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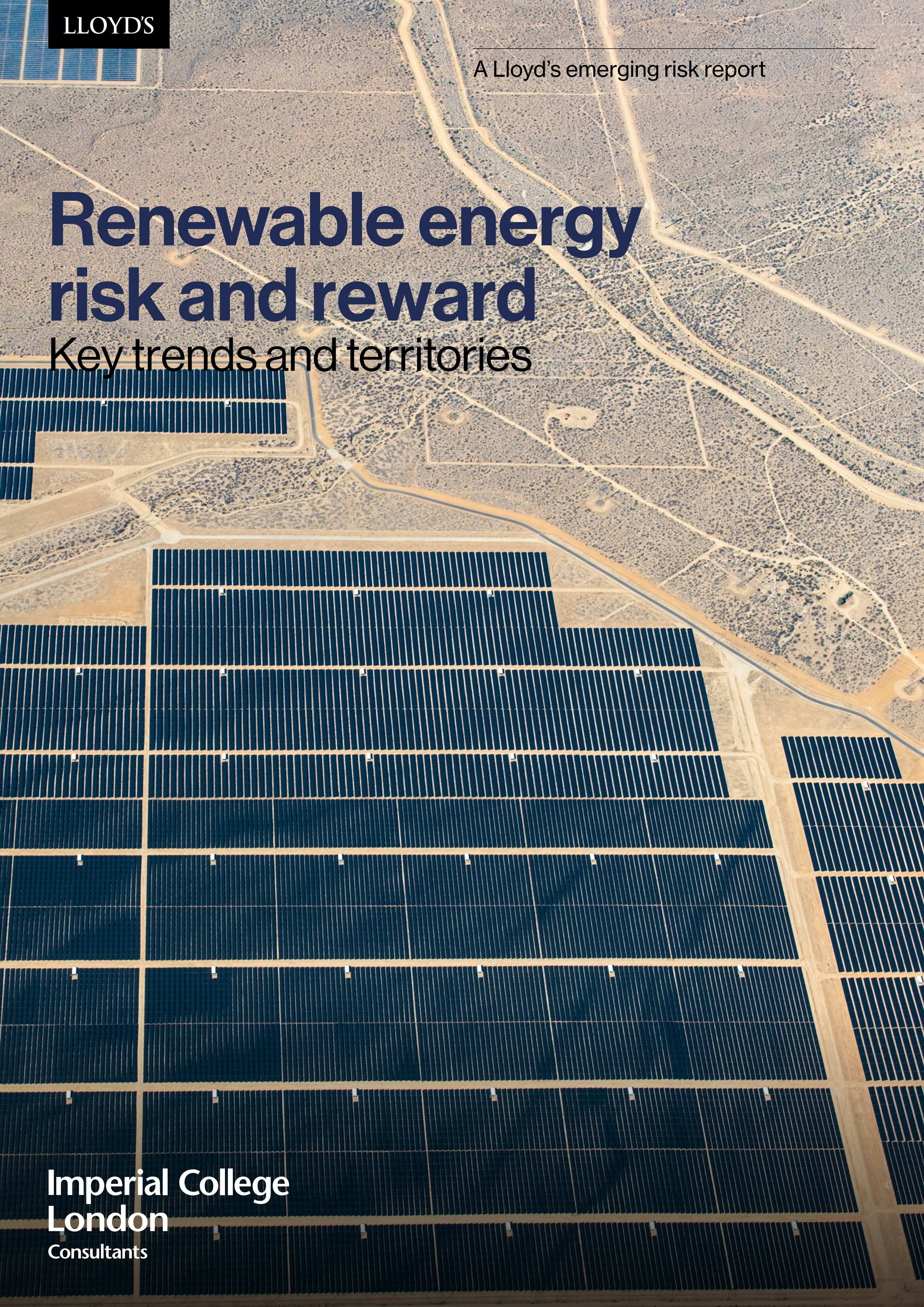
A Lloyd's emerging risk report

Renewable energy risk and reward

Key trends and territories



Imperial College London Consultants

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Contents

1. Key trends

This report is primarily concerned with the outlook for renewable electricity generation in key global markets. This section sets out some of the key trends and future scenarios, in terms of the volume, costs, and investment levels of different types of renewables, as well trends in the policy environment. Further detail is given on particular regions in Section 2.

In addition to these direct trends, the wider context for the development of the renewable energy sector is important to understand. The status of leading renewable energy options appears to be going through a transition – from early stage or emerging technologies that require subsidies from governments, to mature and cost-effective alternatives. One of the ways in which this is playing out in practice is that many governments are seeking to ensure that the levels of subsidy are substantially reduced. This means that support payments set by governments are giving way to the use of auctions that use market pressure to ensure that lower prices are paid to renewable energy projects. This is beginning to apply increased price pressure throughout the supply chain – from equipment suppliers to project developers and operators. This may be creating new risks, since equipment providers may be pushing forward with less proven technologies, such as much larger wind turbines. Project developers may be seeking opportunities to drive down installation costs, through streamlining processes or minimising material requirements. Overall, these increased price pressures could increase the risk of failure at all stages of project development and operation. Whilst cost reductions are welcome from a public policy perspective if they lead to greater uptake, they could also lead to increasing exposure for the insurance industry, if the risk of failure is increased.

Renewable electricity has different characteristics from traditional power generation, there is less flexibility about when the power is dispatched to the grid, and it can be more geographically dispersed. This is changing the geopolitics and economics of energy. It also changes the design of energy systems, with a greater need for transmission and distribution systems to be able to integrate renewable energy, or a greater role for storage technologies to help manage grid operation. It is also possible that renewables may result in an expansion of smaller scale, decentralised generation leading to fundamental changes to the energy market mechanisms; with potential for blockchain technology to facilitate peer to peer trading by energy prosumers. Against this, some renewable developments may be in remote locations and some wind or solar farms are large. Offshore wind is the most obvious example. Overall, the impacts on power grids are quite mixed, though, on the whole, power system operators try to avoid any negative impacts in terms of reliability or the risk of power failure.

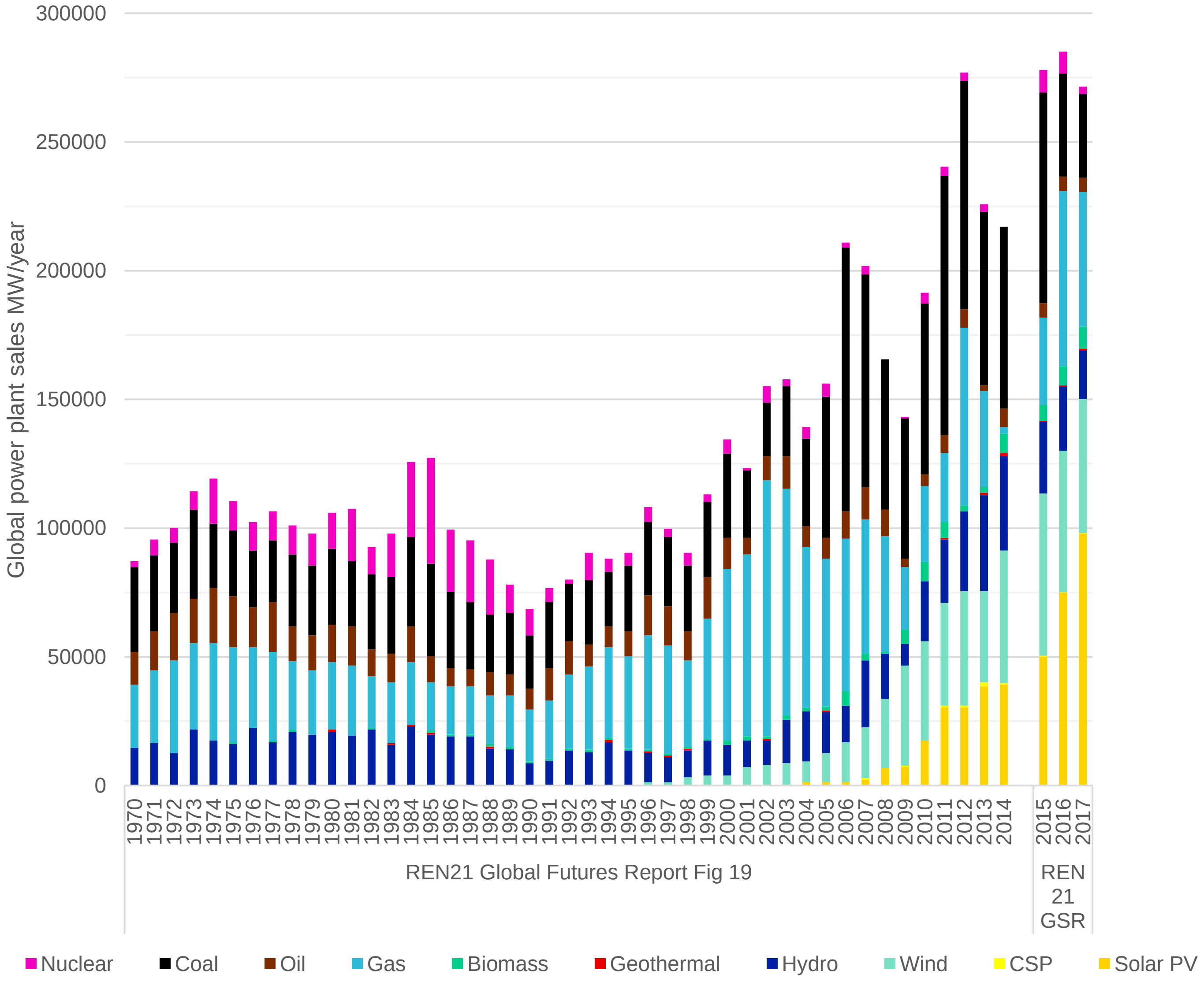
As renewable energy has expanded in leading markets, often as a result of favourable policies that ensure grid access and provide a long-term fixed price contract such as a 'feed in tariff', there has also been an impact on the business models operating in the electricity industry. Large electricity utilities have had to adapt, as the potential for new entrants to develop wind or solar projects has increased. In some countries new classes of investor have been attracted to the stable and secure revenues offered through renewable energy policy.

In the future as 'subsidy free' renewable energy developments become more common there is some uncertainty as to how the mix of policy support and commercial development will unfold. Already some renewable projects have been developed with no policy intervention at all – the power purchase agreements (PPAs) offered by corporate consumers with large electricity demands, such as the server farms operated by digital media giants, have created a new route to market for some renewable energy schemes. At the same time government orchestrated support schemes have moved to a zero-subsidy mode. Governments still intervene to ensure that renewable energy projects can secure the stable revenues that attract investors, but with power prices set at or below the prevailing wholesale prices of the day. The interplay between market design, policy and the roles of different investors is complex and uncertain. Nevertheless, we discuss some of the main issues, both in terms of renewable generation options and facilitating technologies such as electricity storage.

Current status of renewable energy

Over the past 10 years, renewable energy sources have ramped up to such an extent they are now the dominant source of new capacity additions (though it should be noted when interpreting these figures that additions of renewables and fossil fuel plants in capacity terms do not translate into equal amounts of generation)[1]. Figure 1, demonstrates this trend of renewable 's becoming responsible for most new energy additions, and indicates that renewables will eventually take over majority energy production.

Figure 1: Rapid growth in capacity of renewable power output (MW), since the early 2000s.



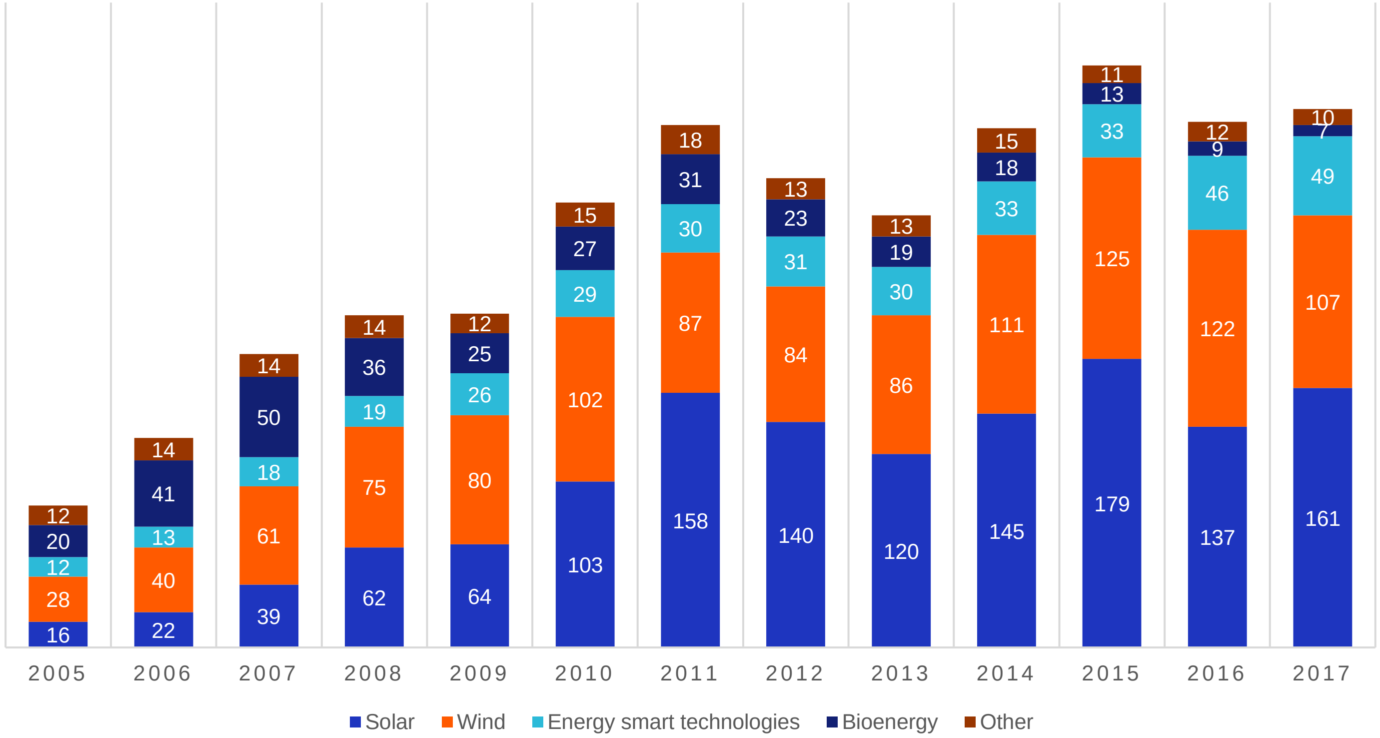
Source: compiled from REN 21 2017, REN 21 2018, and IEA 2018b

Investment in renewables has been flattening since 2010 (Figure 2). Growth of capacity is fuelled by lower cost of power due to economies of scale, efficiencies, and sector getting more adept at delivering projects; technology is becoming more standardised. This recent increase means that renewables in 2017 accounted for 58.2% of global investment in the power sector (**Error! Reference source not found.**a) and for 10.1% of global power generation, or 26.5.% including hydro[2] (**Error! Reference so urce not found.**b).

[1] E.g. a unit of installed capacity (e.g. 1 MW) of gas-fired generation is capable of producing more electricity during the year than an equivalent amount of installed capacity of wind or solar because the sun and wind are intermittent.

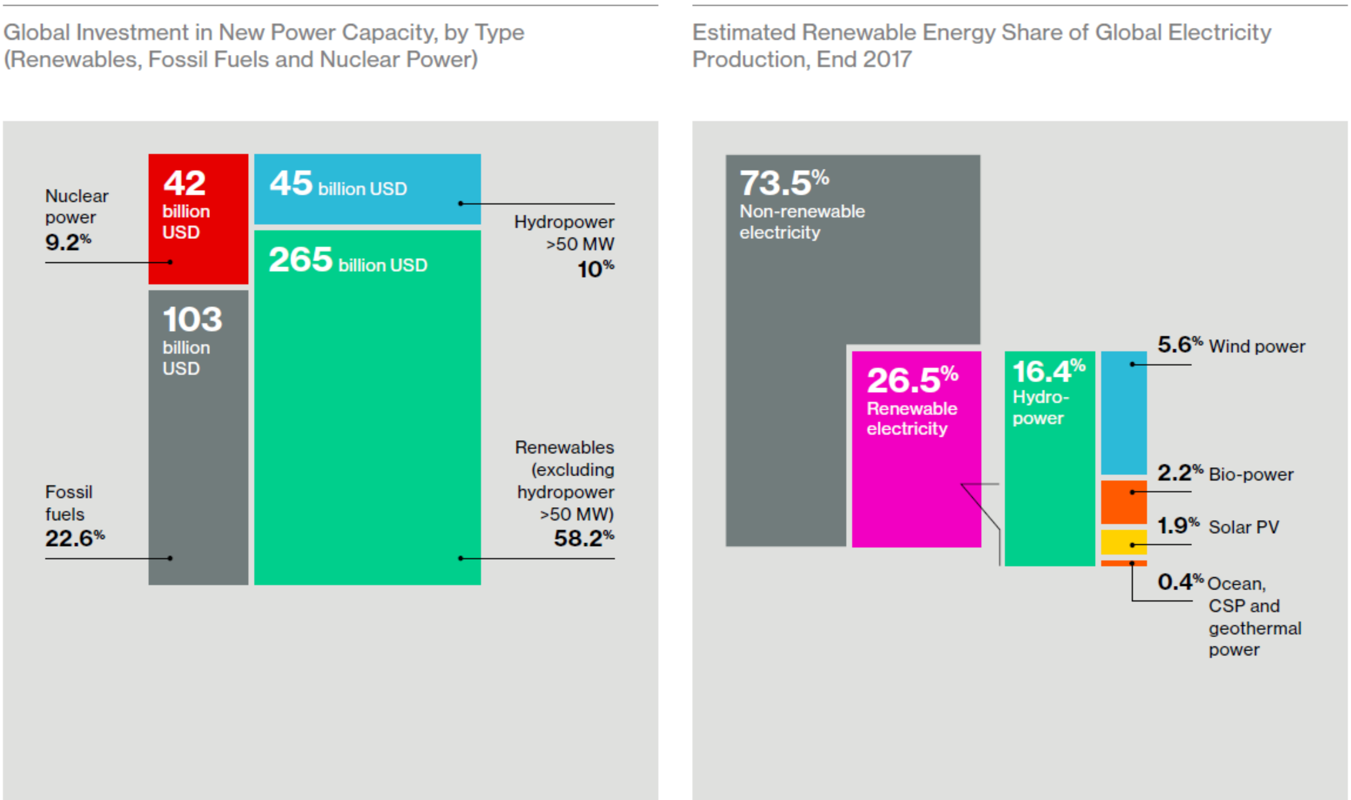
[2] Renewables figures are often quoted separately for non-hydro sources, since hydropower is a mature technology with relatively little room for growth globally compared to other renewable sources.

Figure 2: Investment in renewables levelling out since 2010 ($bn)



Source: UNEP BNEF, 2018

Figure 3: (a) Investment in new power capacity, renewables lead the way (b) renewable energy share of power generation, 2017



Source: BNEF, REN21 Global Status Report

Rapid growth in the renewables industry means there is a need for insurance. But the dynamic nature of this industry is leading to a range of 'growing pains', and new insurers should be cognisant of the particular risks and characteristics of renewable projects and their insurance requirements (LeBlanc 2008).

Discussions with insurers as part of developing this report suggests an increasing exposure to risks such as:

- Individually, compared to traditional fossil-fuelled power plants, projects are often smaller in scale (though collectively they are coming to dominate investment in many regions). This leads to a more fragmented style of market for insurers, with losses likely to be more frequent, but relatively small in size compared to traditional projects.
- The fast-growing nature of the sector inevitably means that new construction and Operations and Maintenance companies need to enter the market. Not all of them have a well-established track record, leading to an increase in claims which stem from poor build quality.

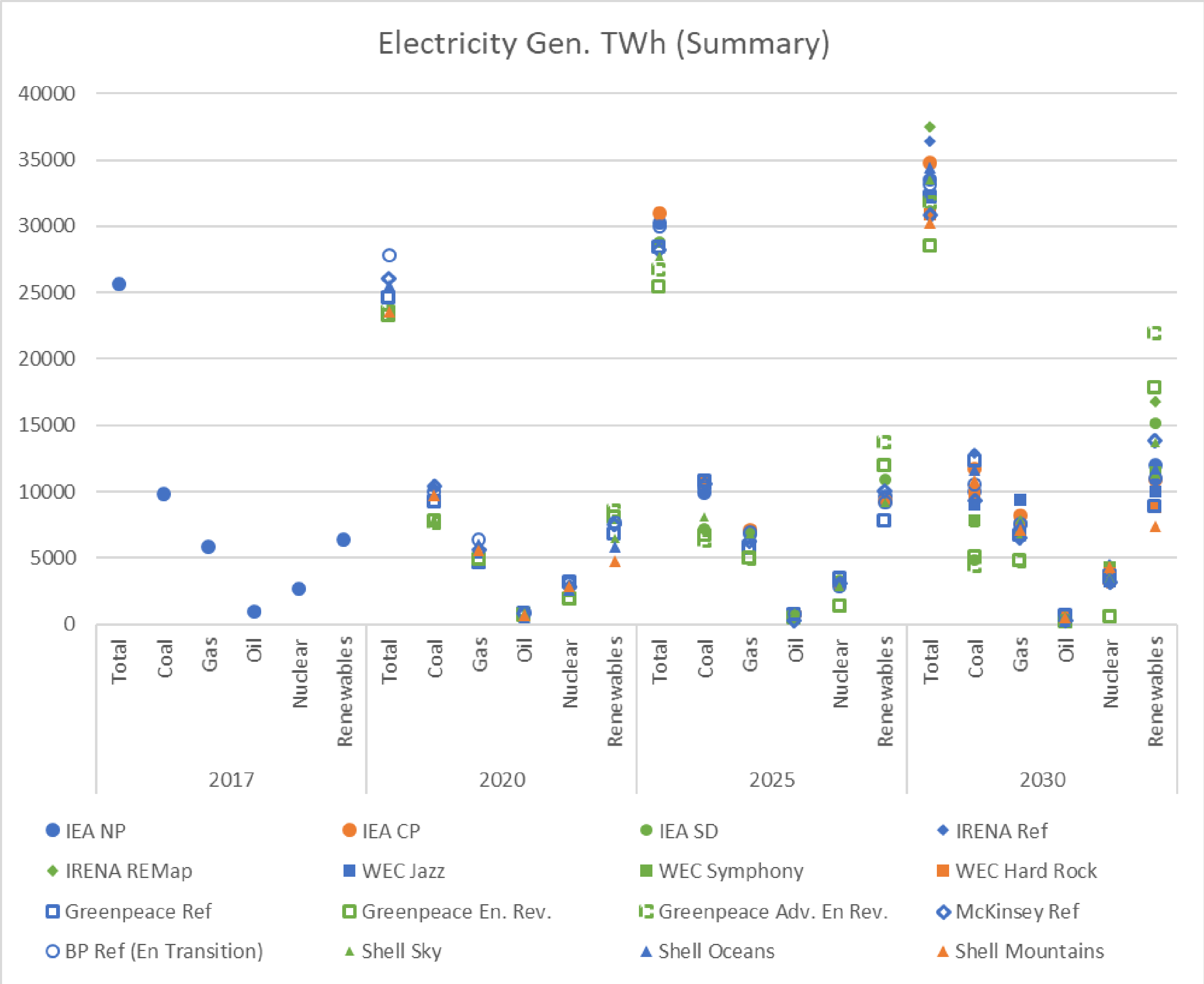
Future scenarios for the share of renewables

As part of this work, we carried out a comparison across a wide range of different scenarios for the role that renewables would play in electricity. The detail of this analysis is presented in Appendix A. Here, we summarise these findings in figure 4 that shows the role of renewables compared to other types of generation based on energy industry experts predictions. Scenarios shown in blue are reference or central scenarios, green represent accelerated renewables scenarios, and orange are slower than expected or pessimistic scenarios. A more detailed explanation of the scenarios is given in the Appendix A. The predictions also show that many believe as demand for energy demand increases renewables will fill that demand with fossil fuels remaining relatively static. There is however a wide range of views on how large the sector will be (Figure 4). Hence, there is a reasonably sizeable range of uncertainty and therefore, risk.

Key messages

- There is considerable variation in total power generation required globally. Overall, there is expected to be a drift upwards over time, reflecting global economic growth and the greater demand for energy services. Around this general trend however, there are two additional key drivers which act in opposite directions. On the one hand, improved end-use energy efficiency will tend to suppress demand increases, whilst on the other hand shifting to electrification of new sectors such as heat and transport will tend to accelerate demand increases. Each scenario reflects a different weighting of these drivers.
- Differences in policy remains the most important variant affecting the outcome for most of these scenarios, although many of the scenarios contain a rich variety of socio-economic drivers.
- The scenarios differ significantly over the rate at which coal is displaced from the system, with ‘green’ scenarios clearly showing a much faster decline in coal, whilst some of the reference and ‘pessimistic’ scenarios show an increase in generation from coal out to 2030.
- These factors combine to give a broad set of potential outcomes, with a standard deviation for the level of electricity generation from renewables of 30% across all the scenarios.

Figure 4: Predicted scenarios of renewables in the power generation based on opinion of experts in energy sector



Source: Authors' calculations based on multiple sources – see Appendix A

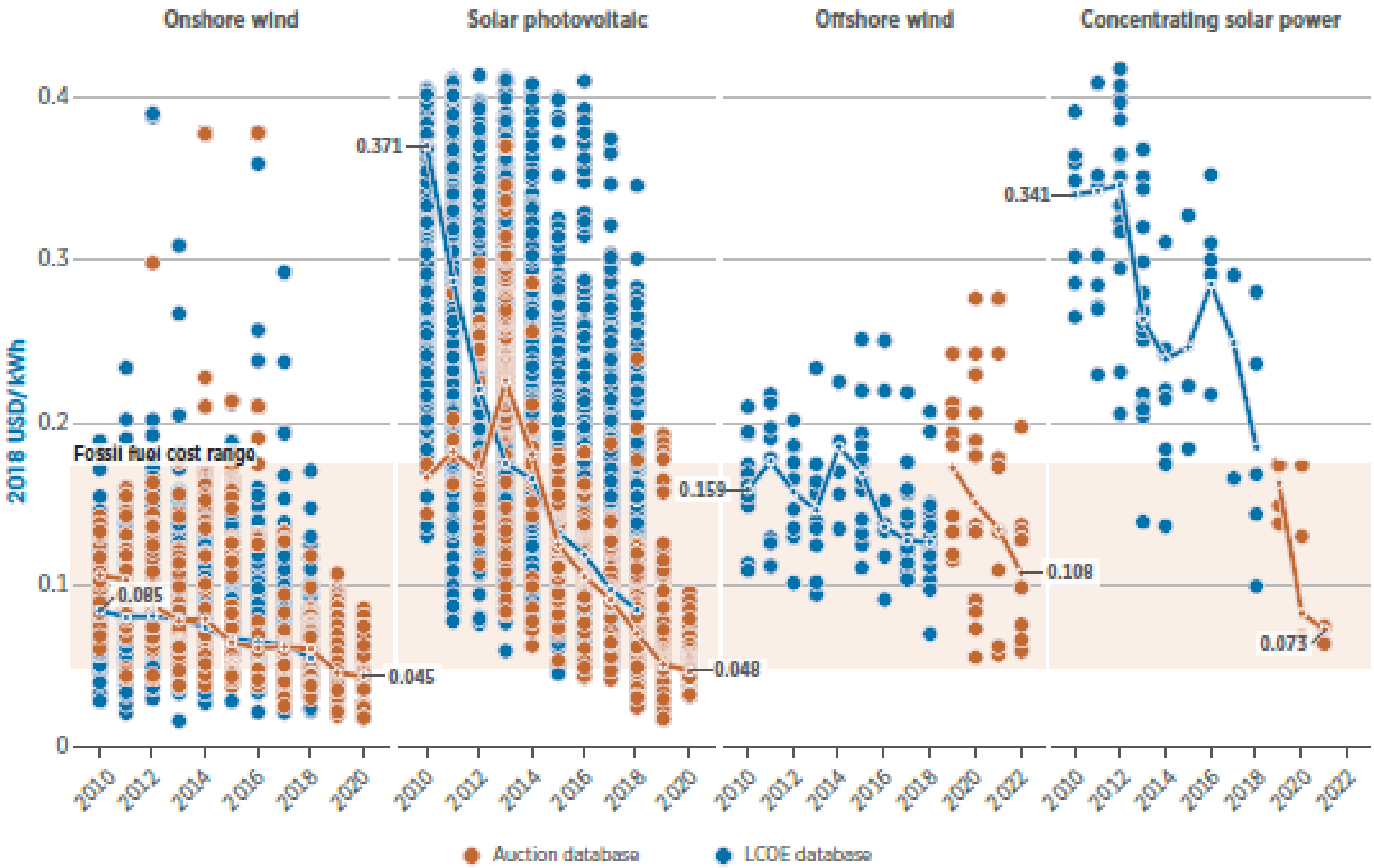
Cost trends

Analysis of global projects by IRENA shows steep reductions in the costs of some renewable technologies, and static or slightly increasing average costs for other renewables technologies over the period 2010-2017 as shown in figure 5 (IRENA, 2018). The extent to which past cost trends will continue is clearly uncertain, and we have addressed this by looking at a range of different scenario providers (see Appendix 1).

Record low auction prices for solar PV in 2016 and 2017 in Dubai, Mexico, Peru, Chile, Abu Dhabi and Saudi Arabia have shown that a levelised cost of energy (LCOE) of US$ 0.03/kWh is possible from 2018 and beyond, given the right conditions. These include: a regulatory and institutional framework favourable to renewables; low offtake and country risks; a strong, local civil engineering base; favourable taxation regimes; low project development costs; and excellent solar resources.

Similarly, very low auction results for onshore wind in countries such as Brazil, Canada, Germany, India Mexico and Morocco have shown that onshore wind is one of the most competitive sources of new generation capacity. For concentrated solar power (CSP) and offshore wind, 2016 to 2018 have been breakthrough years, as auction results around the world have confirmed that a step change in costs has been achieved and will be delivered in projects commissioned in 2020 and beyond. Indeed, recent auction results suggest that projects commissioned from 2020 onwards for both technologies could fall in the range US$ 0.06 and US$ 0.10/kWh. Some view the auction results with some caution however, as it is not always clear that projects will necessarily be realised at the level of the auction outcomes. Figure 5 demonstrates that renewables are starting to compete and in some cases outcompete fossil fuels with many projects coming within the cost range (orange bar) of fossil fuels sold at auctions. Therefore renewables are playing a disruptive role in energy markets and are likely to become more competitive into the future.

Figure 5: Global levelised cost of electricity from utility-scale renewable power generation technologies 2010-2020

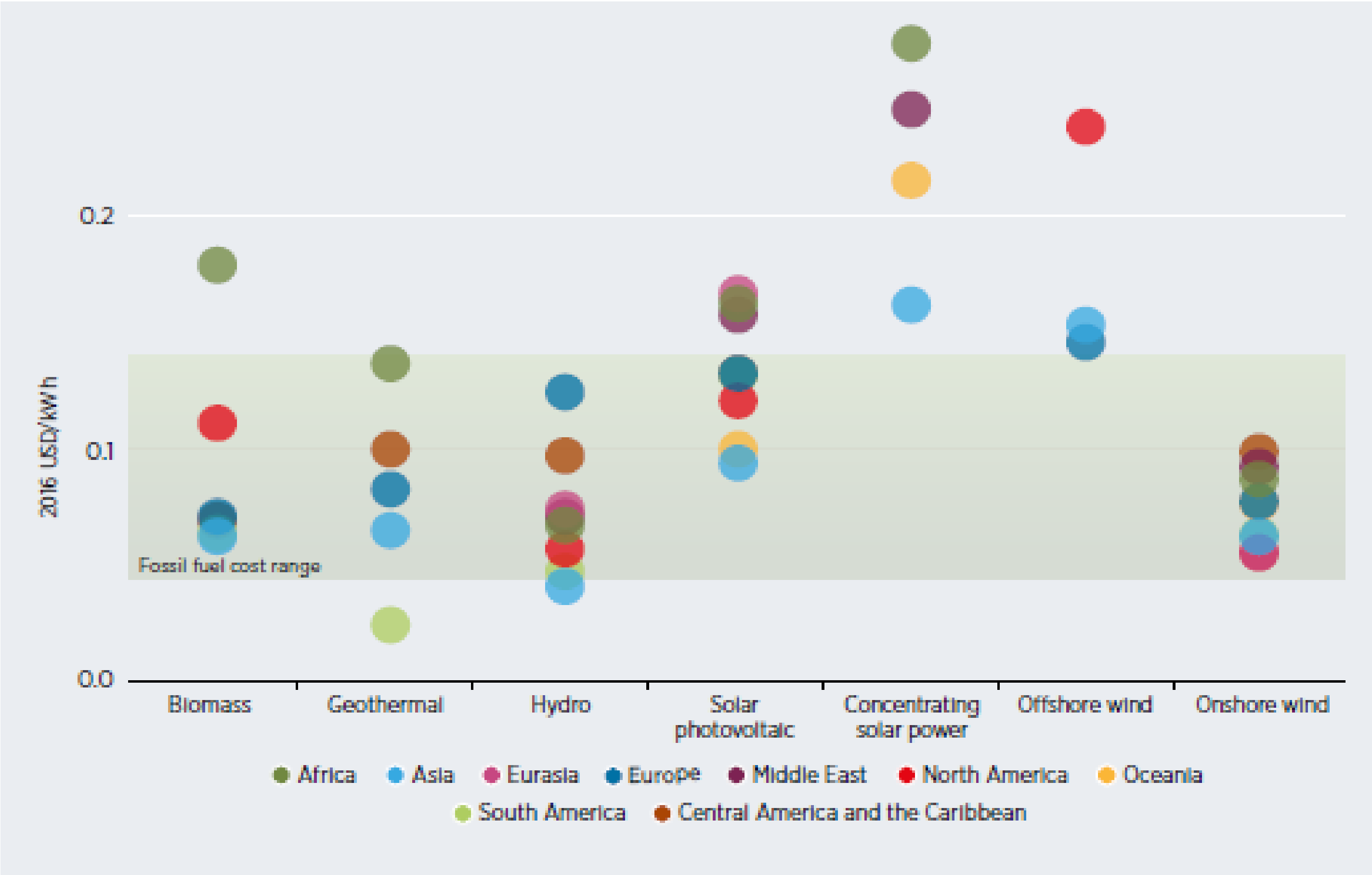


Source: IRENA, 2019

Note: Each circle represents an individual project or an auction result where there was a single clearing price at auction. 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.

In practice, costs vary considerably in different countries, driven by differences in financing costs, project logistics, and the cost of the Engineering, Procurement, and Construction (EPC) costs. Figure 6, based on data from IRENA (2018a) shows the average cost of projects in different regions for different renewable technologies and provides a comparison with the global range for the cost of electricity generation from fossil fuel plant (shaded in green). For each region, there will be a spread in costs around these averages. Asia stands out as a region with the lowest average costs across all the technologies. This is due to a mixture of excellent resource endowment and lower than average installed costs, notably for solar PV and onshore wind in China and India, who both dominate equipment manufacturing deployment in the region. These large regional markets have also led to the development of a particularly competitive EPC market in these countries[3]. Recent reductions in the cost of solar PV projects in Australia have likewise been ascribed to reductions in EPC contracting costs (PV Manazine, 2018)[4]. Conversely, projects in Africa have tended to be at the upper end of cost ranges due to higher cost of capital (linked to higher risk ratings affecting many types of investment), and less competitive EPC markets due to smaller market size and greater logistics costs, though there are exceptions to this.

Figure 6: Regional cost of electricity by renewable power sources, Asia cheapest in most cases



Source: IRENA, 2018a

The recent reductions in the cost of renewables equipment described above have led to market expectations of ever-cheaper projects, driven in part by a shift in policy towards use of auctions rather than fixed feed-in tariffs. This has put further competitive pressure on companies to reduce construction and O&M costs as the next main front for cost reductions. This market pressure on prices has tended to force EPC contractors to cut contingencies, potentially adversely affecting project quality and increasing the risk of losses that insurers might have to pick up later in the project cycle.

[3] EPC company rankings by volume available at https://www.pv-tech.org/editors-blog/ihs-markit-reveals-2017s-global-solar-epc-rankings

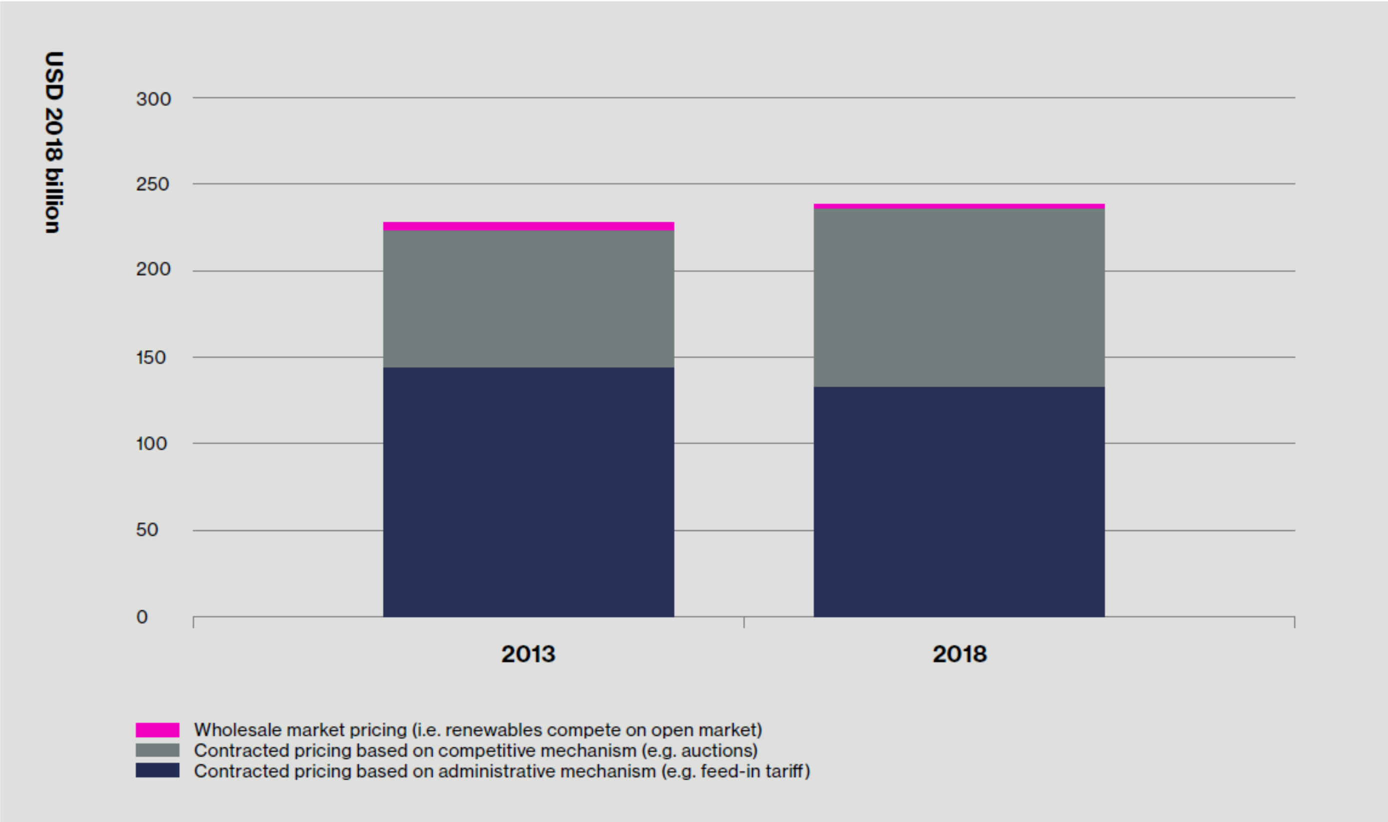
Policy trends

A key issue for renewable energy is that it remains driven by policy instruments. It is estimated by the IEA (2019) that 95% of utility-scale renewable power is contracted based either on a publicly run competitive mechanisms (such as auctions) or other administrative mechanisms such as feed-in tariffs or other subsidies (Figure 7).

This does not mean to say that only 5% of projects are unsubsidised – many of the projects contracted through auctions are in open competition with fossil-fired plant. In 2018, around 45% of utility-scale renewables spending was in projects whose contractual remuneration is determined by competitive mechanisms. These are mostly government schemes - such as auctions, which play an increased role in Europe, India and have started in China, among others – but include other arrangements, such as corporate procurement, which is growing rapidly.

Projects based solely on wholesale market pricing are relatively rare, partly because lifetime remuneration risks are not well-matched to the financing risks associated overwhelmingly with upfront capital costs. As noted by Gatzert (2016), this reliance on public contracting creates a policy risk for projects which is problematic since insurance coverage tends to be limited. In practice, this lesson has been learned by policy-makers who strive to create reliable policy frameworks and avoid retrospective changes that would adversely affect project financial performance. Figure 7 shows that auctions are growing in importance when determining price, demonstrating increased competition between renewable companies and providing evidence that the market is maturing.

Figure 7: Auctions a growing method for determining pricing (evidence that renewables are becoming a mature market)



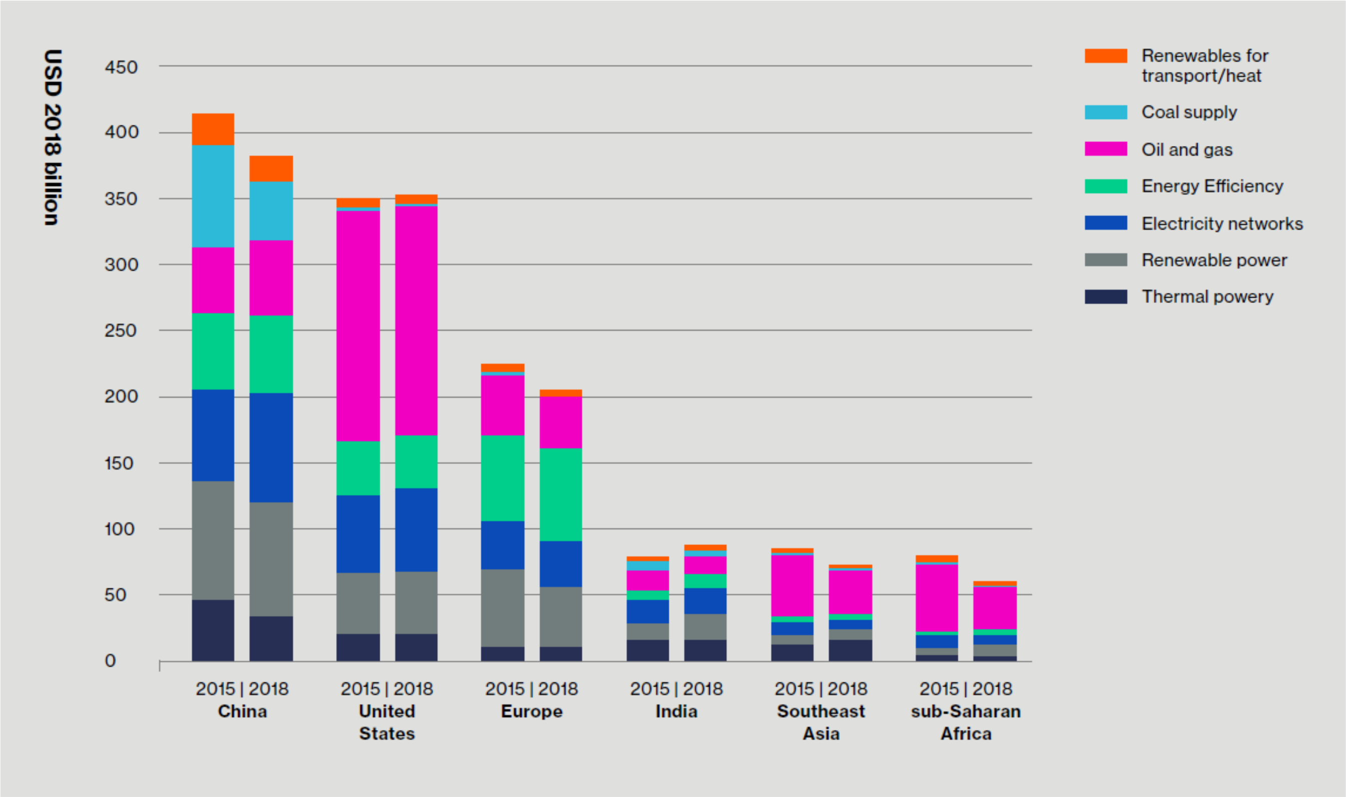
Source: IEA, 2019

Investment trends

Who is investing in what?

Since 2016, total worldwide investment in the power sector has outstripped investment in the oil and gas sector for the first time in decades. In 2018 China, US, Europe and India are were driving investment with over $230 billion in new renewable energy (excluding hydropower) (Figure 8).

Figure 8: Energy investment by sector in selected markets, renewable investment substantial compared to fossil fuels globally



Source: IEA, 2019

Global investment in renewables worldwide (excluding hydropower) in 2018 amounted to £288bn, the bulk of which is asset finance for new projects. Of this total, $236m was invested in utility-scale projects (roughly equally split between wind and solar, with $15m across all other technologies combined), and $37bn in small distributed (mostly solar) generation capacity. Box 1 below sets out the main sources of this finance.

Sources of finance for renewable energy

The cost of capital for renewable energy projects has been exceptionally low in recent years, which has helped to push down levelised costs of electricity for these technologies. Examples of the two main types of finance include:

1. On-balance-sheet finance: this tends to be done by utilities, which in turn rely on bond markets to provide their central funds. Italy-based Enel was one of the largest single investors in renewable energy projects in 2016 and 2017. In January 2017, its Enel Finance International entity issued EUR 1.25 billion of 10-year bonds at a coupon of 1.375%. In October 2012, it issued EUR 1 billion of 10-year bonds at a coupon of 4.875%.
2. Non-recourse debt finance for projects: most often, this takes the form of bank loans. Bloomberg New Energy Finance estimates are that the initial all-in cost of debt for an onshore wind project in France, after agreeing an interest rate swap to fix the cost of borrowing, was around 5% in 2012 but had fallen to between 2% and 2.5% in cheaper interest rate swaps all contributed to this shift.

These helpful effects do not necessarily last. Often, after that original funding and after they progress to a somewhat lower-risk phase, projects are refinanced. This is often post-construction, but sometimes immediately pre-construction or during construction. This refinancing stage has become the commonest method for institutional investor cash to be deployed into the equity of renewables projects.

Institutional investor commitments to European renewable energy projects hit a record in 2017, of $9.9 billion, up 42% on 2016. Two of the biggest transactions of 2017 were Copenhagen Infrastructure Partners' raising of $2.1 billion for its third private equity fund oriented towards renewables; and the purchase for $2.7 billion of a 50% stake in Orsted's 659MW Walney Extension offshore wind project in the U.K. North Sea, backed by a bond issue.

Development Banks and ECAs

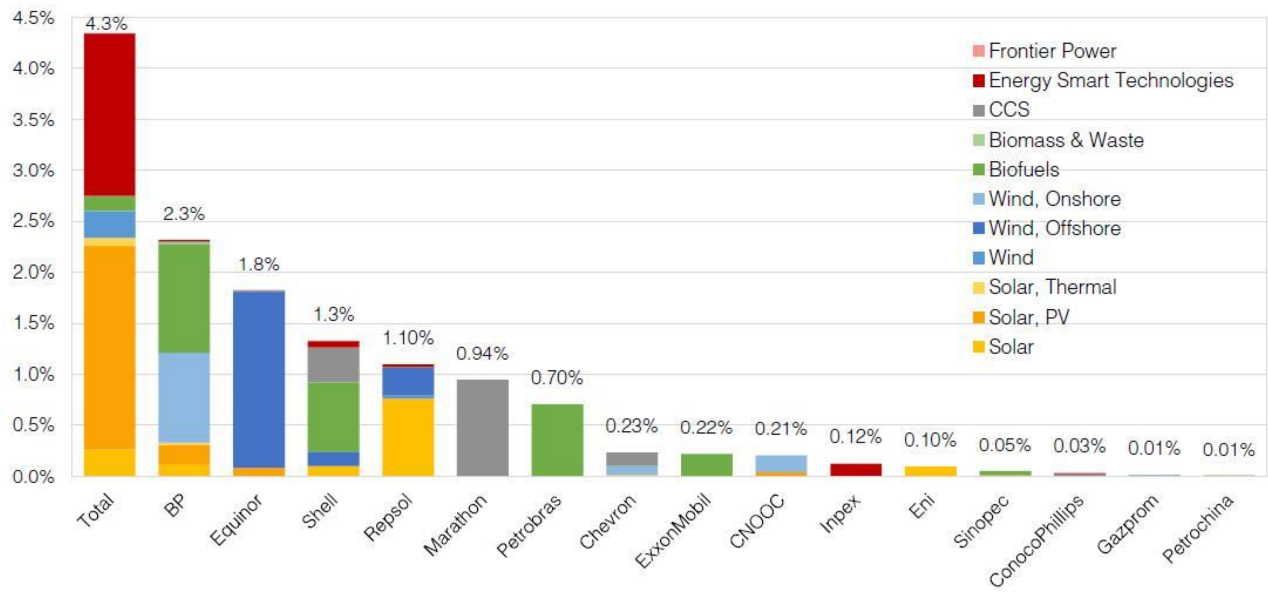
Multilateral development banks have been important providers of finance for renewable energy for more than a decade, often backing projects in countries where commercial banks are concerned about risk, or in technologies where commercial banks are only just starting to get comfortable. Eight of the largest development banks, led by KfW of Germany, the European Investment Bank and the World Bank Group, lent $55 billion between them to clean power in 2016, a figure comparable to that in other recent yeas. This total includes funding for energy efficiency and transmission, as well as for renewables projects. KfW was by far the largest contributor, with $34.1 billion of commitments, up from $30.7 billion in 2015.

Export credit agencies, or ECAs, have also become vital elements in financing packages, particularly for large-ticket projects. Their presence has the effect of covering at least in part the exposure of bank lenders to the project, protecting them from problems such as equipment failure or breach of contract by the electricity off-taker. Because it takes away some of the risk from lenders, it has the effect of reducing the interest rate payable on debt. In some cases, this may be the difference between a project being economically viable, and it not being so. One of the biggest ECA interventions in 2017 was the cover by German ECA Euler Hermes for just under half of the EUR 500 million of debt provided for the 650MW Markbygden Ett onshore wind project in northern Sweden.

Source: Global Trends in Renewable Energy Investment 2018 (Frankfurt School-UNEP Centre/BNE, 2018)

Relative to utilities and other investors, oil companies are minor players in renewable infrastructure for now. As a whole, the world's top 24 publicly-listed oil and gas companies spent just 1.3% of total CAPEX (amounting to $3.4bn) on low carbon energy in 2018, with European companies spending more and US companies spending less than the average (Figure 9[5]) (Reuters, 2018). In total, this expenditure from oil majors represents around 1.5% of the total asset finance for renewable energy projects globally, this suggests that fossil fuel companies will either use mergers and acquisitions to add to their renewable mix or will be disrupted with the market contracting or remaining static as renewables increase production capacity.

Figure 9: Disclosed low-carbon investment by major oil and gas companies as a proportion of their total CAPEX (2010 – Q3 2018)



(i) Includes Asset Finance, M&A and Venture Capital spend

Source: CDP and BNEF

Financing trends and allocation of risks

The renewables energy sector faces different conditions compared to the renewable energy insurance class. Like other energy sectors, the insurance market for renewables is subject to similar pressures of high capacity and low premiums. However, unlike some other energy sectors the renewable energy sector is growing at a significant rate. In Europe and the US, the use of project financing models (i.e. direct investment) has increased significantly over the past decade, compared to traditional bonds in fossil fuel companies (Figure 10). This means that demand for insurance products is also growing rapidly, since insurance is a pre-requisite for provision of project finance to transfer a variety of risks, including financial distress.

[5] Note that the column "Total" in figure 10 is for the French company Total – it does not represent the aggregate of all companies.

Figure 10: Asset finance of renewable energy by type 2004-2017, $bn, project finance (direct investment in projects has become more popular over last decade)

Source: UNEP, BNEF 2019

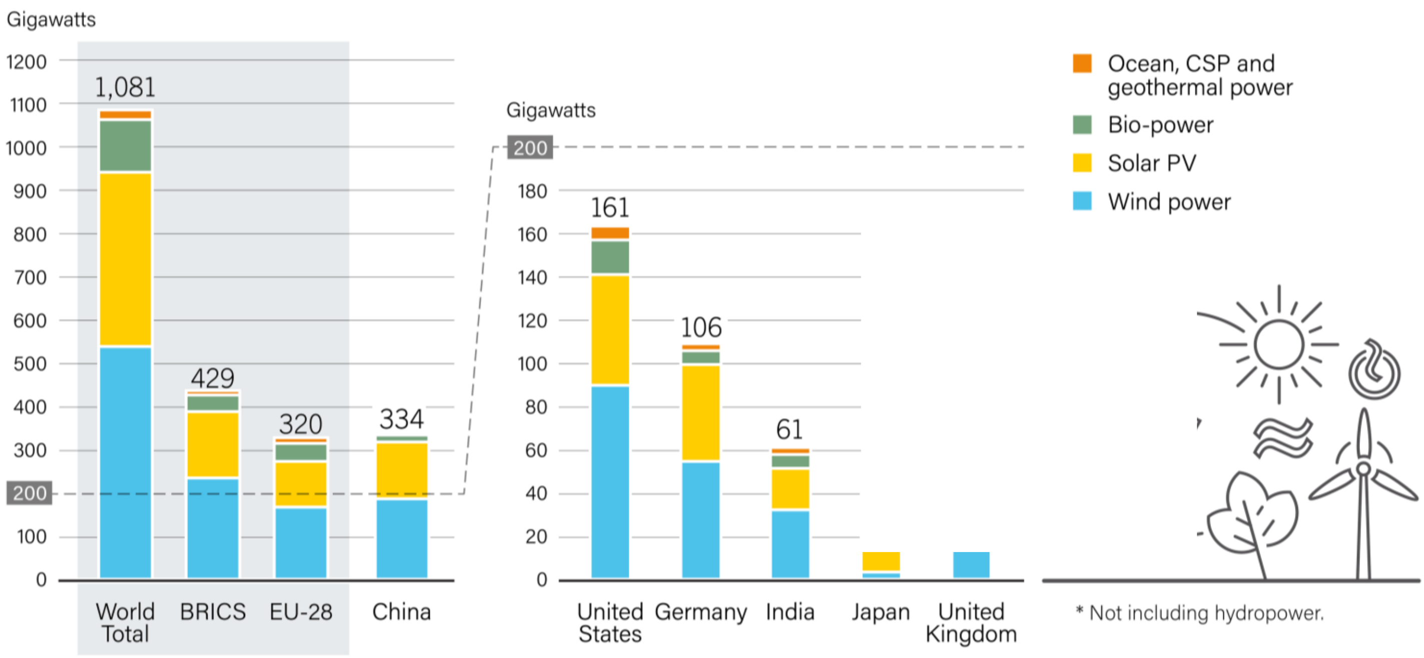
Balance sheet investment comes mostly from electricity utilities, whilst project finance represents a wider range of project development companies. This trend is exacerbated by a shift from traditional 'build, own, operate' business models towards selling on the asset to new owners once construction has been completed, and providing 2-year warranties on the build, which tends to further reduce prioritisation of quality of build and equipment used.

In both cases of utilities and project finance however, investment typically follows a similar structure, with different types of risk distributed across the three main types of party. Ideally, contractual negotiations during project design will include allocation of these risk to the party in the best position either to prevent and/or bear the burden of potential losses. Once the risks have been allocated, each firm can seek appropriate insurance cover. The report 'Risks and Technologies' sets out the typical allocation of risks across the project cycle.

2. Regional focus

Renewable power capacity is widely distributed geographically. Excluding hydropower, the top 6 countries in terms of installed capacity in 2017 were China, USA, Germany, India, Japan, and the UK (Figure 11). This reflects the distributed nature of the energy resource, as well as a relatively widespread and diverse technology and manufacturing base across the world. China dominates the installed capacity of renewables - although per capita Germany is ahead (Figure 11).

Figure 11: Geographical spread of installed capacity of renewables



Source: REN21 Global Status Report, 2018

Outside of these main regions, renewables are still growing, but typically at a slower rate. In Latin America, Brazil's renewable capacity is expected to increase 21 GW over the period to 2023 (IEA 2018a), led by hydropower, onshore wind and solar PV, with notable contributions from bioenergy. Improvement in several main macroeconomic indicators encourages a more optimistic outlook for renewable financing. Having successfully implemented its renewables auction scheme, Argentina is emerging as an important growth market, and with concessional financing and off taker guarantees available, the economic attractiveness of wind and solar projects has improved significantly. However, timely grid connections and macroeconomic uncertainties are still key risks to delivery in these markets (IEA 2018a).

Renewable power capacity in sub-Saharan Africa (SSA) is set to expand from 37 GW to 64 GW between 2017 and 2023. This represents only 2.5% of the global growth but surpasses that of the Middle East and North Africa and Eurasia. Hydropower continues to lead the expansion, with most new projects in Ethiopia, Nigeria, Angola and Zambia. However, enlarged use of capacity auctions, coupled with other supportive policy measures and falling technology costs, are driving solar PV deployment across the region (IEA 2018a).

China

In China, a combination of unique project characteristics and favourable market and regulatory conditions, including robust incentives and improved debt financing, have enhanced the economics of commercial-scale distributed solar PV projects and boosted investment.

Data from IEA World Energy Investment (IEA 2018b) indicates that nearly 60% of China's solar PV deployment took place in East and Central provinces in 2017, where the bulk of load is concentrated and where curtailment remains at much lower levels compared with Northeast and Northwest provinces. Availability of a central government incentive of CNY 420 per MWh (US$ 50 per MWh), available through 2017, which was added on to the avoided retail price for self-consumed electricity or the wholesale coal-fired tariff for electricity sold to the grid, resulted in very attractive rates of return for such projects, even at minimal levels of self-consumption, compared with selling power solely under the traditional utility feed-in tariff (Figure 1.16). For a 10 MW ground-mounted installation in Zhejiang – an eastern province with one of the highest solar PV deployment rates – the estimated project internal rate of return (IRR) in 2017 for an investment in a distributed plant ranged from 14% to 25%.

However, the government announced in the summer of 2018 marked changes to policies that would, reduce the incentive level almost 25% below 2017 levels and encourage local authorities to allocate projects through competitive bidding mechanisms, in addition to reductions in tariffs and the introduction of competitive bidding mechanisms for utility-scale plants. A joint statement by the National Development and Reform Commission, Ministry of Finance and National Energy Administration said the allocation of quotas for new projects had been halted until further notice, and tariffs on electricity generated from clean energy will be lowered by 0.05 yuan per kilowatt hour, a cut of 6.7 to 9 per cent depending on the region. Forecasts by industry advisors of Chinese investments have been reduced significantly by 25-50% for the 2019-2020 because of these changes (South China Morning Post, 2018). These policy changes are aimed at keeping in check the more than 100 billion-yuan (US$15.6 billion) deficit in a state-run renewable energy fund, which is financed by a surcharge on power users' bills. Partly as a result, power investment in China declined by 7% in 2018 relative to 2017, the first fall this century, largely due to a continued reduction in spending on coal power, but also from lower solar PV and grid investment (IEA 2019).

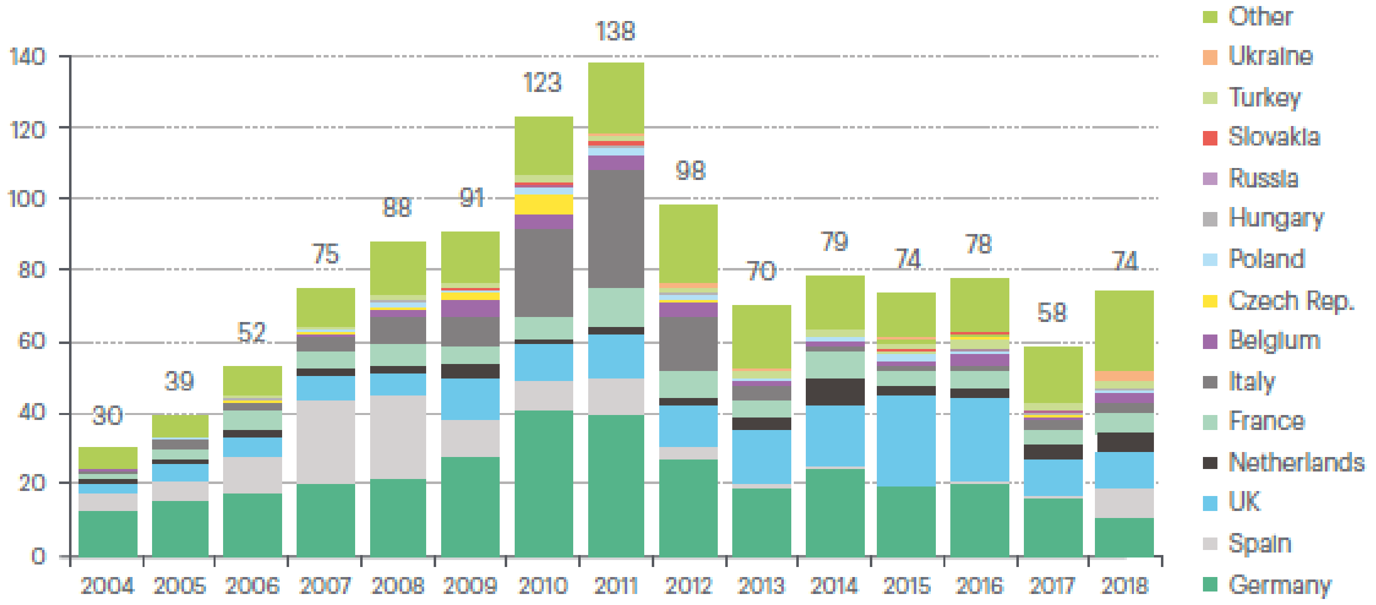
The knock-on effect of these reductions in Chinese installations is that the cost of panels from China has dropped substantially, since equipment manufacturers are now facing surplus capacity. The challenge for insurers will be to ensure that the way they model, and rate solar parks continues to be sustainable. Whilst panels make up the majority of the value of solar parks, they do not necessarily make up the majority of claims (WTW 2019).

Recognising the importance and development of the Chinese market, in 2019 China Re launched a renewable energy consortium within Lloyd's to provide reinsurance for the construction and operation of offshore windfarms around China. The consortium covers construction all risks, erection all risks and third-party liability and can provide up to US$225mn per risk. China Re is supported by Canopius, Travelers, Axis, GCube and Chaucer syndicates at Lloyd's.

Europe

Overall investment in the power sector, including fossil fuels, in the European Union declined by 4% in 2018, and Europe is investing half as much as it did in 2010. Its share of global power investment has halved to around 15%, though this partly stems from spending on relatively higher-cost renewables in the early part of the decade. This continues a longer-term trend which has seen overall decline in investment (Figure 12), but with increasing share of renewables. Energy investment in the European Union has declined by 7% over the past three years, but the share going towards low-carbon energy has risen to nearly 60%. Energy efficiency has been the lone growth area for spending. Renewable power spending has slowed, in part from falling costs, but has fallen less than the average expenditure in the sector, and now accounts for over 80% of generation spending, whilst 2018 investment in electricity grids in the region rose by 8% mainly in transmission projects (IEA 2019). Oil majors are not the major players in global renewable electricity markets, although the European oil companies are investing more than their US counterparts.

Figure 12: New clean energy investment in Europe (excl. hydro >50MW), in US$ billions



Source: Bloomberg New Energy Finance, 2019

Investment in wind power projects in Europe declined but remained the largest source, and offshore wind projects accounted for around half of wind investment. In Europe, there is increased interest from industry in financial risk management strategies for renewables, amid changing policies and increasing roles for sources of remuneration outside of government schemes. Europe dominates the global market for offshore wind, with operation and maintenance (O&M) markets alone expected to grow by 17% annually to €11 billion by 2028 (Wood Mackenzie, 2019a). Europe is the largest contributor with €6.7 billion in value. Operational offshore wind farms in Europe are relatively young – 80% of the installed base will remain within the first half of their design lives by 2028. Subsidy-free projects are commonly seen in established markets, but more than 27 GW of capacity are expected to come out of subsidy in the 2030s. That said, maintenance optimisation is playing a key role in maximising revenue, especially for projects exposed to merchant risks (Wood Mackenzie, 2018).

Europe is further leading the way on regulation for PV solar panels and waste control after they are decommissioned with regulations including PV-specific collection, recovery and recycling targets. The EU Waste of Electrical and Electronic Equipment (WEEE) Directive entails all producers supplying PV panels to the EU market to finance the costs of collecting and recycling EOL PV panels in Europe (Chowdhury et al, 2020). No other regulation has been laid out worldwide and it is likely that the EU's regulation will guide other countries regulation with manufacturers carrying much of the risks once PV panels are decommissioned.

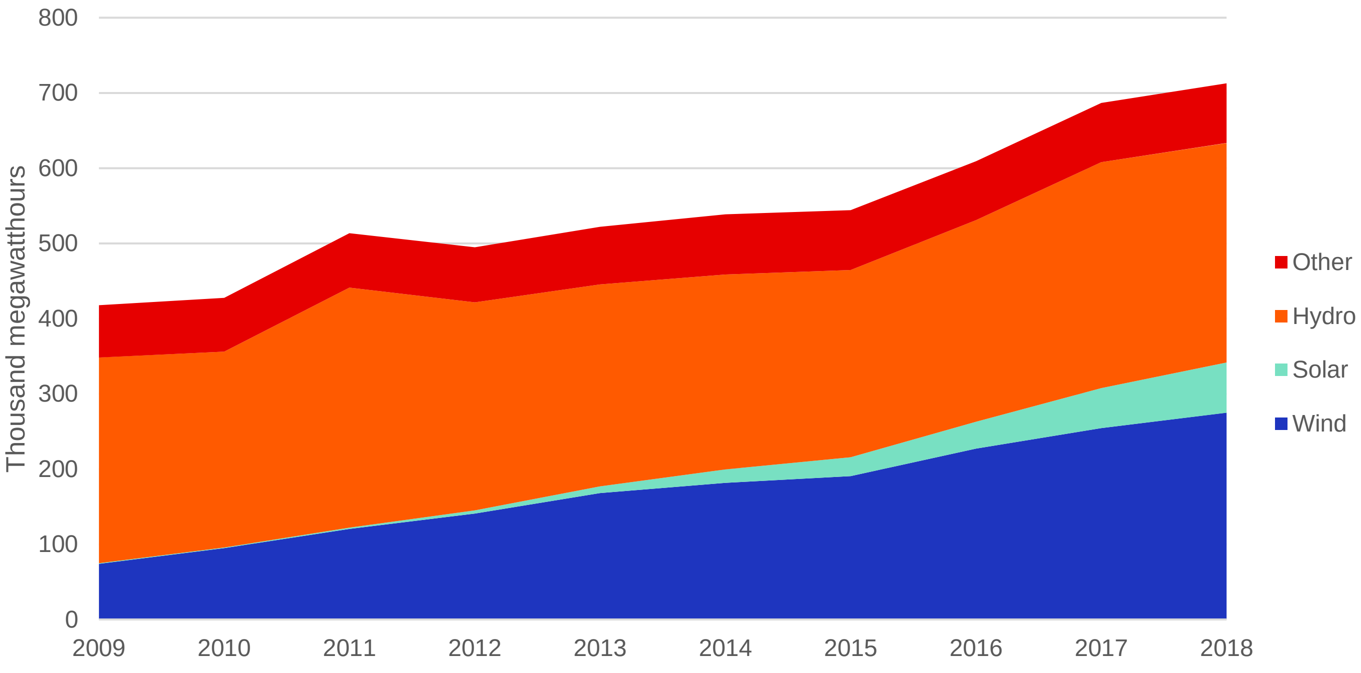
Global capital spending on grid-scale battery storage increased by 30% in 2018 compared with 2017, totalling more than 1.2 GW installed in 2018. Deployment in Europe (particularly the United Kingdom) and the United States comprised half of this 2018 investment, supported by capacity mechanisms and contracts (IEA, 2019).

After more than two years of negotiation, the EU's Clean Energy Package aims to shape the long-term future of the RES sector in Europe (European Commission, 2019). This sets a target for the EU of 32 percent of gross final consumption from RES by 2030, up from the 20 percent target set for 2020, and notably higher than the 27 percent level set for 2030 in the November 2016 proposals. Member states must produce national energy and climate plans and long-term strategies, on which the European Commission subsequently reports on adequacy and progress. Member states can trade shares of their renewable energy supplies and count imports from third parties as contributions towards their targets under certain circumstances. The package states a preference for technology-neutral tenders as a key incentive mechanism to bring forward investment. Priority dispatch for existing renewables will continue to apply. For new projects, it will be replaced by new rules on curtailment, including giving compensation for lost revenues in countries where re-dispatch is not market-based. Details of each countries' renewable energy policies are available at http://www.res-legal.eu/.

USA

Renewables provided 17.6% of electricity generation in the United States in 2018. Data from the US energy information administration (US Energy Information Administration, 2019a) shows that US renewable electricity generation almost doubled between 2008-2018, with 90% of the increase coming from wind and solar (Figure 13). Wind generation rose from 55 million MWh in 2008 to 275 million MWh in 2018 (6.5% of total electricity generation), exceeded only by conventional hydroelectric at 292 million MWh (6.9% of total generation). U.S. solar generation has increased from 2 million MWh in 2008 to 96 million MWh in 2018 (2.3% of total generation). In 2018, 69% of solar generation, or 67 million MWh, was utility-scale solar.

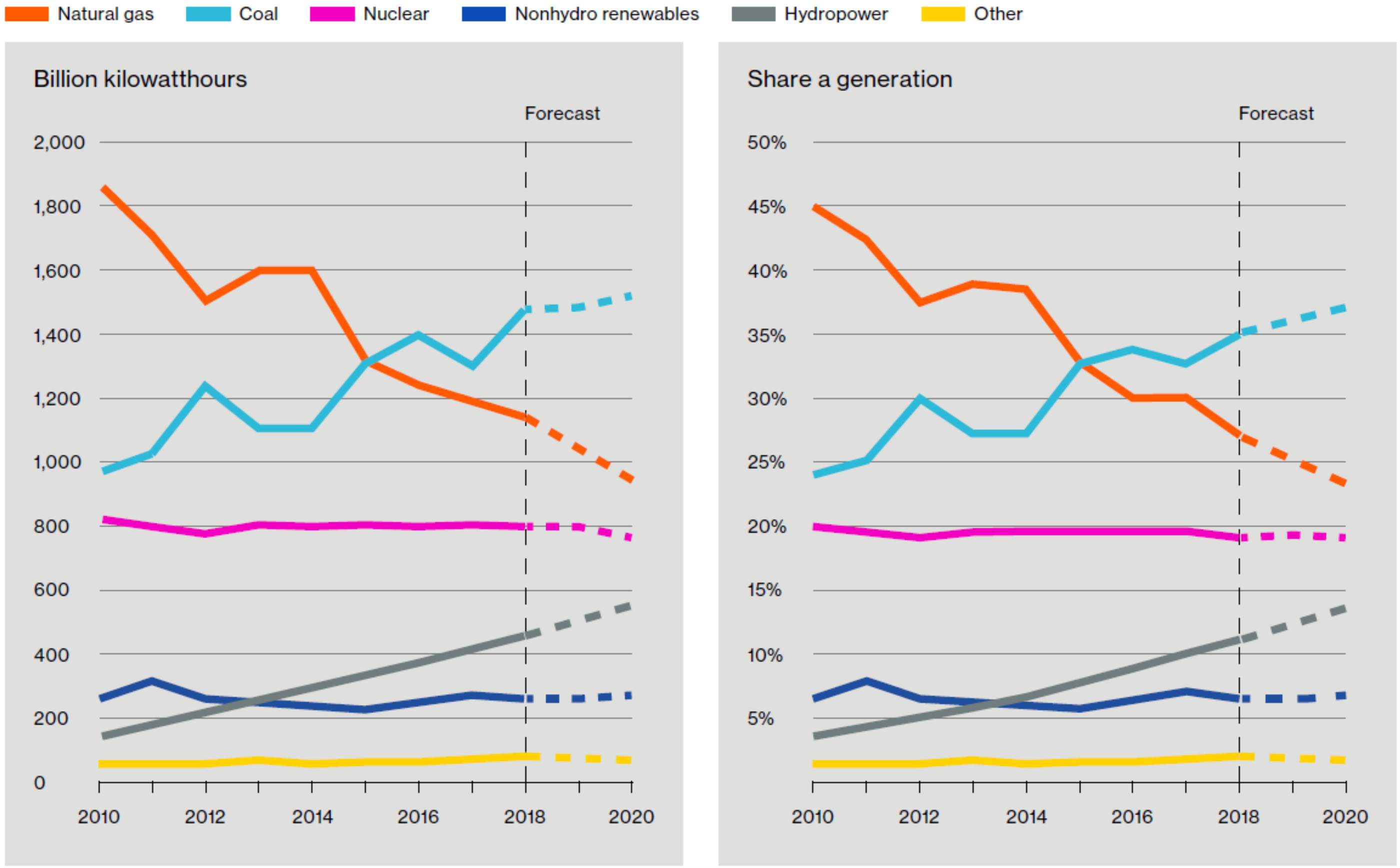
Figure 13: USA annual net generation from renewable sources, solar and wind growing rapidly



Source: Lloyd's based on US Energy Information Administration, 2019a

The EIA expects non-hydroelectric renewable energy resources such as solar and wind to be the fastest growing source of U.S. electricity generation for at least the next two years, forecasting that electricity generation from utility-scale solar generating units to grow by 10% in 2019 and by 17% in 2020 (US Energy Information Administration, 2019b). This projected growth includes about 11 gigawatts (GW) of wind capacity scheduled to come online in 2019, which would be the largest amount of new wind capacity installed in the United States since 2012. EIA expects electricity generated from wind this year will surpass hydropower generation. An additional 8 GW of wind capacity is scheduled to come online in 2020. The share of total U.S. generation from wind is projected to increase from 7% in 2018 to 9% in 2020. Solar is the third-largest renewable energy source in the United States power sector, having surpassed biomass in 2017. The U.S. electric power sector plans to add more than 4 GW of new solar capacity in 2019 and almost 6 GW in 2020, a total increase of 32% from the operational capacity at the end of 2018. EIA forecasts that small-scale solar generating capacity will grow by almost 9 GW during the next two years, an increase of 44% (Figure 14).

Figure 14: US electricity generation by energy source, sharp drop in coal as natural gas and renewables grow (2010-2020)



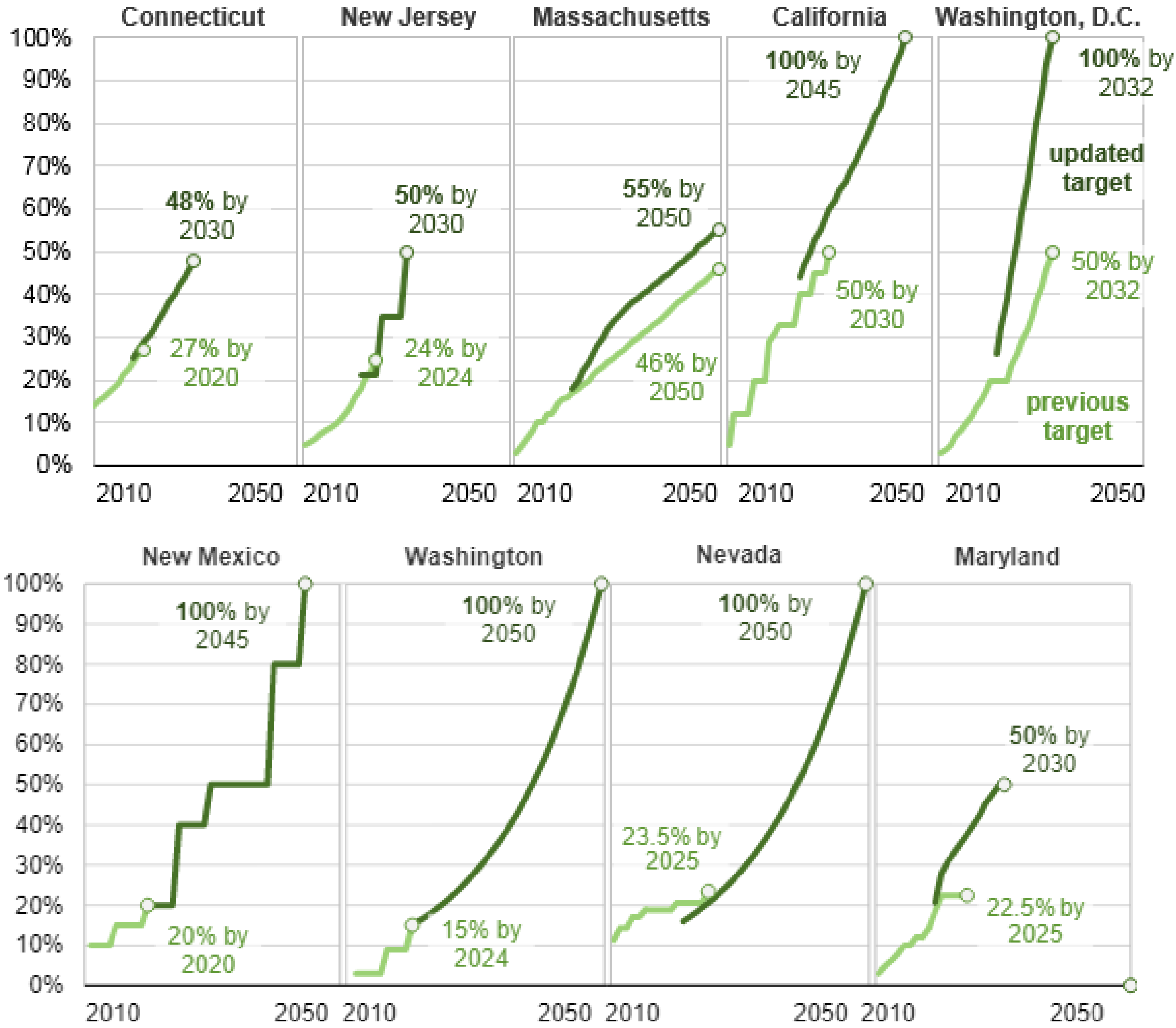
Source: US Energy Information Administration, 2019c

Changes in annual capacity additions for wind in the United States are often explained by changes to tax incentives. The U.S. production tax credit (PTC), which provides operators with a tax credit per kWh of renewable electricity generation for the first 10 years a facility is in operation, was initially set to expire for all eligible technologies at the end of 2012 but was later retroactively renewed. The high level of annual capacity additions in 2012 was driven by developers scheduling project completion in time to qualify for the PTC. Similarly, the increase in annual capacity additions for wind scheduled for 2019 is largely being driven by the legislated phaseout of the PTC extension for wind.

When renewed in 2013, the PTC provided a maximum tax credit for wind generation of 2.3 cents per kilowatt-hour (kWh) for the first 10 years of production. Under the PTC phaseout, the amount of the tax credit decreases by 20 percentage points per year from 2017 through 2019. U.S. wind project developers who want to receive the full 2016 value of the PTC must begin operations by the end of 2020. Facilities that begin construction after December 31, 2019, will not be able to claim the PTC (US Energy Information Administration, 2019c).[6]

The focus of policy will then shift to renewable portfolio standards (RPS) applied in many US States which require a minimum share of renewables to be achieved by electricity suppliers. Updated RPS are expected to drive further increases in renewables penetration in several US states. As of the end of 2018, 29 states and the District of Columbia (DC) had renewable portfolio standards (RPS), polices that require electricity suppliers to supply a set share of their electricity from designated renewable resources or eligible technologies. Although no additional states have adopted an RPS policy since Vermont in 2015, Connecticut, New Jersey, Massachusetts, California, and the District of Columbia extended their existing targets in 2018 or early 2019, continuing a trend in recent years across the United States. States with legally binding renewable portfolio standards collectively accounted for 63% of electricity retail sales in the United States in 2018. Figure 15 shows the recent updates in these states, with the light green figures indicating the RPS targets prior to 2018, and dark green figures showing the updated values, showing they have been made more stringent and extended further into the future.

Figure 15: Some US states show strong ambition in their renewable energy production targets – States that have recently updated their targets.



Source: US Energy Information Administration, 2019d and 2019e[7]

Africa

Africa possesses rich renewable energy resources. Analysis by IRENA suggest that Africa could meet nearly a quarter of its energy needs from indigenous and clean renewable energy by 2030. Modern renewables amounting to 310 gigawatts (GW) could provide half the continent's total electricity generation capacity. This corresponds to a sevenfold increase from the capacity available in 2017, which amounted to 42 GW. A transformation of this scale in Africa's energy sector would require average annual investment of 70 billion US dollars (US$) to 2030, resulting in carbon-dioxide emissions reductions from the power sector around 60% compared to current trends (IRENA, 2015, IEA, 2018).

South Africa has been a dominant market for solar and wind projects in the region, and this is expected to continue, with a project pipeline of over 1 GW of wind capacity expected to be built in 2020 and 2021. This surge in final investment decisions by IPPs results from the signing of long-pending PPAs in April 2018 by the South African Government (Wood Mackenzie, 2019). Much of the investment was driven by the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), a competitive tender process that was designed to facilitate private sector investment into grid-connected renewable energy (RE) generation. This was broadly considered a success, driving the cost of renewable power down significantly (Eberhard 2017). The recent integrated resource plan produced in 2018 suggests a continued shift to renewables so that by 2030 the electricity mix would include 5GW of PV and 8 GW from wind, meaning that wind would account for 15% of installed capacity, gas 16% and PV 10%, representing a significant decline in the share of coal in the capacity mix (South Africa Department of Energy, 2019).

Past trends and projections by the IEA for Africa (excluding South Africa) are shown in Figure 16. This shows two scenarios, solid lines indicate the 'New Policies' scenario, which includes currently announced energy development plans, and dotted lines indicate the 'Sustainable Development' scenario in which countries meet sustainable development goals including energy access, health targets and contribute to a global goal of limiting global temperature increases to well below 2°C. Therefore, it can be expected that renewable projects in Africa will increase rapidly in the next decade. Much of the oil and gas in these figures relates to installations in North Africa, whilst sub-Saharan Africa has a much greater share of hydro power. Analysis of investment in 2018 for sub-Saharan Africa (IEA, 2019) suggests that the power sector saw investment decline by 15% compared with three years ago, with less oil and gas spending offsetting a small increase in renewables. Insufficient regulatory frameworks, challenging project development, persistent financial strain for utilities and a limited pool of public finance are identified by the IEA as on-going constraints to power sector growth in the region.

Analysis of current trends (African Energy, 2018) indicates the role of renewables growth across Africa within the wider context of energy sector developments:

- Natural gas and dual-fuel plants have increased from 40% of generation capacity in 2010 to nearly 48% in 2018. Much of these are located in North Africa. In sub-Saharan Africa, gas and dual-fuel plants are expected to account for 19% of capacity by end-2018, up from around 14% in 2010.
- Coal-fired installed capacity has grown by 13% since 2010 and is expected to peak in capacity terms in 2022, at about 60GW. Its share has fallen from around 29% of the generation mix in 2010 to 20% in 2018; in sub-Saharan Africa, coal's share has diminished even further, from 47% to 35%.
- Installed solar – mostly photovoltaic (PV) – capacity has increased more than 45 times since 2010 and is expected to double again in just two years, reaching as much as 8.7 GW by end-2020, from 4GW in 2018.
- Wind capacity is set to nearly double by 2021, increasing from 5.7GW to more than 10GW.
- Despite promising trends in a few key markets, geothermal and biomass barely register at an aggregate level. However, geothermal development is expanding rapidly: projects progressing in Kenya and Ethiopia mean that geothermal capacity should double by 2020 and could treble by 2023.
- There has been a spike in the development of liquid fuels (diesel, HFO, and other fuel oils) in North Africa, where plants powered entirely using liquid fuels have increased by 72% since 2010 – despite the region's abundance of natural gas and renewable resources.
- In sub-Saharan Africa, plants powered entirely by liquid fuel account for 12.4% of capacity in 2018 compared with 10.3% in 2010. (The data does not include the huge number of smaller diesel-fired gensets that still dominate generation in Nigeria and other countries in sub-Saharan Africa.)
- Despite this longer-term trend, in the eight months to 1 September, the proportion of liquid fuels in the generation mix has fallen slightly in all regions other than Southern Africa.
- The total capacity of projects signing power purchase agreements in Africa has increased from less than 1GW/year in 2010 and 2011 to 5-6GW/year in 2016-17.
- Off-grid stand-alone systems and mini-grids represented about 6% of new electricity connections worldwide between 2012 and 2016 and continued to provide access for new populations in 2017.

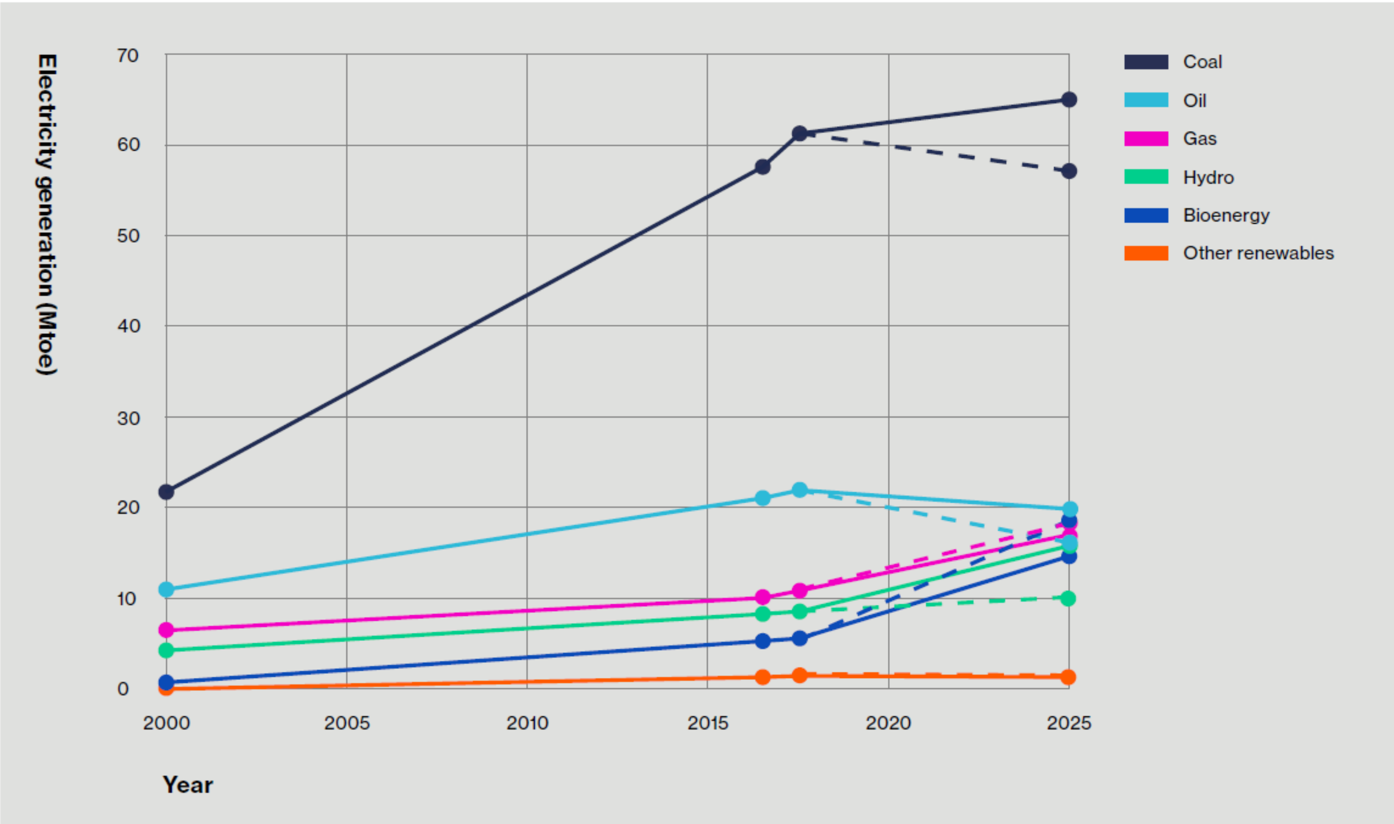
Small scale on the big scale

On the distributed energy side, such systems are estimated to be the least-cost option to supply electricity to nearly three-quarters of the people living in remote areas of sub-Saharan Africa – the population that is considered the most difficult to serve worldwide (REN21 2018).

To serve this market, there has been an increase in the number of private companies providing a *last mile distribution service* of solar generation products. The focus of these companies' business models is to make relatively expensive solar home systems accessible to low income households by providing microfinance payment plans. Depending on the strategy of the company, manufacturing and financing can be conducted internally or may be outsourced to a specialist.

One business model, coined as the 'Banker' model (Lighting Global, 2018), focuses on the customer facing functions of the value chain, whilst outsourcing the technology development and manufacturing. PEG Africa is a company using this model to bring solar power to rural communities in Western Africa. The benefit of this operating model is the increased investment in infrastructure to support customer acquisition and management, this core competency has propelled PEG Africa to establish itself as the PAYGO solar company market leader in West Africa (appsafrica, 2019). Distributed energy such as this provides an opportunity for insurance to serve this large market of people now with a 'credit history' and a means of digital payment. PEG Africa is already starting to explore the application of insurance within this space by offering Healthcare Micro-insurance as a free reward to customers who are loyal and pay in a timely manner (PEG Africa, 2019).

Figure 16: Electricity generation trends in Africa (excluding South Africa), renewable projects expected to grow



Source: authors' calculations based on IEA, 2018

India

Renewable energy investments in India are outpacing spending on fossil fuel power generation, a sign that the world's second-most populous nation is making good on promises to shift its coal-heavy economy toward cleaner power. Its switch to more renewable power in the past few years has been driven by a combination of ambitious clean energy policies and rapidly decreasing costs of solar panels that have driven large utility-scale solar projects across the country. IEA investment data (IEA, 2019) indicates that renewable power investments in India exceeded those of fossil fuel-based power for the third year in a row, and that spending on solar energy surpassed spending on coal-fired power generation for the first time in 2018. The World Energy Outlook scenarios (IEA, 2018) projects that coal-fired power will decline from 77% of total electricity generation today to 60% in 2040 under current policies whilst renewables increase from 2% currently to 14% by 2040. More aggressive climate policies in line with a 2-degree warming target could reduce coal power to as little as 10 percent of generation by 2040, with 34% coming from renewables.

In 2015, India pledged to install 175 gigawatts of renewable energy capacity by 2022 as part of a commitment under the Paris climate agreement, and it appears to be on track to meet that goal. A key challenge for India's power supply, however, will be addressing a surging demand for air conditioning driven by rising incomes, urbanization, and warming temperatures driven by climate change.

It now has more than 77 gigawatts of installed renewable energy capacity, more than double what it had just four years ago. Additional projects totalling roughly 60 gigawatts of renewable energy capacity are in the works (Inside Climate News, 2019).

Middle East

Power generation in the Middle East is dominated by gas (65%) and oil (33%), with less than 0.5% currently met through non-hydropower renewables. However, the energy landscape is rapidly evolving, and significant developments have taken place. In 2016, US$ 11 billion were invested in renewables across the Arab region compared to US$ 1.2 billion in 2008, a nine-fold increase in eight years. Today, several countries in the region are among the global frontrunners in renewable energy development. The recent auctions resulted in the world-record solar prices, including, 17.8 US$/MWh for the Sakaka project in Saudi Arabia, 24.2 and 29.9 US$/MWh in Abu Dhabi and Dubai, respectively (IRENA, 2018).

In February 2019, Abu Dhabi, switched on “the world’s largest virtual battery plant”, able to store 648 MWh to balance demand on the grid and keep the city supplied for up to six hours in the event of an outage. That launch followed the operational start-up of what is claimed to be the world’s biggest solar plant, the Noor Abu Dhabi. At 1,177 MW it has double the capacity of the previous record holder, the 550 MW Desert Sunlight solar farm in California. Last year, Dubai completed a major battery energy storage facility at its huge Mohammed bin Rashid Al Maktoum solar park. Dubai has also commissioned the development of a hydroelectric power plant at the Hatta Dam in the Hajar Mountains. Solar energy will be used to pump water to a high-level reservoir during off-peak times, and stored water will be released to power the hydroelectric plant during the peaks. The UAE is channelling its considerable oil revenues into alternative energy. By 2030 it plans to spend $160 billion on renewables, with the declared aim of generating two-thirds of its electricity from carbon-free sources by the middle of the century. This ambitious target – among the most challenging in the region – has also been driven by concerns about climate change. The low-lying coastal cities of the UAE are vulnerable to rising sea levels (World Economic Forum, 2019).

Future scenarios (IEA, 2018) suggest that by 2040 renewable power under current policies could grow to 9% of power generated, or up to 36% under their sustainable development scenario which keeps emissions in line with achieving a goal of keeping global temperature rise below 2°C.

Geopolitics and strategic implications

Electricity accounts for 19% of total final energy consumption, but its share is expected to grow as increased electrification of end-use sectors takes place. The deployment of heat pumps and electric vehicles, for example, permits electricity to be used for heating, cooling, and transport. Electricity has been the fastest growing segment of final energy demand, growing two thirds faster than energy consumption since 2000. This trend is set to continue. Since 2016, the power sector has attracted more investment than the upstream oil and gas sectors that have traditionally dominated energy investment, another reflection of the ongoing electrification of the world's top 10 economies. The main story in the electricity sector, and the key driver of the energy transition, is the rise of renewables, particularly solar and wind, and the future decline of fossil fuels, particularly driven by the potential rise of electric transport and heating. This will have different impacts on countries depending on their dependence on oil imports, and their position in development of renewable technologies (IRENA, 2019).

The analysis of each territory has led to several observations.

- The United States is close to energy self-sufficiency, largely due to the shale revolution. It became a net exporter of natural gas in 2017 and is projected to become a net oil exporter early in the 2020s. The US is well positioned in the clean energy race: US companies hold strong positions in new technologies, including robotics, artificial intelligence, and EVs.
- China will gain from the energy transformation in terms of energy security. It has a leading position in manufacturing, but also in innovation and deployment of renewable energy technologies. It is the biggest location for renewable energy investment, accounting for more than 45% of the global total in 2017. Currently, it remains highly dependent on oil imports which have been growing steadily.
- Europe and Japan are major economies which are very dependent on fossil fuel imports. They also hold strong positions in renewable technologies. In Europe, Germany leads the way with almost 31,000 renewable energy patents. Germany's domestic Energiewende, or 'energy transition', has made the country a frontrunner in renewable energy deployment.
- India has been among the fastest-growing economies in the world in the last few years, lifting millions out of poverty. It is projected to have the world's largest population by 2024 and is poised to overtake China as the world's largest energy growth market by the end of the 2020s. India has set itself an ambitious target of 175 GW of renewables by 2022. This represents a massive increase, considering that India's total installed power generation capacity in October 2018 was only 346 GW.

Appendix A

Policy scenario analysis

Several organisations have published global energy scenarios, each developed with different objectives and using different approaches and models. Collectively, they help illustrate the range of opinions about the potential future of different renewable energy sources time. These studies use scenarios to reflect a range of different socio-economic assumptions, with climate and environmental policy as one of the strongest drivers of the scenarios. The following sources have been used for this analysis:

1. International Energy Agency. The World Energy Outlook (IEA 2018), published annually, provides projections of global and regional energy trends. The WEO presents three scenarios:
   - New Policies (NP): based on announced energy and climate change policies and targets of countries
   - Current Policies (CP): based on currently implemented energy and climate policies – assumes no new policies are enacted.
   - Sustainable Development (SD): based on policies that would achieve the Paris agreement of limiting warming to well below 2°C, and other sustainability criteria.
2. International Renewable Energy Agency. IRENA publishes renewables roadmaps by country, which collectively show a potential global pathway for expanding renewable energy capacity (IRENA 2018):
   - Reference (Ref): assumes modest increases in renewables share in total final consumption from 18% in 2015 to 25% in 2050, and continuation of historical rates of energy intensity improvement in the global economy.
   - RE roadmap (REMap): assumes much faster acceleration of renewables, reaching 65% of total final consumption by 2050 and 1.5 times faster rate of energy intensity improvement relative to historical rates.
3. World Energy Council. The latest scenarios (WEC 2016) are designed to illuminate how enterprise strategies and government policies, initiated in the period to 2030, might play out over the longer period, based on different assumptions about the state of the world.
   - "Modern Jazz" represents a digitally-disrupted, innovative, and market-driven world.
   - "Unfinished Symphony", a world in which more 'intelligent' and sustainable economic growth models emerge as the world drives to a low carbon future
   - "Hard Rock", a more fragmented scenario, which explores the consequences of weaker and unsustainable economic growth with inward-looking policies.
4. Greenpeace (2015). These scenarios aim to provide a narrative showing how a future with much higher penetration of renewables might be achieved.
   - Reference (Ref) assumes continuation of current trends and policies
   - Energy revolution (En. Rev) reaches over 95% renewables, and phase out of nuclear power by 2050
   - Advanced energy revolution (Adv. En. Rev.) reaches 98% renewables, with phase out of nuclear and coal, and significantly higher volumes of electricity for transport and heat.
5. McKinsey (2019) is a reference case scenario of how the energy transition will unfold over the next decades. Some information is also provided in the public domain for a separate 2018 'Auctions' scenario with reduced technology costs (McKinsey, 2019).
6. Oil and gas companies. Oil companies are now routinely publishing energy scenarios in response to investor concerns regarding these companies' exposure climate change risks. The following scenarios have been incorporated:
   - BP (2018); a reference scenario based on continuation of current trends and policies, an energy transition scenario with an accelerated shift to renewables, with a series of policy variants to this transition.
   - Exxon (2018); a reference scenario based on continuation of current trends and policies.
   - Shell (2018); three different socio-economic scenarios with widely different sets of assumptions. 'Oceans' describes a world with well-functioning institutions and markets, whilst 'mountains' presents more obstacles to these, whilst 'sky' presents a technically possible but challenging approach to meeting climate change targets.

Although they take very different approaches, broadly speaking, the above scenarios fall into one of three categories:

1. Central, or reference scenarios (colour coded blue in the charts)
2. Accelerated renewables (colour coded green in the charts), developed as normative scenarios that accelerate progress towards decarbonisation to meet climate and other environmental targets.
3. Slower than expected / pessimistic outlook regarding progress on environmental outcomes (colour coded orange in the charts)

The biggest driver of difference between these scenario categories is assumptions about policy, and the associated ability of institutions and markets to respond through appropriate development and implementation of technologies. One exception is McKinsey's scenario in which a purely cost-driven alternative is explored – this is presented separately below.

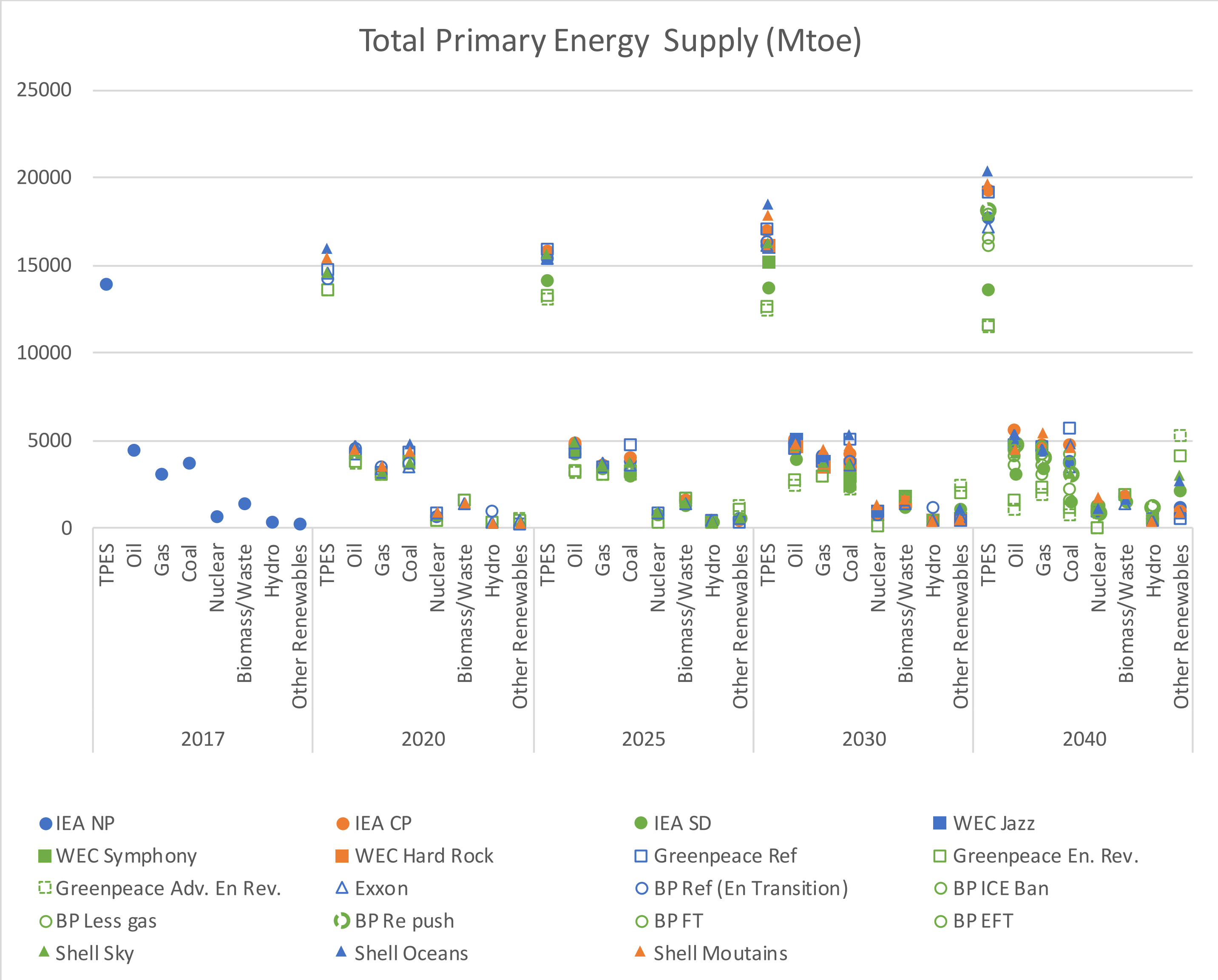
Total primary energy scenarios

Total primary energy supply (TPES) is the aggregate measure of all sources of energy input to the economy, upstream of any conversion processes such as generation of electricity. It includes energy inputs to transport, heat, industrial uses, buildings as well as non-energy uses such as chemicals feedstocks. Scenarios of primary energy supply by source are shown in Figure 189.

A striking feature of the 'green' scenarios compared to the others is the reduction in overall total amounts of energy consumed – on average, they are 13% below the reference scenarios. This reflects the strong role that energy efficiency plays in these green scenarios.

As expected, the 'green' scenarios show reductions in consumption of fossil fuels and increases in use of renewables. Nevertheless, despite the rapid expansion of renewable energy sources outlined above, the long lifetimes and large installed capacity of existing fossil fuel plant, as well as the current low base of renewable energy for transport, heat and industrial use mean that the turnover of the sector towards renewables is a relatively slow process. On average across the scenarios, the share of energy from 'other renewables' is projected to increase from 1.8% of TPES in 2017 to 4.1% (reference scenario), 8.3% (green scenario) and 3.2% (slow progress scenario) by 2030. Including hydropower with other renewables takes these figures from a 4.3% share in 2017 to 7.4%, 11.3% and 5.6% respectively.

Figure 18: Total primary energy supply predicted scenarios from energy industry



Source: author calculations based on references identified above

Electricity generation

Total power demand projections vary widely across the scenarios. Unlike the variations in projections of TPES, there is no clear trend between the green and reference scenarios as to which show higher consumption. This is because there are competing trends in the green scenarios, with greater increases in efficiency on the one hand, outweighed on the other hand by greater consumption driven by electrification of new sectors such as transport and heat. All scenarios show an increase in aggregate electricity consumption over the period to 2030.

As shown in Figure 19, renewables start from a higher base in the power sector than for energy as a whole, representing 9% of generation in 2017, or 25% including hydropower. The share of non-hydro renewables is on average expected to double to 18% by 2030 under the reference scenarios, increasing to 31% on average under the green scenarios, and 14% under the slower progress scenarios. On aggregate, the scenarios suggest that the normative changes assumed in the 'green' scenarios could increase renewable energy uptake compared to the reference case by around 70% excluding hydro, or 40% including hydro. This gives some sense of the sensitivity of the renewables sector to policies, institutions and market assumptions.

Figure 19: Scenarios of renewables in the power generation, expected to compete with fossil fuels

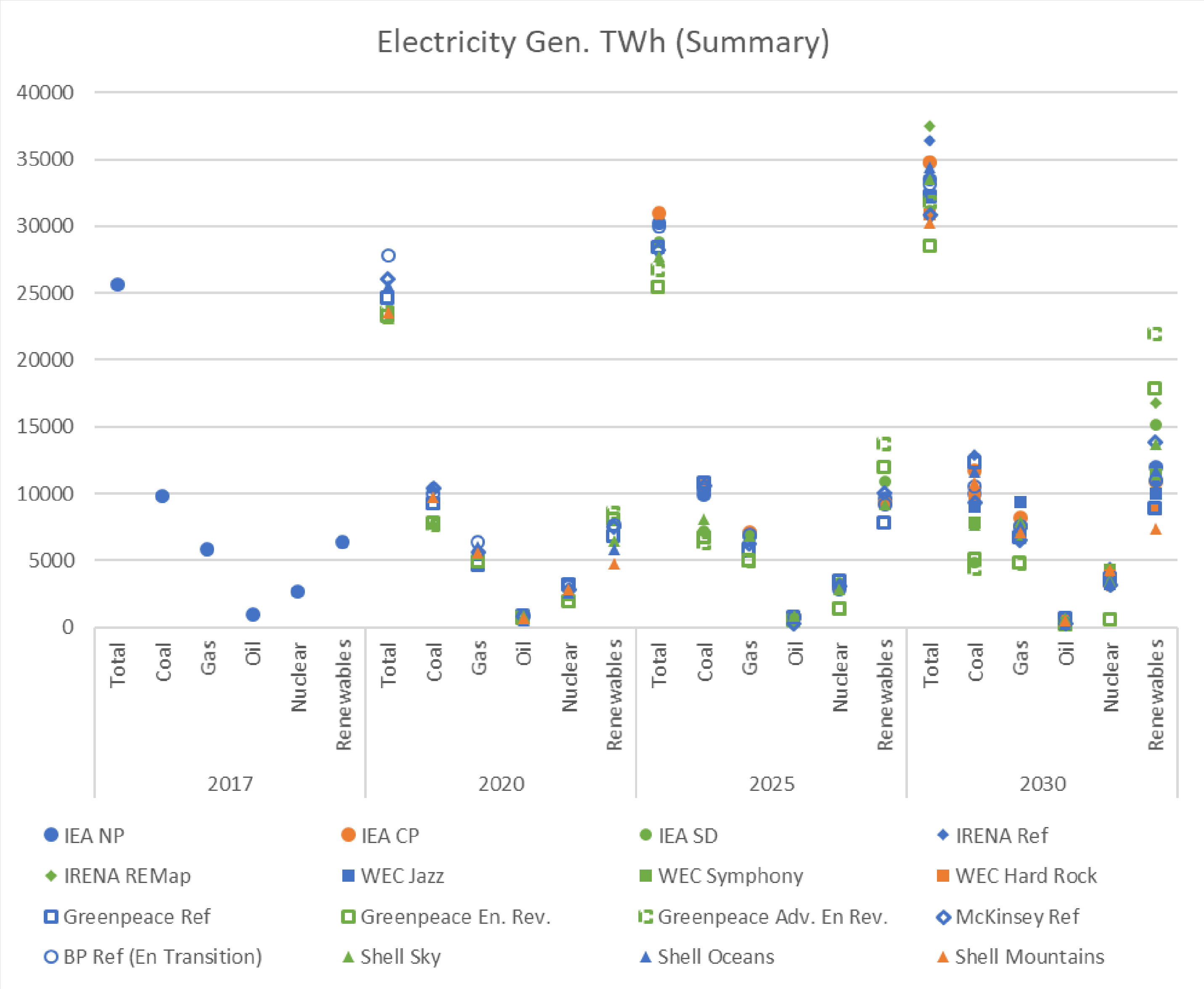


Figure 20 focuses in on the role of particular types of renewables. It shows that by 2030, there is a very wide range in the projections of generation for individual technologies, even within a particular category of scenario. Much of this range reflects differences between the scenarios in the overall role of renewables, and there is closer agreement between the scenarios as to which are the main areas of growth. Particularly in the higher renewable growth scenarios, wind and solar PV tend to dominate, whilst growth in hydro is also significant, and takes a relatively higher share in the lower overall renewable growth scenarios. Taken together with the variations across the scenarios for the role of renewables as a whole, the resulting wide ranges across the scenarios reflect the uncertainty faced in the sector regarding the likely growth rate and market share of any particular technology. The average share by technology across all scenarios is shown in Table 1.

All scenarios indicate much smaller roles for other technologies. Geothermal accounts for less than 6.5% (average 4%) of renewables growth between 2017-2030 in all but one of the scenarios. Concentrated solar power (CSP) accounts for around 1.5% of growth under reference scenarios, increasing to 6% under the 'green' scenarios, this average being strongly impacted by much higher estimates in the Greenpeace scenarios compared to other scenarios. Marine and other technologies (where they are identified separately in the scenarios), typically account for less than 0.5% of the growth in renewables to 2030, and no scenario puts this figure above 2.3%.

Figure 20: Breakdown by renewable type of scenarios for generation

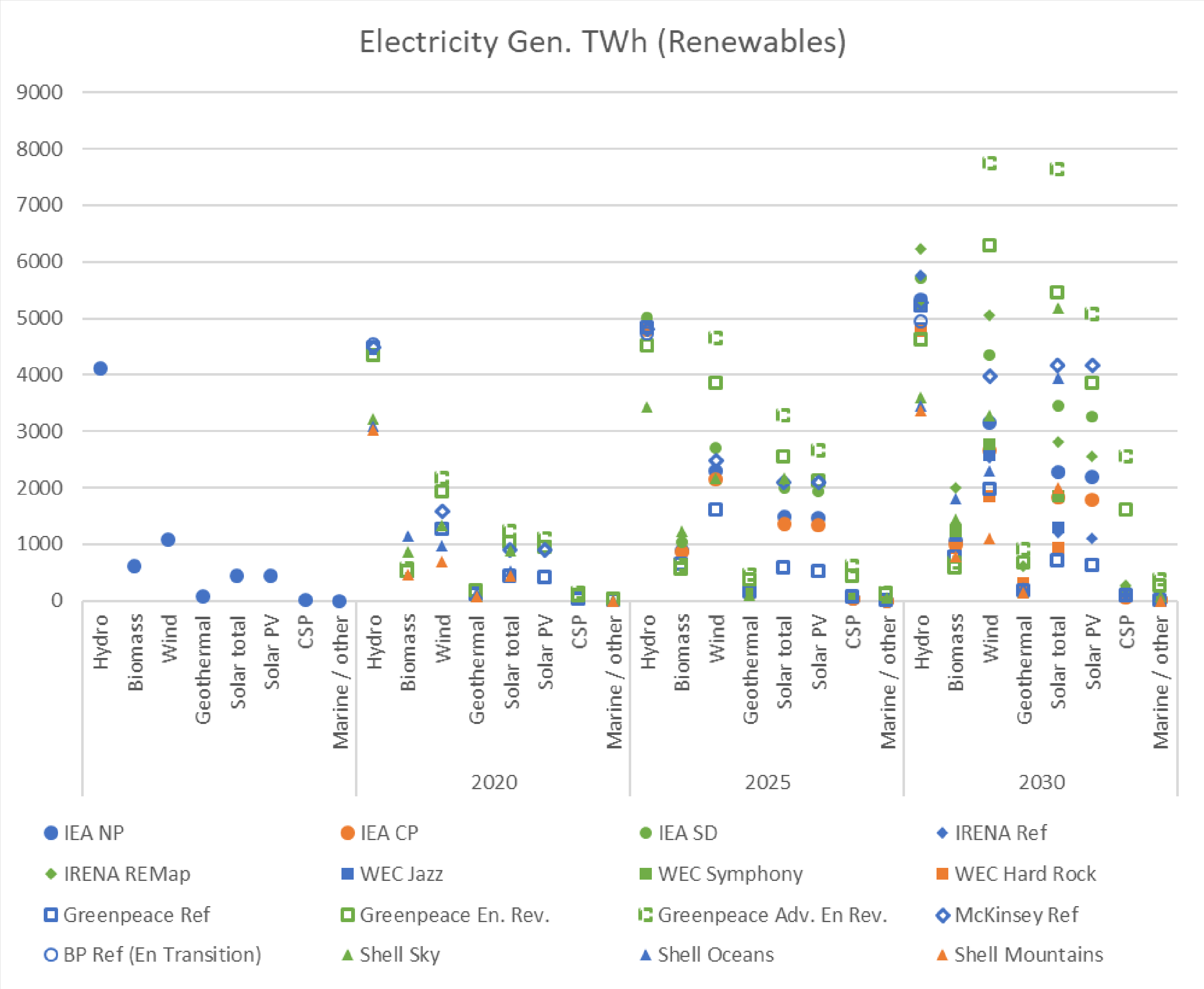


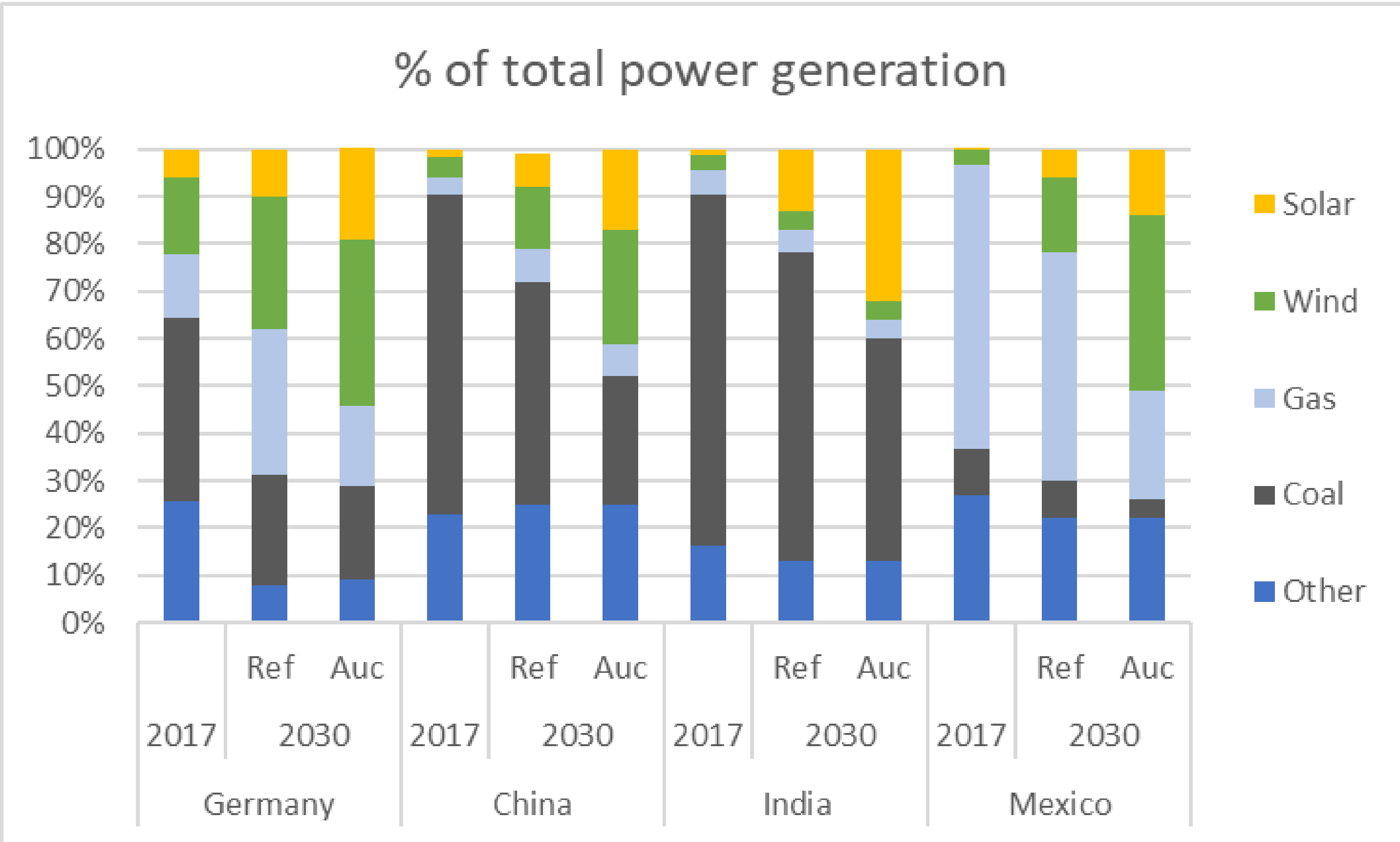
Table 1: Share of each technology in the generation mix 2030 – average of all scenarios

	2017	2030 Reference scenarios	2030 'Green' scenarios	2030 'Slower progress' scenarios
Coal	38%	33%	22%	34%
Gas	23%	23%	21%	24%
Oil	4%	2%	1%	2%
Nuclear	10%	11%	10%	12%
All Renewables	25%	34%	46%	28%
Hydro	16%	15%	16%	14%
Biomass	2%	3%	4%	3%
Wind	4%	8%	13%	6%
Geothermal	0%	1%	1%	1%
Solar total	2%	7%	12%	5%
Solar PV	2%	6%	10%	6%
CSP	0%	0%	2%	0%

Cost scenarios

Future uptake of renewable energy will clearly be sensitive to technology costs, though the relationship is complex. Although many of the policy, institutional and market assumptions made by the scenarios above would have at least indirect impacts on technology cost, only one of the scenarios studied singled out technology cost specifically as a separate driver of market uptake of renewables. This is the McKinsey 'auctions as reality' scenario which identifies the uptake that would occur if the recent low-priced outcomes of various auctions held around the world were reflective of actual realised market prices. This scenario reflects some uncertainty about whether observed auction results are realistic assessments of the state of technology costs, or whether there is a risk that project developers have been overoptimistic in their bidding. The 'auctions' scenario is only provided in the public domain for Germany, China, India and Mexico (Figure 21). Taking the combined solar and wind components, the McKinsey scenarios suggest that based solely on price sensitivity, uptake of renewables on average[8] across these countries could be as much as double the amount indicated in the reference scenario if recent auction prices are realised in the wider market. This suggests that technology prices are at least as significant as policies and wider enabling market conditions as a driver of renewables uptake. In practice, renewables policies, and technology costs are intimately related through economies of scale as market shares increase. Further information on the outcomes of recent auctions is provided in the more detailed technology discussions in the following section.

Figure 21: McKinsey technology cost scenarios show uptake is sensitive to technology cost assumptions, cheaper results in more renewables used



Source: McKinsey, 2018

[8] Weighted by countries' 2017 electricity generation

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