public markets investment will have totaled about $86 billion, and VC/PE financings about $32 billion. Together with asset finance of utility-scale projects and the funding of small-scale projects, these elements will take overall investment in renewable energy over the whole decade to $2.8 trillion.