

World Energy Investment 2020



INTERNATIONAL ENERGY AGENCY

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Abstract

The worldwide economic shock caused by the Covid-19 pandemic is having widespread and often dramatic effects on investments in the energy sector. Based on the latest available data, the International Energy Agency's *World Energy Investment 2020* provides a unique and comprehensive perspective on how energy capital flows are being reshaped by the crisis, including full-year estimates for global energy investment in 2020.

Now in its fifth edition, the *World Energy Investment* report is the annual IEA benchmark analysis of investment and financing across all areas of fuel and electricity supply, efficiency, and research and development. In addition to a full review of the 2019 trends that preceded the crisis, this year's analysis highlights how companies are now reassessing strategies – and investors repricing risks – in response to today's profound uncertainties and financial strains.

The energy industry that emerges from this crisis will be significantly different from the one that came before. The vulnerabilities and implications vary among companies, depending on whether they are investing in fossil fuels or low-carbon technologies, as well as across different countries. The new report assesses which areas are most exposed and which are proving to be more resilient. The analysis also provides crucial insights for governments, investors and other stakeholders on new risks to energy security and sustainability, and what can be done to mitigate them.

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Introduction

Introduction

The worldwide shock caused by the coronavirus (Covid-19) pandemic has drastically altered the course of the global economy and energy markets. In response, this year's *World Energy Investment (WEI)* has expanded its coverage to integrate the latest data and insights on the unfolding crisis in 2020, in addition to a full review of 2019.

As the International Energy Agency's (IEA) annual benchmark for tracking energy capital flows, the focus in this report is on investment and financing trends across all areas of energy supply, efficiency, and research and development (R&D). Our aim is to provide timely and authoritative data and analysis to policy makers, investors and other stakeholders, as well as insights on risks to energy security and sustainability, and what can be done to mitigate them.

Broadening the scope of the *World Energy Investment* to include a perspective on 2020 requires a view on the severity and duration of the ongoing public health crisis and economic slowdown, and recognition of the huge uncertainty that surrounds these factors. The assumptions that underpin this analysis follow those of the IEA *Global Energy Review 2020*, released in April (IEA, 2020a), which assessed energy and emissions trends for the year.

The baseline expectation for 2020 is a widespread global recession caused by prolonged restrictions on mobility and social and economic activity. With a gradual opening up of economies currently under lockdown, the recovery is U-shaped and accompanied by a substantial permanent loss of economic activity. Global gross domestic product (GDP) is assumed to decline by 6% in 2020, an outlook broadly consistent with the International Monetary Fund (IMF) longer outbreak case (IMF, 2020).

The effects on energy investment in this scenario come from two directions. First, spending cuts due to lower aggregate demand and reduced earnings; these cuts have been particularly severe in the oil industry, where prices have collapsed. Second, the practical disruption to investment activity caused by lockdowns and restrictions on the movement of people and goods.

Our assessment of 2020 trends is based the latest available investment data and announcements by governments and companies, as of mid-May (including first-quarter company reporting), tracking of progress with individual projects, interviews with leading industry figures, and incorporates also the latest insights and analysis from across IEA work. Our estimates for 2020 then quantify the possible implications for full-year spending, based on assumptions about the duration of lockdowns and the shape of the eventual recovery.

There is some potential upside to this assessment if medical and macroeconomic crisis management efforts are more successful than in our base case, allowing for a more rapid V-shaped economic recovery and a more pronounced pickup in investment activity in the latter part of the year.

By the same token, there is also the distinct possibility of an even more profound slump in investment spending, especially in the event that a second wave of infections later in the year prompts renewed restrictions and lockdowns. Whichever ways events unfold, policy responses – whether targeting energy or the economy at large – will have a major impact on the outcome.

Introduction: The global energy and emissions picture in 2020

The impacts of the Covid-19 crisis on energy demand and emissions provide an essential backdrop to this *World Energy Investment* report. The most pertinent elements of this picture are summarised here, and described in more detail in the IEA *Global Energy Review 2020*.

A key insight from the analysis of daily data (through mid-April) is that countries in full lockdown are experiencing an average 25% decline in energy demand relative to typical levels and countries in partial lockdown an average 18% decline.

Oil is bearing the brunt of this shock because of the curtailment in mobility and aviation, which represent nearly 60% of global oil demand. At the height of the lockdowns in April, when more than 4 billion people worldwide were subject to some form of confinement, year-on-year demand for oil was down by around 25 mb/d. For the year as a whole, oil demand could drop by 9 mb/d on average, returning oil consumption to 2012 levels.

After oil, the fuel most affected by the crisis is set to be coal. Coal demand could decline by 8%, not least because electricity demand is estimated at nearly 5% lower over the course of the year. The recovery of coal demand for industry and electricity generation in the People's Republic of China (hereafter, "China") could offset larger declines elsewhere.

The impact of the pandemic on gas demand in the first quarter of the year was more moderate, at around 2% year-on-year, as gas-based economies were not strongly affected. But gas demand could fall

much further across the full year than in the first quarter, with reduced demand in power and industry applications.

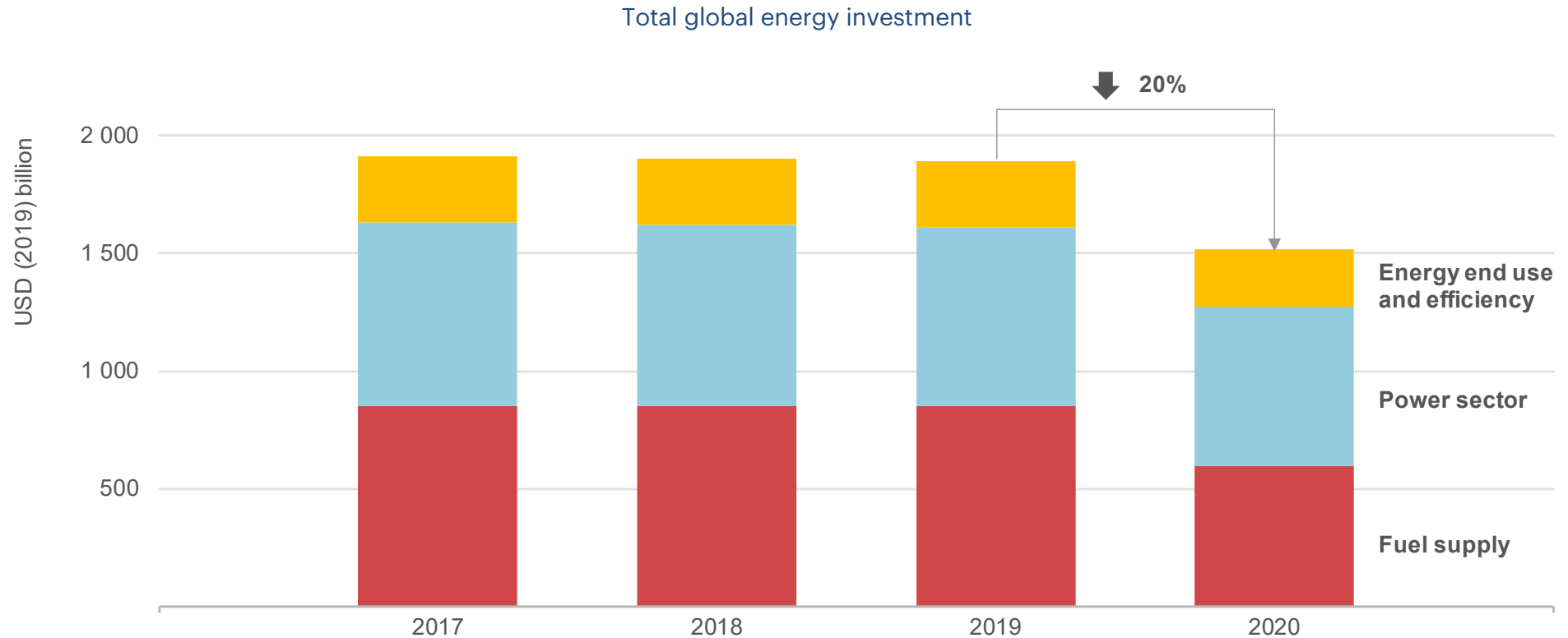
In the electricity sector, demand has been significantly reduced as a result of lockdown measures, with knock-on effects on the power mix. Electricity demand has been depressed by 20% or more during periods of full lockdown in several countries, as upticks for residential demand are far outweighed by reductions in commercial and industrial operations. Demand reductions have lifted the share of renewables in the electricity supply, as their output is largely unaffected by demand. Demand has fallen for all other sources of electricity, including coal, gas and nuclear power.

For the year as a whole, output from renewable sources is expected to increase because of low operating costs and preferential access to many power systems. Nuclear power is expected to decline somewhat in response to lower electricity demand. In aggregate, this would mean that low-carbon sources far outstrip coal-fired generation globally, extending the lead established in 2019.

Global CO₂ emissions are expected to decline by 8%, or almost 2.6 Gt, to the levels of ten years ago. Such a year-on-year reduction would be the largest ever, six times larger than the previous record reduction of 0.4 Gt in 2009 – caused by the global financial crisis – and twice as large as the combined total of all previous reductions since the end of World War II. After previous crises, the rebound in emissions has been larger than the initial decline. Whether this is the case also on this occasion is largely contingent on what happens to energy investment.

Overview and key findings

Energy investment is set to fall by one-fifth in 2020 due to the Covid-19 pandemic

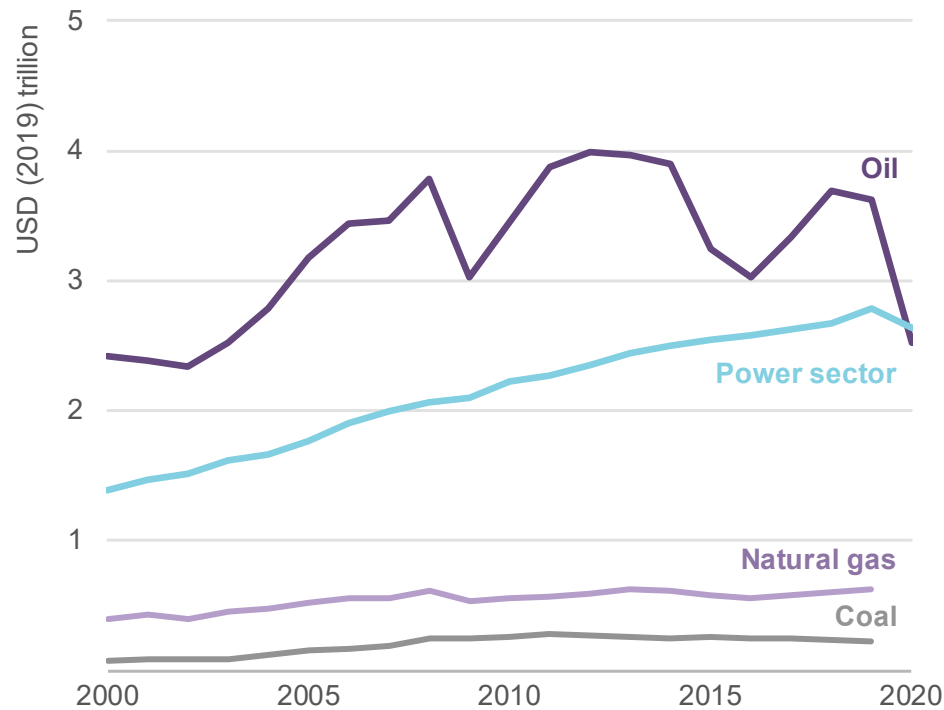


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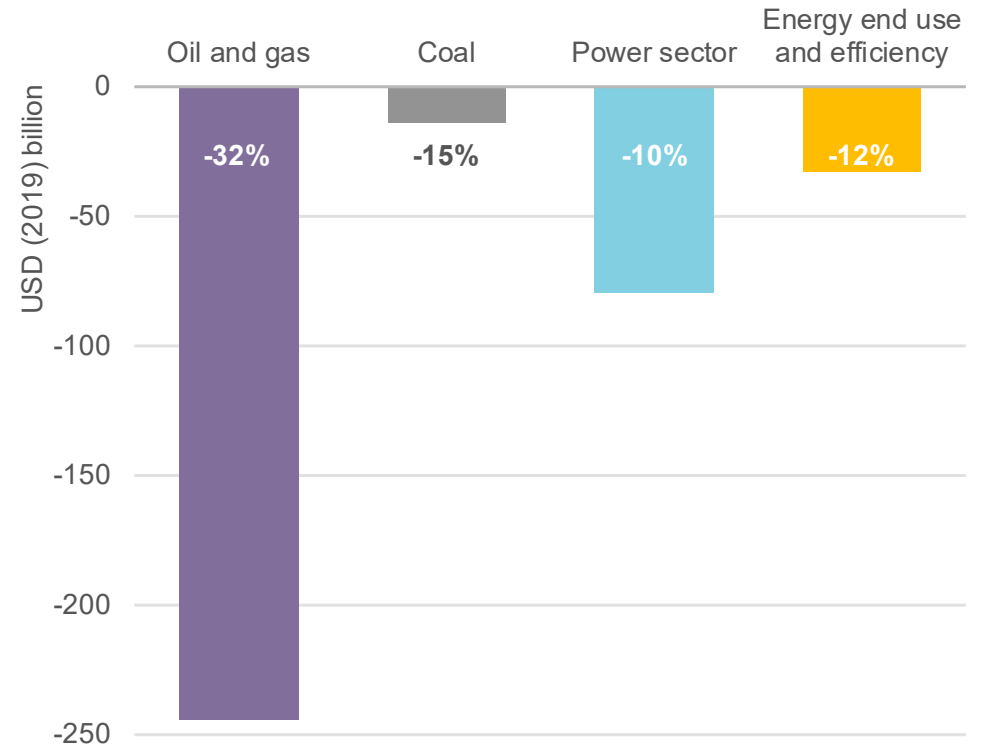
Notes: Investment is measured as the ongoing capital spending in energy supply capacity and, in the case of energy efficiency, the incremental spending on more efficient equipment and goods. The scope and methodology for tracking energy investments is available [here](#). “Fuel supply” includes all investments associated with the production, transformation and provision of solid, liquid and gaseous fuels to consumers; these consist mainly of investments in oil, gas and coal supply, but include also biofuels and other low-carbon fuels. “Power sector” includes the capital spending on all power generation technologies, as well as ongoing investments in grids and storage. “Energy end use and efficiency” includes the investment in efficiency improvements across all end-use sectors, as well as end-use applications for renewable heat.

Investment activity has been disrupted by lockdowns but also by a sharp fall in revenues, especially for oil

Global end-use spending on energy



Change in estimated 2020 investment versus 2019, by sector



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Pre-crisis expectations of modest growth have turned into the largest fall in global energy investment on record

The speed and scale of the fall in energy investment activity in the first half of 2020 is without precedent. Many companies reined in spending; project workers have been confined to their homes; planned investments have been delayed, deferred or shelved; and supply chains interrupted.

At the start of the year, our tracking of company announcements and investment-related policies suggested that worldwide capital expenditures on energy might edge higher by 2% in 2020. This would have been the highest uptick in global energy investment since 2014. The spread of the Covid-19 pandemic has upended these expectations, and 2020 is now set to see the largest decline in energy investment on record, a reduction of one-fifth – or almost USD 400 billion – in capital spending compared with 2019.

Almost all investment activity has faced some disruption due to lockdowns, whether because of restrictions on the movement of people or goods, or because the supply of machinery or equipment was interrupted. But the larger effects on investment spending in 2020, especially in oil, stem from declines in revenues due to lower energy demand and prices, as well as more uncertain expectations for these factors in the years ahead.

Oil (50%) and electricity (a further 38%) were the two largest components of worldwide consumer spending on energy in 2019. However, we estimate that spending on oil will plummet by more than USD 1 trillion in 2020, while power sector revenues drop by USD 180 billion (with demand and price effects accompanied in many countries by a rise in non-payment). Among other implications, this would mean an historic switch in 2020 as electricity becomes the largest single element of consumer spending on energy.

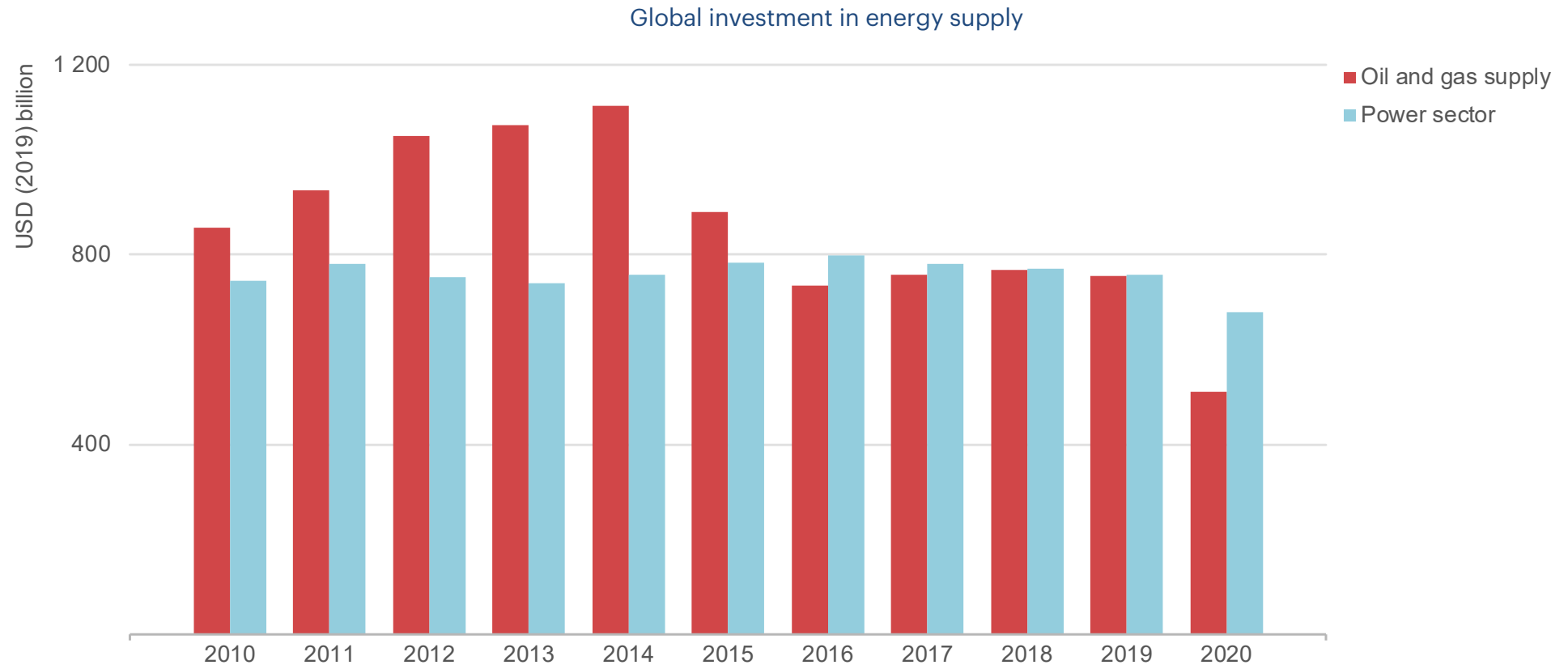
Not all of these declines are felt directly by the energy industry. Energy-related government revenues – especially in the main oil and gas exporting countries – have been profoundly affected, with knock-on effects on the budgets available to state-owned energy enterprises.

The revisions to planned spending have been particularly brutal in the oil and gas sector, where we estimate a year-on-year fall in investment in 2020 of around one-third. This has already triggered an increase in borrowing as well as the likelihood that restrained spending will continue well into 2021.

The power sector has been less exposed to price volatility, and announced cuts by companies are much lower, but we estimate a fall of 10% in capital spending. In addition, sharp reductions to auto sales and construction and industrial activity are set to stall progress in improving energy efficiency.

Overall, China remains the largest market for investment and a major determinant of global trends; the estimated 12% decline in energy spending in 2020 is muted by the relatively early restart of industrial activity following strong lockdown measures in the first quarter. The United States sees a larger fall in investment of over 25% because of its greater exposure to oil and gas (around half of all US energy investment is in fossil fuel supply). Europe's estimated decline is around 17%, with investments in electricity grids, wind and efficiency holding up better than distributed solar PV and oil and gas, which see steep falls. Developing countries, especially those with significant hydrocarbon industries, see the most dramatic effects of the crisis, as falling revenues pass through more directly to lower funds for investment.

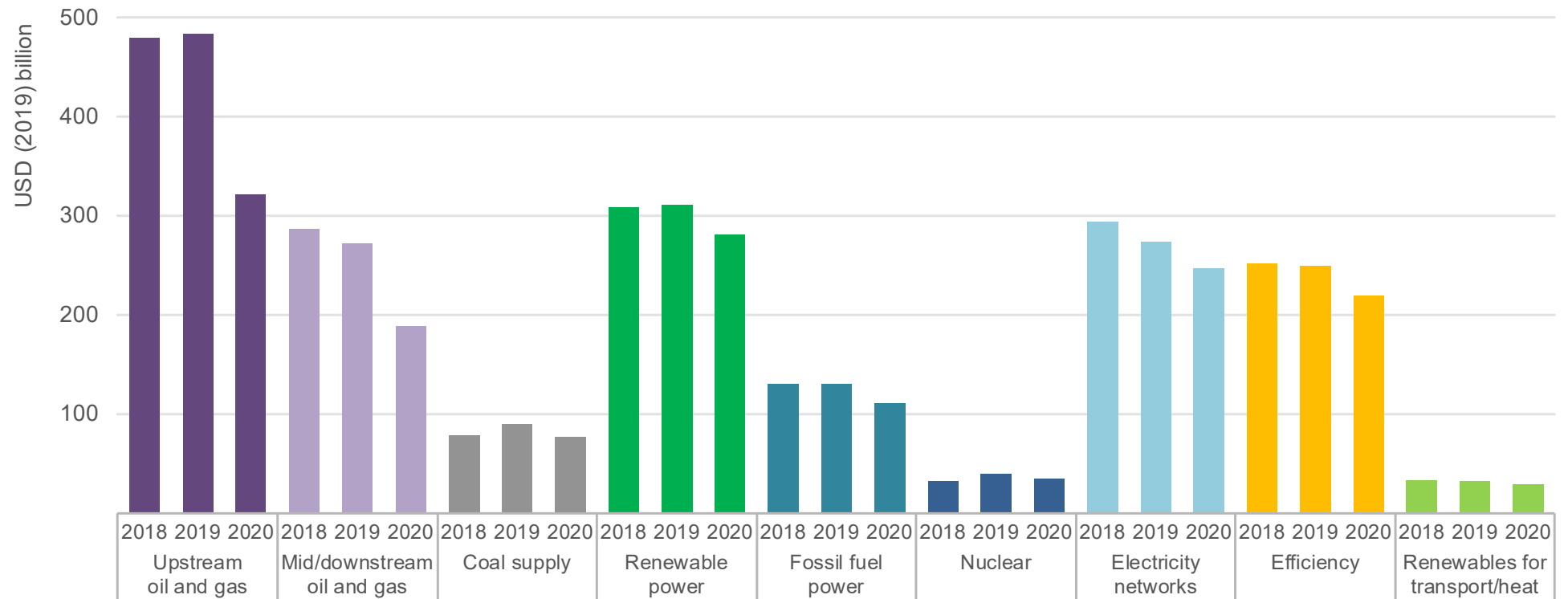
Over the last ten years, power sector spending has been relatively stable compared with the rollercoaster ride for oil and gas



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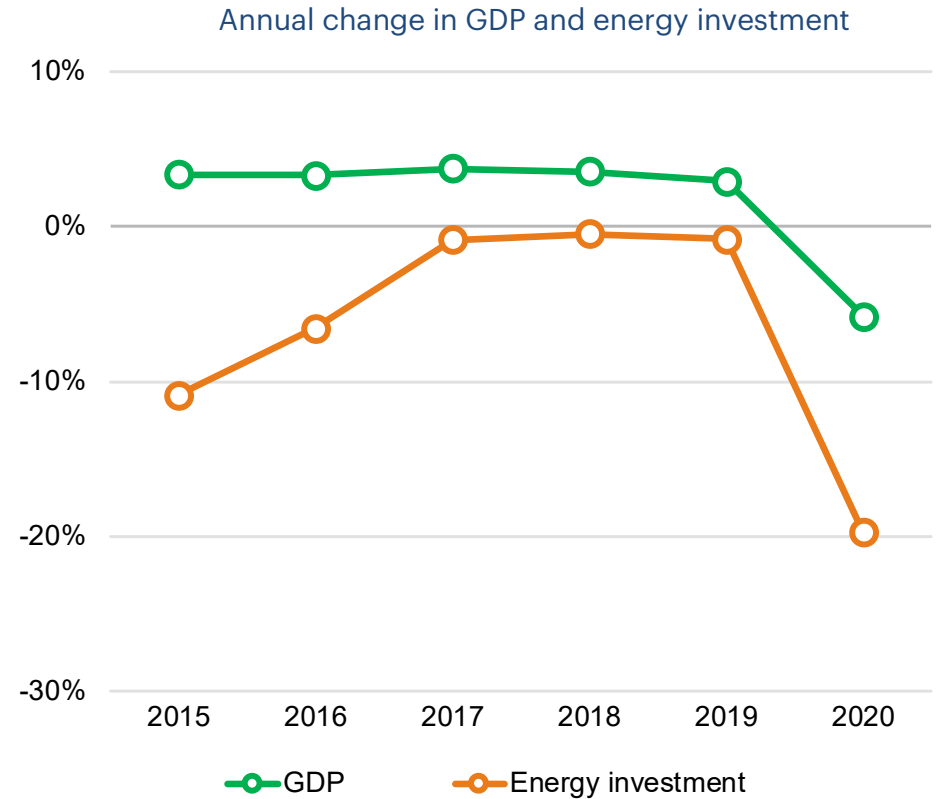
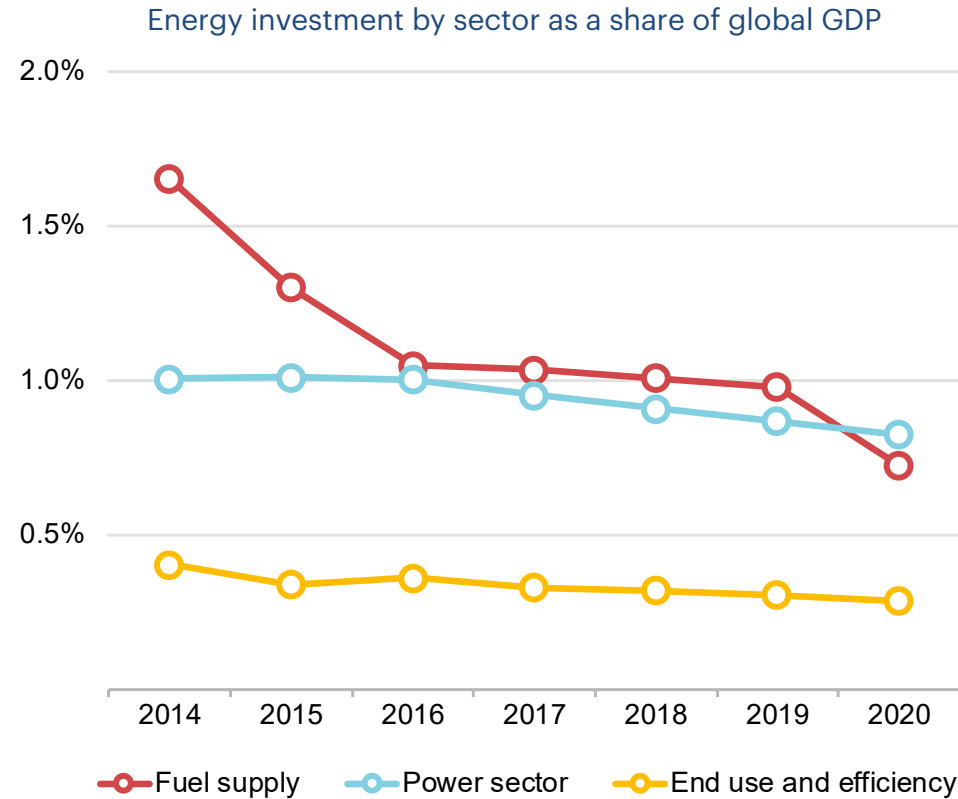
Fuel supply investments have been hit hardest in 2020 while utility-scale renewable power has been more resilient, but this crisis has touched every part of the energy sector

Energy investment by sector



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Energy should be in the front line of the world's push for sustainable development, but the investment data reveal a harsher reality



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The crisis has underscored existing vulnerabilities and created new uncertainties

Investment in fuel supply has fluctuated markedly over the last decade, with typical cyclical elements common to all commodities overlaid with growing structural pressures to reduce emissions and switch to cleaner technologies. By contrast, investment in the electricity sector has been more stable, buoyed by its central place in economic development and energy transition strategies, and by growth in electricity demand that has consistently outpaced overall energy demand. For the fifth year in a row, investment in power is set to exceed that in oil and gas supply.

The cuts in fuel supply investment in 2020 apply to all types of resources and company, but a few elements stand out. Some of the most dramatic cuts in the oil and gas sector – in many cases above 50% – have been among highly leveraged shale players in the United States, for whom the outlook is now bleak (although it is too soon to write off shale as a whole). Funds available to some indebted and poorly performing national oil companies (NOCs) have also dried up, as governments scramble to make up for acute shortfalls in revenue.

Further downstream, a surge in investment in recent years in refining, petrochemicals and liquefied natural gas (LNG) has left each of these sectors now facing a major overhang of capacity, putting intense pressure on margins and pushing back many investment plans and timelines. Natural declines in upstream fields offer a hedge against overinvestment, but there is no such protection further down the value chain against demand coming in below expectations.

In the power sector, the ability of many companies to invest in new capacity has also been weakened by this crisis. This is particularly true of state-owned enterprises (SOEs) in emerging economies, many of which were already under financial stress, as well as equipment suppliers. Larger renewables-focused utilities in advanced economies

appear on firmer footing, but also face some revenue risks from shifting market demand and price trends.

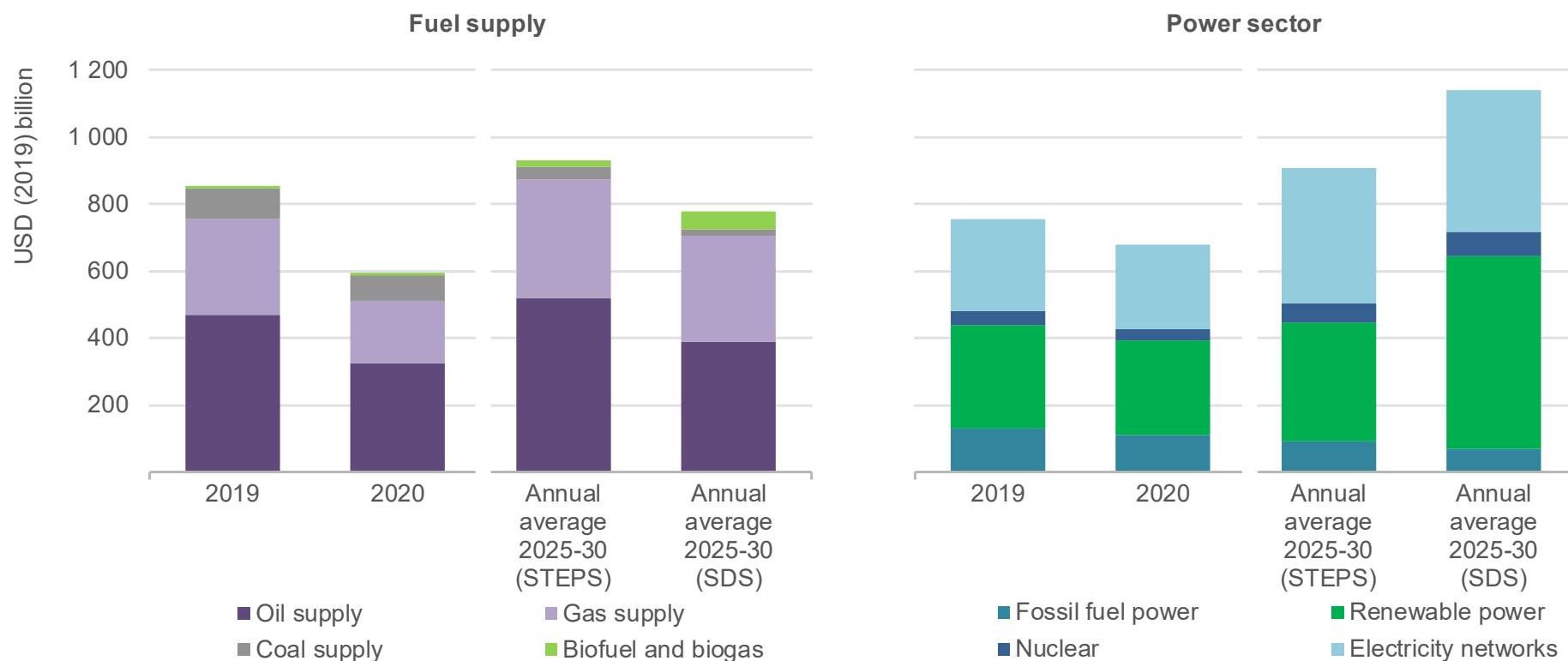
Overall, ongoing investment in renewable power projects is expected to fall by around 10% for the year, less than the decline in fossil fuel power. Capacity additions are set to be lower than 2019 as project completions get pushed back into 2021. Final investment decisions (FIDs) for new utility-scale wind and solar projects slowed in the first quarter of 2020, back to 2017 levels. Distributed solar investments have been more dramatically hit by lower consumer spending and lockdowns.

The crisis is prompting a further 9% decline in estimated global spending on electricity networks, which had already fallen by 7% in 2019. Alongside a slump in approvals for new large-scale dispatchable low-carbon power (the lowest level for hydropower and nuclear this decade), stagnant spending on natural gas plants, and a levelling off of battery storage investment in 2019, these trends are clearly misaligned with the needs of sustainable and resilient power systems.

There are also some worrying signs in the data for the energy sector as a whole. In recent years the share of energy investment in GDP has declined and is set to fall to under 2% in 2020 – down from around 3% in 2014. Economy-wide investment also declined as a share of GDP over this period, but the declines in energy have been particularly steep. In part, this reflects a retreat from the boom years of oil and gas spending in the earlier part of this decade. However, the trend is visible too in the power sector and elsewhere, reflecting the lack of progress in boosting key clean energy technologies at the pace required by rising global needs and the imperative to address climate change.

Even before 2020, investment trends were poorly aligned with the world’s projected needs

Global energy supply investment by sector in 2019 and 2020 compared with annual average investment needs 2025-30

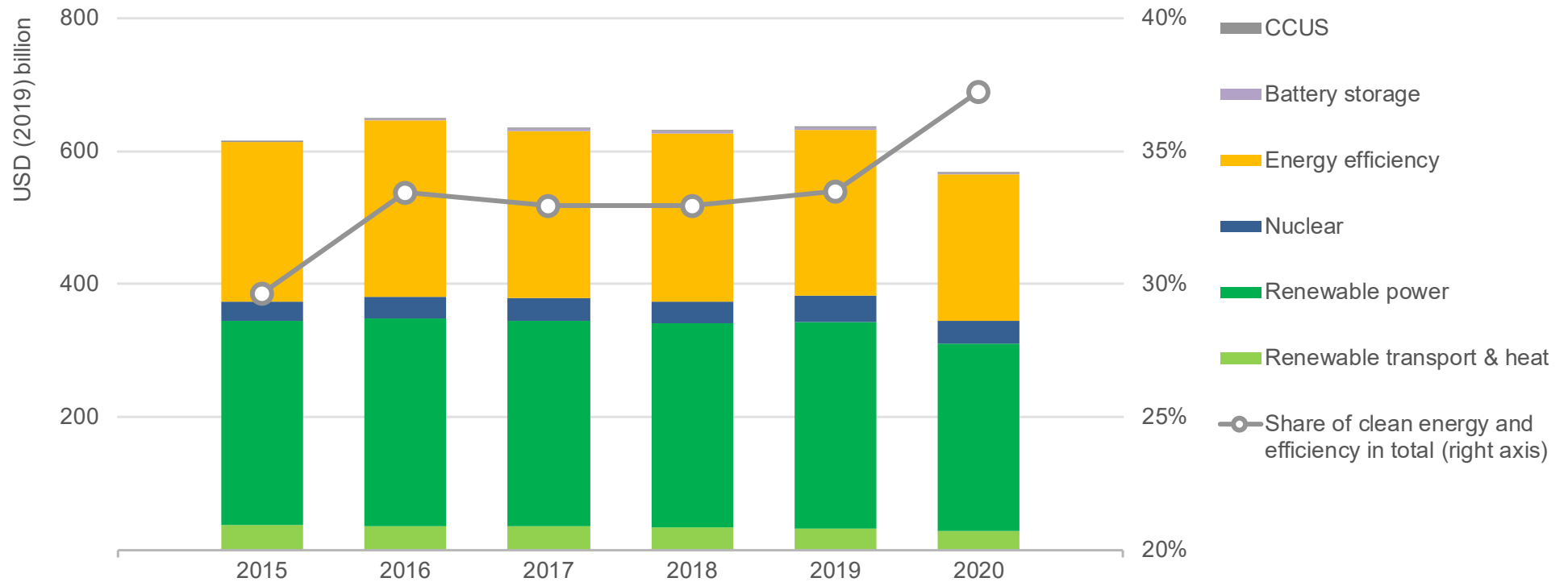


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Notes: STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario. Electricity networks include also battery storage investment. Projected investment levels are from the *World Energy Outlook 2019*; the point of comparison is the period from 2025-30 in order to provide an indicative post-recovery benchmark for spending levels.

Clean energy investment has been relatively resilient in the downturn, but a flat trend of spending since 2015 is far from enough to bring a lasting reduction in emissions

Global investment in clean energy and efficiency and share in total investment



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Note: CCUS = Carbon capture, utilisation and storage.

The implications of the current investment slump depend on the speed and sustainability of the world's economic recovery

The Covid-19 pandemic has brought with it a major fall in demand, with high uncertainty over how long it will last. Under these circumstances, with overcapacity in many markets, a cut in new investment becomes a natural and even a necessary market response.

However, the slump in investment may not turn out to be proportional to the demand shock, and the lead times associated with energy investment projects mean that the impact of today's cutbacks on energy supply (or demand, in the case of efficiency) will be felt only after a few years, when the world may be well into a post-recovery phase. As such, there is a risk that today's cutbacks lead to future market imbalances, prompting new energy price cycles or volatility.

In addition, even before the crisis, the flow of energy investments was misaligned in many ways with the world's future needs. Market and policy signals were not leading to a large-scale reallocation of capital to support clean energy transitions. There was a large shortfall in investment, notably in the power sector, in many developing economies where access to modern energy is not assured. Although today's crisis in some ways represents an opportunity to change course, it also has the potential to exacerbate these mismatches and take the world further away from achieving its sustainable development goals.

The implications in practice will depend on a few key variables. The duration of the disruptions to economic activity and the shape of the recovery are major uncertainties. So too are the policy response to the crisis and, crucially, the extent to which energy investment and sustainability concerns are baked into recovery measures. Among

consumers, it remains to be seen whether the crisis has fundamentally reset views on mobility, tourism, or working and shopping from home.

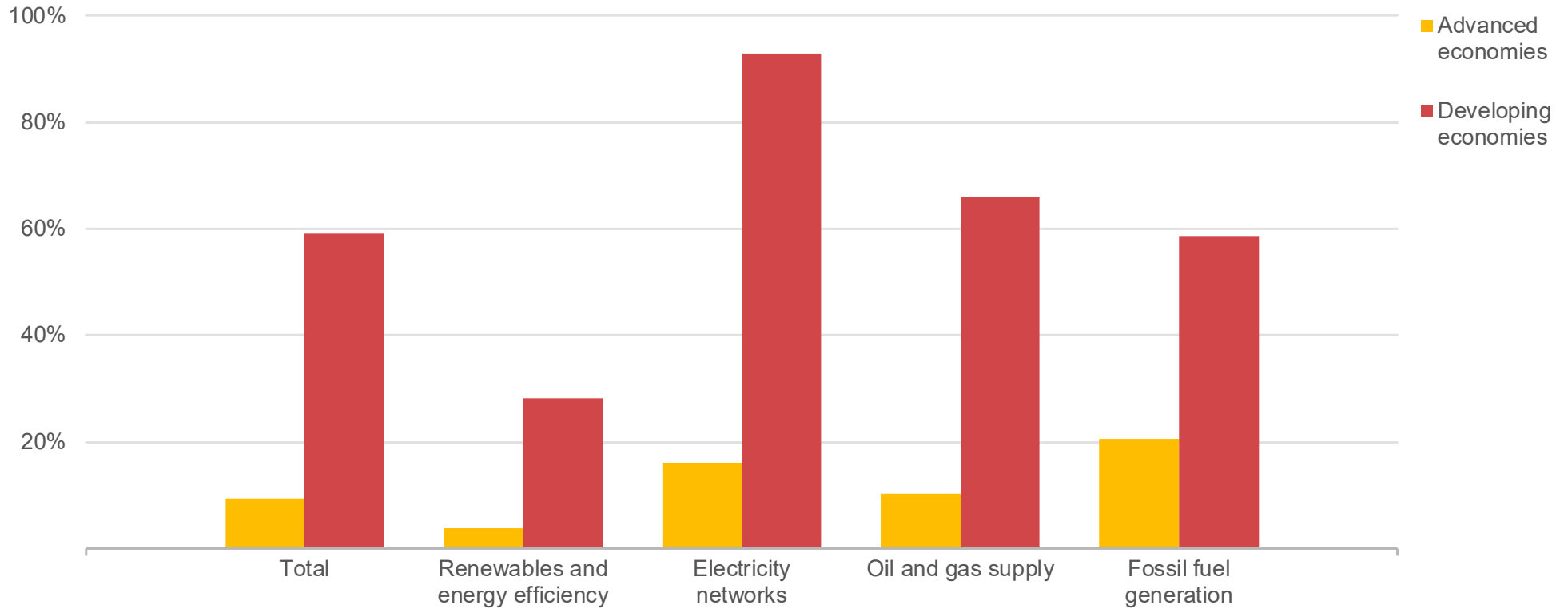
There are questions too about the shape of the post-crisis energy industry and its financial strength, strategic orientation and appetite for risk. And finally, there are the economic factors that drive investment trends, in particular whether oil prices remain low, and how quickly costs for some key clean energy technologies continue to come down.

A key indicator will be the capital going into clean energy technologies. This has been stable in recent years at around USD 600 billion per year, although unit cost reductions have meant that this is associated with a steady increase in actual deployment for some technologies such as solar photovoltaic (PV), wind and electric vehicles (EVs). Even though this "clean" spending is set to dip in 2020, its share in total energy investment is set to rise. However, these investment levels remain far short of what would be required to put the world on a more sustainable pathway. In the IEA SDS, for example, spending on renewable power would need to double by the late 2020s.

If, by contrast, the world were to return to anything like its pre-crisis pathway (as might be expected in the absence of a notable policy shift) then a different set of risks come into view. In oil markets, for example, if investment stays at 2020 levels then this would reduce the previously-expected level of supply in 2025 by almost 9 million barrels a day, creating a clear risk of tighter markets if demand starts to move back towards its pre-crisis trajectory.

The respective roles of state versus private investors vary widely in different countries ...

The share of state-owned energy investments by sector



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Note: Data are for 2019.

... and those economies most in need of investment have a narrower range of financing options

Today's crisis will inevitably leave governments and large parts of the corporate sector with larger burdens of debt. Governments are providing direct and indirect support to keep households and companies afloat, but most energy companies are set to emerge from this crisis with significantly weaker balance sheets. The natural response to these stresses is for companies to consolidate, sell assets where they can, and reassess investment and employment plans. Some of these effects could endure well beyond 2020.

How this plays out in practice will vary widely in different parts of the world, depending on the types of companies investing in energy, the fiscal space available to governments, and the broader financial and institutional environment. One of the starkest variations across different geographies is the respective roles of state versus private actors; detailed analysis in this year's report reveals that SOEs account for well over half of energy investment in developing economies, but less than 10% in advanced economies.

SOEs, in the shape of NOCs, have strong roles in global oil and gas supply investment and an even higher share of output, as their assets tend to have lower development and production costs. They also dominate the picture in many developing economies for investment in thermal generation and in electricity networks. By contrast, with the notable exception of hydropower, private actors take the lead everywhere in renewables (although many renewable projects rely on incentives set by governments and sales to state-owned utilities).

Pathways out of today's crisis depend heavily on the financial sustainability and strategic choices of these SOEs and their host governments. There is a risk that some state actors fall back on familiar levers for economic development, pushing up coal use and emissions.

Liquidity constraints could well become a lasting risk for investment, especially in long-term or capital-intensive projects.

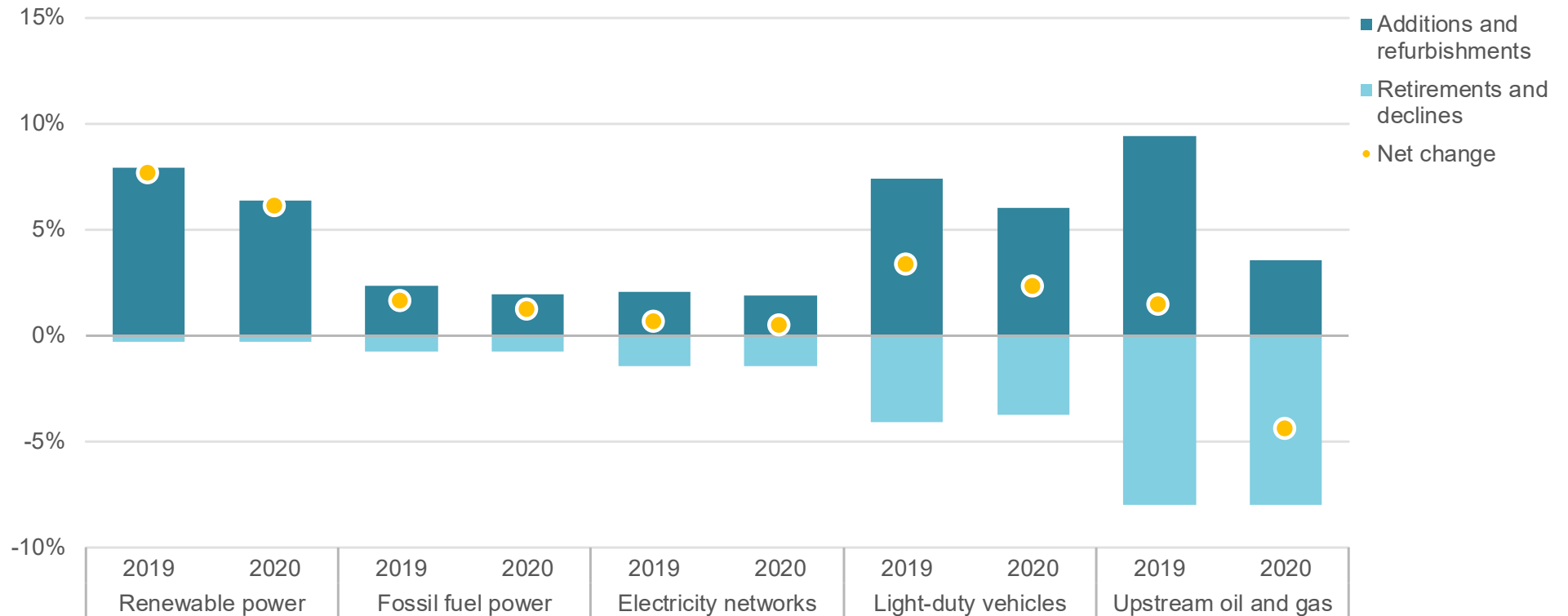
A focus on value and quick delivery, as well as environmental gains, could provide an opening for some cleaner technologies, especially in power where solar PV and wind are not only among the cheapest options for new generation, but also have relatively short investment cycles. These investments also make good sense for financial investors: new joint analysis with Imperial College London shows that renewable power companies in advanced economies have delivered higher equity returns over the past decade than those in fossil fuel supply, and weathered the storm in 2020 better as well.

However, this does not yet make 2020 a tipping point for attracting more investment to clean energy transitions. Renewables generally do not yet offer all the characteristics that investors are looking for in terms of market capitalisation, dividends or overall liquidity. Opportunities for newer sources of low-cost clean energy finance to enter the mix, e.g. from institutional investors, are still concentrated in Europe and North America. Although investments in coal power are down in many parts of the world, global approvals of new plants in the first quarter of 2020 (mainly in China) were at twice the rate seen in 2019, and there is a long pipeline of projects under construction.

The pace of change in the power sector puts it in the vanguard of energy transitions, but it does not represent the entire energy system - the share of electricity in final energy consumption is only around 20%. Alongside a rising role for low-carbon electricity, investment in a much wider range of energy technologies, including energy efficiency and low-carbon fuels for industrial heat and long-distance transport, will be crucial to reduce emissions across the energy system as a whole.

The crisis is hastening the retirement of some older plants and facilities, but also dampening consumer spending on new and more efficient technologies

Changes to the energy-related capital stock in 2019 and 2020 as a share of total stock in the preceding year



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Covid-19 is a huge shock to the energy system, but the response also presents an opportunity to steer the energy sector onto a more resilient, secure and sustainable path

Every year, a certain portion of the existing energy-related capital stock is retired or requires replacement. This applies to a wide range of energy-using equipment and infrastructure, including appliances, vehicles, buildings, large industrial machinery and power plants. It is also the case for existing oil and gas fields, which decline over time.

The speed of this turnover is a major determinant of investment flows, and it varies by sector. A large share of investment in upstream oil and gas, for example, goes just to combat declines and keep output stable, meaning that the upstream is capable of adjusting more quickly to fluctuations in demand than other parts of the hydrocarbons supply chain such as refineries or LNG plants.

Elsewhere, this rate of renewal serves as an indicator for how quickly newer, more efficient or cleaner technologies can increase their market share, e.g. high-efficiency air conditioners, or EVs or more fuel-efficient cars. There is no guarantee, however, that new purchases always follow this pattern, as demonstrated by the popularity of less-efficient sport utility vehicles (SUVs) in recent years, which has more than offset the emissions reductions from higher sales of EVs.

The current crisis, and the policy response to it, will influence the rate of change in the energy-related capital stock. The economic slowdown is putting enormous pressure on some of the more exposed parts of the global economy. A surfeit of productive capacity in some areas, at a time of suppressed demand, is accelerating the closure or idling of low-efficiency parts of the capital stock. Within the energy

sector this is already visible among refineries and in lower utilisation of some coal-fired power plants.

However, the crisis could slow the pace of change in other areas. A reluctance to commit capital to new projects could leave cash-constrained governments, companies and households using existing assets for longer, delaying the speed with which newer technologies are introduced into the system. Low oil prices and a reluctance to pay higher upfront costs could even usher in a new cycle of cheaper, less-efficient vehicles and appliances. This raises the spectre of an energy system characterised by systematic underinvestment in new technologies and overreliance instead on its existing capital stock, with all that this implies for emissions.

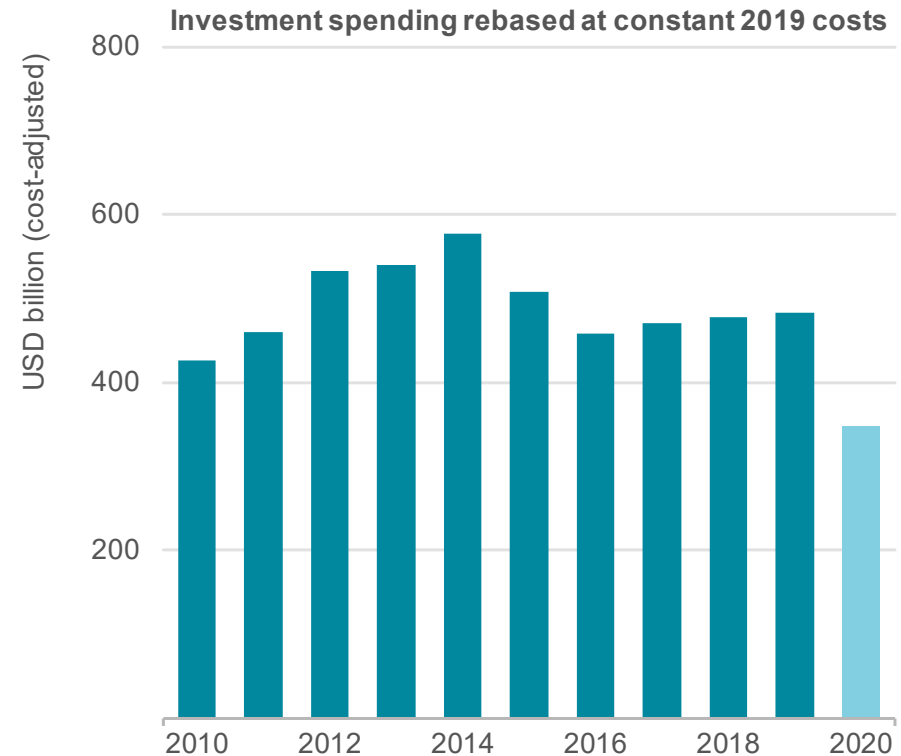
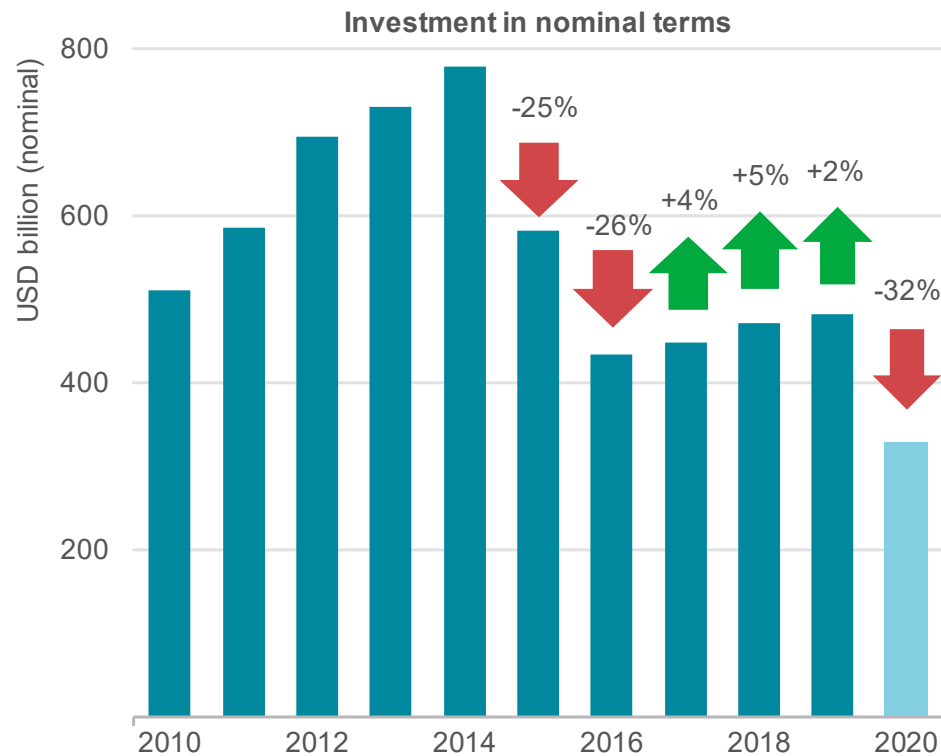
Policy makers have the opportunity to design their responses to the crisis with these elements in mind, combining economic recovery with energy and climate goals. They can kick-start consumer spending, for example by providing incentives to replace old, poorly performing products with new, more efficient models. Much-needed investment in electricity networks and storage can ensure that tomorrow's power systems remain resilient and reliable even as they are transformed by the rise of clean energy technologies. The way that policy makers respond to the crisis today will determine the energy security and sustainability hazards that the world will face tomorrow.

Fuel supply

Overview and 2020 update

Planned 2020 investments in upstream oil and gas have been slashed under pressure from the collapse in oil prices and demand

Global upstream oil and gas investment



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Note: The right-hand figure adjusts the entire time series using 2019 upstream costs; it therefore strips out the effects of underlying changes in costs over this period.

Upstream spending in 2020 is set to be down almost one-third from 2019 as the industry scrambles to adjust to an unprecedented shock

Only a few years after the major cuts seen in 2015 and 2016, investment in the oil and gas sector was hit with an even greater shock in 2020. Markets, companies and entire economies reeled from the effects of the global crisis caused by the Covid-19 pandemic, and the impacts were felt all along the global hydrocarbon supply chains.

Oil markets were hit particularly hard. The industry had to react to precipitous declines in oil demand and prices as the pandemic slashed fuel use in the transport sector, aggravated in the early months of the year by the removal of restraints on supply from the OPEC+ grouping.

Consumers in lockdown cannot take advantage of lower prices, so a traditional stabilising element in markets was missing. Instead, the task of balancing the market in 2020 fell almost entirely on the supply side. The dramatic extent of the second-quarter declines in oil consumption were well in excess of the industry's near-term capacity to adapt, even with the output deal eventually agreed by OPEC+ in April.

The crisis has forced some existing production to halt, in part because the economics do not support continued operation but also because a rapid build-up of oil stocks saturated available storage capacity in some parts of the world, even leading to negative prices at times. For some producers, there was simply no place for their oil to go.

Natural gas prices (already low before the crisis) and consumption have also been affected by lockdowns, although not to the same extent as oil. But oversupplied gas markets are likewise showing signs of strain and these pressures could intensify later in the year as gas storage facilities, already at record highs, fill up even further.

Companies have responded with sharp downward revisions to their 2020 investment. The *initial* reductions in capital expenditure average around 25% compared with the plans that had previously been outlined for the year. In our view, given continued financial stress, practical difficulties with project implementation and some disruption to supply chains, the likely net result for the global upstream sector is a drop of almost one-third in investment compared with 2019.

Following the previous oil price fall in 2014, the effect of cuts in capital expenditure were mitigated in practice by declines in upstream costs. As a result, the 40% reduction in nominal spending from 2014 to 2019 turns into a much smaller 12% reduction in upstream activity. However, the scope for further cost reductions today is much more limited, because much of the efficiency gains have already been harvested. As a result, today's declines in investment are translating more directly into reductions in activity.

The cutbacks and financial stress are especially stark among some independent US companies and shale producers, many of which were already facing demands from investors to shore up business models and improve cash flow before the recent price crash. Some producers – of shale and other resources – have hedged a portion of 2020 output at higher prices, but this protection rarely extends far into the future, and the design of some existing hedges has not provided much of a shield in these extreme market conditions.

Reductions in upstream activity have meant renewed strain on the companies that provide services and supplies to the oil and gas industry. This has been reflected in multiple announcements of layoffs.

Covid-19 lockdowns have disrupted global oil and gas investment activity and supply chains

Alongside the sharp cuts in capital expenditure, the crisis has also had practical implications for investment activity by disrupting existing investment projects and the supply chains on which they rely. These effects can be grouped into four broad categories:

- Risks to teams living and working together on existing onshore or offshore projects. Workers on these facilities typically stay in close quarters in camps or on rigs, making social distancing almost impossible. Regular rotations of staff also increase the possibilities for infections to spread. Companies have been trying to mitigate these risks with regular health screenings, by limiting the number of people on site and by extending the stays of those who remain. Even without an outbreak of the infection, the risk-mitigation measures affect the speed at which projects move ahead.
- Restrictions on movement of personnel. Companies rely on national and international mobility to staff their projects and provide services, and this has been severely curtailed. This inevitably creates delays where either the company itself, or the sending or receiving country, has introduced restrictions on travel, especially when a company is looking to start or ramp up investment activity. This has contributed to a raft of announced project delays: for example, Siccar Point Energy delayed its planned sanction date for the Cambo project, located west of Shetland, to 2021 “given the uncertainty of the global situation, including whether any people, goods and services can be mobilised”.
- Supply chain disruptions. Production and delivery of material and machinery for projects have been interrupted in some cases because of lockdowns, either because the factories themselves

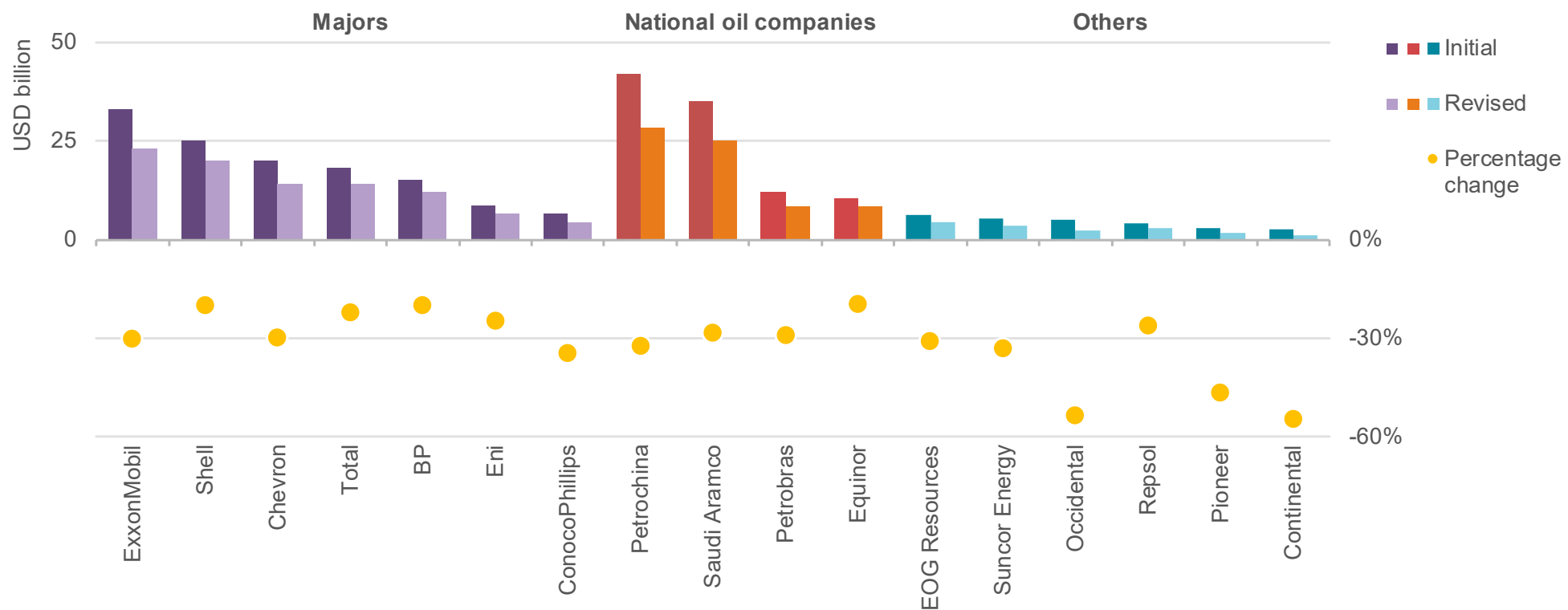
are affected or because transport (e.g. port facilities) is disrupted. For example, out of a global total of 28 floating production, storage and offloading vessels that were under construction in the first quarter of 2020, 22 were being built at shipyards in China, Korea and Singapore, all countries where industrial activity was severely affected. Likewise, the Lombardy region of Italy, which was among the first areas of Europe to be locked down, is a major manufacturing centre for specialised engineering equipment for the oil and gas industry.

- The current crisis has been an eye-opener for many companies about vulnerabilities in their supply chains: in general, local supply chains have proved beneficial, and this could have implications for investment and procurement strategies in the future.
- Delays in licensing rounds, approvals and permitting processes because of disruptions to the work of the regulatory authorities. Several countries, including Bangladesh, Brazil, India, Liberia, Senegal, South Sudan, Thailand and the United Kingdom, have already changed planned licensing round activities.

Alongside planned reductions in capital expenditure, these practical considerations are delaying start-up or implementation of many projects, representing a further downside risk to spending in 2020 as activity is pushed back into 2021 (or beyond, in some cases). This is why our estimate for upstream spending is lower than what would be suggested only by company announcements.

Planned upstream spending for 2020 has been cut across the board ...

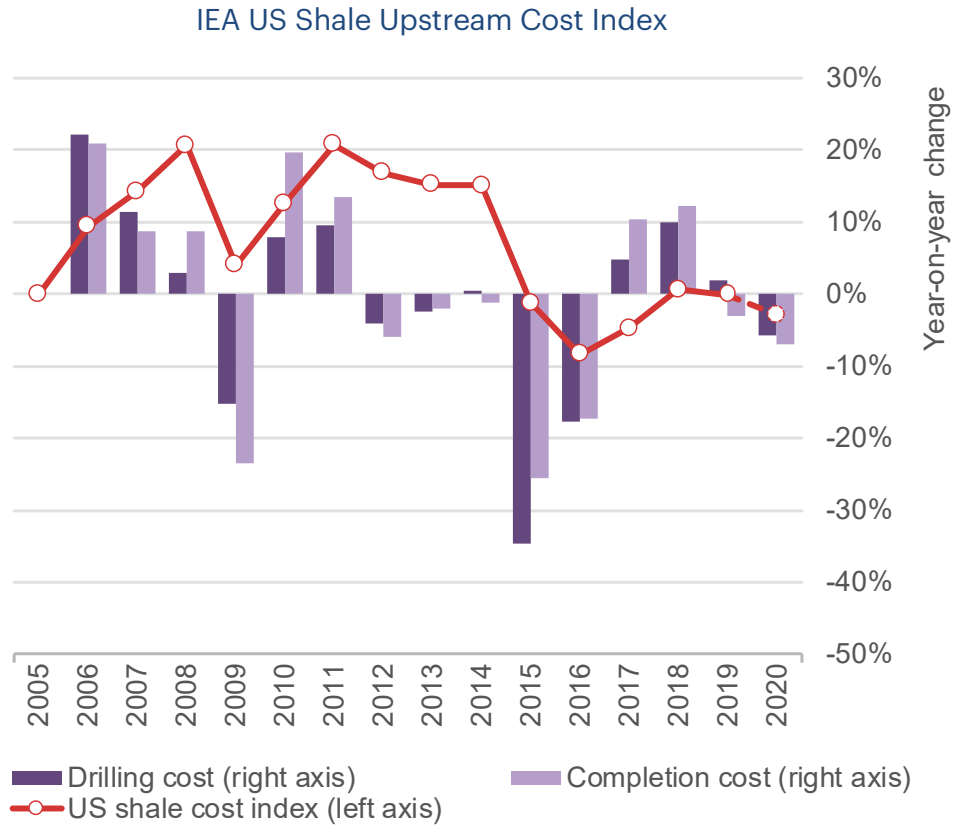
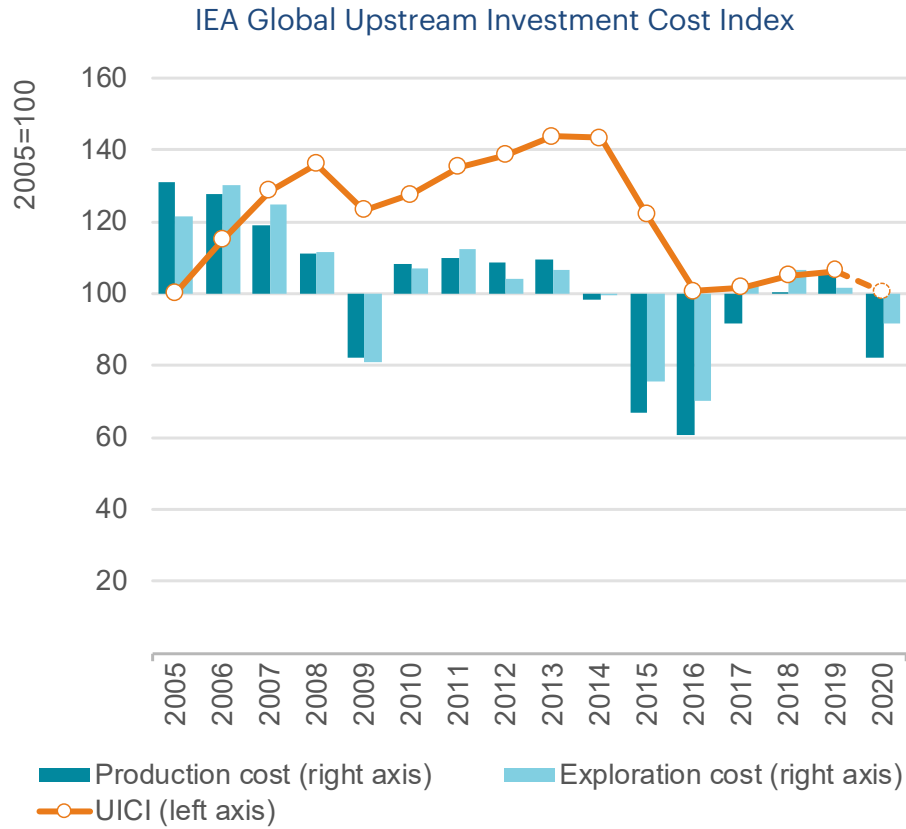
Change in announced spending for 2020 versus initial guidance for the year



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Source: IEA tracking of company announcements.

... while the scope for additional cost reductions is significantly lower than in 2015-16



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All spending commitments are undergoing renewed scrutiny, and no company or resource type has proved immune

Companies have a limited number of choices as they adjust their spending to the fall in the oil price. They can delay or shelve planned activities, or they can seek to make their activities less costly via efficiency gains or by pushing contractors to reduce costs (or by reducing their own overheads).

The pressures on companies may appear similar to those that followed the last price fall in 2014-15, but in practice the cost-cutting options open to companies today are much more constrained. The investment projects that are on the table today are already much leaner and cost-competitive than they were five years ago, having undergone intense screening in the meantime for opportunities to trim excess costs via simplified and standardised project designs.

Likewise, the oilfield services and equipment sector has undergone major streamlining over the last few years and there is much less scope for additional savings this time around. Global upstream costs are expected to drop by around 5% in 2020, largely because of anticipated reductions in engineering and project management costs as well as services, but this is much less than the headline fall in capital expenditure. Costs in the shale industry are expected to come down by a similar amount, mainly due to oversupply of rigs and pumping equipment, lower anticipated labour costs, and inflation.

The patterns of project delays and cost-cutting are visible across all types of company and all regions, but there are some strong variations in the severity of the measures taken. The largest cuts – in many cases above 50% – have been among the independent North American upstream operators, especially those in shale (see next page).

Announcements from independent companies outside North America vary quite widely but are generally lower, in the 10-25% range. Announced cuts by the Majors average more than 25%, with ExxonMobil – the Major with by far the largest announced investment spend – making the largest reduction.

There have been fewer formal announcements made by national oil companies (NOCs), but the precipitous declines in hydrocarbon revenue to the companies and their host governments are working their way through into investment plans. Adnoc and its partners have announced the cancellation of major tenders. Saudi Aramco has said that it plans to cut capital expenditure by as much as 25% from 2019's USD 33 billion.

This appears to be indicative of the overall trend among NOCs: Brazil's Petrobras and PetroChina have both announced a 30% cut in spending. The retrenchment in some places has been even more severe, for example the 50% fall in investment for Algeria's Sonatrach. Russian companies are also exposed to the crisis, although investment spending has been supported by a devaluation of the rouble (which effectively means a reduction in dollar-denominated costs) and also by the structure of the tax system, in which the government absorbs most of the hit when oil prices fall.

The shock has been most severe for some smaller and medium-sized North American operators, although it's too soon to write the obituary for shale

The latest downturn has been painful across the board, but there are three parts of the industry that are particularly vulnerable. First, medium-sized and smaller companies in North America – often heavily invested in shale – that had been under financial pressure already before the price collapse. Second, weaker NOCs in countries that are heavily reliant on hydrocarbon revenues. And third, the service companies that are bearing the brunt of the cutbacks in capital expenditure.

The shale industry as a whole was struggling to generate significant free cash flow at prices above USD 50/bbl (West Texas Intermediate [WTI]), so it is no surprise that at oil prices of USD 30/bbl or less, the outlook for many highly leveraged shale companies looks bleak. Some are already seeking bankruptcy protection, with Whiting Petroleum being the first of the larger producers to do so, and strains will intensify for a good portion of the sector (see also the Energy Financing and Funding section). We estimate that upstream spending on shale (tight oil and shale gas) is set to decline by 50% year-on-year in 2020.

Unlike in 2014-16, today there are few prospects for companies to sell upstream assets as a way to service debt or raise capital. The fall in the oil price also means that companies that use reserve-based lending face a significant revision in their value of available debt. This will hit small and medium-sized companies particularly hard (not just in shale). With the possibility of more constrained access to capital in the future, one consequence of the current crisis may well be a consolidation of the industry towards larger players with deeper pockets.

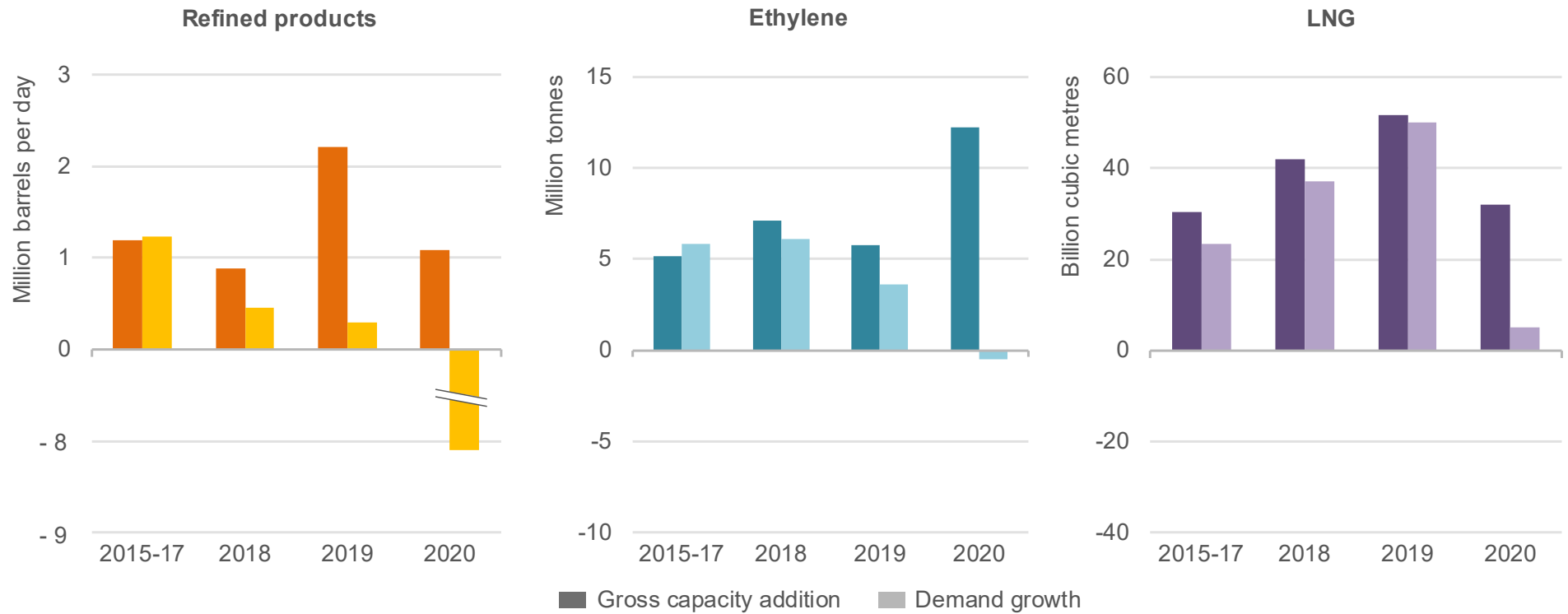
The damage to investor confidence and to available financing will take time to repair, but it is too soon to write off shale. Drilling new wells would naturally require a rebound in prices (for most plays and operators, well into the USD 40s/bbl), but shale has proven its resilience in the past and investment can pick up when market conditions allow. After a wave of bankruptcies, though, it will be a different industry from the one that we have known until now.

Some indebted and poorly performing NOCs are also being hit very hard by the current crisis, with knock-on effects on host governments that rely on oil and gas revenue to provide essential services. The crisis is playing havoc with reform initiatives, such as Angola's plans to restructure Sonangol and bring in new players to the country's upstream. The deterioration in asset quality could have ripple effects across the banking sector in countries such as Nigeria. In a worst case, some higher-cost NOCs risk falling into a spiral of lower revenue, investment and lower output, along the disastrous path that Venezuela's PDVSA has followed in recent years.

Companies providing services and supplies to the oil and gas industry are also facing another very difficult adjustment. Jobs servicing the shale sector are being hardest hit, but the effects would be widely felt across the industry. Petrofac, which operates extensively in the Middle East, is anticipating a "considerable impact" on demand for its services in 2020 and is reducing its own capital expenditure by 40%, alongside a 20% reduction in staff numbers.

The crisis is widening the near-term gap between capacity additions and demand growth for midstream and downstream infrastructure ...

Annual capacity/demand growth for refined products, ethylene and LNG



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Note: The 2015-17 numbers are annual average values.
 Source: IEA analysis based on S&P Global Platts (2020) (ethylene).

... raising questions about the “safe havens” of investment in petrochemicals and LNG

In recent years, investment in new refining, petrochemicals and LNG capacity had already started to run ahead of near-term growth in consumption: the effects of the crisis on demand mean that this problem of overcapacity now looms very large. There are clear opportunities in all of these sectors, especially given that longer-term demand expectations for plastics and for gas are relatively robust. However, there are risks as well given that these sectors involve large, capital-intensive investments that require high levels of utilisation over time. Unlike the production declines in the upstream, there is no natural protection against the risk of demand coming in below expectations.

New LNG project announcements had a record year in 2019, even without considering Qatar’s drive to expand its own export capacity. But these plans have now been jolted by lockdowns, weak gas demand, and falling oil and natural gas prices. The selection of contractors and partners for the Qatari projects has been pushed back; planned projects in North America face delays because of both local workforce disruption and the closure of Asian fabrication facilities making modules for the plants; and travel restrictions are preventing work from scaling up on Mozambique’s first onshore project. New project announcements, initially anticipated for 2020, are also being postponed.

A similar dynamic is visible in the petrochemical industry, where a surge of investment over the past few years (also linked in part to the shale revolution) has led to concerns about overcapacity. Prices for chemical products were falling already in 2019, and 2020 has put further pressure on the economics of production facilities. This is

likewise triggering a reassessment of the timelines for some of the planned projects that have not yet started construction.

In both LNG and petrochemicals, uncertainty around the trajectory of demand and prices and the shape of an eventual recovery from the economic slowdown are going to weigh heavily on investment decisions. By pushing down prices worldwide, the crisis has also – for a while at least – removed the competitive edge afforded to US exporters by the shale revolution. Spot natural gas prices are hovering around the short-run marginal costs of US LNG exports, and low oil prices are now erasing the traditional cost advantages that US ethane crackers have enjoyed versus their naphtha-based counterparts in Asia and Europe.

Refiners are coming under huge pressure as well. In normal times, low crude oil prices are not necessarily bad news for refiners. However, the plunge in demand really squeezes refinery margins and volumes. Refiners are responding by cutting run rates and accelerating the yield shift from gasoline, which is hardest hit by the lockdowns, to diesel.

The Majors and independent refiners are taking a hard look at planned investments and divestments. Many will re-evaluate their existing portfolios, possibly leading to another wave of closures as some refineries at the higher end of the cost curve shut down (and then struggle to reopen). This would accelerate the restructuring of the global refining industry towards regions benefiting either from cheaper inputs, such as the Middle East, or close to still-growing demand, such as in developing countries in Asia. The role of NOCs in global refining is likely to strengthen as a result.

Coal investments may not suffer quite the same volatility as oil in 2020, but low oil prices are bad news for biofuels

Shrinking coal demand, lower prices, environmental pressures and disruptions to supply chains and investment operations are set to bring a substantial decline in coal supply investment in 2020. However, the estimated 15% decline compared with 2019 is not quite as severe as those seen in oil and gas supply.

The main mitigating factor relates to China, which accounts for more than two-thirds of global spending on new coal supply. An expansion in Chinese investment in existing and new mines was the key reason behind a 15% rise in global coal supply investment in 2019. And the gradual resumption of Chinese industrial activity is a key factor limiting our estimated decline in 2020. By early March, more than 80% of China's coal mining capacity was already operational, and investment in existing and new mines has been on a cyclical upswing after a wave of consolidation and restructuring in 2016-17.

The recovery in coal demand in China for industry and electricity generation, after a sharp fall in the first quarter, is offsetting in part some profound declines elsewhere. Coal demand in Europe, North America and in some key emerging markets – including India – has fallen because of lower electricity consumption, the low marginal costs (and priority dispatch) of renewables and rock-bottom prices for natural gas. Overall, the IEA estimates that global coal demand could fall by 8% in 2020 – a higher figure than the 5% anticipated drop in electricity consumption.

The lower demand outlook is feeding through to the supply side: after holding up in the first quarter, prices for thermal coal tumbled in April. The impacts have been particularly strong in export-oriented

producers, such as Indonesia, where coal supply investments are reported to be well below the USD 7.6 billion target set by the government for the mining sector in 2020. However, this is not yet the case in China and India, where large state-owned companies follow long-term strategies driven by factors such as energy security and local jobs, which are structural considerations beyond the (longer or shorter) effects of Covid-19. Coal India, the dominant producer in India, reported an all-time high production level in March 2020.

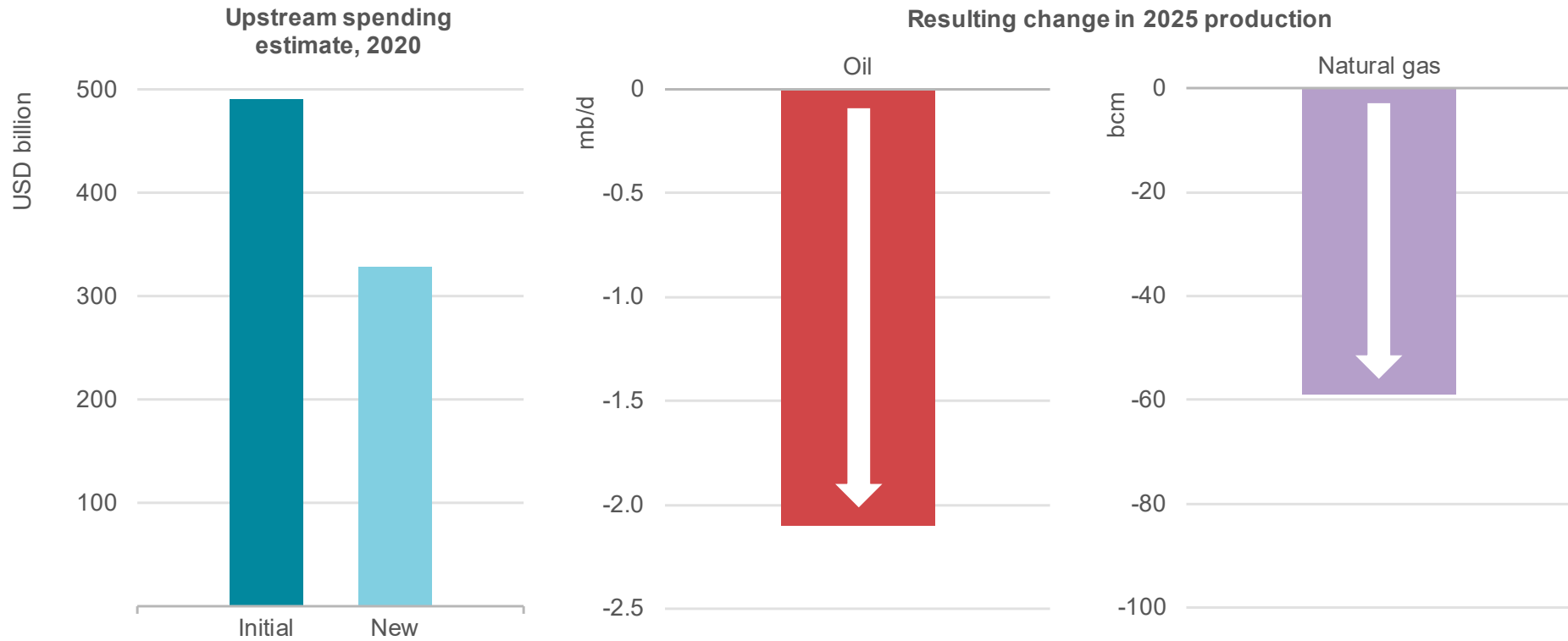
The economics of coal supply are helped somewhat by a lower oil price, as oil products represent a significant share of coal mining and transportation costs. The share of oil products in coal operating costs is technology-dependent, but typically ranges from 5-30%, i.e. a drop in oil prices of 30% would translate into a reduction of operating costs between 2-10%.

Low oil prices bring renewed uncertainty to the biofuels sector, where capital investments were already at a decade-long low in 2019. In the absence of strong policy support, the erosion of operating margins may lead to the idling of plants and a further cutback in investment until conditions improve – a trend already visible in the United States. In addition, a low oil price environment may undermine implementation of biofuel mandates and slow movement towards higher blends.

We estimate that investment in new biofuels production capacity will take another hit in 2020, well short of the levels implied by existing policy targets, let alone the amounts that would be required to help meet international climate goals.

What do the investment cutbacks mean for energy security and emissions?

Effect of lower upstream investment in 2020 on oil and gas balances in 2025



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Note: The initial estimate reflects the early guidance provided by companies as to their upstream spending for 2020, before the spread of the Covid-19 pandemic.

The answer depends on how quick and how sustainable the economic recovery proves to be

The downturn means that significant oil and gas resources that would otherwise have been available to the market in the coming years will not be there. Some of this is deferred, i.e. production that will take longer to come to market. Some of it will not come through at all, either because new projects are simply shelved or because some existing production is shut in due to the crisis and not restarted.

What does this mean for future supply-demand balances and for energy transitions? Already, the decline in investment in 2020 takes an estimated 2.1 mb/d away from anticipated oil supply in 2025, and some 60 billion cubic metres (bcm) off natural gas output. However, if investment were to stay at 2020 levels for the next five years then this would reduce the previously-expected level of oil supply in 2025 by almost 9 mb/d, and bring down natural gas output in that year by some 240 bcm.

Today's crisis could also lead to small additional losses (primarily for oil) due to production capacity that is shut-in and not regained. This would arise because of lower productivity from some tight oil wells that are shut in and then re-started, as well as permanent closure of some older, low-productivity fields with relatively high operating costs.

The implications of these reductions in future supply for market balances are highly uncertain, and depend largely on the shape of the economic recovery from the Covid-19 crisis, and the extent to which climate and sustainability concerns are baked into that recovery.

If the recovery is relatively rapid and the world returns to its pre-crisis demand trajectory, this increases the risk of an eventual tightening of markets. Previous analysis in the IEA *World Energy Outlook* and *WEI* already highlighted that investment may be falling short of what would

be required in such a scenario. The pickup in conventional project approvals in 2019 (discussed below) appeared to lessen the chances of a supply crunch, but the decline in investment in 2020 has brought this possibility back into focus.

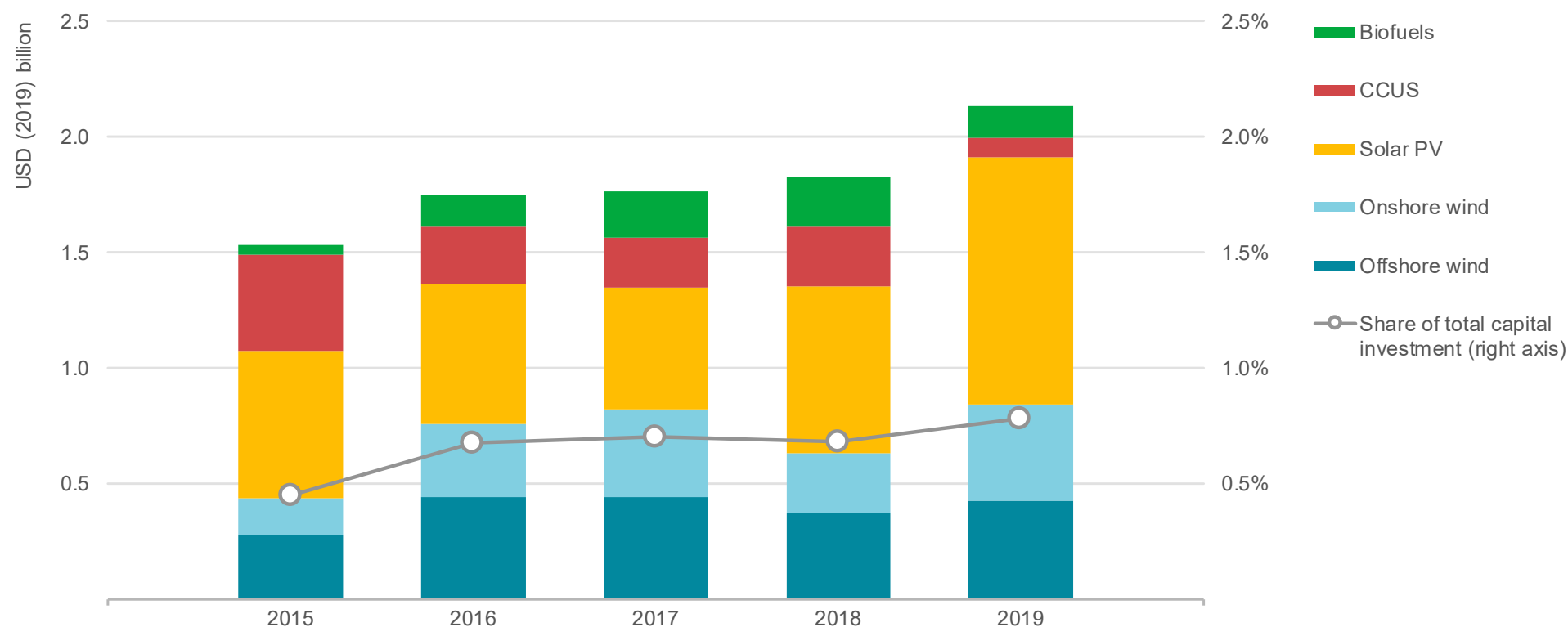
If, however, the recovery is slower or – from a more positive perspective – if efforts to kick-start economies also incorporate policies that accelerate clean energy transitions, then the risks of a future shortfall in oil and gas supply would be significantly lower. Investment in hydrocarbons is still required even in the rapid energy transitions modelled in the SDS, mainly to compensate for declining output at existing fields, but by the latter part of the 2020s upstream spending in the SDS is already a quarter below the levels in the STEPS.

The lasting implications of today's crisis also depend on the scars that it leaves on the oil and gas industry. A prolonged period of lower prices could provoke a profound industry shake-out, with weaker or higher-cost players forced to the sidelines or out of the business altogether (unless governments are willing to reduce their own take in order to ensure the viability of domestic players). A more concentrated and risk-averse industry could struggle to invest adequately in new supply, given the likelihood of continued fiscal strains in many resource-rich countries and potential investor apathy elsewhere.

From an environmental standpoint, there could be marginal gains from such a shake-out for the industry's greenhouse gas profile, as some higher-cost resources are also more emissions-intensive. However, this crisis also has the potential to squeeze the funding available for investment by the industry in cleaner energy technologies.

The crisis underlines the strategic rationale for oil and gas companies to diversify investments, but also cuts their means to do so

Capital investment by Majors and selected other companies in new projects outside oil and gas supply



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Notes: Capital investment is measured as the ongoing capital spending in new capacity from when projects start construction and are based on the owner's share of the project. Companies include the Majors and selected others (ADNOC, CNPC, CNOOC, Equinor, Gazprom, Kuwait Petroleum Corporation, Lukoil, Petrobras, Repsol, Rosneft, Saudi Aramco, Sinopec, Sonatrach). CCUS investment is in large-scale facilities; it includes developments by independent oil and gas companies in Canada and China and capital spend undertaken with government funds.

Companies are set to be more selective about investments – of all types – during a period of high uncertainty

The social and environmental pressures on many oil and gas companies raise complex questions about the role of these fuels in a changing energy economy and the position of these companies in the societies in which they operate. These questions become even more challenging in the revenue-constrained world of 2020.

Many large oil and gas companies have made specific commitments to diversify spending in favour of lower-emissions technologies and reduce their emissions. These commitments vary in scope and ambition, but a notable recent evolution has been for some emissions-reduction pledges to encompass not just a company's own operations, but also the emissions resulting from the energy that they sell to end consumers, i.e. the combustion emissions from transport fuels, or from gas used for heat or power. BP's commitment from February 2020 to reduce all emissions from the oil and gas that the company produces to net zero by 2050 is a prominent case in point.

This implies a massive ramp-up for companies in the share of investment that goes to low-emissions energy, whether that is electricity or low-carbon fuels.

So far, investment by oil and gas companies outside their core business areas has been less than 1% of total capital expenditure, with this indicator reaching around 5% for the leading individual companies. The largest outlays have been in solar PV and wind. In addition, some companies have moved into new areas by acquiring existing non-core businesses, for example in electricity distribution, EV charging and batteries.

Companies that have made strong pledges to diversify spending and support energy transitions will be wary of breaking these commitments. Indeed, the current environment should make returns on some low-carbon investments appear more attractive – especially when adjusted for risks such as oil price volatility (see Energy Financing and Funding section).

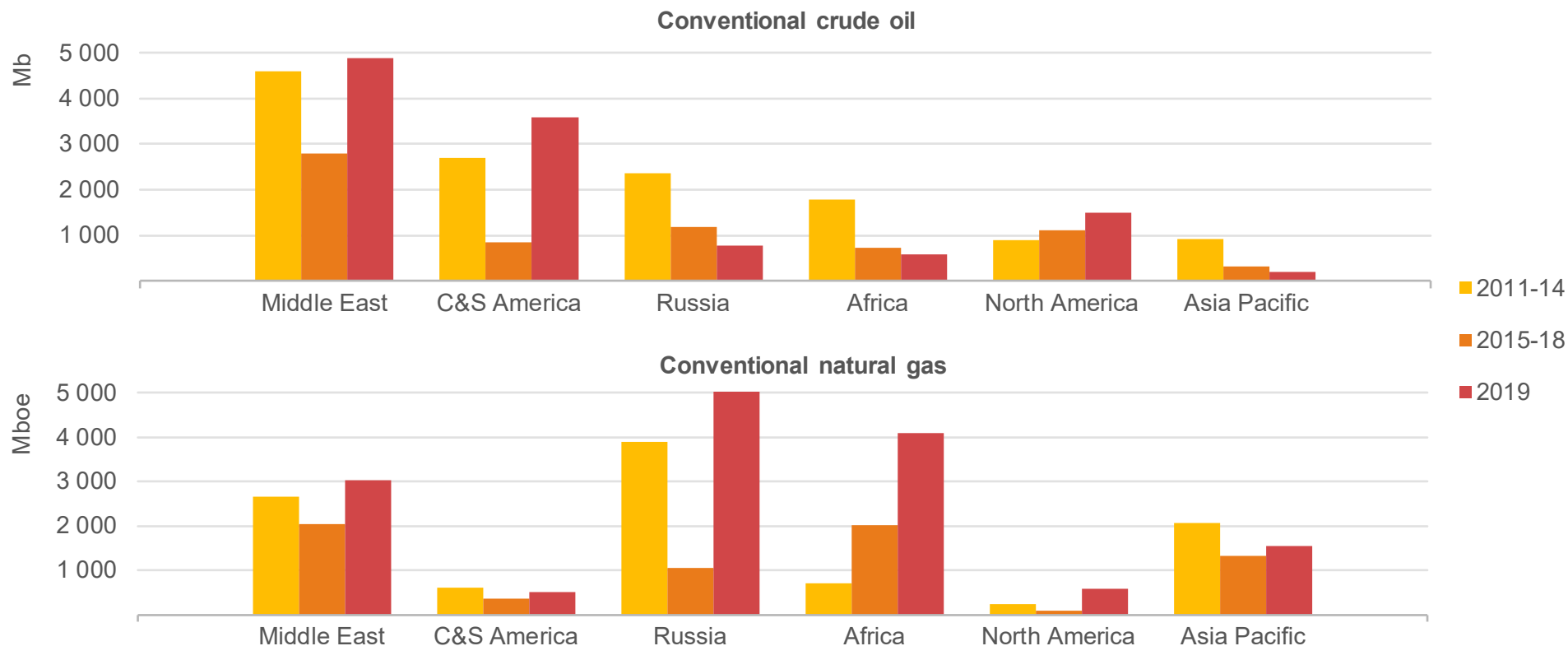
Our monitoring suggests that the flow of investment into low-carbon projects by oil and gas companies has continued into 2020. There was almost USD 1 billion in new investment decisions, all in solar PV, announced by subsidiaries of BP, Shell and Total in the first quarter of the year, plus a large onshore wind project from YPF in Argentina. This is an amount equivalent to around half of the total 2019 spending. In addition, Equinor, Shell and Total announced in May a final investment decision on the Northern Lights CCUS project, which will take captured industrial sources of CO₂ and inject them in subsea storage in the North Sea.

It is too early to judge whether momentum behind all aspects of company low-carbon strategies can be maintained. A plausible outcome is that cash-constrained companies will be very selective about their spending, with only the very best projects having the chance to move forward. This could favour clean technologies with established business models, such as solar PV and onshore and offshore wind. Progress on projects in low-carbon hydrogen, advanced biofuels or CCUS will depend on supportive policies and public-private collaborations.

Upstream oil and gas investment

The calm before the storm: while spending on US shale fell back, some companies felt more confident about approving new conventional investments in 2019

Conventional oil and gas resources subject to FIDs, average annual approvals by region



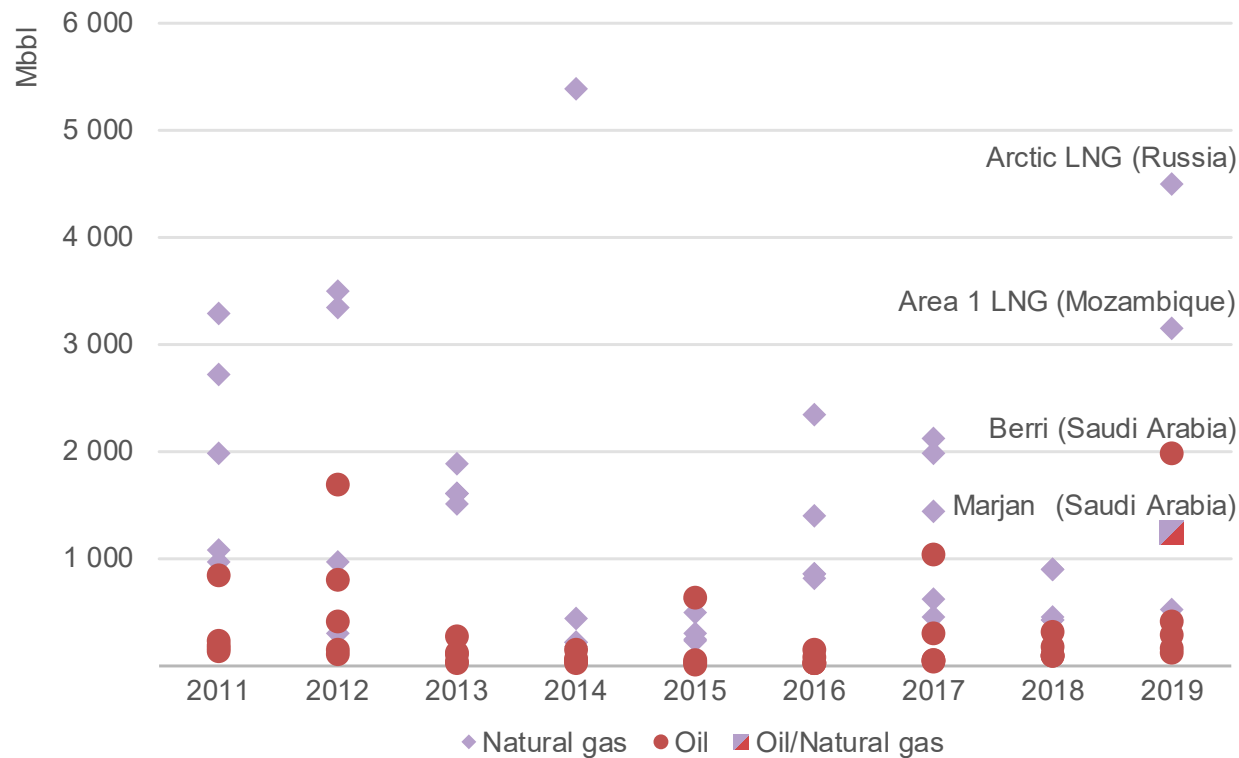
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Note: C&S America = Central and South America.

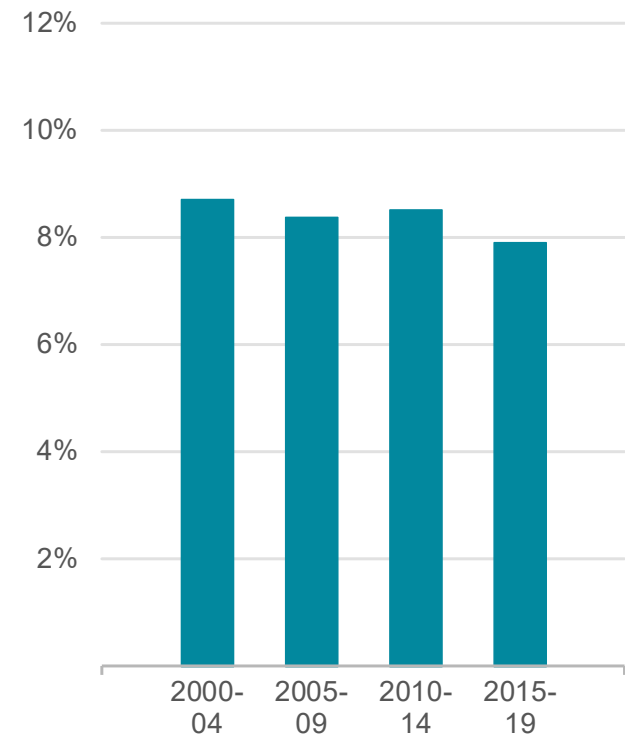
Source: IEA analysis based on Rystad (2020).

Larger-scale project approvals came back in 2019 ... and decline rates for some conventional oilfields have slowed

Five largest oil and gas FIDs (of each), by year



Decline rates for mature non-OPEC fields



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Note: Decline rates analysis is for non-OPEC fields that have already fallen below 50% of their peak production.

Source: IEA analysis based on Rystad (2020).

Developments in 2019 eased concerns about the adequacy of future supply, while events in 2020 could reawaken them

Against the pre-crisis backdrop of robust demand growth, the IEA has expressed concern over the implications of a prolonged slump in new conventional oil and gas resource approvals since 2014. In particular in the oil market, these approvals had fallen to levels that relied on continuous rapid growth in US tight oil to pick up the slack and meet rising demand.

In 2019, however, the balance changed somewhat. Overall upstream spending was up by 0.6% in real terms (2% in nominal terms, slightly below the guidance provided by companies to the market). The growth in investment came from conventional projects rather than from shale, which experienced a decline in spending for the first time since 2016 (although not necessarily a decline in output – US tight oil, for example, continued to grow by over 1.2 mb/d).

The volumes of conventional resources subject to FIDs were significantly higher in 2019 in the Middle East and the Americas (for oil), due mainly to deepwater plays in Brazil and Guyana. The same was true for natural gas in the Middle East, the Russian Federation (hereafter, “Russia”) and Africa, in many cases related to the rise in approvals for large LNG projects (see below).

Successive *WEI* reports have also noted the strategic shift in recent years in favour of smaller, more modular investments with shorter lead times. This was a way to limit upfront capital spending, accelerate paybacks and reduce exposure to long-term risks. However, 2019 saw some much larger projects being approved, chief among them Russia’s Arctic LNG, Mozambique’s Area 1 LNG, and the expansion plans for the huge Berri and Marjan projects in Saudi Arabia. This

indicated a renewed degree of comfort within the industry for larger project sizes, albeit while retaining the emphasis on short times to market and for simplified and standardised project designs.

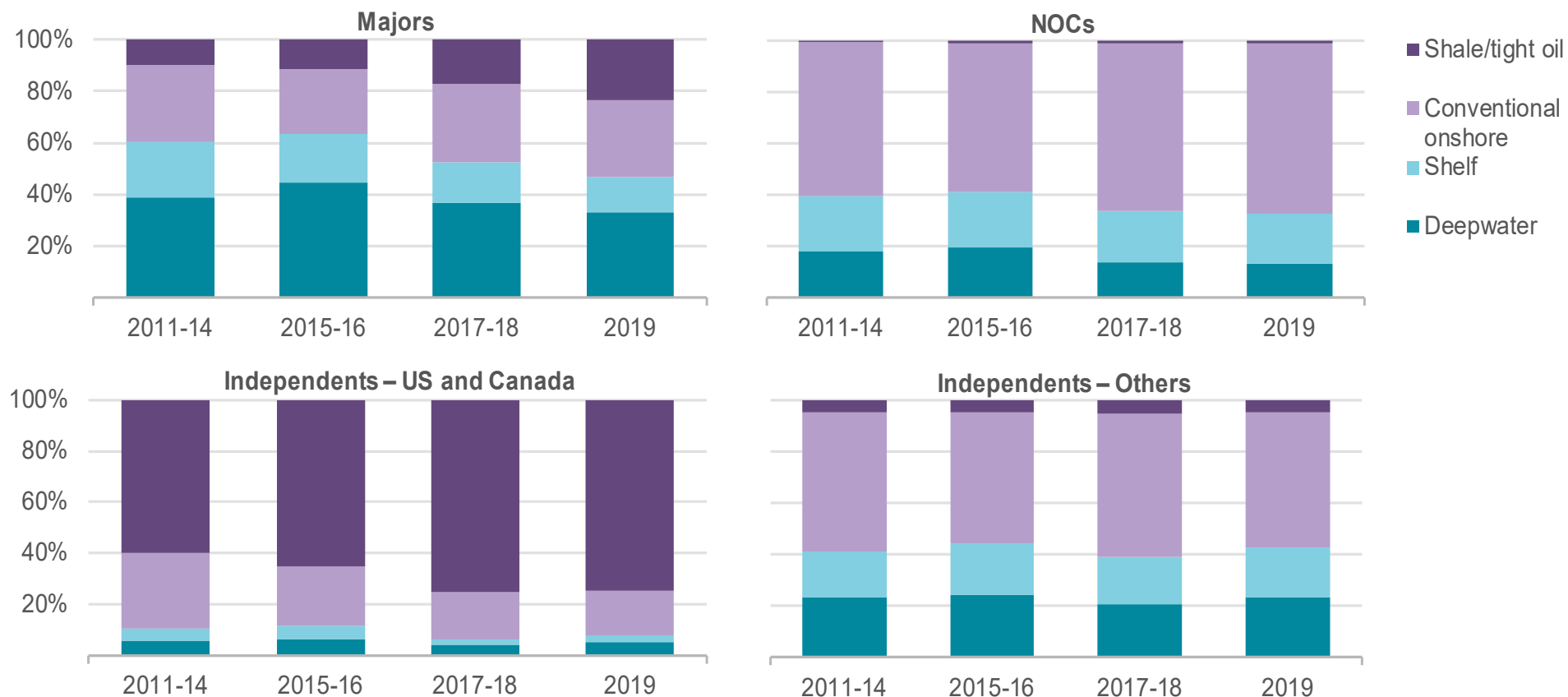
Another development that eased concerns about the adequacy of future supply (until the 2020 shock) was some evidence that decline rates for conventional fields have slowed. This topic was covered in detail in the 2018 *World Energy Outlook* (IEA, 2018); in this follow-up analysis, to avoid any potential impact of market management policies on field production histories, we focused only on non-OPEC fields that have already fallen below 50% of their peak production.

The five-year average decline rate of these fields (with fields weighted by their cumulative production) suggests that decline rates have dropped by about 0.5 to 1 percentage points in the period since 2015. A key explanation for this drop is that after the oil price fell in 2014, companies focused on getting the most out of their brownfield assets rather than taking on major new projects.

A small fall in decline rates may not seem very significant. However, around 50% of oil production today comes from post-peak conventional crude oilfields. If we were to assume that a 0.5% reduction in decline rates was a structural change across the board, then by 2025 production from all post-peak fields would be 1.3 mb/d greater, significantly reducing the amount of investment in new fields that would be required to balance the market. The impact of the 2020 drop in investment on decline rates will require careful monitoring to see if these gains are being maintained.

Distinct divergences in upstream spending across different types of company ...

Allocation of upstream investment by resource type and company type



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Source: IEA analysis based on Rystad (2020).

... reflect variations in access to resources and strategic judgements about the future of hydrocarbons

The allocation of upstream investment spending varies considerably across different types of oil and gas companies. These variations reflect the types of resources to which these companies have access, but also the pressures that different companies feel from investors and societies, as well as different perceptions of future risks.

There has not been any clear change in recent years in the allocation of upstream spending by NOCs; the strategic shift has rather been towards vertical integration strategies via an expansion of investments in refining and petrochemicals (discussed below). Within the upstream, the tendency has been towards internationalisation of some NOC operations led by companies such as Equinor, Gazprom, Petronas and the Chinese NOCs, lately joined by others such as Rosneft and some key companies in the Middle East. The intent has been to seek out new opportunities for growth as well as to acquire new expertise. However, there is no visible shift in aggregate investment towards “frontier” technology areas such as deepwater or shale. The bulk of spending remains in traditional areas of NOC strength, in resources to which these companies typically enjoy preferential access: conventional resources found either onshore or in shallow water.

By contrast, the Majors have undergone a strong shift in their capital spending over the last decade. The precise direction varies by company, but overall there has been a strong move into shale, which now accounts for one-fifth of total spending, up from less than 5% at the time of the last oil price crash in 2014, and out of oil sands. Deepwater investments have retained a prominent place, reflecting

investment opportunities in the Gulf of Mexico and offshore Latin America (notably Brazil and Guyana).

The emphasis on technology leadership among the Majors has been accompanied by a preference for projects that combined cost advantages with easily realisable commercial prospects – including short lead times and proximity to existing infrastructure.

The Majors’ investment strategies appear to be designed with future uncertainties and transitions in mind, whereas most NOCs are locked into a more traditional hydrocarbons paradigm. However, although natural gas features prominently in the Majors’ priorities, there are few signs in the combined data of a shift towards upstream gas investments. The share of gas investment in the early years of the decade was boosted by the large investments made in gas to supply LNG export facilities in Australia, but this effect dissipates after 2016.

Independent exploration and production companies headquartered in North America have an even greater exposure to unconventional resource types, mostly shale. This has been a vulnerability in today’s downturn, and this segment has seen the largest revisions to anticipated investment spend in 2020.

Outside North America, though, the allocation of spending by “independents” is more traditional, albeit with a higher share of deep water (thanks to companies such as Galp, Kosmos Energy, and specialised operators across Latin America and Africa), and a higher share of spending on natural gas.

After a mild upswing in 2019, exploration is coming under renewed pressure in the downturn

Oil and gas exploration spending has been on a consistent downward trend in recent years, with only a slight bump in 2019. With investment budgets under renewed pressure in 2020, the share of exploration spending in total investment may hit historic lows.

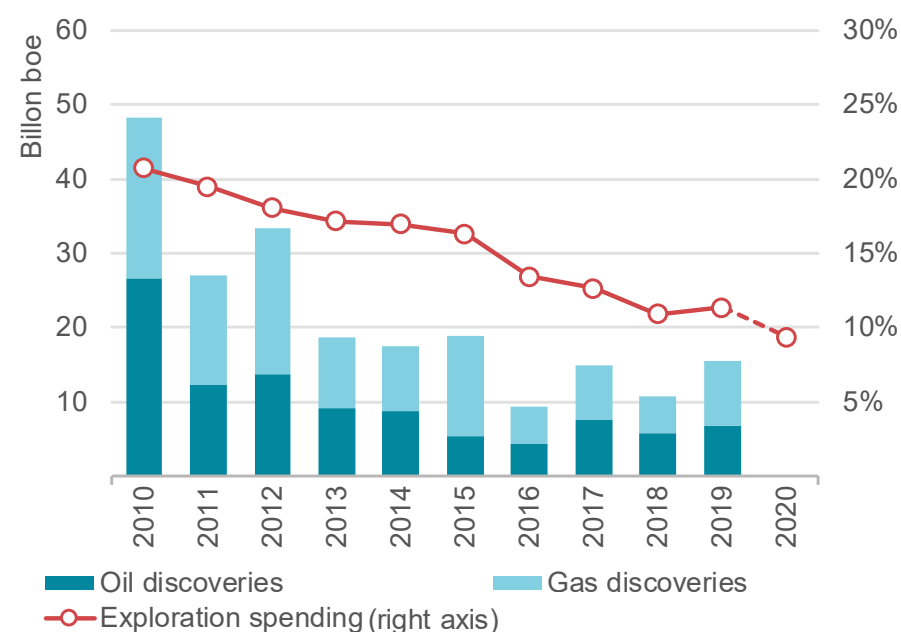
Exploration is being tested by more than a cyclical downturn: many companies and their investors do not attach the same importance to reserve replacement as they have in the past, especially given the relative abundance of onshore unconventional resources (for which there is no formal exploration process as such). As a result, while incentives remain for companies to seek out more advantaged resources and upgrade their portfolios, there is not the same impetus for companies to explore and discover as there once was. This is especially true given that the remaining prospective or underexplored areas in the world are increasingly remote or difficult to access.

Exploration often finds itself in the firing line when companies are looking for ways to cut costs. In our estimate, exploration spend is likely to be down again in 2020, both because of cuts in allocated investments and because of practical difficulties in moving personnel and equipment to the desired areas. Planned exploration wells across Africa and Latin America could be delayed as a result.

That said, 2019 was a moderately successful year for conventional discoveries. The countries that added the most to their conventional resources were Iran, Russia, Guyana, and Trinidad and Tobago, and there were also significant discoveries in China, Malaysia, Indonesia, Norway and South Africa. This made 2019 the most successful year for oil and gas discoveries since 2015. The trend in discoveries is towards natural gas, and 2019 was another significant year with large finds in Russia, Mauritania, Iran and Cyprus.

The record of discoveries thus far in 2020 is some 40% below the same period in 2019, although notable finds have included the Jebel Ali gas discovery in the United Arab Emirates, which opens up the possibility of reducing the country's reliance on imported gas, and further finds in the Guyana-Suriname basin.

Global conventional resources discoveries and exploration spending as % of total upstream investment

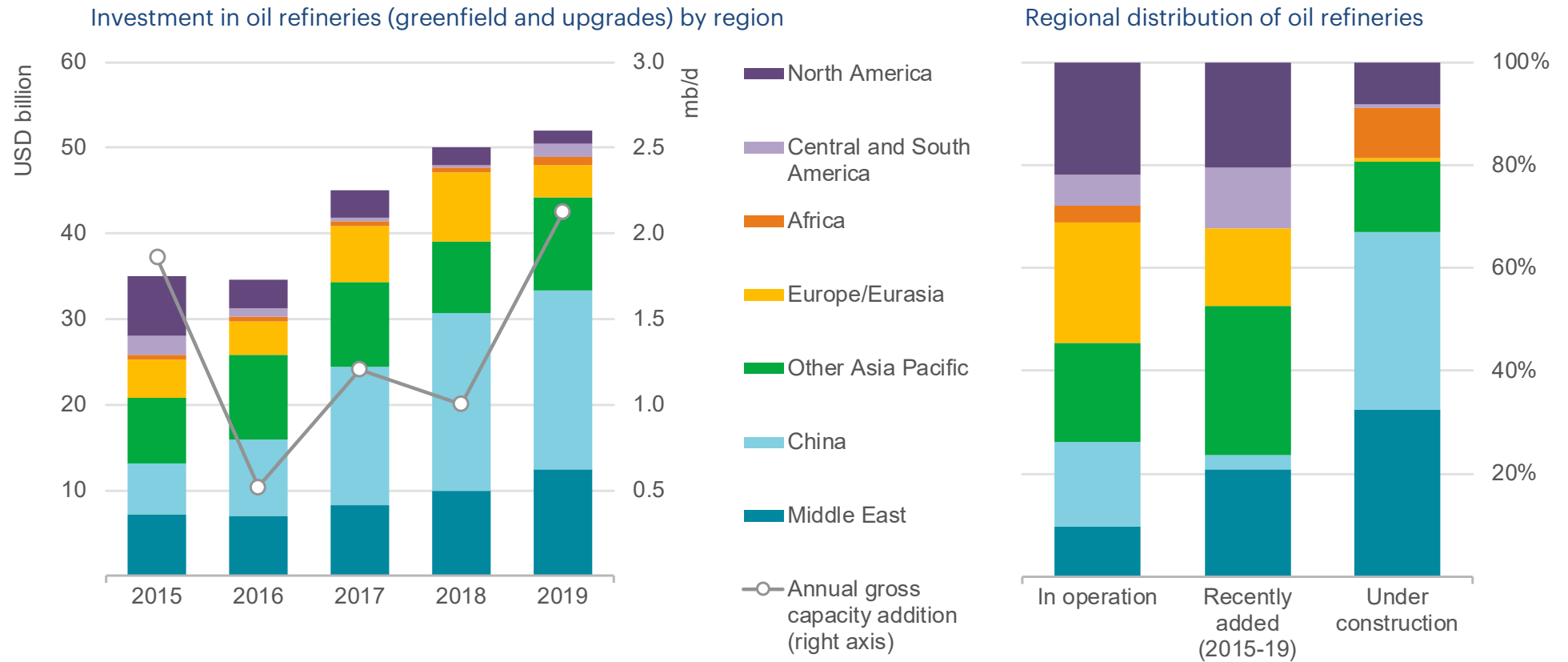


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Source: IEA analysis based on Rystad (2020).

Midstream and downstream oil and gas investment

Refining: A surge in investment in recent years resulted in more than 2 mb/d of new refining capacity coming online in 2019 – the highest level since 2010

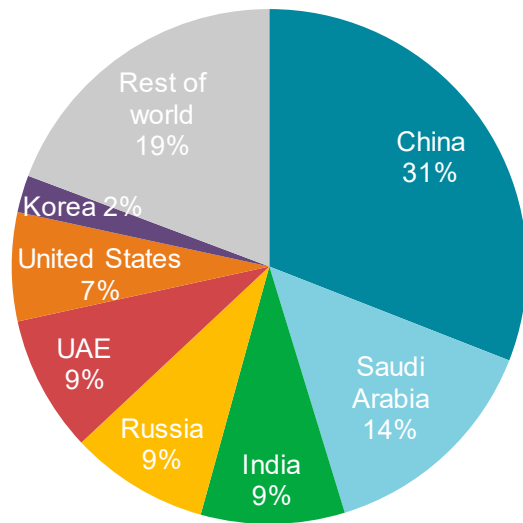


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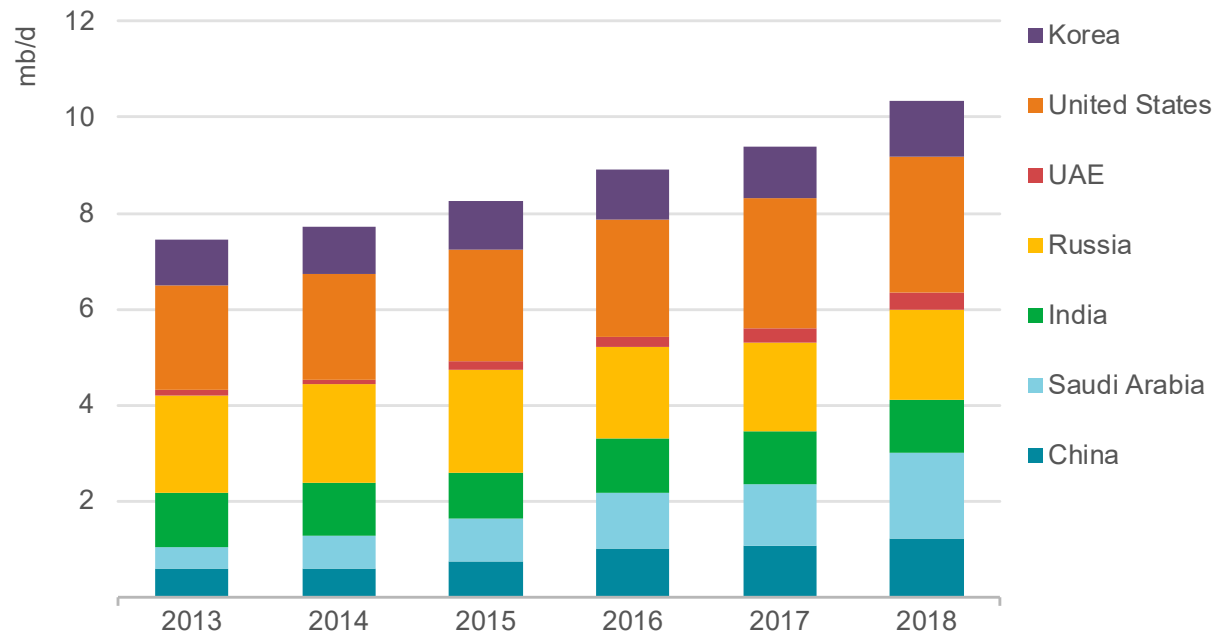
Notes: The figures reflect estimates of ongoing capital expenditures over time and do not include maintenance capex. Gross capacity addition includes crude distillation units and condensate splitters.

Countries adding refining capacity also strengthened their positions as oil product exporters, adding to the competitive pressures facing refineries elsewhere

Share of refining capacity addition by country, 2013-18



Gross refined products exports of top countries



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Notes: UAE = United Arab Emirates. Refined products include gasoline, diesel/gasoil, kerosene and fuel oil.

Source: JODI (2020) (for refined products exports).

Recent investment trends are creating a major overhang in refining capacity that will reshape the industry

Refining investments have surged since 2015. Spending on new refinery builds and upgrades amounted to some USD 52 billion in 2019 (USD 75 billion if maintenance spending is included). Several years of heightened investment led to a record amount of new refining capacity (2.2 mb/d) coming online in 2019, including two mega refineries in China integrated with petrochemical operations (400 kb/d Hengli and 400 kb/d Zhejiang phase 1).

Capacity additions of 2.2 mb/d in 2019 were significantly above the annual increase in oil demand of 0.8 mb/d. A further host of new refinery units (around 6 mb/d) is planned for the next five years (IEA, 2020b). Even before the health and economic crisis of 2020, it was clear that these new refinery additions would be likely to outpace the rise in demand.

Recent investment activities have been concentrated in regions with structural advantages, either cheap feedstock (e.g. the Middle East) or growing demand in domestic markets (e.g. developing Asia). The Middle East and developing economies in Asia account for less than 40% of today's operating refineries, but have recently been attracting considerable investment; the two regions account for two-thirds of all refineries that have come online over the past five years, and over 80% of those currently under construction.

Investments in the Middle East have been driven by the strategic ambition to extract more value from the region's hydrocarbon resources, with Saudi Arabia, the United Arab Emirates and Iran taking the lead. Kuwait plans to follow suit with the completion of the 615 kb/d Al-Zour refinery, the largest in the region. With these new additions,

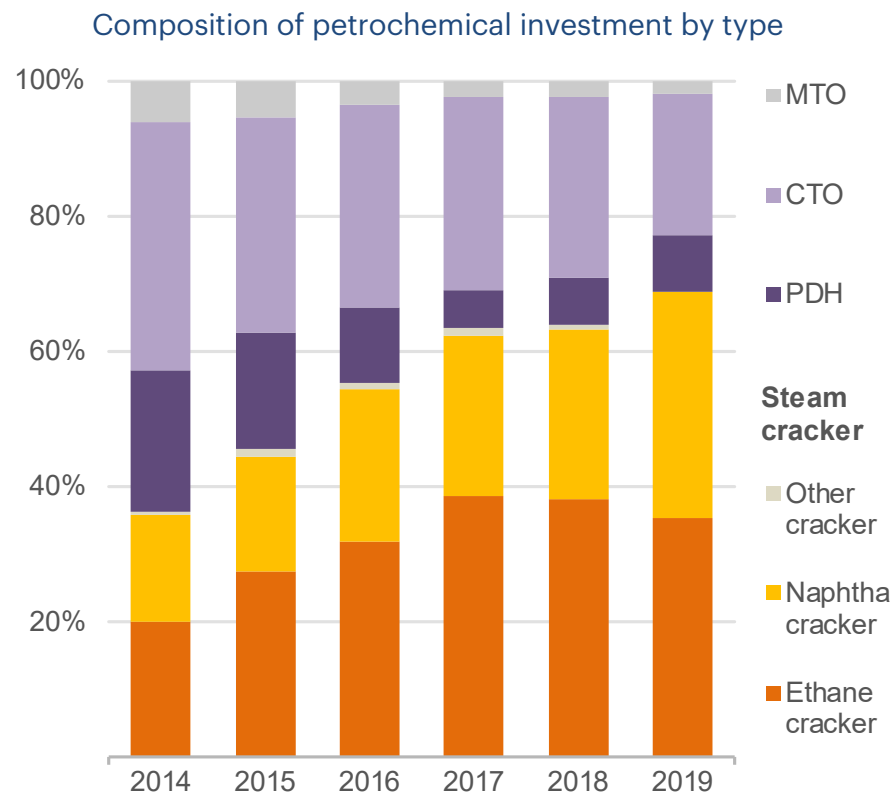
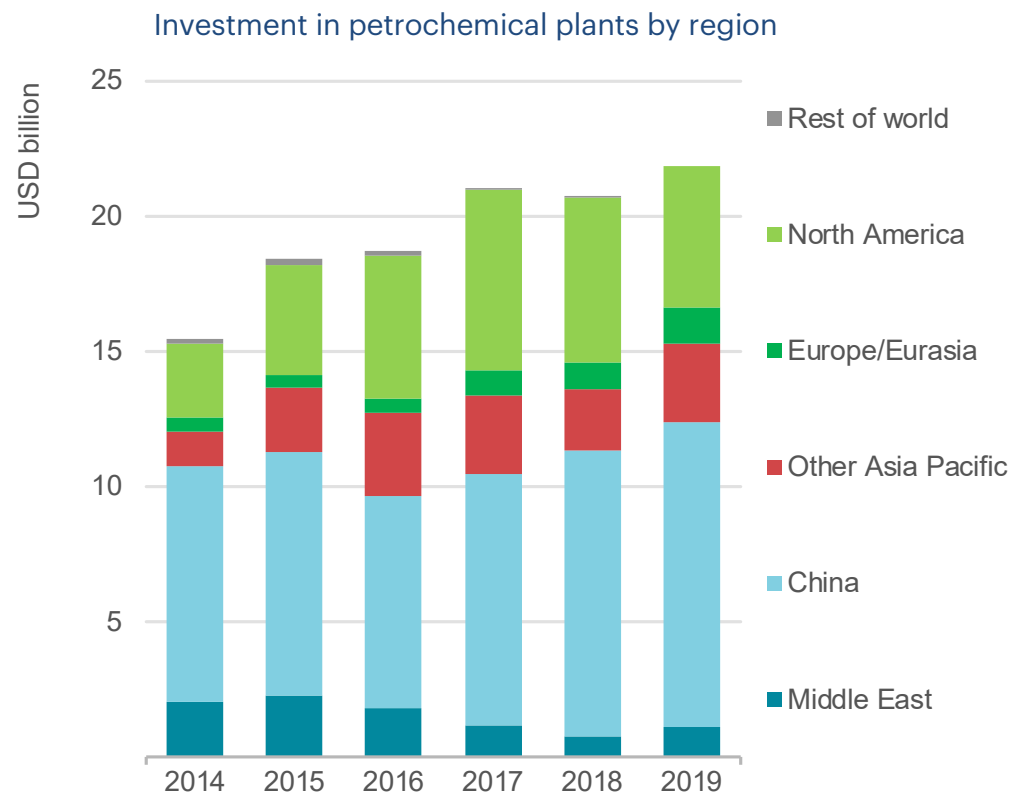
several countries are emerging as major oil product exporters in addition to their traditional role as major crude oil exporters. Many Middle East NOCs have also set up trading arms to expand their presence in crude and product trading.

In Asia, while the main motivation is to serve growing demand in domestic and adjacent markets, capacity is growing faster than demand in certain countries, notably in China. Product exports from some of these countries have also risen, putting additional pressure on less advantaged refineries in other parts of the world.

For example, some 2 mb/d of refineries in Japan and Europe have shut down their facilities since 2013. Several European plants have been converted to bio-refineries (e.g. Total's La Mede, Eni's Venice and Gela), which also serve EU biofuels policy targets (see below). Brazil's Petrobras has scrapped the second phase of the Comperj megaproject and has instead kick-started the process of divesting its refineries as part of its portfolio optimisation programme.

The sentiment towards refining investment varies by company type. NOCs in the Middle East and developing Asia have been active in strengthening their presence in the downstream value chain. NOCs own around 30% of the refineries in operation today, but hold a 46% share of those under construction. On the contrary, Majors have been selective in refining investment in recent years. Independent companies have remained an important actor in new refining investment in China, Russia and the United States, but their involvement is shrinking in recent investment decisions. All of these strategic trends are likely to be reinforced as a result of the 2020 crisis.

Petrochemicals: An investment boom has been driven by higher industry margins, US shale production growth and optimism about future demand



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Notes: The figures reflect estimates of ongoing capital expenditures over time and do not include maintenance capex. The scope of investment includes steam crackers, propane dehydrogenation (PDH), coal-to-olefin (CTO) and methanol-to-olefin (MTO) units. "Other cracker" includes steam crackers using off-gas, liquefied petroleum gas (LPG) or gasoil.

Petrochemical investment has shifted towards steam crackers, increasingly integrated with refinery operations

Since 2014, some USD 120 billion has been invested in building new petrochemical capacity or expanding existing plants. More than 70% of this investment took place in just two countries, China and the United States.

There was a noticeable shift in investment in recent years. Until around 2015, most investments were in a series of coal-to-olefin (CTO) and methanol-to-olefin (MTO) facilities in China. These were accompanied by propane dehydrogenation (PDH) plants to capture market opportunities to supply propylene using low-priced LPG feedstock.

However, MTO investment in China fell back as the rise in imported methanol prices damaged project economics. CTO investment continued, partly helped by lower coal prices, but at a slower pace than before. Instead, the balance of global petrochemical investment shifted towards steam crackers, as investment decisions started to respond to the shale boom in the United States.

The United States has added more than 7 Mt of ethane crackers since 2015 with more capacity set to come online in the next few years. With limited domestic outlets and competitive feedstock costs, the country is building several terminals to export ethylene and is poised to establish a strong foothold in global petrochemical markets (although the plunge in oil prices in 2020 is undermining their cost advantages).

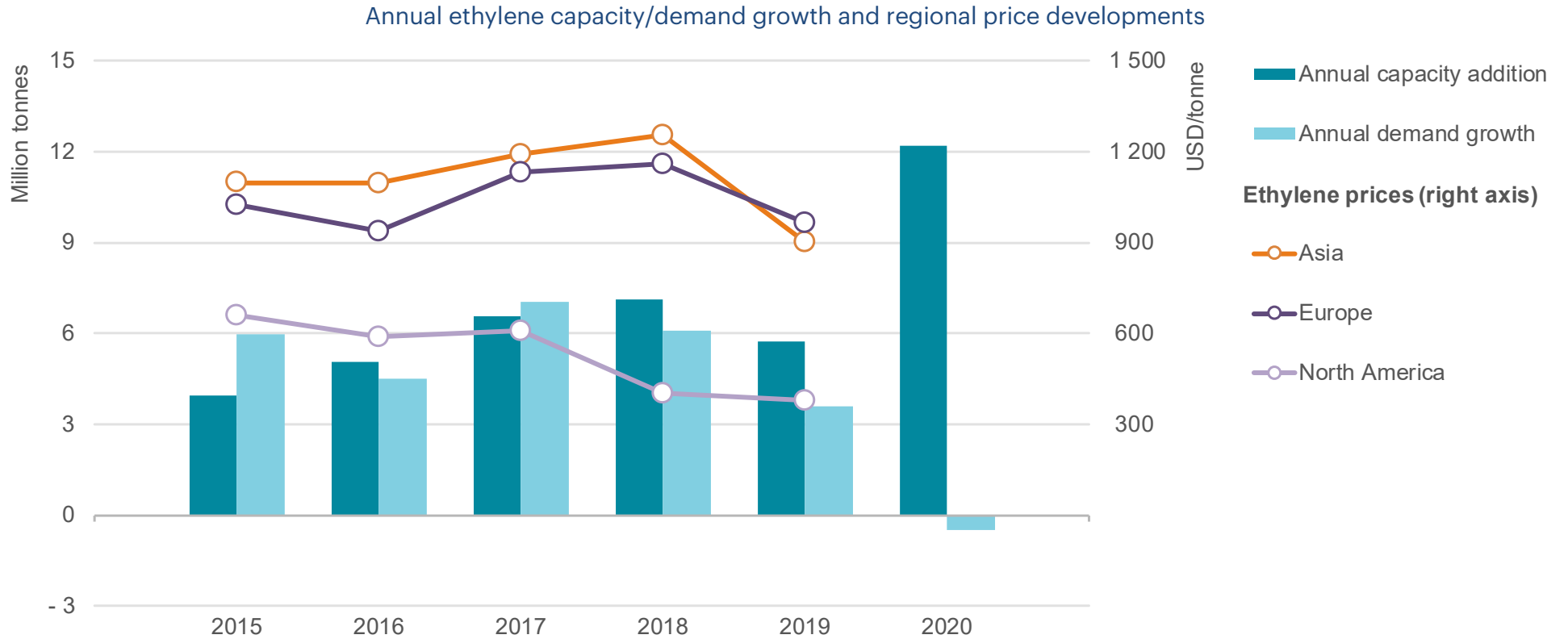
The United States has accounted for around 40% of global steam cracker capacity addition in recent years, but was not the only country to make a move in this direction. A number of new naphtha crackers

also came online in China, Korea, Malaysia and the Middle East. Strong demand growth in emerging markets and healthy industry margins partly drove these investments, but robust prospects for demand growth and companies' strategic intentions to secure a long-term competitive edge also played a major role.

For many oil companies, refiners in particular, expansion into petrochemicals was seen as a strategic hedge against weak demand growth for transport fuels. More than three-quarters of naphtha crackers that came online in 2018 and 2019 were integrated with refineries to some degree, a dramatic jump from around 10% for those that came into operation in the mid-2010s. Most of the planned naphtha cracking capacity addition is also expected to have some degree of integration with refineries.

Feedstock flexibility is another feature of recent investments. After witnessing volatile price movements of different feedstocks, several companies invested in retrofitting their naphtha crackers to be able to process a higher portion of lighter feedstocks (primarily LPG). Additionally, many planned crackers are coming with an enhanced ability to select their optimal feedstock mix depending on market conditions (therefore often being called "mixed feed crackers").

Ethylene additions were already outpacing growth in demand in 2018-19, with even more new capacity scheduled to start in 2020

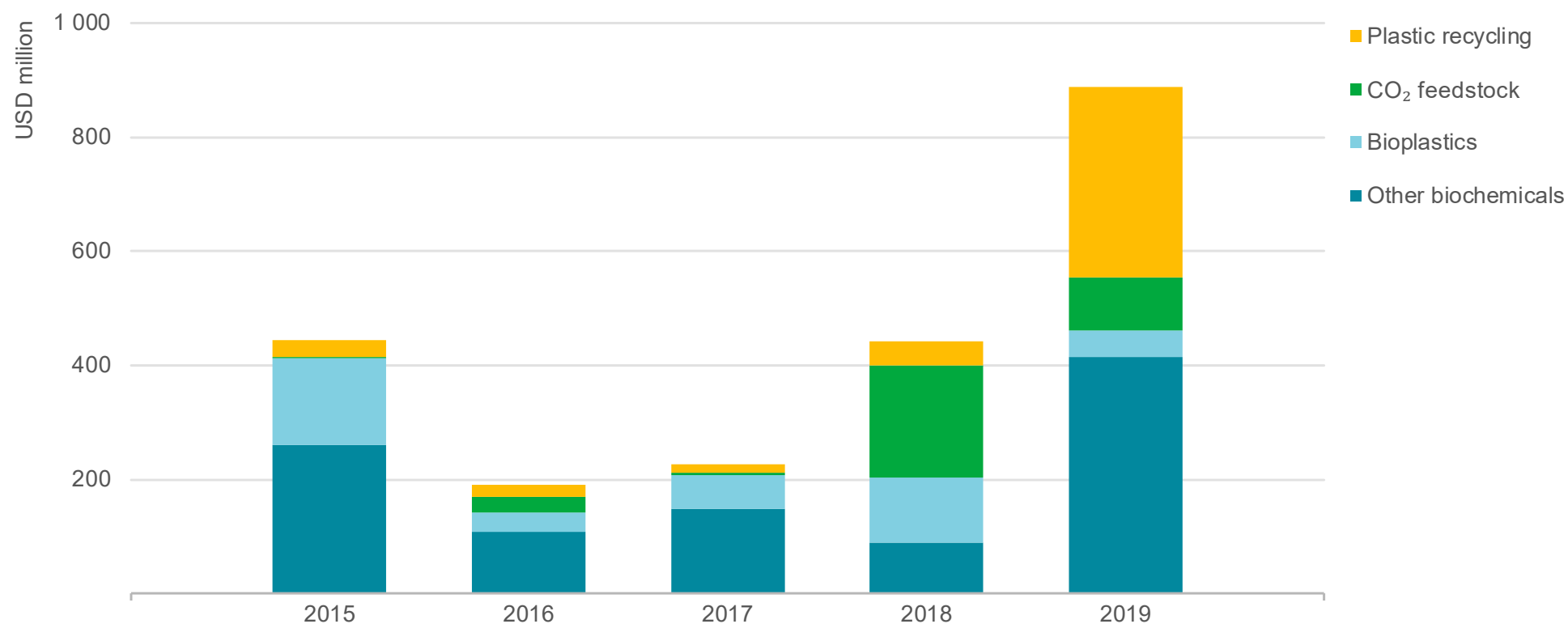


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Source: S&P Global Platts (2020).

Companies and investors are trying to respond to growing consumer awareness and regulatory pressure on plastic waste

Investments in alternative feedstock and plastic recycling start-ups



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Notes: "Other biochemical" include agrichemicals, specialty chemicals and pharmaceutical applications derived from biomass feedstock, but do not include biofuels. Investments include grant, equity investment (at various stages), structured loan and private investment in public equity.

Sources: IEA analysis based on Cleantech Group (2020), i3 database.

The petrochemical investment boom implies lower margins and utilisation in the coming years despite relatively robust long-term demand prospects

As in the refining sector, the pace of investment in petrochemical facilities in recent years has moved well ahead of the rate of demand growth. In 2019, for example, the annual increase in global ethylene production capacity was 60% higher than the level of demand growth, which led to a significant drop in ethylene prices across the board. Earnings of many commodity chemical companies fell sharply, by 60-80%, compared with 2018.

This mismatch extends out into the future and could be exacerbated by the economic slowdown caused by the Covid-19 pandemic. In 2020, some 12 Mt of new ethylene capacity are expected to come online, the largest capacity addition since 2010, if all projects go ahead as scheduled. These additions coincide with a significant deterioration in trade and industrial activity, which may weaken the demand outlook for chemical products. While demand for petrochemicals remains robust in the longer term in the IEA *World Energy Outlook*, a confluence of weakened economic outlook and overcapacity casts clouds over industry margins and utilisation rates in the coming years.

Petrochemical producers are also facing headwinds from a growing backlash against plastic waste, reflected in pledges by manufacturers of consumer goods to reduce the use of plastics in their products and boost the use of recycled material, and in the increasing number of government policy targets and plans to ban single-use plastics. These commitments are also now extending beyond countries in the Organisation for Economic Co-operation and Development (OECD): China, one of the world's largest plastic consumers, announced its ambition to phase out single-use plastics across the country. As a first

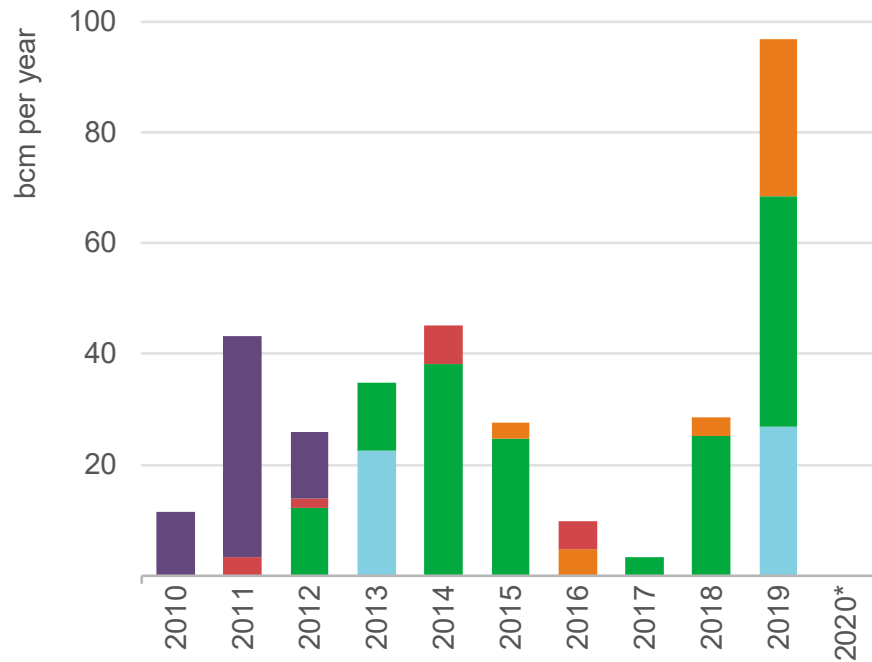
step, single-use plastic bags will be banned in major cities by the end of 2020 and in all cities and towns by 2022.

While these measures are unlikely to make a strong dent in demand in the short term, they encapsulate some longer-term commercial and reputational risks facing chemical companies. And these companies and investors are responding to the widespread social demand for sustainability by exploring new business opportunities in this area. Investments in alternative feedstock and plastic recycling start-ups are still relatively small (less than USD 1 billion in total), but they almost quadrupled between 2017 and 2019.

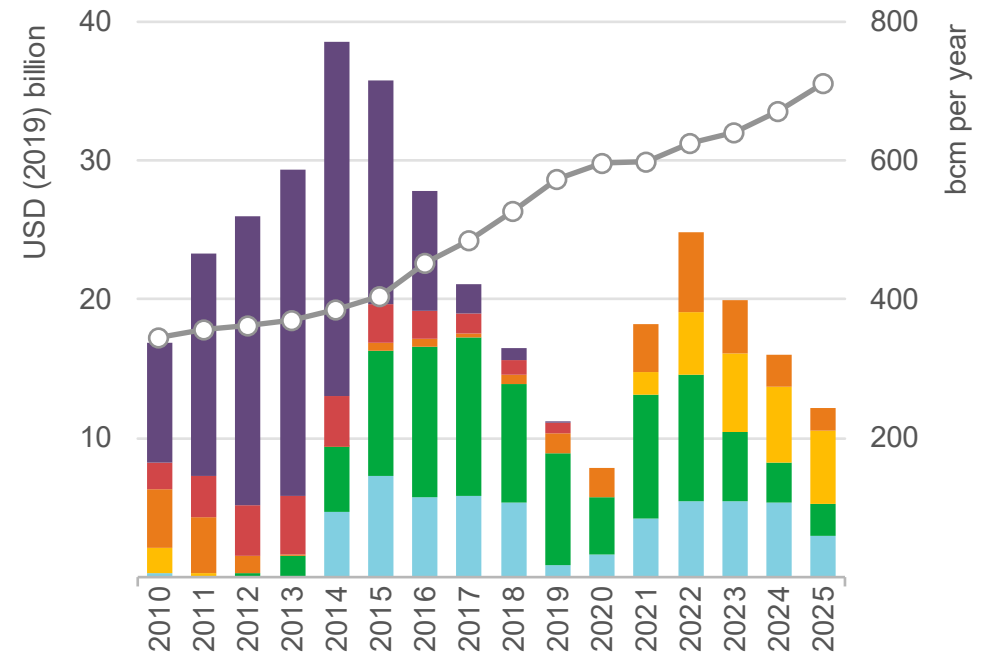
Biochemicals (including bioplastics) attracted a large portion of the capital, but plastic recycling is also receiving growing attention. The latter includes both mechanical recycling (e.g. robotics to allow more efficient sorting and picking) as well as chemical recycling, where plastic waste is broken down into monomers or feedstock to allow a wider range of waste to be recycled. Several pilot plants are being built to test the technical and commercial viability of chemical recycling processes. Companies' engagements in these areas are likely to expand as they strive to find a new competitive edge amid growing consumer awareness and tighter regulations on plastic waste.

LNG: 2019 was a record year for new project announcements ...

Sanctioned LNG capacity by year of announced FID



Investment in new LNG capacity (sanctioned projects plus Qatari expansion plans)



Legend: Europe (dark blue), Russia (light blue), North America (green), Middle East (yellow), Africa (orange), Others (red), Australia (purple), Cumulative capacity (right axis) (grey line with circles)

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* Year to date: no new LNG capacity has yet been approved in 2020. Qatar’s LNG expansion is not included in the “sanctioned LNG capacity”, as no formal decisions have been taken, but anticipated spending is nonetheless included in the “project investment” chart.

... with Qatar also planning a major expansion of low-cost capacity

As noted in the previous section, there was a rebound in the average size of oil and gas projects approved for development in 2019. No sector demonstrated this newfound comfort with large-scale investments better than LNG, which had a record year for new projects.

A drought in new project announcements that started in 2016 was broken in October 2018 by the approval of the LNG Canada project, followed by the smaller Greater Tortue Ahmeyim project that straddles the border between Mauritania and Senegal in West Africa. The momentum continued with a slew of announcements in 2019. Almost 100 bcm/y of new liquefaction capacity was sanctioned over the course of the year, more than the preceding four years combined.

The United States has been the largest presence in the latest investment cycle, and 2019 approvals included Golden Pass LNG (Qatar Petroleum and ExxonMobil), train 6 of Cheniere's Sabine Pass and the Calcasieu Pass facility (Venture Global LNG).

There were also major announcements from Mozambique, with approval of the Area 1 LNG project (this Anadarko-led project was then acquired by Total), and from Russia as Novatek's Arctic LNG 2 project got the go-ahead. Nigeria's long-awaited seventh NLNG train was also approved in late 2019.

Although not yet accompanied by formal investment decisions, the LNG expansion plans of Qatar Petroleum have been a very prominent part of the emerging picture. Since announcing its intention in 2017 to continue development of the huge low-cost North Field, Qatar has steadily upgraded its ambitions to increase the country's liquefaction capacity. The initial intention was to add three LNG trains (each of

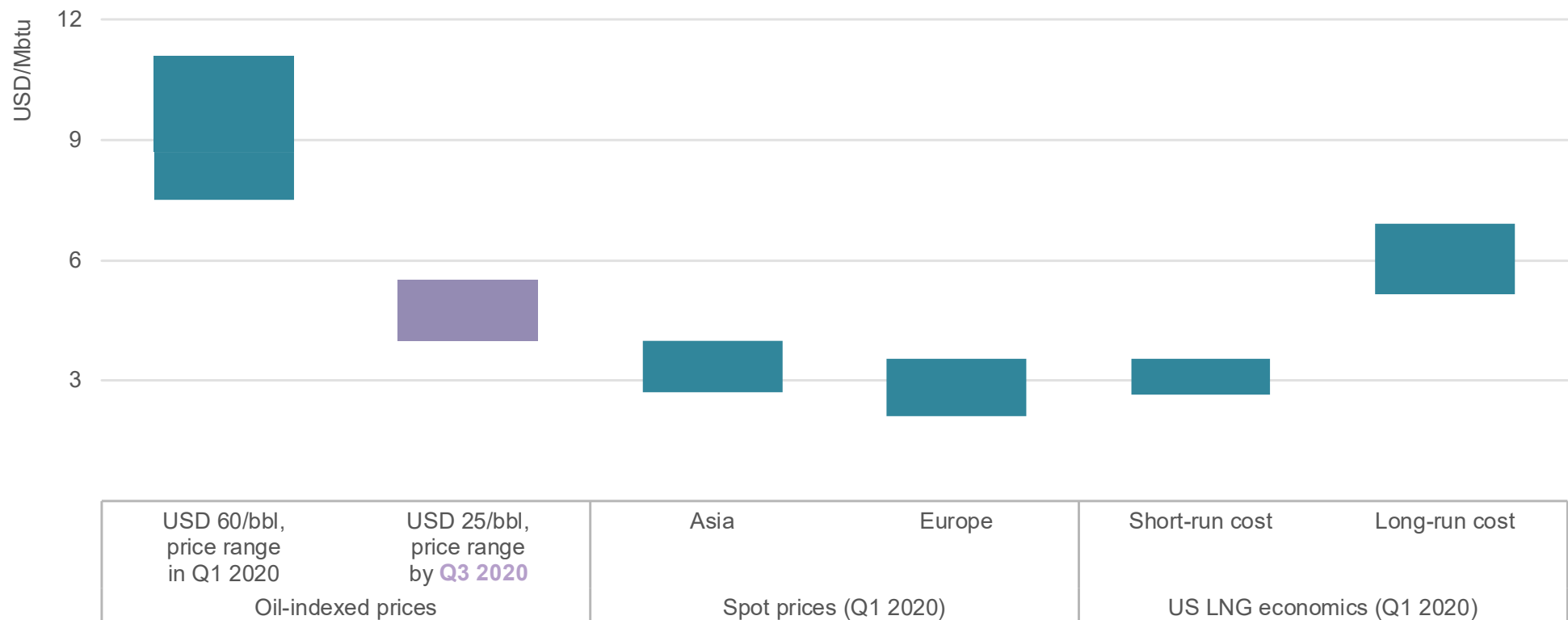
around 8 Mtpa of capacity), then a fourth was added to the plans and, in 2019, a fifth and sixth. The target date to complete this expansion is 2027, by which time these six trains would bring Qatar's total liquefaction capacity to 126 Mtpa (roughly 170 bcm/y), up from 77 Mtpa (105 bcm/y) today.

The wave of interest in LNG reflected the relative abundance of natural gas in the world – especially after the shale revolution – as well as a view among investors that this type of investment is relatively resilient to more ambitious climate scenarios. Majors such as Shell, BP and Total have increased the share of natural gas in their portfolios over the past decade, and have made several large-scale strategic investments across the natural gas supply chain, particularly in LNG. The rise of the “portfolio” marketing model has also marked a change in the way LNG projects are financed, with large, well-capitalised players willing to use their balance sheets instead of relying entirely on long-term contracts with committed buyers to move projects ahead.

This disconnect between LNG investment decisions and firmly committed demand has taken place against an emerging backdrop of oversupply and downward pressure on gas prices. It now coincides with a profound shock to gas consumption resulting from the global health and economic crisis in 2020.

An oversupplied gas market now casts a shadow over the new wave of LNG investments ...

Natural gas price ranges for oil-indexed supply (Q1/Q3 2020), current spot prices and US LNG economics (Q1 2020)



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Notes: Oil-indexed prices are a range based on contractual “slopes” that dictate the strength of the oil/gas price link. Prices in Q3 2020 assume Brent averages USD 25/bbl from March-September 2020. Spot prices for Asia are an average of reported spot prices for LNG deliveries, and for Europe are the day-ahead prices quoted on the Netherlands’ Title Transfer Facility (TTF). The ranges for short-run costs of US LNG reflect the tolling model for LNG off-takers = Henry Hub price (range in Q1 2020) + 15% + shipping costs to Europe or Asia (excluding regasification). Long-run costs include the capital costs of the liquefaction facility.

... playing havoc with development schedules and near-term commercial prospects

The record year for new LNG project approvals in 2019 took place at a time when prices were falling in all major gas-consuming regions. By the first quarter of 2020, spot prices for LNG cargoes had fallen into the range of USD 2/MBtu-USD 4/MBtu, enough to cover operating costs in most cases but well below the levels required for projects to return their invested capital.

This was a consequence of subdued demand at a time when significant amounts of new supply, including both LNG and pipeline capacity, were coming online. Among the pipeline projects, the largest was the new 38 bcm/y “Power of Siberia” connection between Russia and China that was launched in December 2019.

Some LNG suppliers were immediately been exposed to both volume and price risk because of the crisis. Others have had a measure of protection because volumes were specified in long-term sales agreements, with prices often linked in part or in full to oil. However, the collapse in the oil price in 2020 means that the latter protection is set to disappear over the typical six- to nine-month period in which movements in oil prices filter through into natural gas contract prices. The precise implications will vary from company to company. But oil at USD 25/bbl would leave more international gas suppliers struggling to cover their operating costs.

This disparity between short-term market conditions and the readiness to sanction new LNG projects can be explained by a number of factors:

- A widely shared anticipation of longer-term demand growth for LNG and an awareness that, in part because of the dearth of new project approvals in 2016-18, there was a potential shortfall in

supply emerging in the mid-2020s that could be plugged by projects taking FID in 2019.

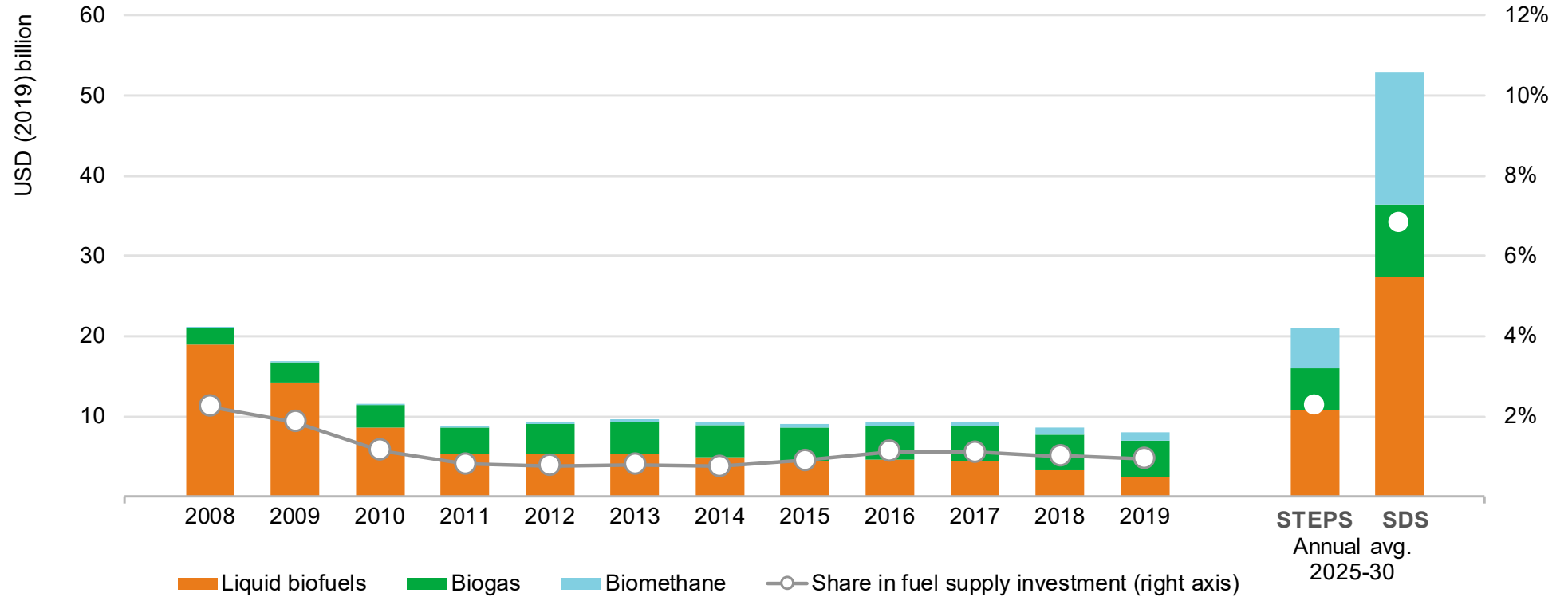
- A larger share of new projects were sanctioned through equity lifting, where project partners receive a share of LNG volumes proportionate to their equity stake and take on their own marketing and selling responsibilities. This contrasts with traditional project finance structures, which require buyers agreeing to purchase a minimum quantity of LNG under long-term delivery commitments.
- Strategic considerations for some of the world’s major resource-holders. In the case of Qatar, a drive to ensure the country’s pre-eminence in the LNG market, based on some of the lowest-cost gas in the world. For Russia, a desire to increase the range of export destinations and balance reliance on pipeline exports. In other cases, a strategic calculation – perhaps reinforced by the possibility of intensified action on climate change – that the risks of going ahead early were less than the risks of delay.

However, the opportunities for the next wave of planned LNG projects are now much less clear; near-term oversupply and price uncertainty have reduced readiness among buyers to conclude long-term deals, and the economic challenges resulting from low prices have severely constrained capital budgets among developers, leading to deferrals and project reviews. FIDs have been postponed by US and Canadian independents (Tellurian’s Driftwood and Pacific Oil and Gas’ Woodfibre) as well as oil majors (ExxonMobil’s Rovuma project in Mozambique), while Shell backed out of the Lake Charles LNG project in the United States).

Biofuels investment

Biofuels investment fell to its lowest level in a decade in 2019

Investment in biofuel production capacity



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Source: IEA analysis based on IEA (2019a) and F.O. Licht (2020).

Policy support remains the key determinant for investment in new biofuels capacity

Global biofuels investment – including liquid biofuels, biogas and biomethane – has fallen to under 1% of the total investment in fuel supply. Since the late 2000s, when biofuels enjoyed much more widespread policy support and rapid market expansion, the amount invested in new production facilities has dropped substantially. While investment in biogas has been relatively stable, spending on new production facilities for liquid biofuels fell sharply over this period.

In 2019, investments in liquid biofuels production capacity declined again by around 30%, largely due to developments in China, where investment in ethanol production facilities halved compared with the previous year. China has suspended the extension of its 10% ethanol blending mandate nationwide to reduce competition for corn production and assure food security. As 10% blending is still extending to some new provinces, investment in China could rebound somewhat in 2020, supported by new plants that are already under construction.

Policy-driven investment in ethanol production facilities continued in the United States and Brazil. The Renewable Fuel Standard (RFS2) is the key federal policy mechanism supporting US biofuel consumption. In Brazil growth is driven by the new Renovabio scheme. However, shut-ins of biofuel production capacity in the United States and Brazil in 2020, due to plummeting gasoline demand, are likely to dampen near-term appetite for new investments.

Continued investment in biodiesel facilities in 2019 was driven almost entirely by hydrotreated vegetable oil (HVO) plants in Europe and the United States. Policy support for HVO is coming from Europe's updated Renewable Energy Directive for 2021-30 and in the United States from the RFS2 and California's Low Carbon Fuel Standard.

One reason for slower momentum behind liquid biofuels in the US market is the "blend wall" effect, which refers to structural challenges relating to vehicle suitability and fuel distribution infrastructure for ethanol blends higher than 10%. A regulatory reform permitting year-round sales of a 15% ethanol blend (E15), introduced in 2019, could increase ethanol penetration in the United States. However, only around 1% of service stations offer E15 nationally, and expanding supplies to the approximately 20 states where the blend is not currently available will take time.

Instead, future developments are likely to be led by Asia, where several economies have announced ambitious blending targets, for example, India with a 20% share of ethanol in gasoline (E20) by 2030 and Indonesia with a 30% share of biodiesel in diesel (B30) in 2020. The investment required to meet these targets is a key reason for higher projected spending in the IEA STEPS.

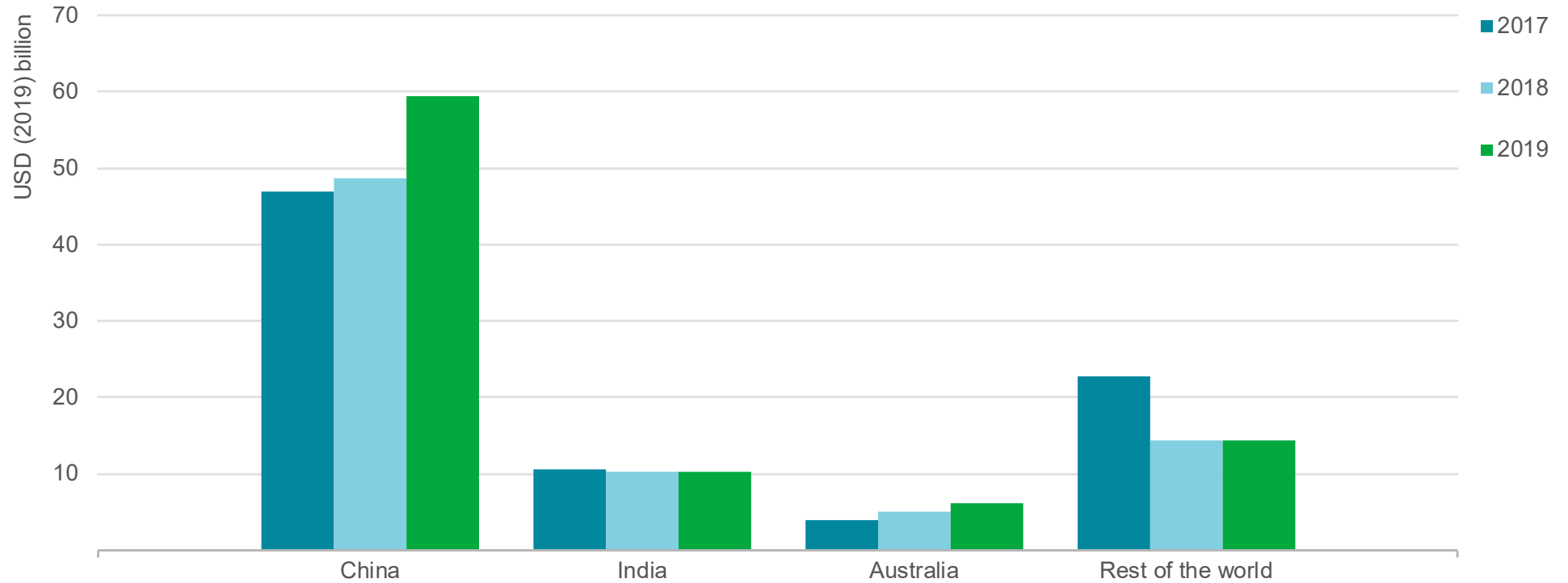
Investment in biogas and biomethane has averaged around USD 5 billion per year over the last decade, which is less than what the natural gas industry typically spends every week. The development of biogas has been uneven across the world, as it depends not only on the availability of feedstocks but also on policies that encourage its production and use. China, Europe and the United States account for almost 90% of global production of low-carbon gases.

To meet sustainability goals, biofuels investment would need to increase by more than six times over the next decade, reinforcing the importance of policy support to scale up sustainable biofuel deployment, especially during a period of low oil prices.

Coal supply investment

China was instrumental in a 15% increase in global coal supply investment in 2019

Coal supply investment



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Despite the intensifying debate about the future of coal, global spending on coal supply increased to USD 90 billion in 2019, up from USD 80 billion the year before

Investment in coal supply was around USD 90 billion in 2019, a 15% increase on 2018. Even with this rise, this is only around 5% of total investment in the energy sector, despite coal supplying more than a quarter of the world's global primary energy. The overall figure includes investment in mining and related infrastructure to bring coal to market, but excludes spending on coal-fired power plants.

China was by far the largest driver of growth in global coal investment in 2019, with some contribution also from Australia and others. This reflects the increasing concentration of global coal demand in Asia, contrasting sharply with the dramatic reductions seen in some other parts of the world. As recently as 2000, Europe and North America accounted for one-third of global production; now that share has collapsed to less than 15%.

Understanding China is the key to understanding coal markets. China represents more than half of global coal demand and almost half of global production, and remains the largest importer in the world. China also accounts for more than two-thirds of global spending on coal supply and for the bulk of global annual changes.

The landscape for investment in coal supply in China has been reshaped by the reforms of 2016-17 that aimed to address a large overhang of capacity, which had in turn been created by an earlier investment boom in the early 2010s. These reforms resulted in the closure of many smaller, less productive mines, often ones with poor

safety records, leaving the sector more efficient, more profitable and safer.

The restructuring coincided with a stabilisation in Chinese coal demand trends after three years of decline from 2014-16, due to strong electricity consumption and renewed support for infrastructure development. As a result, investments in coal supply have picked up again, with the capital not just going to existing mines or those that are under development, but also to new projects.

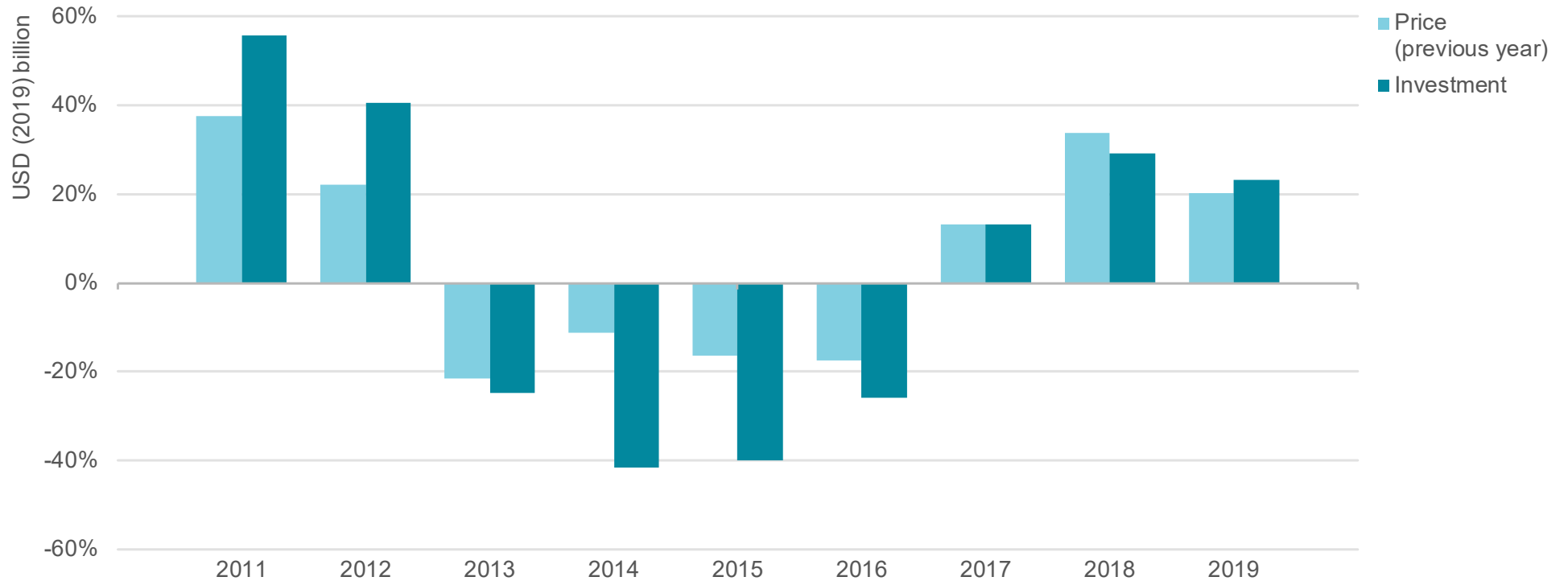
After a two-year halt, the National Energy Administration and the National Development and Reform Commission¹ restarted the process of approval for new mines, accounting for 28 Mtpa of additional capacity in 2017, 68 Mtpa in 2018 and 201 Mtpa in 2019. This is not yet at the scale of the previous spike in coal supply investment, which at its height in 2012 meant that China was investing 50% more than would have been needed to meet demand: the Chinese authorities are very wary of creating a new overhang in capacity, although that risk has clearly increased due to the effects of the Covid-19 pandemic.

Unlike in the previous boom, new investments in coal supply are no longer banking on an increase in Chinese consumption. But they are predicated on a stable outlook for Chinese coal use, i.e. without any sudden intensification of China's energy diversification or emissions policies, or lasting effects of the current slowdown.

¹ Mines below 1.2 Mtpa of capacity are approved by the local authorities.

Social and investor pressures are having an impact, but coal investments still respond to economic signals

Year-on-year change in coal investment in Australia versus movement in coal prices (for the previous year)



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Risks to coal supply projects are growing, but coal prices remain a key driver of investment

The growth in coal supply investment in 2019 can appear counter-intuitive from an energy market perspective – not least because global coal-fired power generation saw its largest-ever drop in the course of the year and came under renewed pressure in 2020. This trend is even more counter-intuitive when viewed against the backdrop of energy transitions and uncertainties over the future of coal demand, a groundswell of public opposition to coal projects, and an increasing number of governments, international financial institutions, investors, insurance companies and other stakeholders limiting or curtailing their involvement in the coal business.

The IEA *World Energy Outlook 2019* looked in detail at the impact of financing restrictions on coal supply projects. These are becoming more widespread and in many countries the process of gaining approval and finance for new coal supply investments is getting harder and longer. In particular, projects that cannot be financed from the balance sheets of larger companies can struggle. More restricted access to capital is one reason some larger supply projects (e.g. Carmichael in Australia, the Boikarabelo mine in South Africa) have been downsized. These trends are also apparent for new coal power projects, as described in the Energy Financing and Funding section of this year's *WEI*.

At the same time, some new projects continue to move ahead – notably in China and India, which are the main countries investing in coal supply. Coal still represents more than one-third of global electricity generation and remains the second-largest fuel in the

global energy mix after oil and the second-largest traded bulk commodity after iron ore. Investments are being proposed on that basis, in response to economic signals coming from the coal market.

Climate-related pressures are visibly affecting some projects and shaping the demand outlook for coal in many countries, creating significant risks to coal investment, especially for thermal coal and lignite (coking coal is less affected, given the more difficult substitution of coal in steel making). However, the overall pattern is that coal supply investment still follows typical commodity (boom and bust) cycles, in which high prices tend to lead to overinvestment, which creates oversupply and hence low prices, which in turn discourages investment until shortages push up prices again.

This dynamic comes through clearly when viewing recent changes in coal supply investment in Australia against prices in the preceding year.² We select Australia because it is the largest exporter by economic value and has very accessible and transparent data for both prices and investments. Data for 2011-19 show that changes in spending are well aligned with the price signals from the preceding period. This suggests that the decline in investment in the 2013-16 period was price-driven rather than policy-driven, and that economic factors remain a key explanatory variable for investment in coal supply. On this basis, downward pressure on the coal price in 2020 is likely to be a primary factor affecting investment decisions in 2021.

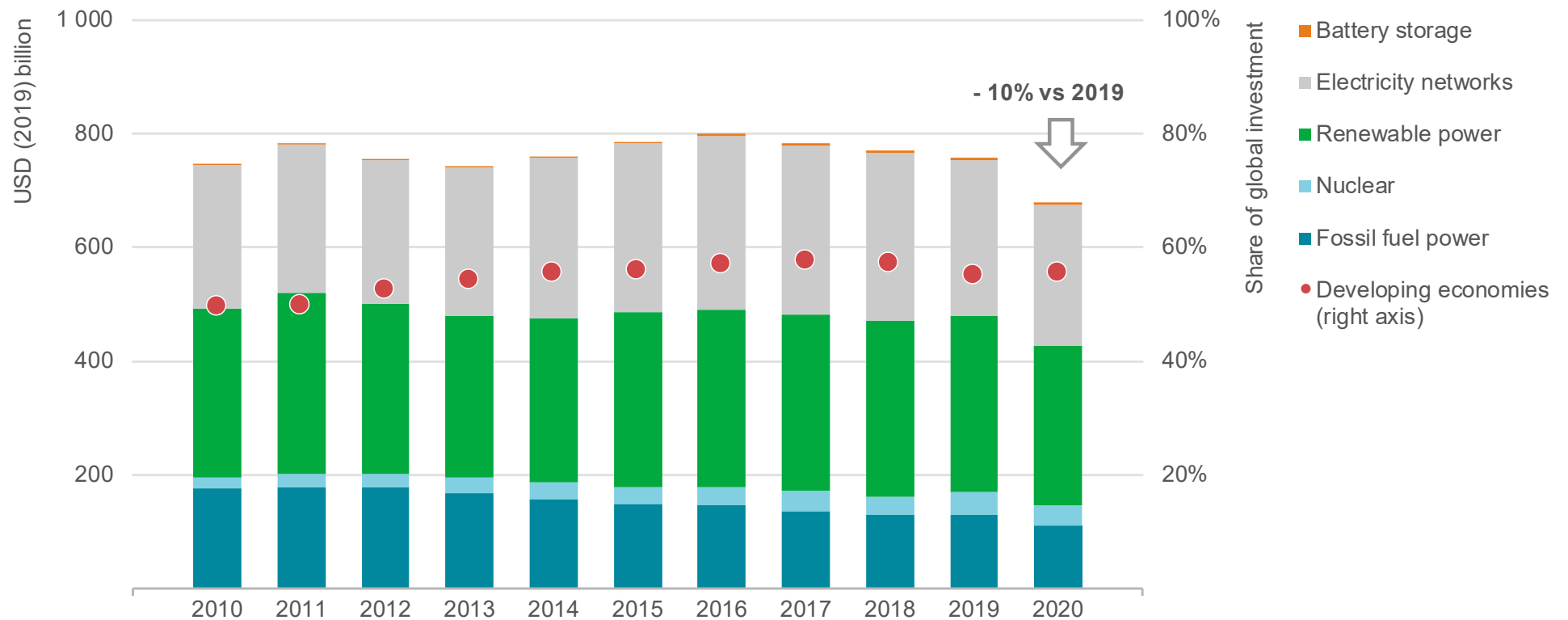
² Price is for thermal price (Newcastle free-on-board 6 000 kcal/kg) and investments also include coking coal. Prices for the preceding year are used to reflect a typical decision-making cycle: companies usually decide the investment one year before the spending occurs.

Power sector

Overview of power investment

Following a small decrease in 2019, global power investment is set to fall to its lowest level in over a decade in 2020

Global investment in the power sector by technology

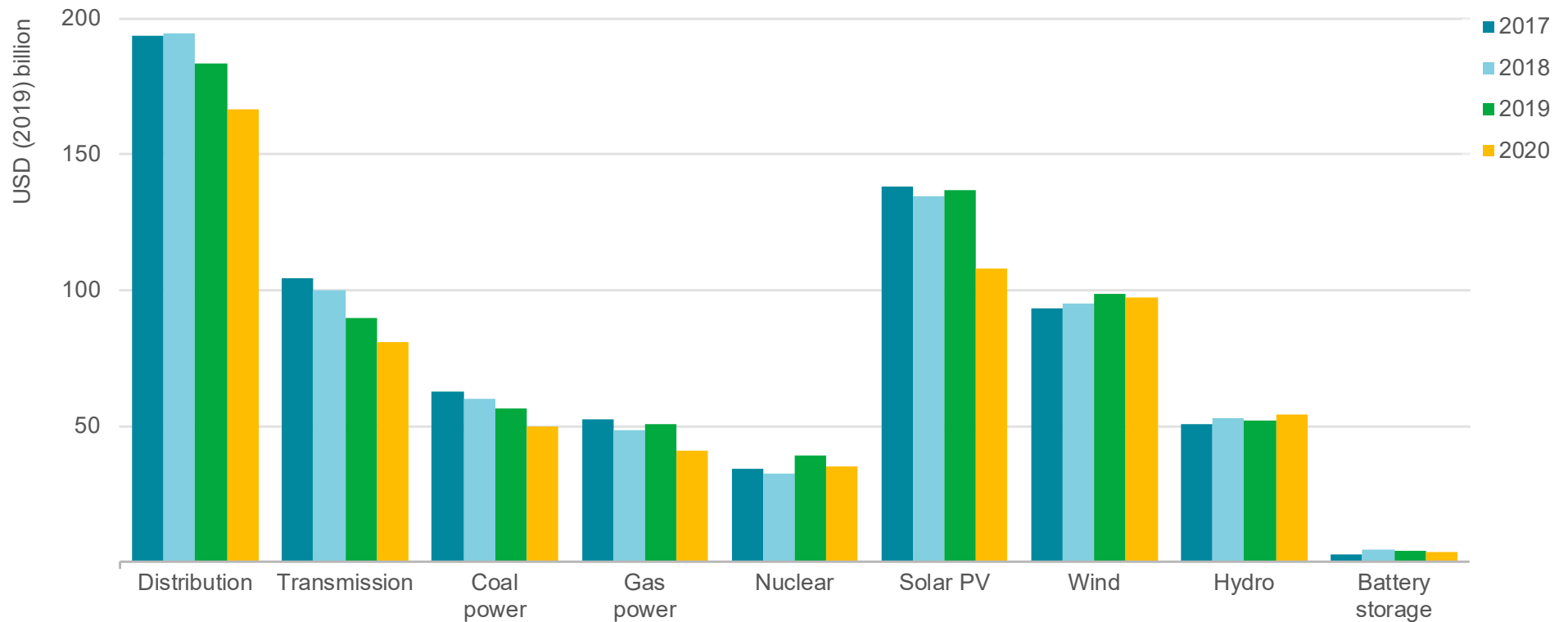


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Note: Investment is measured as the ongoing capital spending in power capacity.

Reversing expectations of an uptick in spending in 2020, all parts of the power sector are set to be affected by mobility restrictions, delays in project development and lower demand

Global investment in the power sector by technology



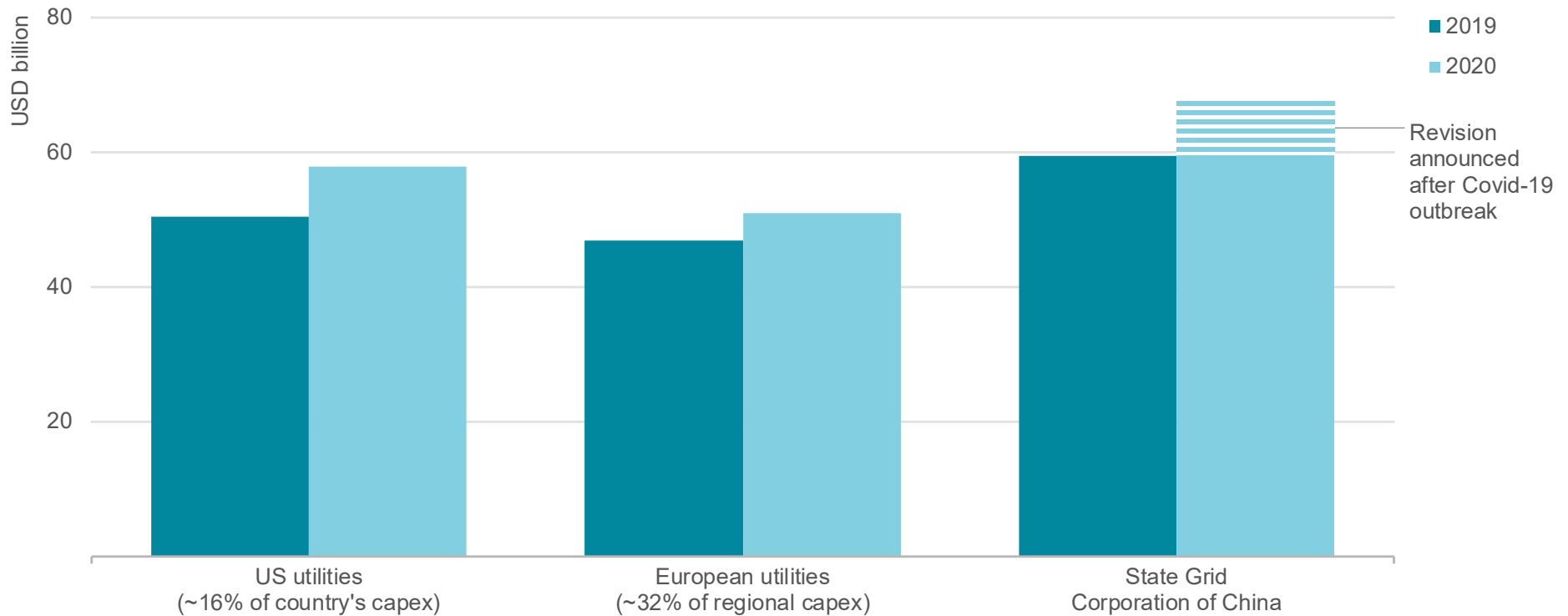
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Notes: Gas-fired generation investment includes large-scale plants as well as small-scale generating sets and engines. Hydropower includes pumped hydro storage.

Source: IEA analysis with calculations for solar PV, wind and hydropower based on costs from IRENA (2020).

While optimistic views on spending plans by some large utilities provide support for investment, this may not fully offset growing risks and uncertainties in a number of markets

Capital expenditures in 2019 compared with spending guidance for 2020 of selected utilities



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Notes: US utilities include: Duke Energy, Southern Company, Sempra Energy, Nextera, Exelon, American Electricity Power (AEP), Edison International; European utilities include: Electricité de France (EDF), Enel, Engie, Energias de Portugal (EDP), RWE Group, Terna. Ratio of utilities' installed capacity / region's installed capacity is based on capacity owned by selected utilities (according to companies' websites) and regional installed capacity based on IEA (2019b).

Sources: Thomson Reuters Eikon (2020) and company announcements as of mid-May 2020.

The drop in investment across different parts of the power sector varies by technology...

Overall power investment around the world is set to decline in 2020 by an estimated 10% as a result of the Covid-19 pandemic. This marks a dramatic break from the situation at the start of the year, when company expectations, capital expenditure planning and ongoing capacity expansion activities suggested a rise of around 2%. Power investment reflects ongoing capital expenditures on projects under construction. As such, this decline is influenced not just by the new capacity additions and refurbishments expected this year, but also spending on assets that would be delivered in the years ahead. Government policies will play a critical role in smoothing the impact, and – as noted in past *WEI* editions – over 95% of power investments are incentivised by regulations and contracts.

Some parts of power investment are more exposed, particularly fossil-based generation, as lower demand and electricity prices create less need for new capacity and add pressure on margins. Investment in new coal-fired plants has already fallen sharply in recent years and is set to decline by over 11%, with cuts concentrated in Asia. Nevertheless, investment activity in China (see next page) may put a floor under further reductions in 2020.

The effects on investment in gas-fired generation arise mainly from delays in gas-rich emerging economies, like the Middle East and North Africa (MENA) region where spending drops by about one-third, given high public-sector participation in the sector, lower expected revenues from commodities and limited fiscal space. We estimate a reduction in total fossil-based power investment of 15% globally compared to 2019.

Higher shares of renewables have been dispatched during the lockdown because of low operating costs and priority access to networks: this, along with long-term contracts, has helped to support

revenues. However, investment in new renewables capacity is affected as lockdowns and mobility restrictions affect production, shipping and construction schedules, as well as shifting demand expectations and policy and procurement measures. We estimate an overall reduction of 10% in spending on renewable power compared with 2019.

Among renewables, distributed PV has been hit hard as households and corporates cut back on spending, and installation activities face the highest disruption from lockdowns. The effect on utility-scale wind and solar PV projects is lower, and spending is also influenced by continued cost reductions, especially in solar PV. Nonetheless, final investment decisions (FIDs) for utility-scale solar and wind in Q1 2020 declined to Q1 2017 levels. Investment in longer-lead time technologies, offshore wind and hydropower, is set to rise supported by ongoing projects around the world, and completion of two mega hydro projects in China, though there are risks of delays in some regions.

Nuclear investment is set to decline given some impact to development schedules, but long associated lead times make spending less volatile.

Investment in grids, which has been declining in a number of countries, is set to fall again, by around 9% in 2020; despite its regulated nature. The impact will be larger in developing countries as most of the investment in networks is financed by state-owned utilities that were in weak financial position before the crisis, and will likely worsen, driven by more limited fiscal capacity from governments and higher financing costs as sovereign risks increase (see Energy Financing and Funding section). That said, grid spending falls less than generation, spurred by ongoing upgrades in some markets (e.g. United States, Europe) to support resiliency and reliability and new support in China.

...and there are also specific regional dynamics, with policies playing a critical role in shaping the impact

Power investment in China, the world's largest market, is set to continue its downward trend in 2020 as the country faces its first recession in decades, with reduced spending in all technologies. Though lockdowns were mostly lifted by April and industrial production resumed, energy investment in China has already been dampened by the disruption to investment activity and supply chains.

Investment in China is nonetheless likely to be less affected, in relative terms, than in other regions, as recent signals provide a buffer. These include an upward revision in State Grid's investment plan for 2020 and a slight year-on-year increase in investment of major power companies in Q1. Spending in coal power may also see a lower percentage drop (compared to other regions of the world and the annual reduction in recent years), as more regions got a green light for construction and 8 GW of coal-fired capacity was approved in March 2020 (a similar amount to the coal-fired FIDs in China for the whole of 2019). Renewables continue to account for the largest share of investment, and decline less than in other parts of the world, as spending on solar PV and wind largely holds up.

Expectations for a robust year for renewables in Europe and the United States, based on prevailing project pipelines, have been reversed by the historic recession, and capital spending in the power sector is now set to decline in 2020. Solar PV and onshore wind see negative impacts, especially distributed PV, but offshore wind grows. Some large European- and US-based utilities have so far maintained a degree of financial resilience – with electricity prices largely hedged in 2020, and increased profits in some cases from continuing operations in Q1 – helping to provide support for grid spending.

A number of major utilities in these two markets have remained optimistic and have maintained their capital spending plans for 2020. Despite this early signalling, a number of uncertainties persist, and it is likely that signs of economic stress become more apparent through the course of the year, as lockdowns affect deployment targets and revenues. Smaller companies with weaker financial standing and tighter margins are likely to be more affected, with many such actors not providing spending guidance at all. First quarter results of power equipment companies point to intensifying challenges for this segment, as delays and increased logistic costs affect revenues and profits in several of the main players, on the back of already tight profit margins arising from fierce competition and trade tensions affecting supply chains. As such, our estimates for overall power spending are less optimistic than the announcements of the largest utilities would suggest.

Regions that rely heavily on public funding are also likely to see deep cuts in spending, such as India and countries in Africa and Southeast Asia. Enabling environments for investment in most of these countries carry a number of risks that can challenge project bankability, though those with strong policies see spending support. The Indian government is taking measures to buffer the investment shock, including extensions for project commissioning, maintaining renewable auctions and trying to boost private capital. In some countries, recent government announcements point to growing investment uncertainties. For example, investment expectations for Mexico and Brazil – the two largest markets in Latin America – have deteriorating, as Brazil is postponing all transmission and renewable auctions and Mexico is slowing down the connection of renewables.

Impacts of Covid-19 pandemic on power sector investment and revenues in 2020

| | Equipment production | Operation of existing assets | Construction/Approvals |
|-------------------|---|--|---|
| Renewable power | <ul style="list-style-type: none"> China, a major supplier of equipment, was more affected in Q1 but has moved towards full production since April. Disruptions in manufacturing of wind turbines and equipment in several European countries (e.g. France, Italy, Spain) and the United Kingdom in March-April and still ongoing in India. Interruptions still expected across solar PV value chain given that mobility restrictions persist in some Southeast Asian countries. | <ul style="list-style-type: none"> Some impacts given mobility restrictions, though operation and maintenance (O&M) often considered “essential business”. Higher share of renewables dispatched in more countries given lower electricity demand. Prices largely buffered from electricity market swings by policies and contract terms. | <ul style="list-style-type: none"> General delays due to lockdowns, affecting project timelines. Higher impact in countries with more strict and longer lockdowns (southern Europe) and where construction is seasonal (e.g. India given monsoon). Limitations of interstate mobility of workers affecting installations in some countries (e.g. India), or domestic rules (e.g. Polish workers have to do a 14-day quarantine when returning to Poland). Robust previous expectations for investment in renewables in 2020 (especially in the United States and Europe) cushion the annual impact on investment, compared with other sectors. Higher impact expected in solar PV investments (compared to wind), particularly small-scale and distributed solar PV. Overall expected decline in investment ~10% (versus 2019). |
| Fossil fuel power | <ul style="list-style-type: none"> Some disruptions given mobility restrictions. | <ul style="list-style-type: none"> O&M relatively unaffected (access permitted to workers). Lower dispatching in many countries. Lower electricity prices given lower commodity prices and lower demand. | <ul style="list-style-type: none"> Lower electricity demand will likely delay capital spending in fossil-based power relatively more than renewable power, given lower need for new firm capacity and reduced power prices. We also anticipate a larger impact in gas-fired investment given region-specific dynamics; important drop in MENA, which accounts for almost 20% of the annual investments in gas-fired power (given countries’ dependency in fossil fuel exports, fiscal positions and overall expected impact in GDP); recent signs of support to coal-fired generation in China (e.g. large approvals). Overall expected decline in investment ~15% (versus 2019). |
| Networks | <ul style="list-style-type: none"> Some disruptions given mobility restrictions. | | <ul style="list-style-type: none"> General delays due to lockdowns, affecting project timelines. Larger impacts expected in lower-income economies where majority of electricity networks are financed through state-owned companies, many which were already financially constrained (e.g. India and most countries in Africa and Southeast Asia). Overall expected decline in investment ~9% (versus 2019). |

Key policy and market announcements affecting investment and revenues in light of the Covid-19 pandemic

| Region | Key policy and market announcements |
|----------------------|--|
| China | <ul style="list-style-type: none"> The China Electricity Council announced that Q1 investment of major power companies increased 0.3% year-on-year – despite suffering the largest demand reduction in Q1. The public utility State Grid of China (which accounts for around a third of the electricity investment) announces investments for a total of 450 billion Yuan in 2020 (-USD 65 billion), with ultra-high voltage (UHV) projects accounting for 40% of total investment. Additional signs of investment expected to increase in some sectors including UHV, pumped hydro storage and coal-fired generation (8 GW of coal-fired capacity were approved in March, close to the entire capacity approved in 2019 and higher than the 2018 approvals). |
| Europe | <ul style="list-style-type: none"> Deadlines for commissioning of generation projects extended (e.g. France, Germany, Italy). Some large-scale renewables auctions postponed (e.g. Portugal), though schedules unchanged so far in other countries (e.g. Denmark, Italy, the Netherlands). Major utilities have so far maintained spending plans from before the crisis (in some case budgets 5-10% higher than 2019) and increased profits in Q1 from continuous operations, while companies continue to raise financing via debt issuance, particularly green bonds. Despite lockdowns, construction has continued in many countries and some large solar PV and offshore wind projects in Spain and the United Kingdom came online in the first four months of 2020. |
| United States | <ul style="list-style-type: none"> The stimulus bills passed so far do not include specific support for the energy sector, though there is expectation that some may come. The largest US-based solar PV project (690 MW) was approved in May. Project includes a 380 MW battery storage system. The government signalled a post-2020 extension of tax credit eligibility for new solar and wind projects, to help account for delays; 1Q wind installations doubled compared with 1Q 2019 and the wind construction pipeline rose to record levels. |
| India | <ul style="list-style-type: none"> Deadlines for commissioning of generation projects extended; Ministry of New and Renewable Energy (MNRE) confirmed extensions for the duration of the lockdown plus 30 days for renewable power projects (treated as force majeure). MNRE declared “must run” status of renewable projects and ordered discoms to pay generators. Still, some relaxation of payments has been allowed, a signal of persistent discom financial stress. Some state governments are also allowing payment delays by consumers on electricity bills. Continuation of solar reverse auctions (a tender for a 2 GW solar PV project, for a price of for USD 34/MWh, was finalised on 16 April). The government has put in place measures to boost power sector investment, particularly private capital (e.g. extending participation of non-financial banking companies, launching a new investment fund and improving bankability of power purchase agreements). |
| MENA | <ul style="list-style-type: none"> Abu Dhabi announced a record low price of USD 13.5/MWh for a 2 GW solar PV plant. Iraq deferred its capital expenditure budget given low oil prices, putting at risk ~7 GW of planned generation expansion (over 5 GW of combined-cycle gas turbines and 1.7 GW of renewables for which planning had already been conducted). |
| Other regions | <ul style="list-style-type: none"> Korea doubled its subsidy for residential and commercial solar rooftop solar (to cover up to 80% of installed costs). All auctions for transmission and large-scale renewable projects postponed in Brazil, and Mexico’s system operator banned renewable energy projects from performing tests required to reach commercial operation during May (to ensure grid reliability). Potential wind curtailments to wind power independent producers from South African’s state-owned utility Eskom given lower demand. Viet Nam may reduce 15 GW of planned coal power by 2025; new feed-in-tariff announced for renewables. |

Disruptions to renewables supply chains have pushed some investment schedules back

Physical restrictions and new uncertainties over equipment demand caused delays and disruptions to renewable supply chains in early 2020, and may continue. Solar PV module manufacturing was idled in China and other locations in Asia as restrictions initially took hold. In Europe, some 20 wind turbine facilities stopped operating in March, mostly in Spain and Italy, with factories in India also stopping production. Longer duration of these disruptions, and their spread to additional locations like Southeast Asia, could derail renewables progress by further delaying the completion of many projects globally.

China has an outsized impact on solar and wind supply chains; it accounted for two-thirds of PV module shipments in 2019. Conditions have eased there, with most factories back up and running by April, though operating margins remain tight on the back of low prices and oversupply – global shipments exceeded project additions by more than 10% in 2019 – and plants requiring time to ramp up production.

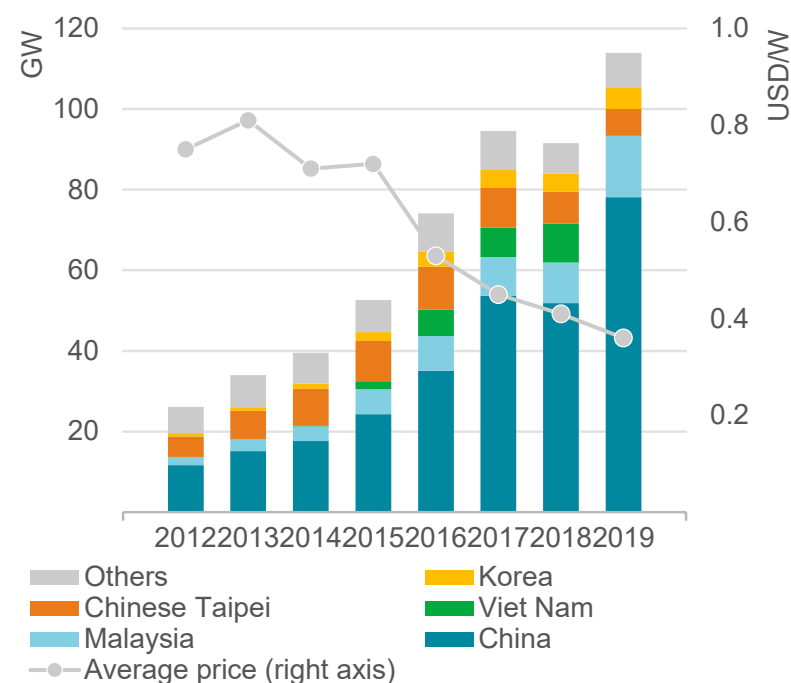
The picture in some other countries has also appeared to ease. In some US states, PV manufacturing is deemed an “essential business”, allowing operation during restrictive periods. By mid-April, operations resumed for some European wind plants. In general, manufacturer service and maintenance businesses have remained up and running.

Many challenges remain for the industry. Before the crisis, equipment manufacturers faced financial pressures (see Energy Financing and Funding section), with tighter margins stemming in part from competitive bidding and lower renewables prices. In 2019, India’s major wind equipment company defaulted on its bonds and is undergoing a large debt restructuring.

Given the uncertainties, some governments and utilities are delaying procurement, which means reduced order books and cash flow for

suppliers, though they may be able to focus on repowering existing assets and adopting more flexible payment terms. Consolidation pressure on smaller manufacturers with weaker balance sheets may accelerate. Larger players may weather the storm with cost-cutting. This may also raise questions over research and development budgets and efforts to advance turbine and module designs, for which there has been good spending progress in recent years (see R&D section).

Solar PV module shipments by country of origin



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Source: Calculations based on SPV Market Research (2020).

In the lead-in to this crisis, spending in 2019 edged higher for renewables, was stable for thermal generation, but declined for electricity networks

Global power sector investment, at below USD 760 billion in 2019, was down by less than 2% compared with 2018, driven mainly by a strong drop in capital spending on electricity networks, which offset the increase in nuclear power and small increase in renewables.

In 2019, China continued to account for more than a quarter of the overall investment, though its spending dropped as a result of lower spending in grids, coal power and solar PV projects. On the other hand, the United States and Europe saw strong increases. The US growth was driven by a big increase in wind power and networks. In Europe, fossil fuel and nuclear power drove spending upwards.

Global spending on coal-fired power plants dropped by 6% in 2019, reaching a decade low. The main reduction occurred, once again, in China (although FIDs in China picked up in 2019). Despite the falling trajectory, the size of the global coal fleet continues to grow as more capacity entered into operation than retired.

Gas-fired power spending reversed its recent trend and increased in 2019, reaching levels similar to 2014-15. Spending continued to slow in two of the largest markets, the United States and MENA (following a considerable slowdown in FIDs in 2017-18), and increased mainly in Europe and Russia.

Renewable power spending, at around USD 310 billion in 2019, grew by 1%. There was increased spending on wind power in the United States, a sector that has been growing fast given good resources, policy support (e.g. production and investment tax credits) and demand from corporate power purchase agreements (see Energy Financing and Funding section). Spending increased slightly in India,

driven by higher investment in wind. China's renewable power spend edged down in 2019 as an increase in hydropower was not large enough to offset lower solar PV (after a reduction in financial incentives). Spending in Europe also edged down, due to wind, even as corporate buying activity increased. Investment in distributed solar PV and battery storage comprised half of total spend in these technologies.

Nuclear power investment edged up again, as several projects started construction in 2018 and four additional ones did so in 2019. This was an important driver of growth in Europe given the two reactors of Hinkley Point that started construction during the period.

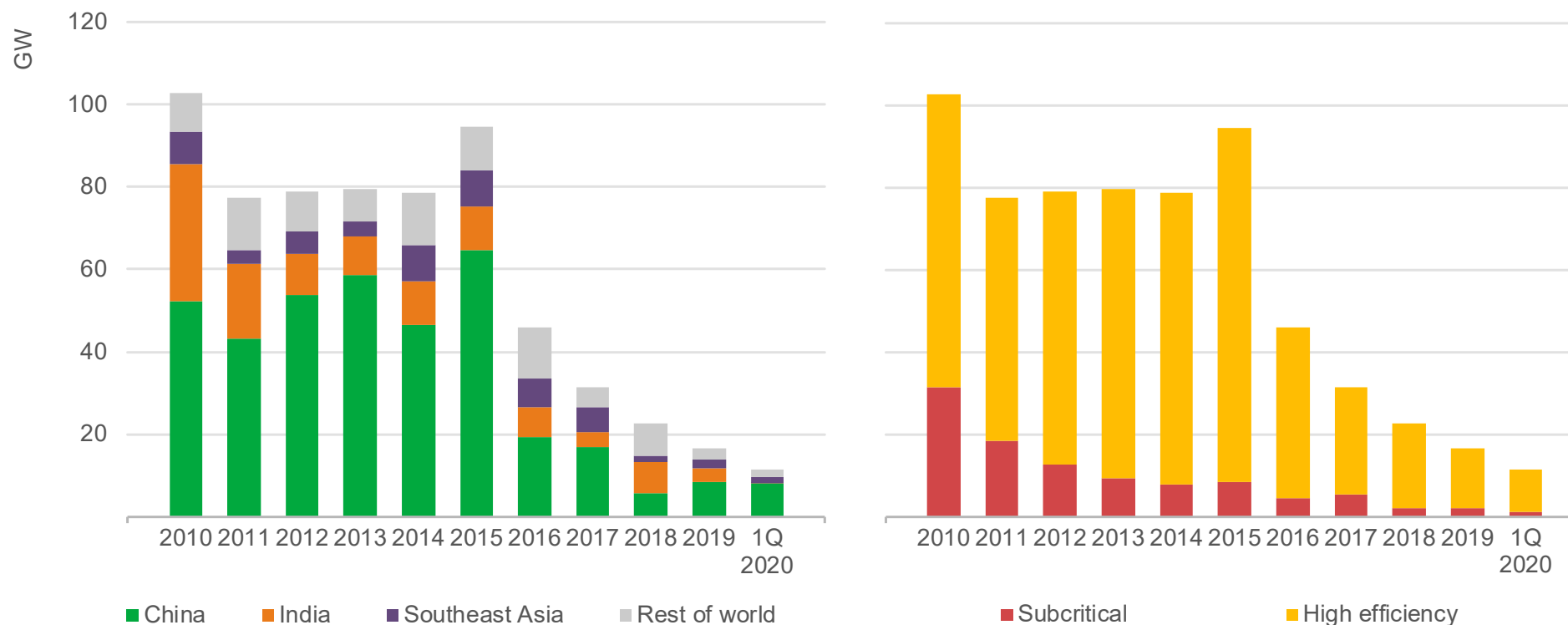
A 7% drop in spending in electricity networks was the main reason for the overall fall in global power investment in 2019. This was mainly due to an 11% drop in China's investments, mostly driven by regulatory changes and reduced grid tariffs, outweighing continuous growth in the United States (which reached the top place for network investments for the first time in a decade). In addition, global spending in transmission reduced to USD 90 billion, below the USD 100 billion level that was surpassed between 2016 and 2018. Investment in battery storage dipped for the first time, by 12% to USD 4 billion in 2019%, though partly due to falling costs.

The overall share of power investment in developing economies dropped to the lowest level since 2013. This was mainly due to the rise in spending in Europe and the United States during the last years – which has also reduced the gap with the largest market (China).

Final investment decisions

FIDs for coal-fired power plants in 2019 declined to their lowest level in 40 years, even as they went up in China, a trend that may continue in 2020

Coal-fired power generation capacity subject to an FID



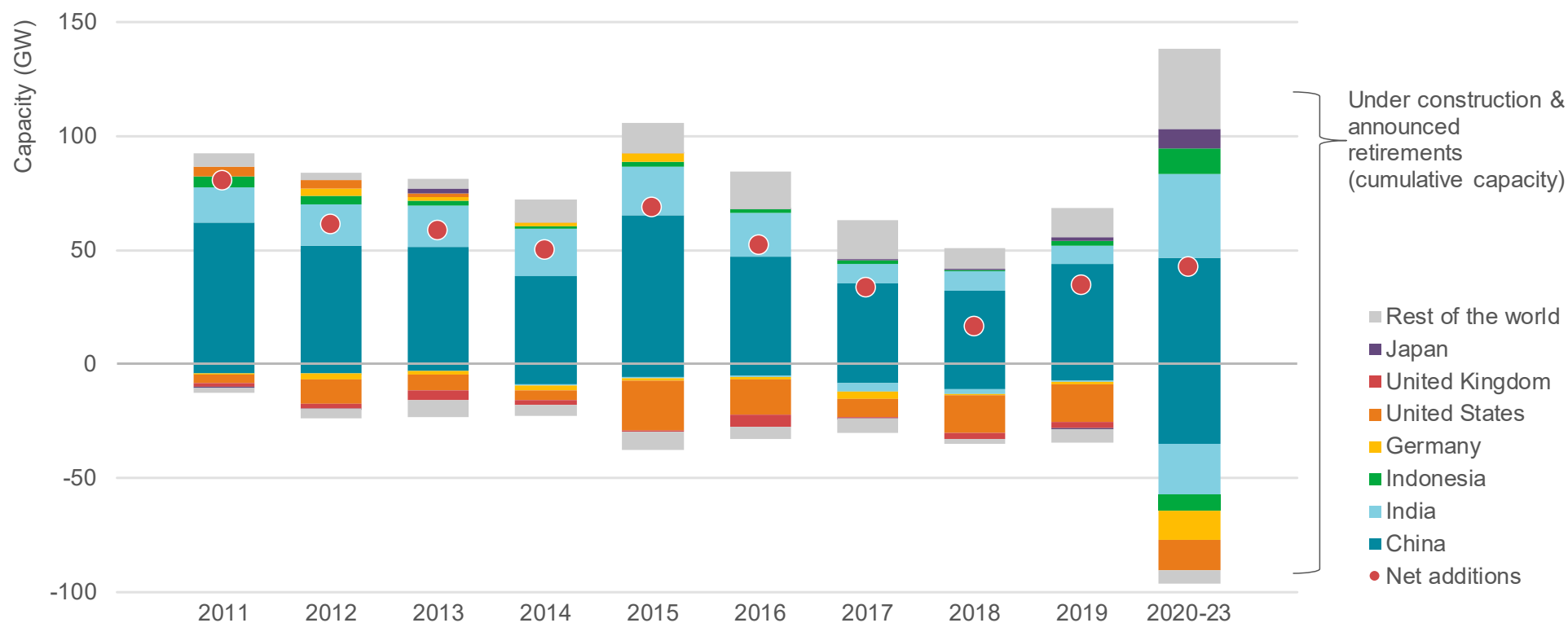
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Note: FID = Final investment decision. 1Q 2020 data are based on announced approvals in China and confirmed FIDs in other regions.

Source: IEA calculations based on McCoy Power Reports (2020).

Despite record retirements and low FIDs, the coal power fleet has continued to expand, particularly in Asia, with a large pipeline of projects under construction

Net annual additions, retirements and construction of coal-fired plants by region, 2011-23



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Note: The 2020-23 column reflects projects under construction and announced retirements (for China, the 2020-23 retirement estimate is based on the annual average of retirements between 2017 and 2019).

Source: Global Energy Monitor (2020).

Low electricity demand in 2020 reduces the need for firm power, piling pressure on older, less efficient coal plants, but there are still fewer retirements than newly commissioned capacity

Global FIDs for coal-fired generation, at below 17 GW in 2019, dropped for the fourth year in a row—the lowest level since 1980, despite an increase in China. Pressure from civil society, more stringent environmental regulation and decreasing availability of finance (see Energy Financing and Funding section) for new coal-fired power is pushing this downward trend. The majority of the 2019 FIDs for coal-fired plants (almost 90%) were once again in higher efficiency plants, with only a very small portion in inefficient subcritical projects, mainly in Indonesia.

Nevertheless, net additions of coal-fired plants in 2019 rose for the first time in five years, driven by an uptick in newly commissioned plants in China and, to a lesser extent, in India. Additions in China were a result of various factors, including: support to industrial and economic activity, utilities' expansion targets and domestic generation plans (linked with issues around security of supply). This growth also came in the face of weakening electricity demand and falling utilisation rates for the existing fleet (which are likely to carry through in 2020), intensifying the risks of overcapacity.

Over 250 GW were retired globally between 2011 and 2019, two-fifths in the United States and almost a fourth in China. The United Kingdom and Germany accounted for an additional 15%. Most of the plants retired were subcritical but as countries face increasing pressure to improve air quality and environmental standards, some more efficient plants are also being retired. A relatively low gas price environment also helped accelerate this trend.

The average size of plants retired was highest in the United Kingdom, while China, India and – until mid-2010s – the United States retired

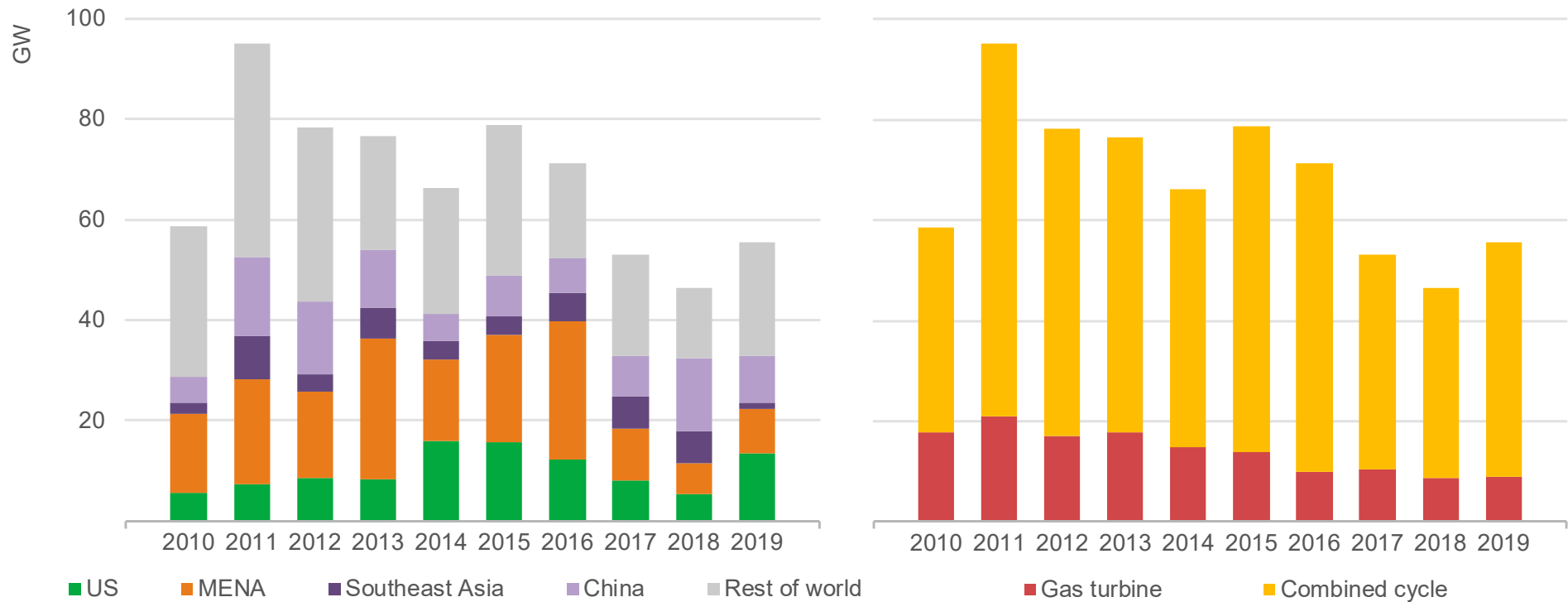
smaller plants (on average), mostly below 200 MW. Except for China, where the average age was 20 years old, most countries retired plants that were at least 40 years old. In the United States, plants operated between 45 and 60 years before being retired, though there seemed to be a trend towards decommissioning younger plants.

More retirements have been announced for the coming years but the global coal power fleet is set to continue expanding, given a large existing construction pipeline. There are some 130 GW of projects under construction that are expected to start operation between 2020 and 2023; taking anticipated retirements into account, this would mean net growth in the global coal fleet of around 40 GW. There continues to be a geographical mismatch between retirements and additions, but there are some new signals coming from countries which until now had been mainly adding capacity. For example, the government of Indonesia announced in early 2020 that it will replace coal-fired plants aged 20 years or older. According to IEA analysis, if this were to be implemented, it would translate to around 7 GW of coal-fired plants being retired.

Lower expected electricity demand and prices in 2020 would likely delay capital spending in coal-fired plants further, given a lower need for new firm capacity. However, pressure to stimulate economic growth in emerging Asia may challenge this. For example, in March 2020, China announced 8 GW of coal-fired capacity approved, a level similar to the overall capacity approved in 2019, and more than 2018. The government also lowered the restrictions to build new coal-fired plants for the third consecutive year, giving a green light for construction in more regions of the country.

FIDs for gas-fired power plants increased for the first time since 2015, driven mainly by the United States

Gas-fired power generation capacity subject to an FID

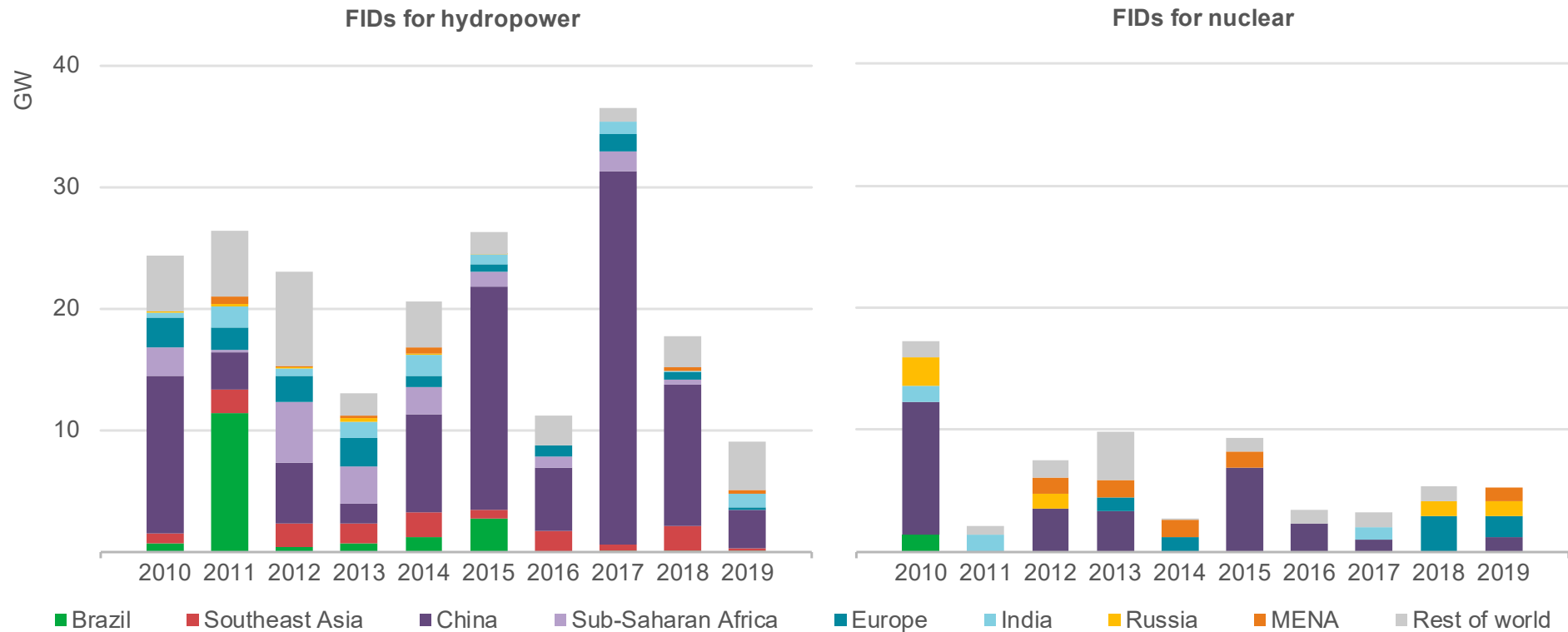


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Note: US = United States, MENA = Middle East and North Africa
 Source: IEA calculations based on McCoy Power Reports (2020).

FIDs for large-scale dispatchable low-carbon power (nuclear and hydro combined) fell to their lowest level this decade

Dispatchable low-carbon power generation capacity subject to an FID

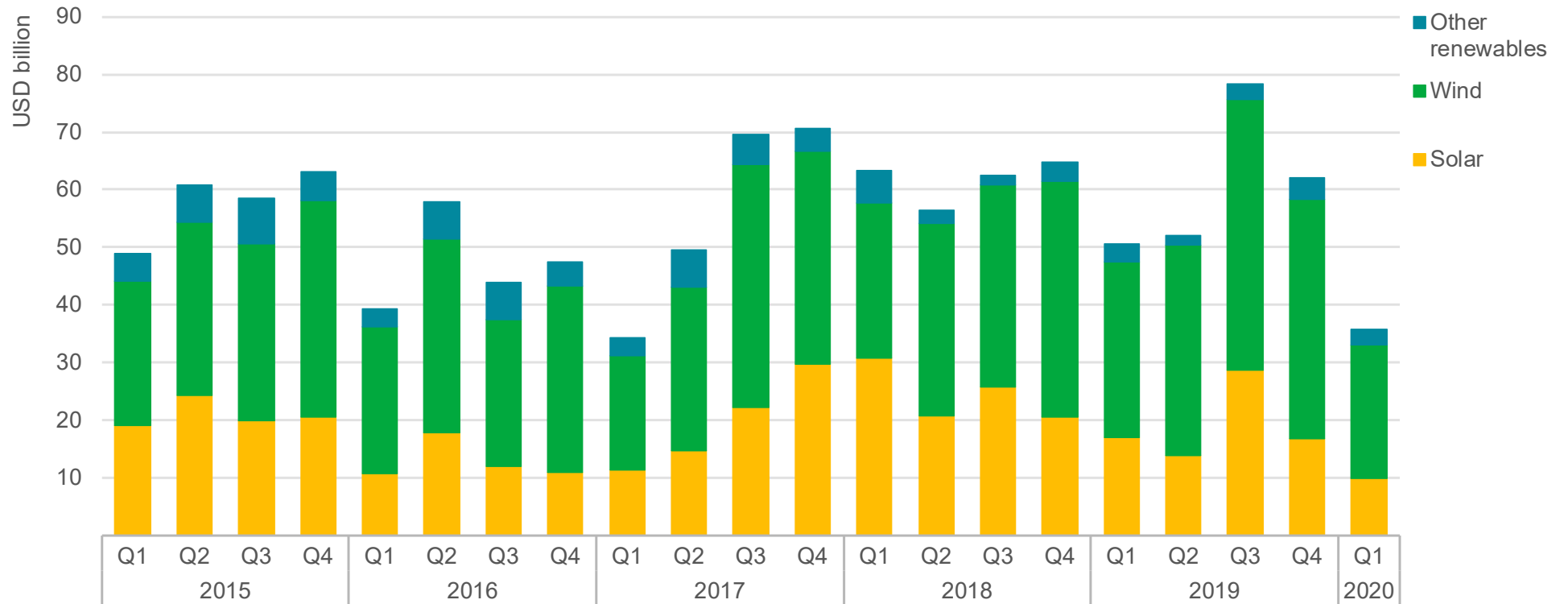


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Source: IEA calculations based on McCoy Power Reports (2020) and IAEA (2020).

FIDs for utility-scale wind increased in 2019 (in spending terms), led by offshore projects, while there were fewer financings of solar PV. In the first quarter of 2020, FIDs fell 30% year-on-year

FIDs for utility-scale renewable plants



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Notes: Excludes large hydropower.

Source: IEA calculations based on Clean Energy Pipeline (2020).

Growth in FIDs in 2019 was concentrated in gas-fired power and large-scale wind projects, while 2020 could see fewer approvals across the board

Overall, FIDs for the main sources of large-scale dispatchable power – coal, gas, nuclear and hydropower – fell to 86 GW, an 8% reduction compared with 2018 and almost 60% lower than in 2010. This is the lowest level in a decade.

Among these sources, FIDs for gas-fired generation were the only ones to see an increase (for the first time since 2015), to over 55 GW. The strongest growth was in the United States, where gas generation, supported by low prices, is teaming up with renewables to displace coal: some 5% of the US coal power fleet retired in 2019. The MENA region also saw considerable growth, particularly in the Gulf Cooperation Council countries. China's investment decisions fell to below 10 GW, even as they remained high in comparison with approvals in recent years, supported by broader targets to increase gas use. In the past decade, the share of FIDs has risen for combined-cycle plants, compared with smaller gas turbines typically used for peaking applications. This stems from a focus on meeting large-scale demand (and replacement) needs, but it may also reflect increased battery storage deployment to provide short-term system flexibility.

FIDs for the largest sources of low-carbon dispatchable generation (hydropower and nuclear) also fell to a combined total of 14 GW, the lowest level this decade. The drop in FIDs for hydropower, also a record low, stemmed from fewer approvals for pumped storage in China. Chinese regulation does not allow transmission and distribution companies to include pumped hydro assets as part of their regulated asset base (used to estimate the tariff these companies charge). With lower electricity demand in 2019, and lower demand expected in 2020, there is also less need for pumped hydro to balance peaks. However, the downward trend in Chinese hydropower investment may reverse in

the coming months. State Grid of China started building a new pumped hydro dam in early 2020 after putting a halt to installations during most of 2019.

FIDs for nuclear also decreased, with only four new plants starting construction, the biggest one the second reactor of Hinkley Point in the United Kingdom, which started construction in December 2019. Outside of a few markets with strong policy support, construction starts for nuclear projects continue to lag, with persistent project development challenges in some markets, and in some cases local opposition.

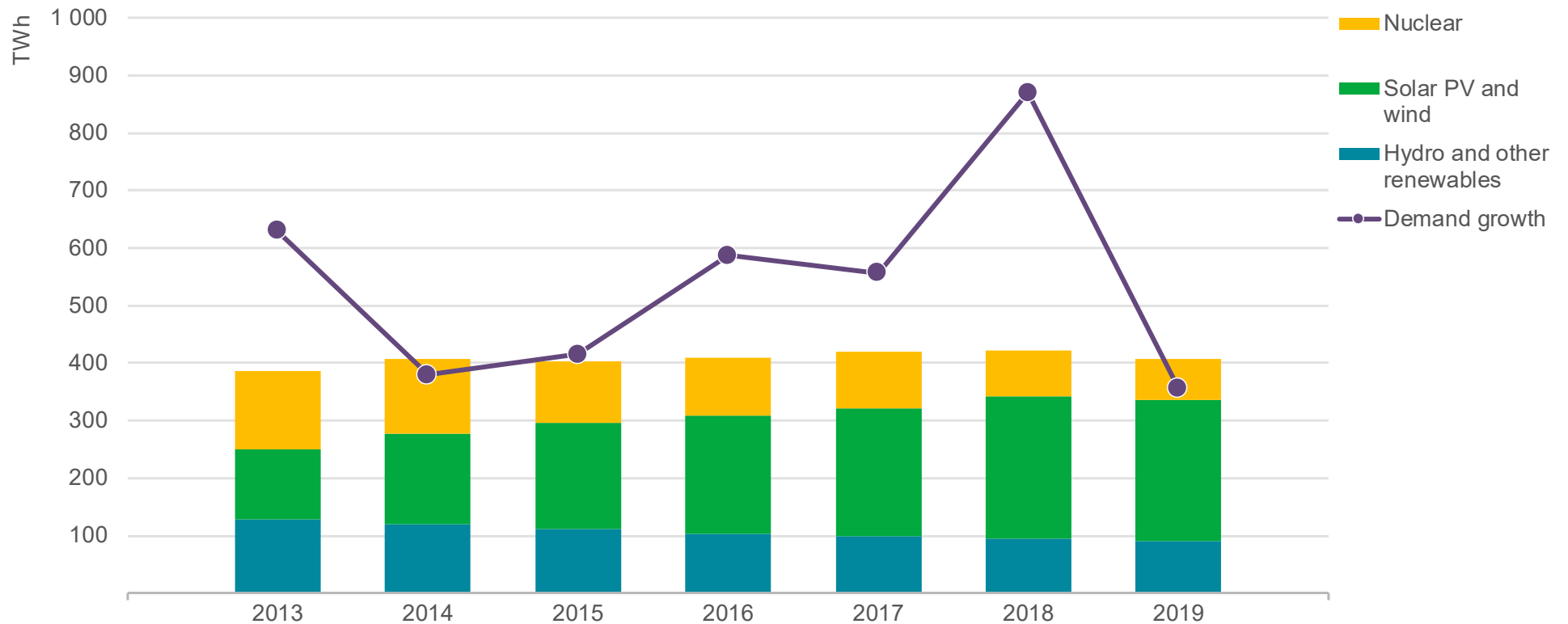
FIDs for utility-scale renewables decreased in spending terms (i.e. nominal USD terms) by 2% in 2019, despite divergences between technologies. Utility-scale solar PV FIDs decreased by 20% as they faced higher regulatory uncertainty and more competitive pressure in developing markets such as China and India. However, while onshore wind FIDs remained flat, offshore wind FIDs increased by 70% and hit a record of USD 40 billion, with investors showing high appetite in China, Chinese Taipei, Germany and the United Kingdom.

Data from the first quarter of 2020 show that FIDs for utility-scale renewables (excluding large hydropower) contracted to first-quarter 2017 levels, with downturns in onshore wind (year-on-year reduction of 50%) and solar PV (down by 20%). This reflects some risk-aversion to financing projects in the near-term given lower demand and wider uncertainties that emerged with the Covid-19 pandemic, and is consistent with a parallel fall in global power sector project finance transactions during that period (see Energy Financing and Funding section).

Implications of power investment

Expected output from low-carbon power investments in 2019 was more than enough to cover lower global growth in electricity demand

Global expected generation from low-carbon power investments compared with electricity demand growth

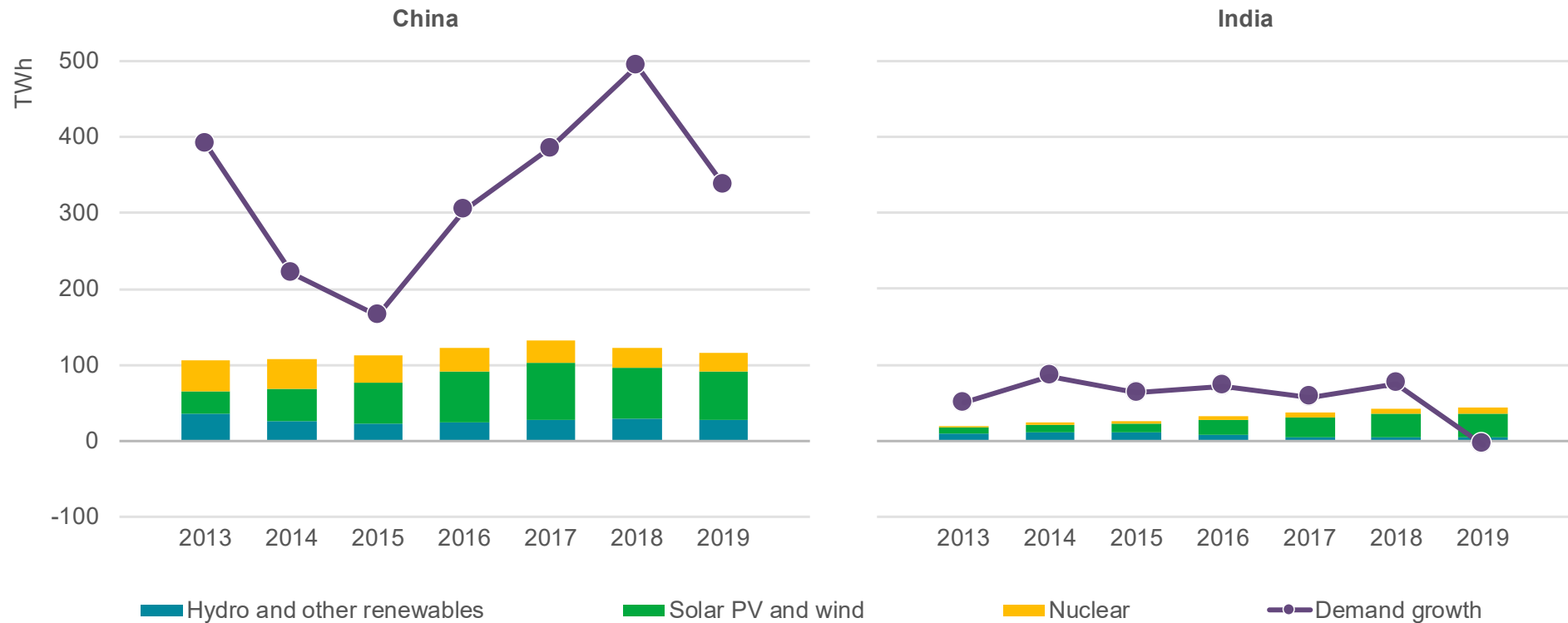


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Notes: Expected generation is based on the expected annualised output of the capacity associated with investment in a given year. Nuclear includes investments on life extensions.

In China, low-carbon investments have not kept pace with electricity consumption growth, while weaker demand in India was surpassed by low-carbon investments for the first time

Expected generation from low-carbon power investments compared with electricity demand growth

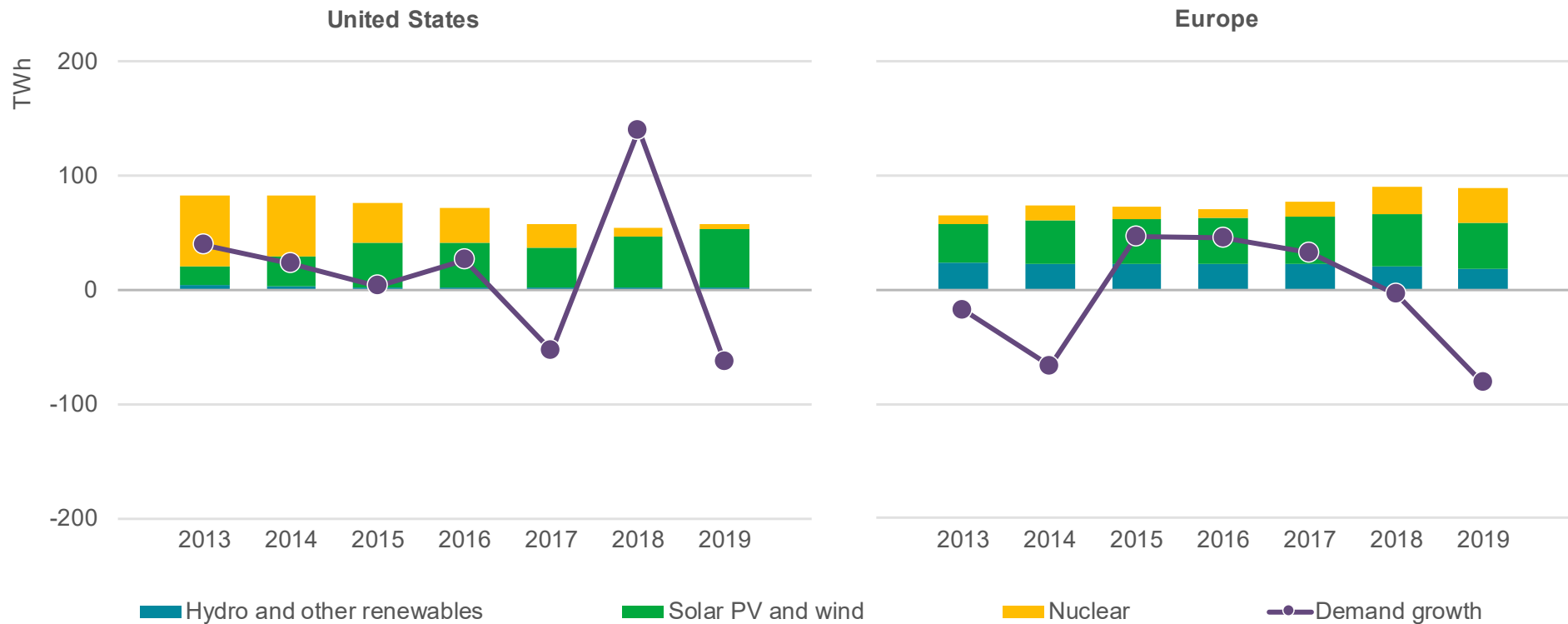


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Notes: Expected generation is based on the expected annualised output of the capacity associated with investment in a given year. Nuclear includes investments on life extensions.

Low-carbon power investments have almost always run ahead of electricity demand in the United States and Europe

Expected generation from low-carbon power investments compared with electricity demand growth

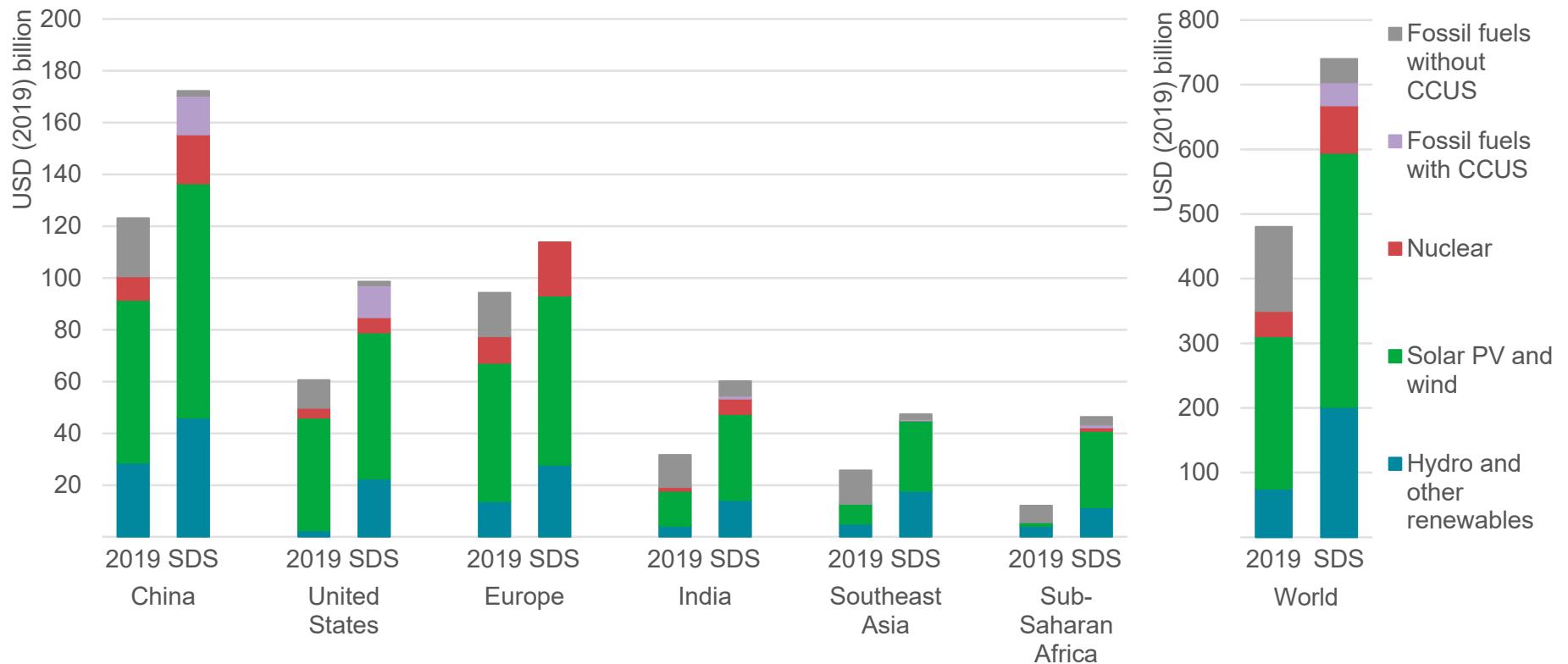


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Notes: Expected generation is based on the expected annualised output of the capacity associated with investment in a given year. Nuclear includes investments on life extensions.

The level and composition of power generation investment in 2019 would need to change rapidly to support a more electrified and sustainable future

Power generation investment compared with annual investment in the Sustainable Development Scenario (2025-30)



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Note: SDS = annual average investment from 2025-30 in the IEA Sustainable Development Scenario.

Electricity is pivotal to modern societies and to energy transitions, but investment in the sustainability and flexibility of power systems is falling short

Understanding the energy impact of power investments is important to assess their contribution to meeting long-term goals. In 2019, the global expected generation from low-carbon power investments outpaced electricity demand growth for the first time in five years. Part of this stemmed from weaker demand, which had the lowest growth in a decade, and a sharp reversal from the trend in 2018. Demand growth was around 30% lower in China, while India saw no growth for the first time in ten years; declines were also registered in the United States and Europe. Part of this reduction in demand may have been temporary (e.g. an exceptional monsoon in India reducing electricity needs for irrigation) but there are considerable downside risks to electricity demand in 2020 given the Covid-19 pandemic. The IEA estimates a drop in global electricity demand of 5% globally in 2020.

At the same time, the expected output from low-carbon power investments rose, largely due to a higher contribution from new solar PV and wind. Here, too, there are significant caveats to this picture, with a slowing of spending from short- and medium-term impacts related to the current crisis.

Current investment levels are not aligned with a sustainable pathway. Compared with the average annual investments projected in the IEA SDS, power sector spending in 2019 was about 35% short of the level required a decade from now. There is a continued need for capital reallocation to meet energy security and sustainability goals, to bring in more low-carbon power and to ensure that renewable-rich systems can operate with sufficient system flexibility.

The largest projected growth in investment to align with such a pathway would be required in solar PV and wind, on average an extra USD 160 billion of spending each year. Electricity networks would require an extra USD 150 billion from today's levels, in addition to a higher level of capital for other renewables and nuclear.

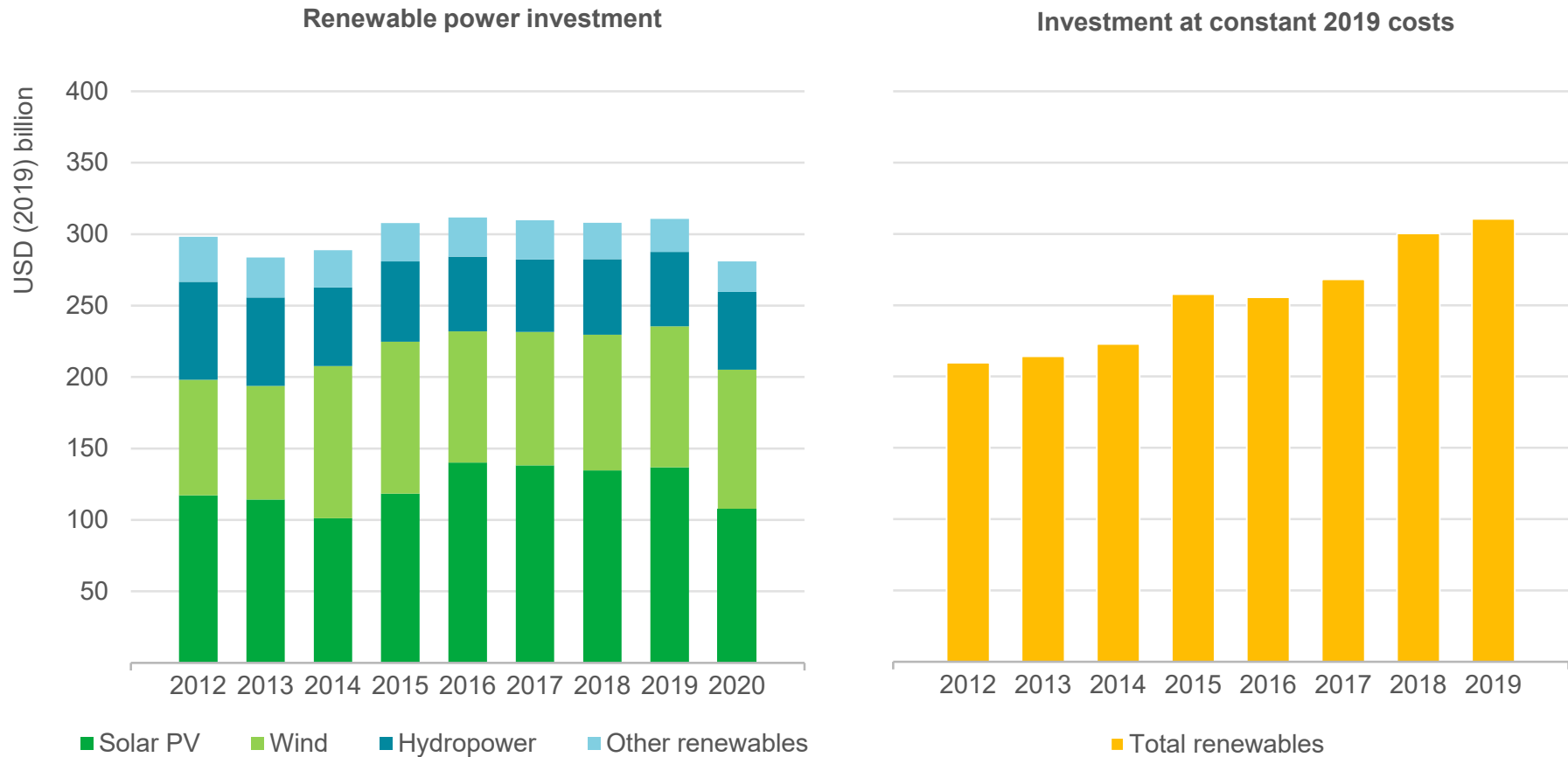
Comparing current trends with projections in the SDS, emerging economies would need to boost spending on renewables, while at the same time supporting other areas of power system flexibility and decarbonisation, such as through flexible operation of thermal plants, fossil fuels with CCUS, grids, energy storage and demand response. Investments in China present the highest divergence. India, Southeast Asia and sub-Saharan Africa would need to more than double renewable investments. Nuclear would likewise see increased investment, particularly in China, with additional annual spending of USD 10 billion, and India, with an additional USD 5 billion.

In advanced economies, the gap is smaller for solar PV and wind, but they would still require uplifts of 20-30% in Europe and the United States. Hydro, other renewables and nuclear remain as key technologies to guarantee security of supply and to meet sustainability goals. However, 2019 spending on these technologies was well short of SDS projections, by USD 10 billion for investments in nuclear for Europe and by USD 20 billion in hydro and other renewables for the United States.

Trends in renewable power costs and investments

Falling costs mean that every dollar invested in renewables buys ever more power

Investment in renewable power – actual spending versus investment at constant 2019 cost levels



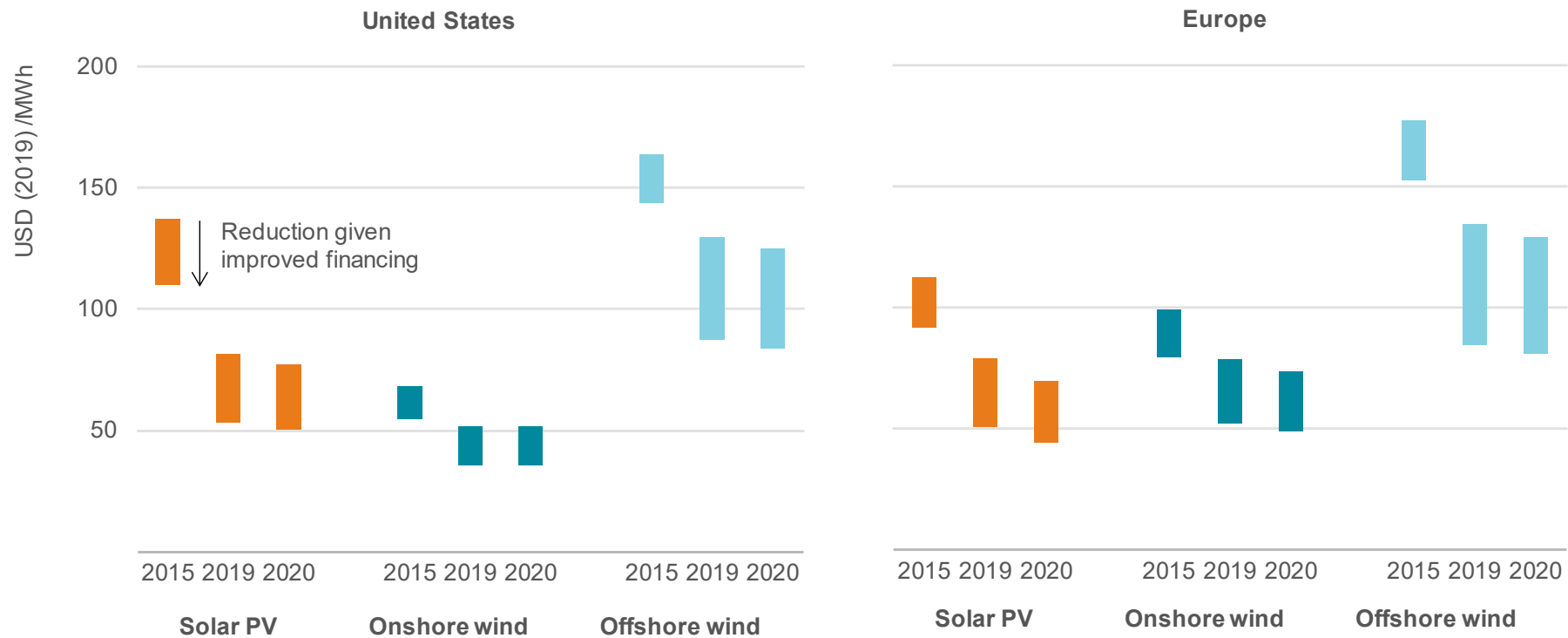
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Note: Investment is measured as the ongoing capital spending in renewable energy capacity.

Source: IEA analysis with calculations for solar PV, wind and hydropower based on capital costs from IRENA (2020).

A combination of more advanced technology, improved operations and lower cost of capital has steadily improved the economics of solar PV and wind ...

Impact on levelised cost of electricity for newly commissioned renewable power capacity, by level of financing costs, 2015-20



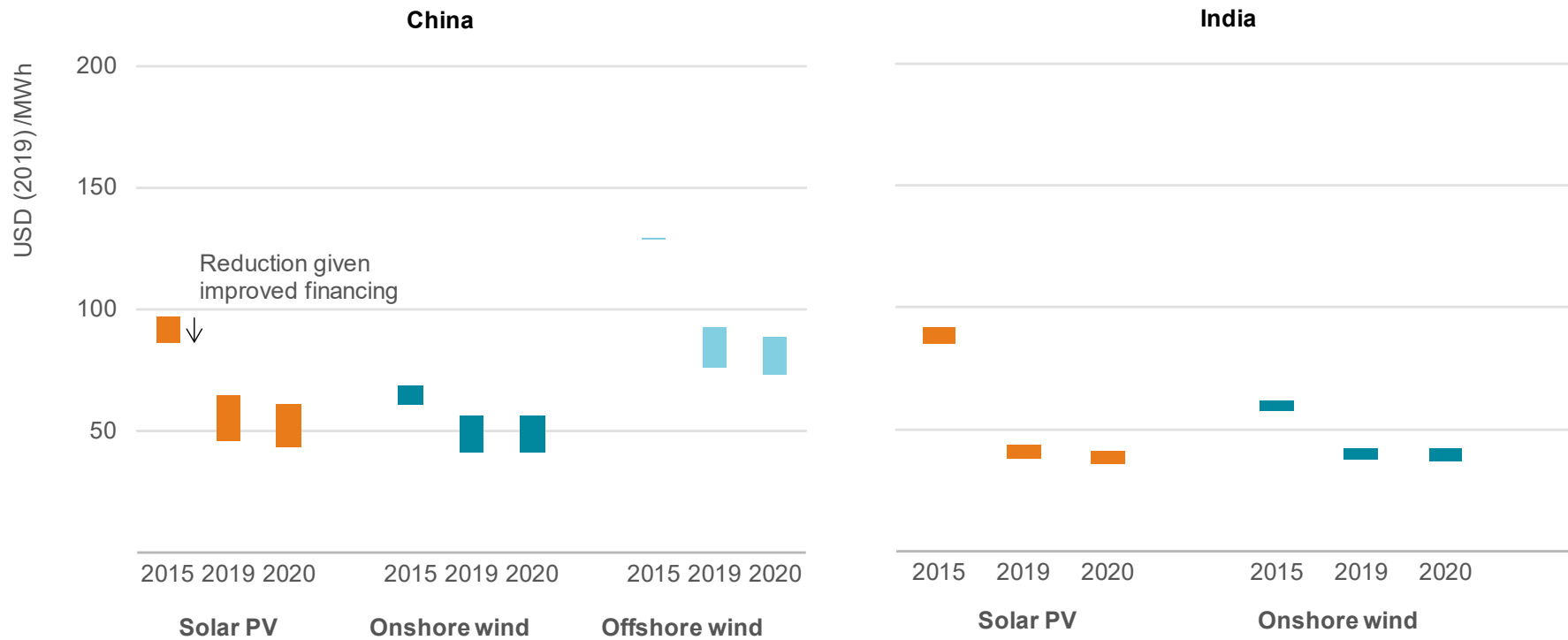
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Notes: Figures are indicative estimates (expressed in real terms). Upper limits of the columns show the levelised cost of electricity (LCOE) using a standard weighted average cost of capital (WACC) representing average market risk (8% in advanced economies and 7% in developing economies). The length of the column illustrates how much the LCOE of the technology in the specific region has dropped as a result of reduced financing costs. Capital costs are based on commissioning dates and the terms of the WACC are based on financial close.

Source: IEA analysis based on technology capital costs from IRENA (2020).

... with improved financing conditions also playing a major role in bringing down costs across technologies

Impact on levelised cost of electricity for newly commissioned renewable power capacity, by level of financing costs, 2015-20



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Notes: Figures are indicative estimates (expressed in real terms). Upper limits of the columns show the levelized cost of electricity (LCOE) level using a standard weighted average cost of capital (WACC) representing average market risk (8% in advanced economies and 7% in developing economies). The length of the column illustrates how much the LCOE of the technology in the specific region has dropped as a result of reduced financing costs. Capital costs are based on commissioning dates and the terms of the WACC are based on financial close.

Source: IEA analysis based on technology capital costs from IRENA (2020).

Benchmark costs have declined steadily, but recent bidding results suggest even lower contracted prices in some markets

While capital expenditures for renewable power increased moderately in 2019, by 1%, driven by onshore wind and hydro outweighing a decline in solar PV, capital costs for some technologies have continued to decrease. For example, utility-scale solar PV installation costs decreased by over 10%, continuing a trend of declines due to supportive policies (e.g. expansion of competitive auctions) and higher deployment in lower-cost and large markets such as India. A given level of investment buys much more renewables than in the past. The expenditure needed for 1 MW of renewables in 2012 enables the construction of 1.5 MW today.

Decreasing capital costs have helped to reduce overall levelised costs of electricity (LCOEs) for solar PV and onshore wind, along with other factors such as the improvement in average load factors. For wind projects, for example, larger turbines and increased hub heights mean wind farms are able to produce a greater amount of power with a smaller number of turbines. This trend is also driving reductions in operation and maintenance costs, favoured by efficiency gains from digitalisation.

Financing costs are also a critical component of LCOEs and reduced WACCs have been vital to scale up renewable deployments globally. For example, applying a standard average real WACC of 8% to a US solar PV project in 2019 produces an LCOE of around USD 80/MWh in 2019. The LCOE for the same project with access to lower-cost financing (4% on average) is just over USD 50/MWh. Actual required returns depend a lot on the degree of associated market risk. Involvement of public finance has been key to reduce the cost of capital in emerging markets, such as India, which on average face higher financing costs (given higher country, technology and revenue risks).

On the debt side, financing terms have improved globally. This is due to lower base interest rates (driven by accommodative monetary policy and lending competition) and lower debt risk premia (from a maturing renewables industry and the risk reduction role of supportive government policies and ambitious goals). For example, evidence shows that lower risk perceptions contributed to improved availability and pricing of project debt finance in India for utility-scale solar PV and wind projects over 2014-18 (CEEW and IEA, 2019). Debt risk premia fell by 75-125 basis points for both technologies over the period, with banks willing to lend for longer tenors. On the equity side, expected returns on equity have also lowered globally, as supportive policies and growing market experience helped reduce investor risk perceptions.

The upshot is that LCOEs for newly commissioned utility-scale solar PV and onshore wind plants have fallen to around USD 35/MWh to USD 55/MWh in China, Europe, India and the United States (assuming low cost financing). Even lower prices have also emerged in competitive auctions for capacity to be commissioned in the years ahead, e.g. prices below USD 20/MWh in Brazil, Mexico, Portugal, Qatar and the United Arab Emirates.

Central banks are likely to keep interest rates low to stimulate growth. Yet some emerging countries may face challenges as sovereign risks increase and there are signs that commercial banks may raise margins on project lending to compensate for higher liquidity costs. Uncertainty can also mean more difficulties to mobilise equity globally. We expect a lower annual drop in indicative LCOEs in 2020 with financing costs staying level or potentially rising as a result of new risks.

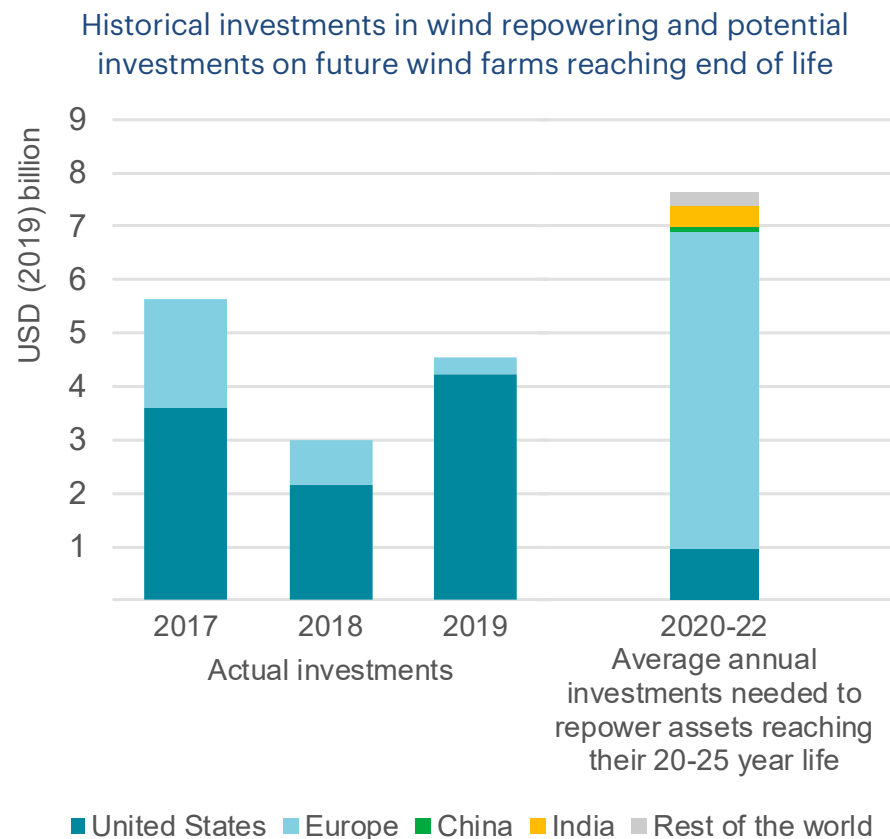
Wind repowering is already an important source of investment in Europe and the United States, and more is yet to come

Wind repowering refers to the refurbishment or upgrading of wind turbine system components with the latest and more advanced equipment. Taking advantage of technological improvements, repowering enables not only to increment the nameplate capacity of an existing wind farm, but also to enhance load factors and to reduce operation and maintenance costs. This is mainly driven by larger turbines and increased hub heights that allow production of a greater amount of power with a smaller number of turbines

More than 10% of total spending in onshore wind has been devoted to repowering in the United States and Europe in the last three years. However, as more and more turbines reach the end of their useful life (20-25 years), global repowering is expected to steadily rise and get close to USD 10 billion per year, two to three times higher than the 2017-19 annual levels.

Wind repowering could surge even faster if properly incentivised by regulation or economics. For instance, India has more than 10 GW of wind turbines with less than 1 MW capacity in very good resource sites. Repowering of these with the latest turbines would more than quadruple the energy generation of these sites. In the United States, investments in repowering in 2017-19 were more than ten times higher the equivalent needed to refurbish the ageing plants.

Repowering may also become an increasingly attractive option for developers reluctant to commit large upfront capital to greenfield developments in light of the current crisis.

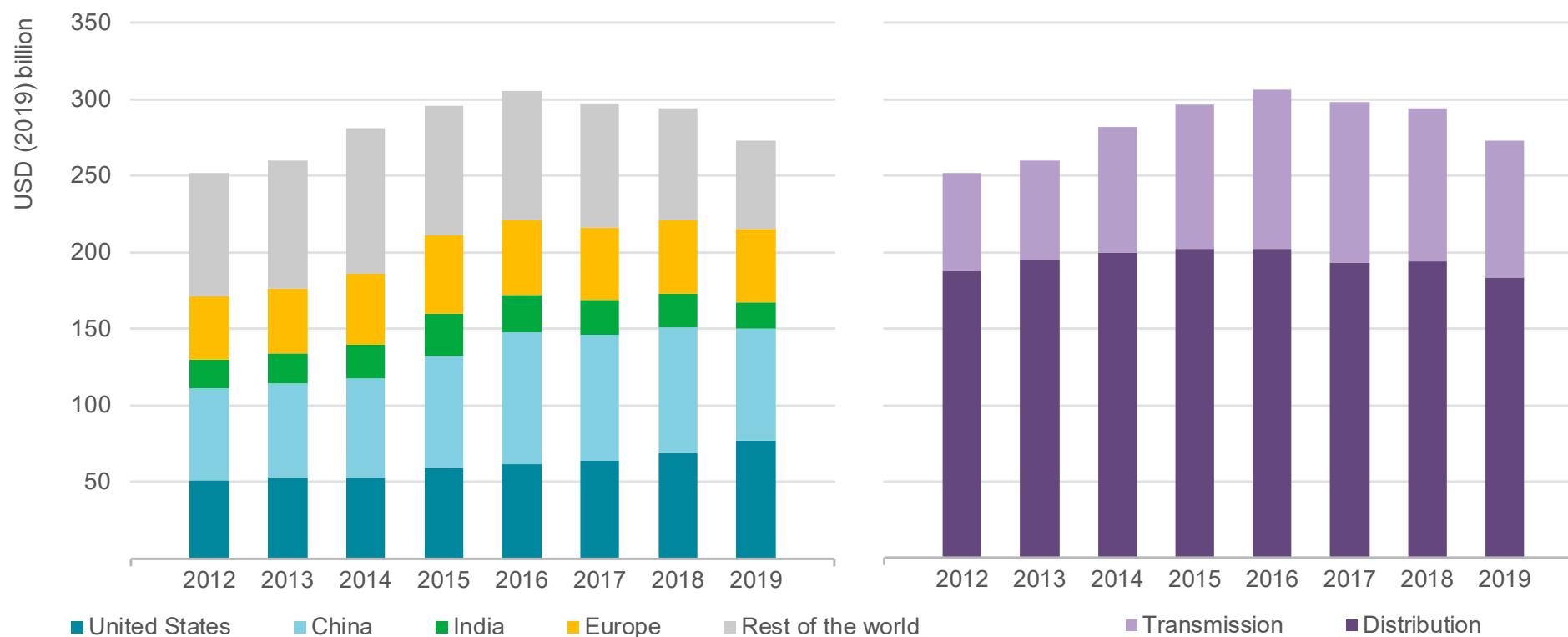


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Networks and battery storage

Global investment in electricity networks fell again in 2019, by 7%, as decreased spending in China outweighed continued growth in the United States

Investment in electricity networks by geography (left) and segment (right)

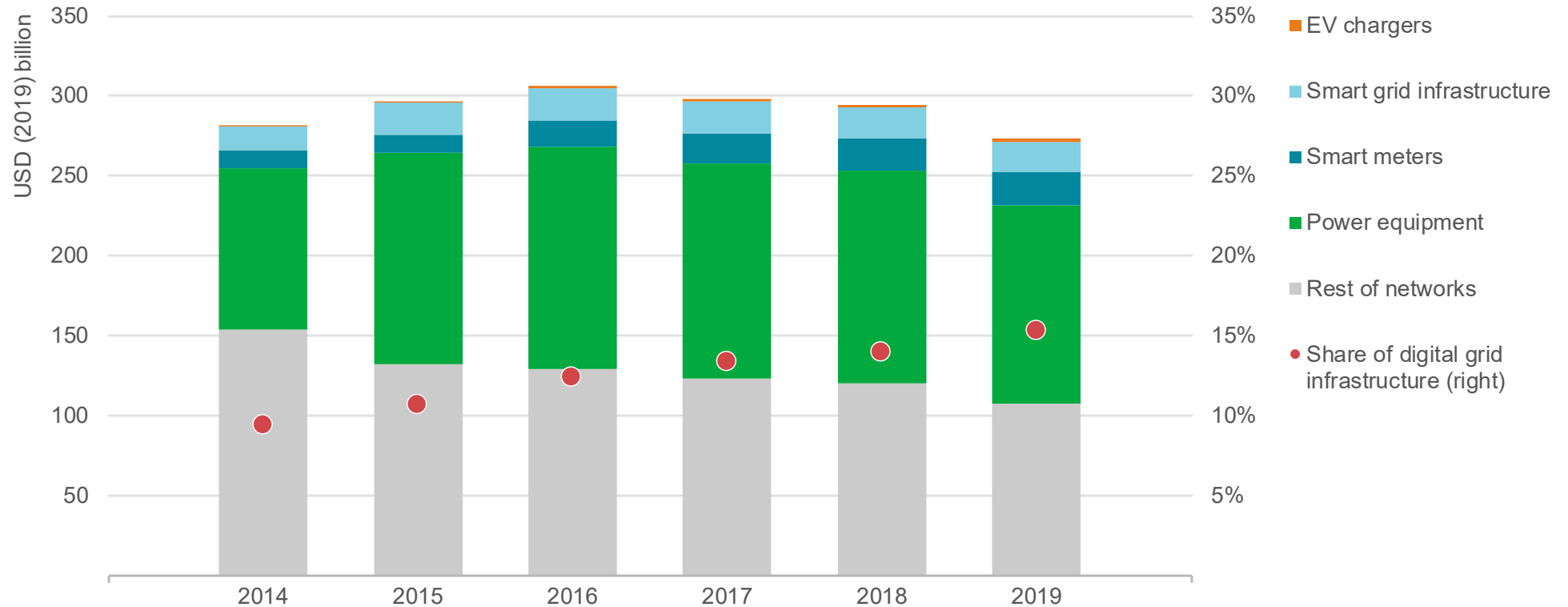


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Note: Investment in electricity networks is calculated as capital spending for installed lines, associated equipment and refurbishments.

Spending on digital grids now makes up nearly a fifth of networks investment

Investment in electricity networks by equipment type



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Notes: Two- and three-wheeler EV charging stations are excluded from the analysis. Smart grid infrastructure comprises utility automation equipment at substation level. Power equipment corresponds to transformers, switchgear, power systems and substations.

Electricity networks are the backbone of today's power systems and they become even more important in clean energy transitions, but investment needs to pick up

In 2019, investment in electricity grids declined for the third consecutive year, by 7% compared with 2018 levels, falling under USD 280 billion. Most of this decline stemmed from a sharp reduction in China, which more than outweighed strong growth from the United States, which took the top spot for grid investment for the first time in a decade. Nevertheless, there are questions over how these trends may play out in 2020, with utilities facing potentially reduced needs to connect new generation and funding constraints; on the other hand, public incentives to increase infrastructure investment in the wake of the Covid-19 pandemic may potentially offer support to spending.

Global spending in transmission reduced by 10% to USD 90 billion. China and India drove this trend. Investment in China's transmission decreased by nearly USD 10 billion, as there was a higher focus on the upgrading of rural power grids and the construction of distribution networks. In India, despite a big push to strengthen inter- and intrastate transmission capacity in the last five years, the pace of buildout slowed in 2019 by USD 2 billion. In addition, several renewable projects on the pipeline are facing higher uncertainties and delays, so there was less pressure on the need for transmission connectivity.

Capital spending in distribution decreased, too, but at a smaller rate (6%). On the one hand, investments in the United States grew for the fifth consecutive year, driven by ongoing focus of regulators and utilities on improving grid resilience and reliability. On the other hand, distribution investment declined worldwide except for Europe and China, where they remained stable. This was driven by lower growth rates for electricity demand.

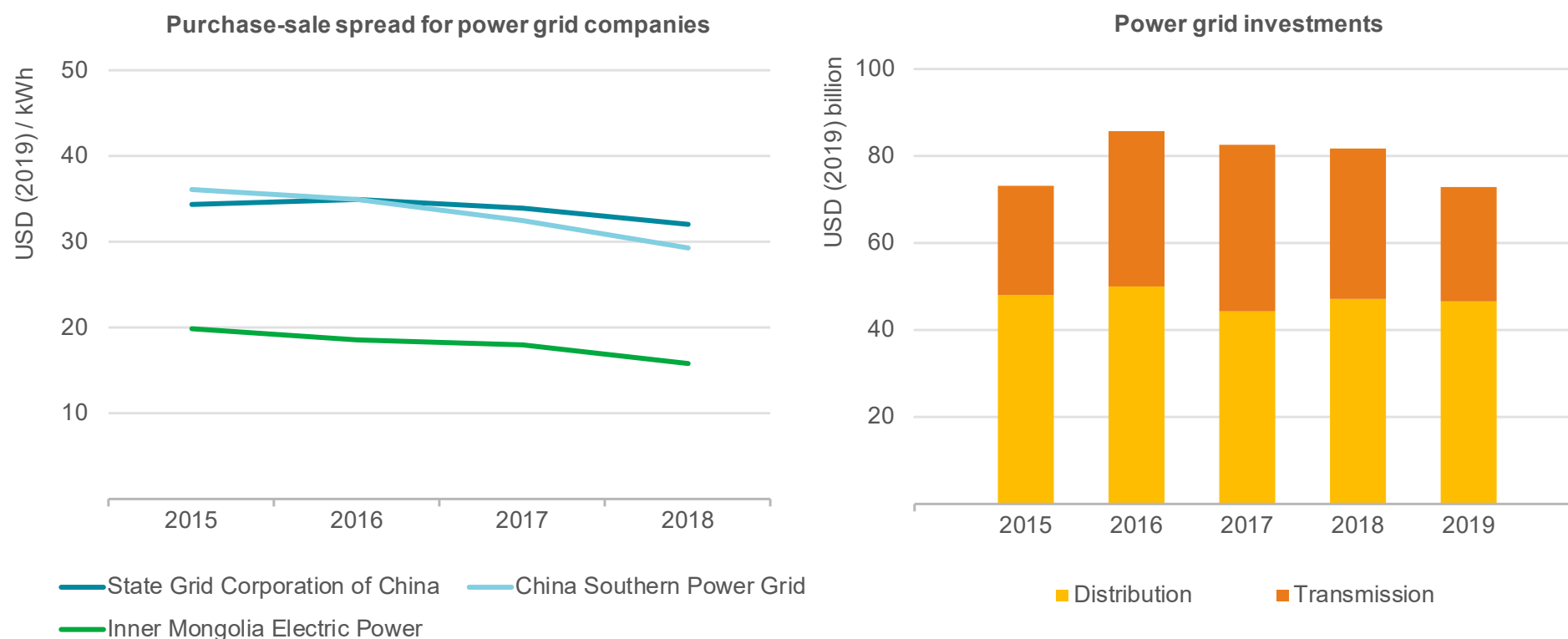
As grids are becoming more digital, distributed and smart, investment depends less on traditional equipment and more on new drivers. Smart meters, utility automation and EV charging infrastructure, at USD 40 billion, now make up more than 15% of total spending. While spending on smart meters and utility automation remained flat in 2019, that for EV charging infrastructure rose to more than USD 5 billion, with utilities, oil and auto companies, and governments announcing new expansion plans. For instance, China Southern Power Grid recently announced plans to invest more than USD 3 billion over the next four years in charging infrastructure.

By virtue of these digital infrastructure investments, electricity systems have augmented their resiliency and ability to operate with greater shares of variable renewables, as demonstrated during recent periods of much lower demand (IEA, 2020a). Such investments are supporting new business models by aggregators to integrate small-scale renewables, demand response, and other distributed resources into power grids, when regulatory conditions and market design are appropriate (see Energy Financing and Funding section). They can also facilitate the integration of power systems with more localised networks for heat supply as another source of flexibility (see Energy End Use and Efficiency section).

The current trajectory of grid spending is at risk of falling short of that needed to support growing renewables and electrification. Overall global grid spending would need to rise by some 50% over the next decade to meet long-term sustainability goals. Spending on digital grids would need to surge, too.

In China, market reforms resulted in reduced margins and greater capital discipline for grid companies, though stimulus packages may support spending in 2020

China: Electricity sales margins for grid companies (left) and total power grid investments (right)



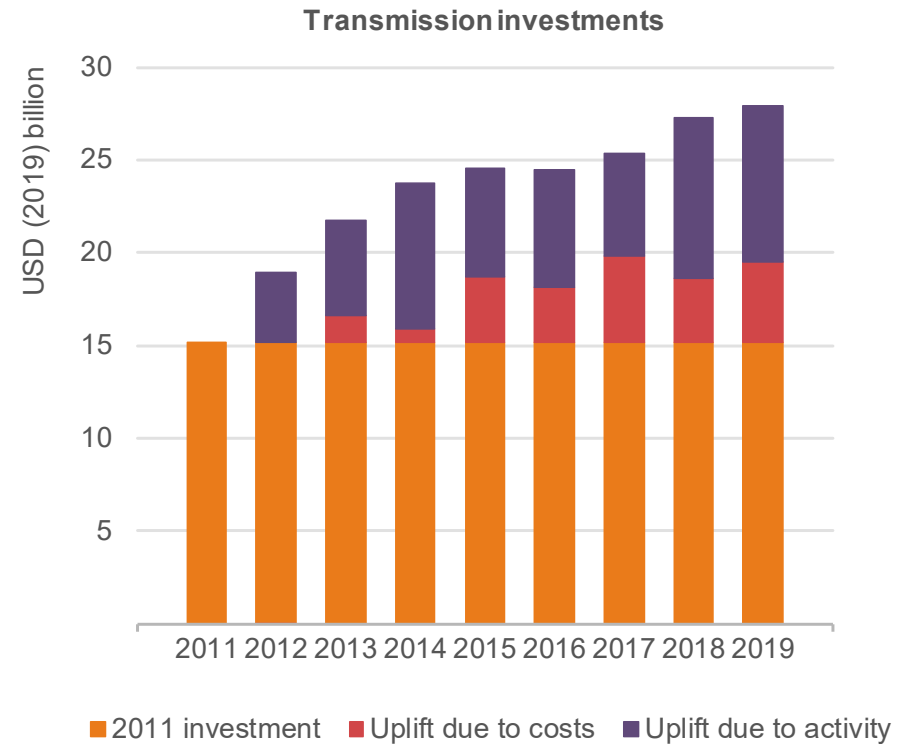
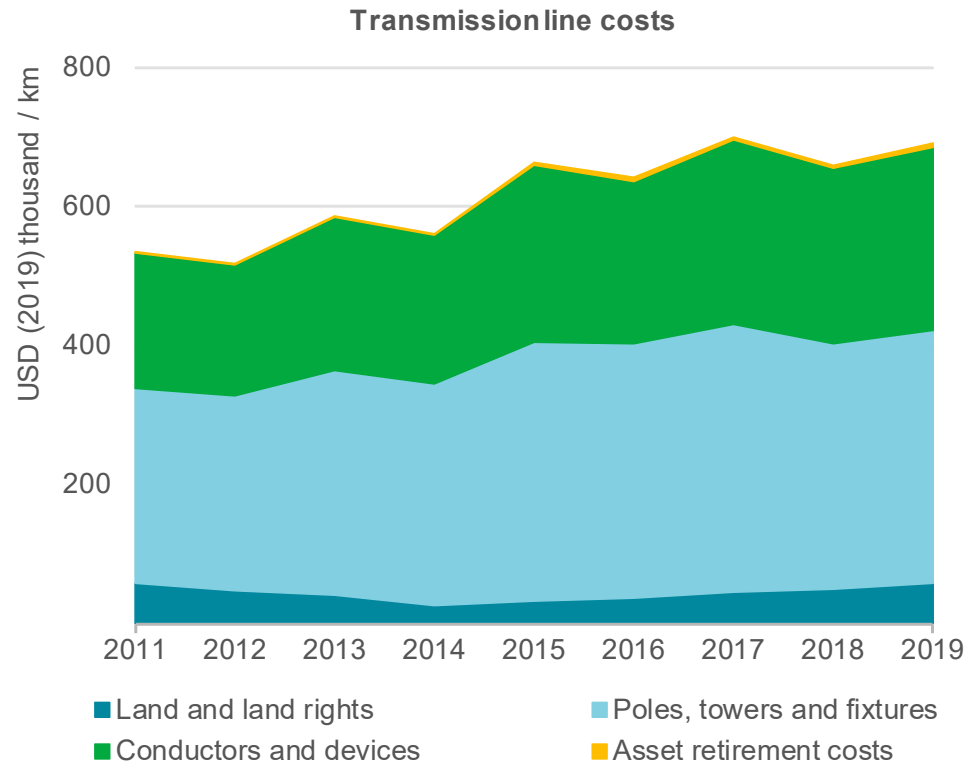
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Note: Purchase-sale spread = difference between the price at which power grid companies purchase electricity from generators and the price they obtain for selling it, including lines losses.

Source: Calculations for purchase-sale spread based on China Electricity Council (2020) and National Energy Administration (2020).

US grid spending has responded strongly to the policy emphasis on network resilience and reliability, though recent investment increases stem in part from rising costs

United States: Transmission investment costs (left) and decomposition of spending growth since 2011 (right)

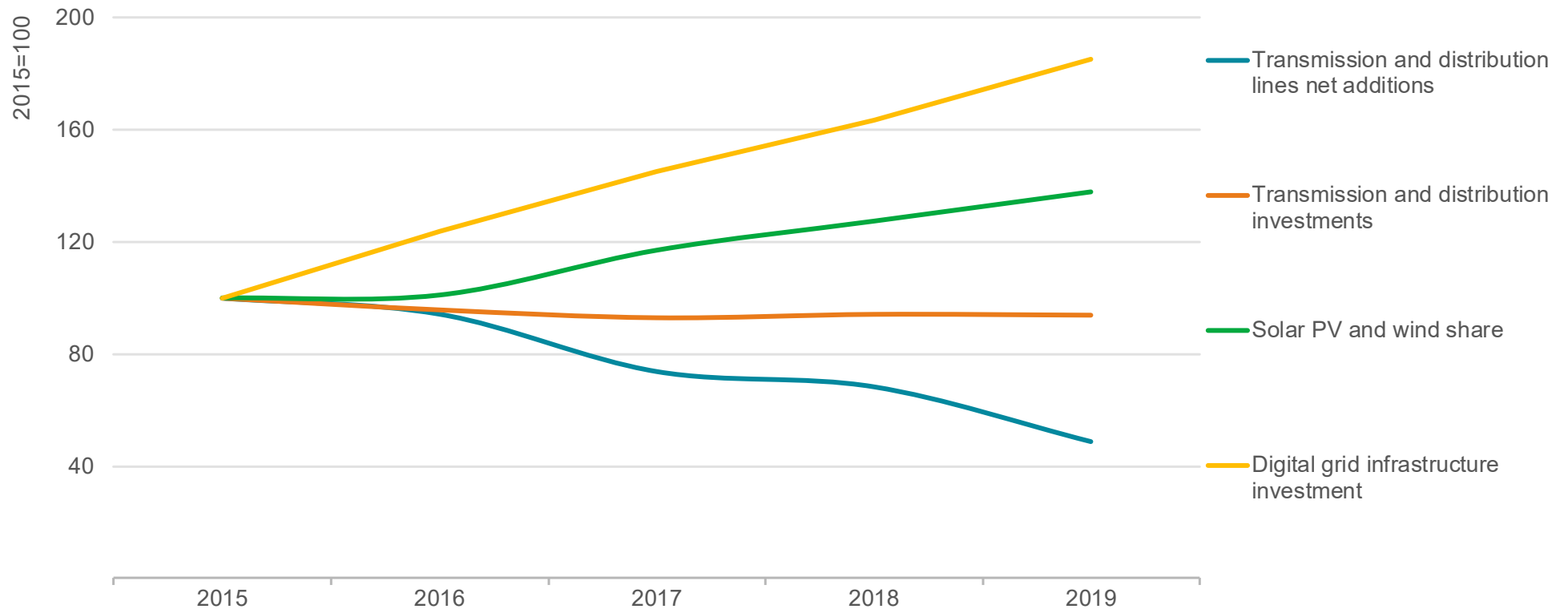


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Source: Calculations for costs based on EIA (2020).

A rising share of Europe’s grid spending supports upgrading and refurbishment, rather than expansion, as variable renewables, digital technologies and electrification have grown

Power grid investment trends in Europe



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Regional variations in grid spending are explained by the balance of different regulatory priorities to support market reforms, boost resilience and integrate new technologies

China's investments in electricity grids accelerated their downward trend and dropped by 11% in 2019, mainly driven by regulatory changes and reduced grid tariffs. Average purchase-sale spreads for grid companies (i.e. the difference between the price at which transmission companies purchase electricity from generators and the price they obtain for selling it, including lines losses) decreased by 10% between 2016 and 2018. This reduction has been incentivised by both the Power Sector Reform of 2016 (which aimed to provide more transparency with regard to network costs) and public measures that sought to reduce the power retail tariff. Furthermore, some intra-provincial and long-distance transmission line tariffs have also been revised down.

Grid investment in the United States increased by 12%, following a continuous upward trend in the last decade. Higher activity was required to upgrade ageing infrastructure, digitalise, electrify sectors such as transport or heat, and secure the grid against natural disasters and cyberattacks. Higher costs have also played a role: transmission costs have steadily increased by an annual rate of 3% since 2011. Poles, towers, fixtures, conductors and devices continue to be the principal drivers of transmission line costs.

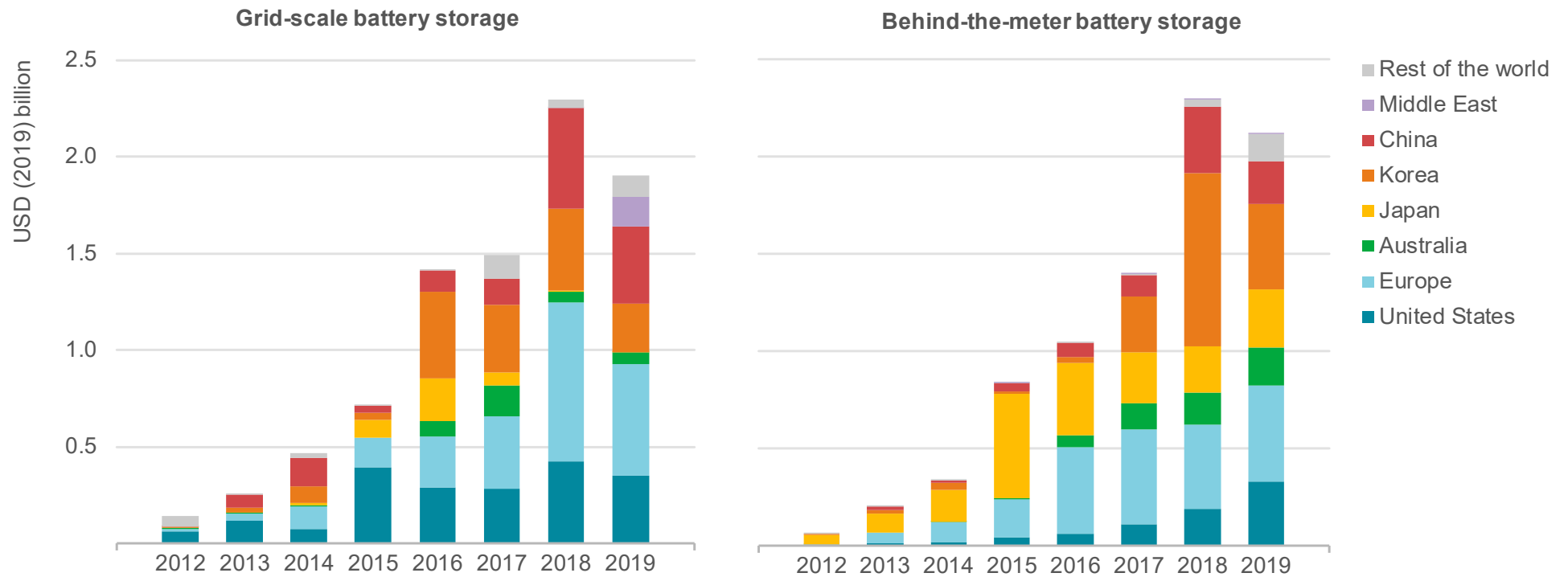
In Europe, investments have remained stable at nearly USD 50 billion, with an increase in spending going to support upgrading and refurbishment of the existing grid, as the role of variable renewables and electrification have grown. This is evidenced by a slower pace in transmission and distribution network expansion since 2015, while investments in digital grid infrastructure have risen steadily.

Despite this slowdown, actual investment spending has remained robust as the focus shifts to new digital infrastructure. Electric vehicle charging infrastructure surpassed 170 000 units in 2019 and smart meters are reaching the roll-out target of 80% market penetration of the European Union by 2020. Investments have also aimed to integrate variable renewables, as solar PV and wind have increased that share in the energy mix from 10% in 2015 to almost 15% in 2019.

Furthermore, a continuous improvement of market coupling schemes both regionally (more markets integrated) and temporally (more time-scale products including some ancillary services) have also led to higher efficiency and better utilisation of existing grid assets. However, the ambitious European Green Deal targets – which will likely surpass the present European Union target of 32% share of renewables in gross final energy consumption by 2030 and aim to speed the pace to carbon neutrality by 2050 – will require much higher investments and greater efforts at integration, not just with the power sector, but with transport and heating systems as well. Offshore wind, in particular, is to play a pivotal role in the future low-carbon power system of Europe, with investments in enabling grid infrastructure potentially increasing tenfold from current levels under targets being considered.

Investments in battery storage exceeded USD 4 billion, but total spend fell for the first time, with falling costs playing a big role

Investment in stationary battery storage



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Sources: IEA analysis with calculations based on Clean Horizon (2020), China Energy Storage Alliance (2020) and BNEF (2020a).

Activity was stronger in behind-the-meter storage than in grid-scale applications

Investment in battery storage declined for the first time, by 13%, though remained above USD 4 billion in 2019. Spending on grid-scale batteries decreased by nearly 15%, while investments in behind-the-meter storage decreased by 5%, as costs continued to fall rapidly.

Globally, average costs continued to come down as battery pack prices fell and developers continued to reduce balance-of-system costs (e.g. mounting equipment, cabling and labour). The trend diverged between segments, with an 8% reduction registered for grid-scale battery storage and a nearly 15% drop in costs for behind-the-meter applications. Greater cost reductions for behind-the-meter were achieved as the market gained traction, improving efficiencies in engineering and construction, reaching higher standardisation around system design, taking advantages of maturing supply chains and increasing competition with new entrants. However, behind-the-meter batteries remain around twice as expensive as grid-scale ones on a USD-per-kilowatt-hour basis (under USD 350/kWh for a four-hour battery versus USD 700/kWh for a two-hour one).

Among markets for grid-scale storage, 2019 spending decreased in almost every region, except for Australia and the Middle East (the latter pushed by several sodium sulphur batteries developed in the United Arab Emirates). In Korea, fires reported at energy storage systems in 2018 led to higher safety and regulatory standards, whereas in China, regulation uncertainty resumed in batteries not being considered as networks fixed assets, thus grid companies losing interest in using batteries as replacements for other network investments. Deployment surpassed the 1 GW barrier for a second consecutive year. Half of this new capacity was devoted to hybrid battery storage projects (coupled with power generation assets). Within these, almost 300 MW of battery

storage was coupled with solar PV and 115 MW with wind. The rest was coupled with thermal power and other renewables.

Grid-scale battery investments in 2020 are expected to decline in response to a broader slowing of power activity, but this pause is likely to be shortlived given their growing role in system security and flexibility. Some large projects have been recently announced, such as from Southern California Edison, who signed contracts to procure 770 MW or Solar Partners XI, LLC project in Las Vegas which aims to develop a 690 MW solar PV plant paired with a battery of 380 MW.

Global behind-the-meter battery storage spending partly reflects the market for distributed solar PV, for which investment slowed in 2019. Investments in China and Korea both nearly halved mainly driven by lower costs, as new entrants and manufacturers are entering the market. Activity was also hit in Korea as investigations into 2018 fires concluded in mid-2019, leading to stronger safety measures. Still, in the United States, spending on batteries nearly doubled, as supported by California's funding for resilience applications serving wildfire-threatened parts of the state. In 2020, global spending is likely to slow, in line with fewer consumer installations of distributed resources.

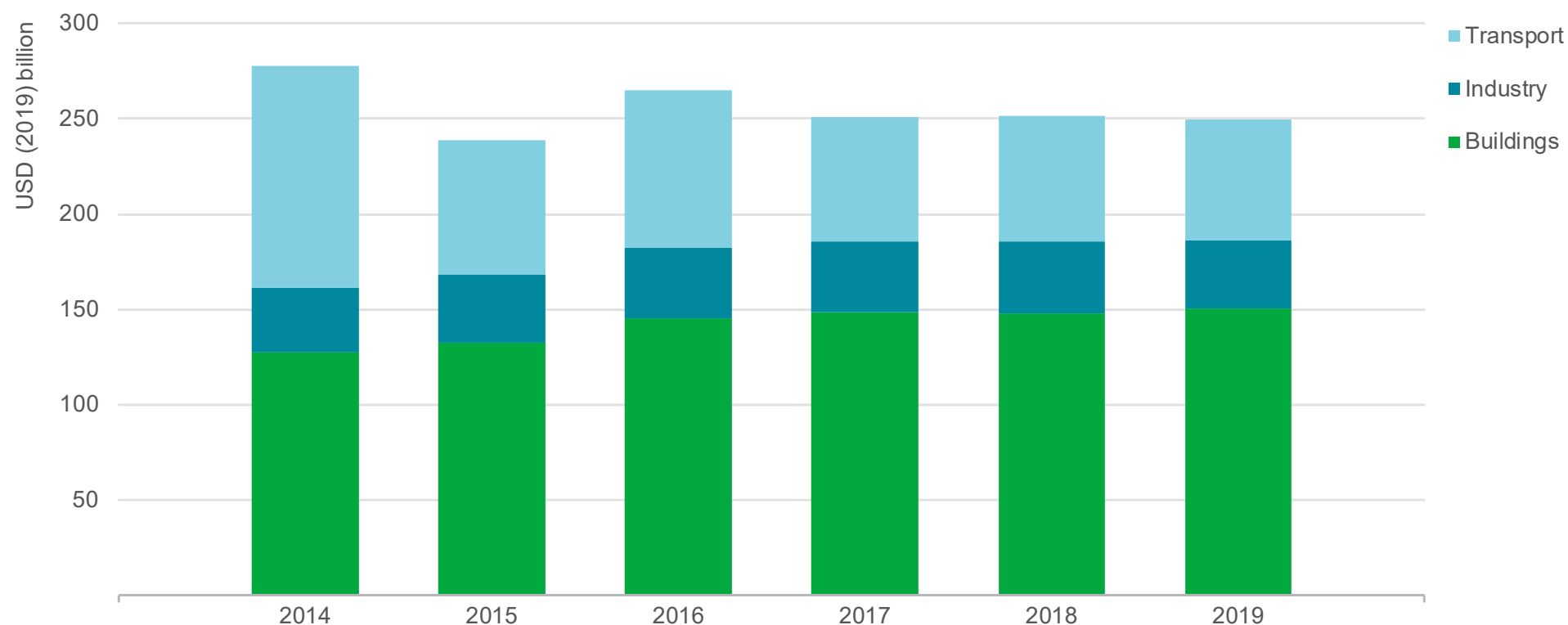
In terms of performance, discharge duration hours (the ratio between energy storage capacity [kWh] and rated power [kW]) for grid-scale batteries increased for a fifth consecutive year and reached a level of 1.8 hours, 60% higher than 2015. This trend is supported by more projects moving beyond short-term applications, such as frequency control, to include a wider spectrum of services, such as energy arbitrage, firm capacity or renewables integration, which also enhance the sources of remuneration (see Energy Financing and Funding section).

Energy end use and efficiency

Overview of energy efficiency investment trends

Global energy efficiency investment remained stable in 2019, as efficiency improvements fall behind targets around the world; spending is set to fall in 2020 with the economic downturn

Global investment in energy efficiency by sector

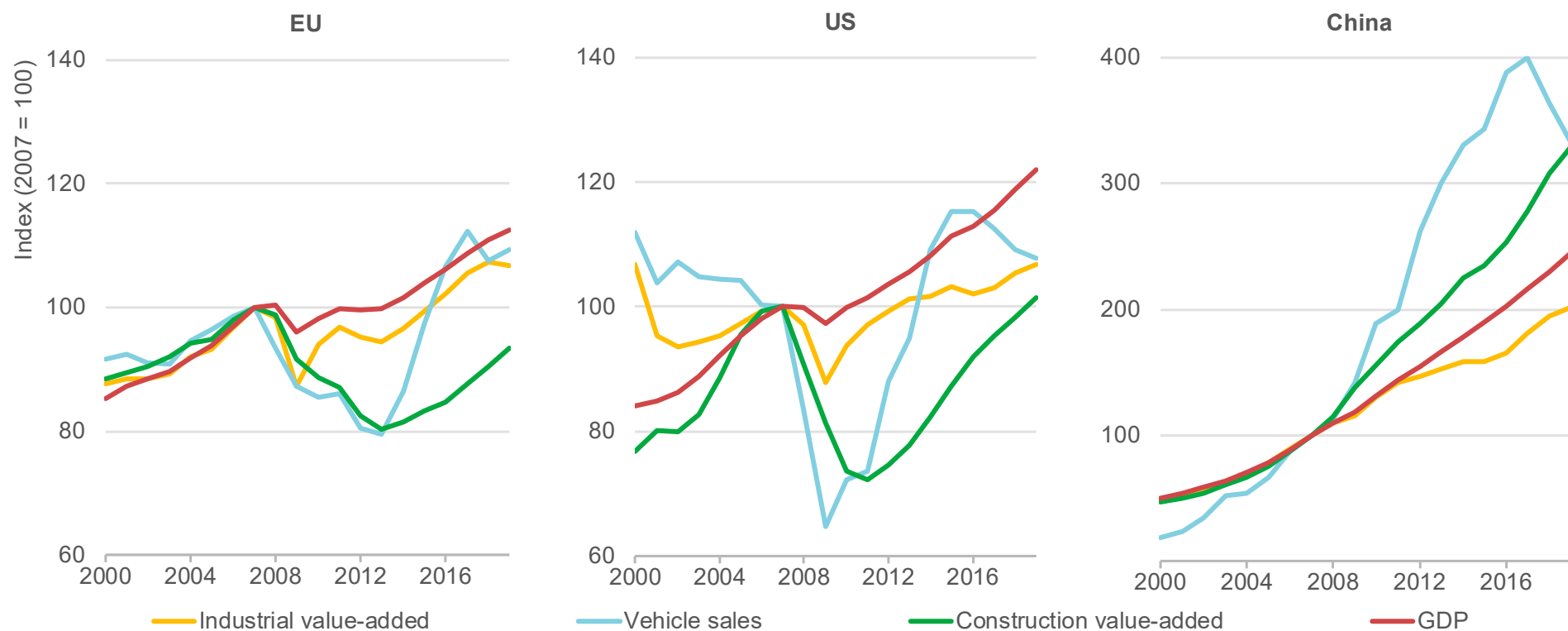


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Note: An energy efficiency investment is defined as the incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy use. The intention is to capture spending that leads to reduced energy consumption. Under conventional accounting, part of this is categorised as consumption rather than investment. The total in all years is slightly higher than that shown in *WEI 2019* due to the inclusion of additional national-level data in the buildings sector. Please see [WEI 2020 methodology document](#).

A recession could trigger spending cuts of over 10% in key sectors for energy efficiency spending this year, if the last economic crisis is a guide; this time China will also be impacted

Trends in sectoral indicators for three major economies that are relevant to key sectors for energy efficiency, 2000-19



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Note: GDP and value-added are in constant currency units.

Sources: IEA calculations based on BEA (2020); Eurostat (2020); NBS (2020); and OICA (2020).

Weak consumer spending in 2019 kept a lid on energy efficiency investment and key equipment sales, while the 2020 outlook is gloomy and more reliant on government policy than ever

A total of USD 250 billion was invested in energy efficiency across the buildings, transport and industry sectors in 2019, the same level as the previous year. While there were signs of new activity in some areas, annual changes for each sector remained moderate. Energy efficiency investment is not enough to meet sustainability goals and reduce the effort required from energy supply. Primary energy intensity needs to drop by an average of 3.6% annually to deliver on climate goals. In 2019, the change was 2%, roughly the same as 2018 (IEA, 2020a).

Policies and energy bills play a big role in influencing capital expenditure decisions to reduce future energy demand. However, overall consumer and business spending serve as the primary drivers. In this light, the global economy was already slowing in 2019 with weakening trade, investment and manufacturing. Global GDP growth dipped from 3.5% in 2018 to 2.9% in 2019. Slower Chinese growth spilled over to other emerging economies, and was amplified by global trade tensions. India's construction growth rate more than halved to 3%. Current weakness in consumer demand and supply chain disruptions have now brought new challenges to already fragile sectors.

The buildings sector is still the largest destination of efficiency spending. After faltering in 2018 in response to reduced government support in Europe, it grew 2% in 2019 to over USD 150 billion.

Transport efficiency investment fell in 2019, as global car sales fell and with the most efficient cars trailing the wider market. A tussle between electrification and preferences for larger cars has dampened fuel economy improvements in major vehicle markets, as higher sales of internal combustion engine SUVs has more than offset the gains by EVs (see below). Spending on more efficient road freight vehicles stabilised

despite a drop in the overall market (including a decline in total sales in China) as fuel economy standards began to make an impact. Still, freight vehicles generally have higher upfront costs, making purchases hard to justify for smaller enterprises despite lower lifetime fuel costs.

Energy efficiency investment may fall by over 12% in 2020, mostly due to the 6% assumed decline in global economic growth, and then potentially in response to less available capital for efficiency projects and lower energy prices, especially for oil. During the economic crisis a decade ago, key indicators for buildings, transport and industry fell by more than the drop in GDP in Europe and the United States. In Europe, a 4% dip in GDP in 2009 paired with a 10% drop in vehicle sales, manufacturing value-added and construction value-added. US trends were similar, with a bigger impact on already declining vehicle sales. The recovery, especially in construction, was slow. The severity of this year's downturn means that China may be impacted more than a decade ago, with knock-on consequences for the global pace of recovery.

Policies provide a buffer for efficiency investments, and the robustness of mandates and incentives will serve as crucial factors in the uptake of efficient goods over the next two years. Preferential support for efficient vehicles and buildings in rapidly deployed economic stimulus plans could help shore up economies and moderate spending declines. The energy intensity of the economy will also be influenced by any changes to mobility and work triggered by this crisis. Some changes will raise efficiency, while governments could help to mitigate negative impacts of others, such as a lowering of urban density.

Energy efficiency investment in buildings is rising, mostly in emerging economies, but the global trend is not keeping pace with overall construction activity

Global investment in energy efficiency in the buildings sector rose 2% to approximately USD 151 billion in 2019, marking a return to steady growth after stabilising in 2018. However, the trend reflects a two-speed market with stronger activity in emerging economies, especially China, and weaker markets Europe and North America.

Broadly, two factors determine buildings efficiency investment. First, there is the overall construction capital spending on new buildings and refurbishments. Second, there are policies seeking to direct more of this capital spending to new buildings with energy performance above buildings codes and to encourage efficient refurbishments of the existing stock, including energy-using equipment such as heating systems. In Europe and North America, the refurbishment market is dominant.

The construction market overall grew by nearly 5% to USD 5.9 trillion in 2019, a slowdown compared with the robust rate in 2018. Activity moderated across key areas including China, the United States, Western Europe, the Middle East and Australia. Efficiency investment growth is therefore not keeping pace with activity directed towards buildings globally, potentially storing up challenges for addressing less efficient building stock during its operational lifetime of many decades.

Construction activity is expected to further weaken and decline in 2020, hurting buildings efficiency investment. Still, the cumulative effect of policies around the world may help to protect energy efficiency construction projects from the worst impacts of the downturn in some countries. In 2019, new or strengthened support for buildings efficiency investment was advanced in Canada, Norway Spain and Switzerland.

In 2019, two-fifths of the buildings efficiency investment was in Europe, where energy efficiency investment growth has outpaced construction activities in some countries. Annual UK efficiency investment grew by 2.3% since 2016, while construction investment saw no growth. Similar patterns were evident in Italy and Switzerland. The European Commission has stated that annual EU buildings efficiency investment must rise to EUR 177 billion to 2030 (EC, 2020). One measure to achieve this, the Energy Performance of Buildings Directive, revised in 2018, seeks to increase the yearly renovation rate to 3%. Norway, with USD 32 million, spent 25% more on residential buildings efficiency and announced a planned increase in its ENOVA funding.

In Canada, the 2019 budget raised federal public spending on buildings efficiency by 20% to CAD 600 million. In the United States, however, overall investment in buildings energy efficiency was stable but the number of states with mandatory building performance standards rose, which should raise future investment.

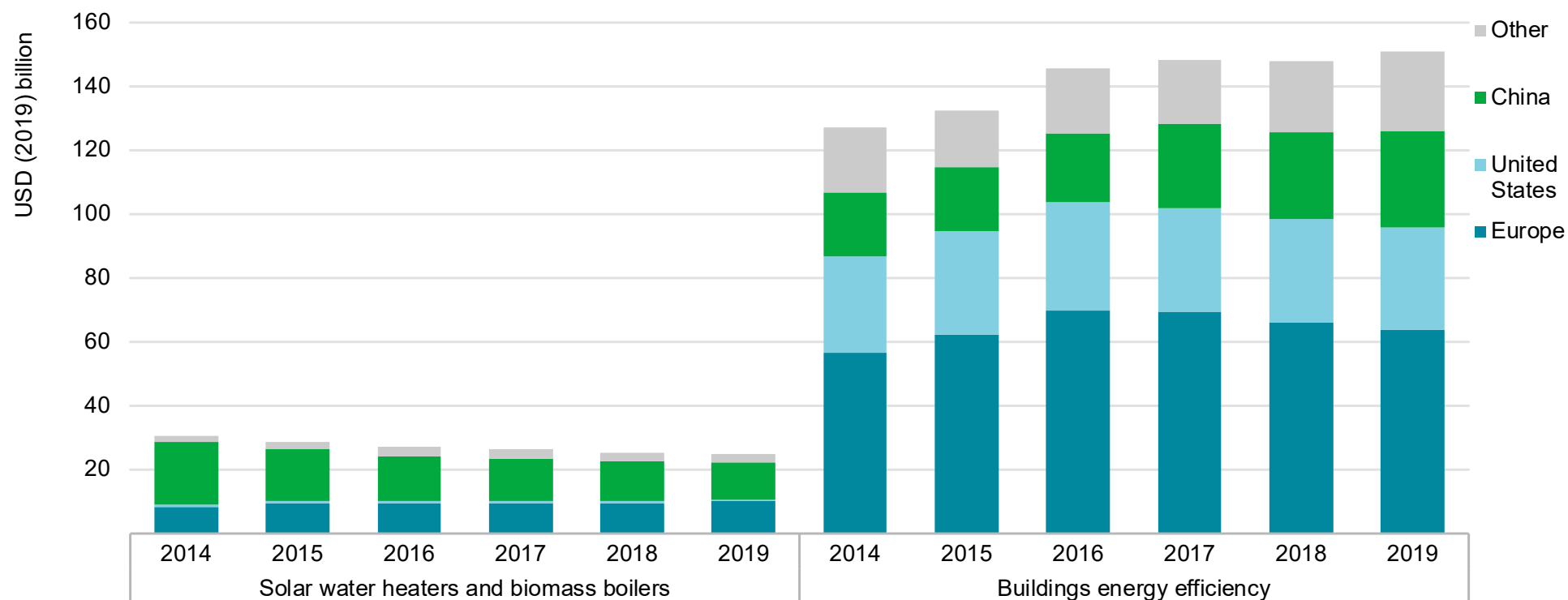
In China, investment in buildings efficiency climbed by an impressive 10% to USD 30 billion, but was outpaced by overall construction investment growth of 13%. As private investment in energy efficiency is around four times the level of public spend, tighter energy performance standards could spur even more improvement in private buildings.

Across India, energy efficiency investment is expected to rise as more stringent buildings codes are published by states, though the outcome will be strongly influenced by their implementation. However, India was less than 5% of the global total in 2019.

Trends in end-use markets

Consumers spend nearly seven times as much on improving buildings efficiency as on purchases of renewable heat equipment, which have declined in recent years

Spending on renewable heat sources for buildings and buildings energy efficiency investments by region



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Notes: Includes residential and commercial buildings. Data on biomass boilers do not include furnaces that circulate heat in buildings using air.

Sources: IEA calculations based on GMI (2019) and SHC-TCP (2019).

Heat is moving to the centre of energy and climate policy discussions, though investment trends show divergence among various strategies for enhancing low-carbon heat in buildings

Heat for buildings, including for space and water heating, accounts for nearly one-quarter of global final energy consumption. The use in buildings of fossil fuels – mostly natural gas and oil – to supply heat contributes around 8% of global CO₂ emissions. More than 65 jurisdictions have established or are considering targets for net-zero emissions by 2050, pushing heat up the policy agenda for many governments, especially in the northern hemisphere (IEA, 2019b). Countries and municipalities have set out different strategies for deep decarbonisation of heat, using five possible approaches:

- lower heating demand: invest in more efficient building envelopes;
- direct electrification: replace fossil-fuel heating equipment with heat pumps, which operate with very high efficiency, supplied by a fully low-carbon grid and/or by self-consumption of renewable power;
- gas decarbonisation: replace gas-fired heating equipment with boilers adapted to hydrogen and boost low-carbon gas delivery
- direct use of renewables: biomass, geothermal, solar thermal;
- district heat expansion: replace individual heating equipment with connections to an expanded heat network delivering heat from renewables, heat pumps and waste heat.

While some of these measures reinforce one another, others will be most effective if all buildings locally adopt the same solution. Deep energy efficiency improvements are compatible with all other options. However, widespread deployment of district heat or direct electrification may not be compatible with upgrading the gas grid, and end-use equipment, to deliver and consume hydrogen and other low-carbon gases, unless paired with hybrid heat pumps.

If countries were on a path towards full decarbonisation of heat by mid-century, we would expect to see growth in each area, with regional differences reflecting different strategies, and a slowdown in expansions of natural gas grids. In 2019, USD 151 billion was spent on buildings energy efficiency, compared with around USD 24 billion on end-use renewables, mainly solar thermal water heaters and biomass boilers.

Global heat pump sales continued to grow in 2019, at around 5%, to roughly 20 million. China remains the largest market as it seeks to modernise its heat supply. Air-to-air heat pumps in new buildings and major refurbishments are the dominant applications. The European heat pump market has experienced double-digit growth in recent years, mostly in countries with high shares of electric heat like France, but also where policy favours them compared to gas and oil boilers. The IEA SDS includes a doubling of heat pump sales by 2025 (IEA, 2020c).

Since January 2019, at least six electrolyser projects that aim to blend some of their produced hydrogen into the gas grid for heating have started operation (see R&D and Technology Innovation). One of these, the UK HyDeploy project (0.5 MW_e, USD 8.5 million) is injecting hydrogen into the grid today. At around half a billion dollars per year, investments in biogas and its upgrading to biomethane for the gas grid are ahead of those in hydrogen, supported by US utility commitments, lower production costs and rising demand for low-carbon gas (IEA, 2020d). District heat investments are the largest at USD 10 billion to USD 15 billion per year in Europe, but not all are in low-carbon sources. However, network upgrades can ease integration of low-carbon heat, raise system efficiency and offer valuable flexibility to the power grid (see below).

District heating networks continue to expand in Europe, with the length of installed pipelines growing by 35% since 2005 and underpinned by investments of USD 6 billion per year

Total operating district heat pipelines in Europe (left) and estimated annual investment in these pipelines (right)



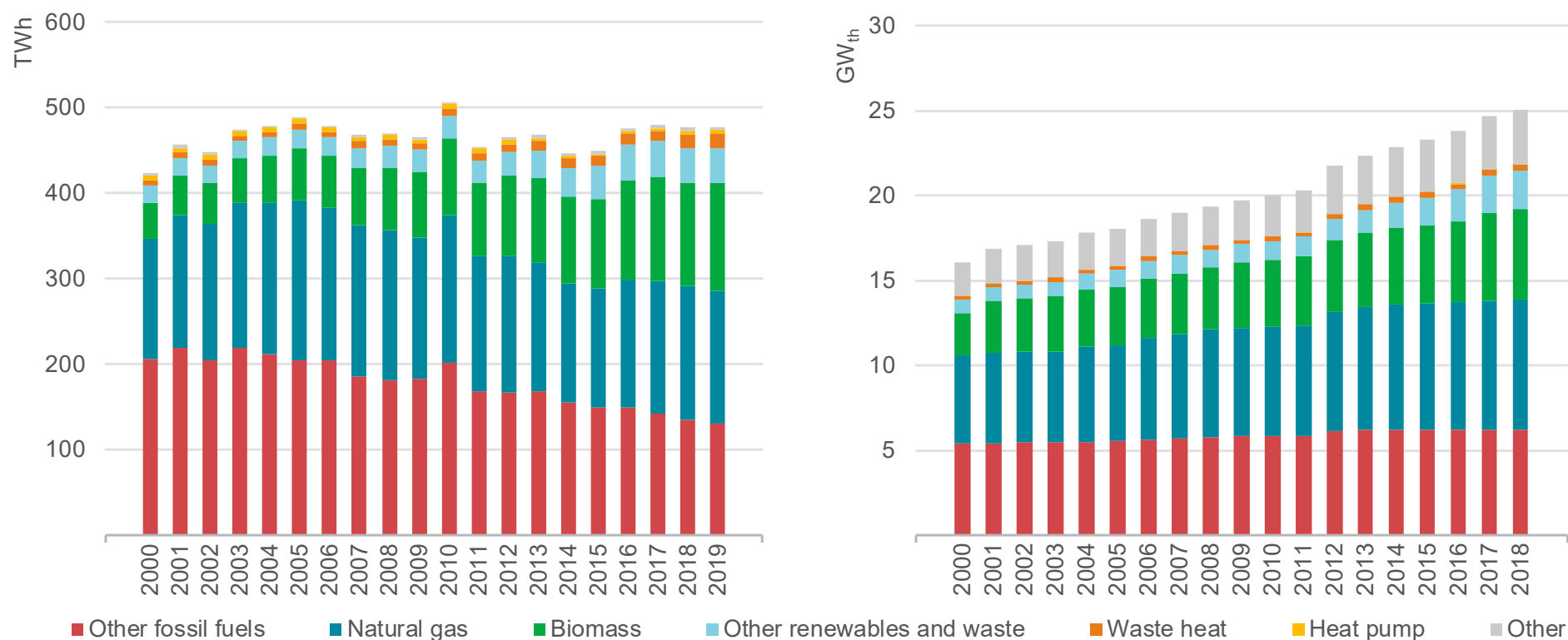
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Notes: Analysis based on published pipeline lengths in all significant European markets. Investment includes capital expenditure on new pipeline material and earthworks, as well as assumed rates of refurbishment. Does not include Russia).

Sources: Euroheat & Power (2019); BSRIA (2019), national statistics for Denmark, Estonia, Finland, France, Germany, Italy, Lithuania, the Netherlands, Norway, Slovakia, Sweden, and the United Kingdom.

The European district heat supply mix continues to evolve towards more renewable energy, but despite network expansions in some countries the total heat delivered has been quite stable

District heat sales in Europe by fuel source (left) and total installed district heat generation capacity in Denmark (right)



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Note: Does not include Russia.

Sources: Euroheat & Power (2019); national statistics for Estonia, Finland, France, Germany, Italy, Lithuania, the Netherlands, Norway, Slovakia, Sweden, the United Kingdom; BSRIA (2019), Danish Energy Agency (2019), IEA (2019c).

Modern district heat networks are efficient options for decarbonising heat for buildings, but they can face policy challenges, especially in countries without widespread existing networks

In some countries, investment in district heat – an insulated network that delivers hot water or steam from co-generation (the combined production of heat and power) or heat-only sources via pipelines to space heating or hot water users in buildings – has risen and encouraged more use of low-carbon energy. Per unit of energy, district heat is often a lower-cost way of integrating low-carbon energy for heating than individual systems. This includes heat from renewables, such as biomass, heat pumps or harnessing heat from industrial processes that would otherwise have been wasted. Including large-scale heat pumps and thermal storage, enabled by digital technology, can also facilitate electrification of heat and provide flexibility to power systems while reducing the capacity they would need to meet peak heat demand (see Power section).

The state of district heating varies widely among markets, even those with high heat demand. Some geographies, such as northern China, Poland and Russia, are upgrading legacy systems that supply up to half of national residential heat and are integrated with power plants, often using coal. Other countries, including Denmark, France, Germany and Sweden, are expanding district heat systems in urban areas based on lower-carbon options such as geothermal, biomass or waste. A third group of countries, including the Netherlands and the United Kingdom, is aiming to create a new momentum for efficient heat networks in towns traditionally dependent on individual natural gas heating and less familiar with collective options. The Dutch Climate Act 2019 foresees an increase of district heat by up to 100% by 2030. A UK Green Heat Network Fund of GBP 270 million was announced in 2019 for 2022-25.

In some countries, a focus on electrification of individual heating, interest in hydrogen or electricity market conditions have reduced

interest in district heat. In China, where extensive networks are largely supplied by steam from coal-fired power plants, heat policy currently favours heat pumps, including for the replacement of older electric water heaters for district heat. However, three new solar thermal district heat systems were commissioned in Tibet in 2019. In the United States, urban plans for reducing emissions from residential heating often focus on individual solutions. However, upgrades of existing heat networks on university campuses has raised interest, with several long-term contracts signed for network modernisation and integration of lower-carbon energy. Even in countries with well-established district heat networks, including some in Central and Eastern Europe, district heat is not always a favoured means of reducing emissions due to the costs of upgrading legacy systems and the economic integration with fossil fuel power.

District heating is a major source of buildings heat in Europe, and networks are expanding, even if it is not promoted in all countries. Around 60 million people there are served by district heat, which represents 12% of all buildings heat supply in the European Union and over 60% in Denmark and Latvia. In energy terms, this 450 TWh of district heat was equivalent to 15% of EU electricity supply.

The total installed length of district heat pipelines expanded by one-third from 2005 to 200 000 km in 2019. Annual investments in pipelines in Europe, including refurbishment, are estimated at around USD 6 billion. Four countries – Denmark, France, the Netherlands and Sweden – account for two-thirds of this. Though data are scarce, investment in heat supply plants and thermal storage is estimated to be higher than for pipelines, raising total annual investment above that of the European natural gas boiler market (USD 11 billion) (GMI, 2019).

Investments in district heat systems can offer low-risk regulated returns, but shifting dynamics in power markets, as well as consumption and fuel choices have knock-on effects for revenues

In Europe, over 10 GW of district heat generation capacity has been added since 2010, reaching 340 GW_{th}. In response to policy incentives to increase the use of renewable energy, biomass and municipal waste have been the focus of much of the investment in new supply since 2000. The share of biomass in district heat supplies in Europe has risen from 10% over 25% in the last 20 years, mostly displacing coal. Heat from coal and oil combined fell from a share of around 50% to 27% over the same period, while natural gas remained near one-third. The displacement of coal and oil has largely been on a like-for-like basis, with biomass also providing high-temperature heat, often from co-generation.

More recently, investment activity has turned to other low-carbon heat-only sources. These include geothermal, solar, industrial waste heat and heat pumps. Three emerging trends are supporting developer appetite for these other low-carbon sources of district heat: deployment of so-called third- and fourth-generation district heat; rising power system flexibility needs; and depressed wholesale power prices.

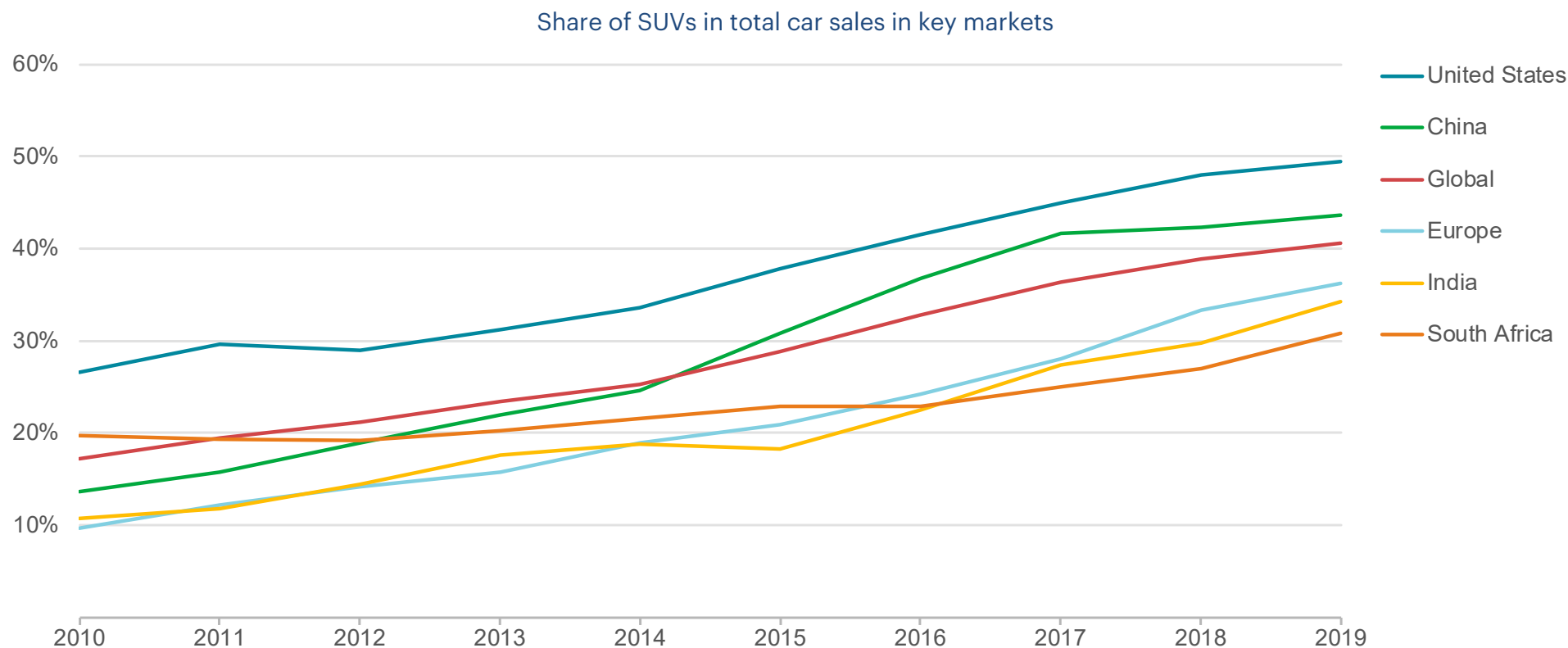
Third- and fourth-generation district heat systems have been developed to operate with lower-temperature water (55-80°C), which has lower distribution losses, can be used directly in homes, and accommodates waste and renewable heat more easily. Since 2010, the share of non-biomass renewables in European district heat rose from 5% to 9%. In 2019, a 3.4 MW geothermal plant was connected in Holzkirchen, Germany, and new projects took final investment decisions in France. Latvia added 15 MW of solar thermal heat. As these modern systems have low losses and can manage multiple smaller heat sources, they can “store” energy when renewable power exceeds grid electricity demand.

Heat pumps supply just 1% of district heat in Europe, but additions are being made. An investment decision for a 13 MW heat pump was taken in 2019 in Helsinki, where fossil fuel co-generation is being phased out by 2029. Shifting electricity market patterns are impacting co-generation plant profitability in countries in the Nordic region due to low power prices. Investment in gas and coal co-generation plants in Europe has fallen around two-thirds, from over USD 6 billion in 2010. These trends have tended to favour heat-only supplies, but have not significantly changed the average share of co-generation in Europe’s district heat supply, which has declined by just 5 percentage points, to 65%.

Denmark is an example of how investment in modern heat networks can transform a legacy system. Heat supply capacity rose from 16 GW_{th} to 25 GW_{th} since 2000, including the addition of 4.5 GW_{th} from low-carbon sources. The use of lower-temperature pipelines has enabled cities such as Aalborg to add waste heat from a crematorium and a 1.2 MW heat pump in 2020. The share of co-generation in district heat supply capacity fell from 47% to 40% between 2000 and 2018 in Denmark.

Financing transactions for district heat increased in 2019 and early 2020, with several networks and businesses changing hands, e.g. Fortum announced the sale of four regional district heating businesses, and district heating companies changed hands in Latvia and Finland. Lyon’s district heating network was refinanced and the refurbishments of two networks in Poland secured project finance. These indicate that capital is available for these assets that often have multi-decade monopoly contracts. However, municipal networks in some European countries struggle to finance upgrades; the European Investment Bank is providing EUR 46 million to operators in Poland.

More than two in every five cars sold worldwide in 2019 were SUVs, which made up nearly half of all US passenger car sales



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Notes: Crossover utility vehicles are not included in SUVs. Pickup trucks reported as commercial vehicles (e.g. for fleets) not included.

Sources: IEA calculations based on CAAM (2020); IHS Markit (2018); Jato Dynamics (2020); and Marklines (2020).

SUV sales accounted for 60% of the global car fleet expansion since 2010, dampening fuel economy improvements and making the challenge of cutting transport emissions harder

When oil demand for passenger cars will peak is hotly debated. It depends on the interplay of several factors that are currently in flux: the steadily improving fuel economy of new cars; the speed of turnover and expansion of the fleet; electrification; and consumer preferences for ever-larger cars. In 2019, the fuel economy of new internal combustion engine cars continued to improve, market expansion slowed globally and electrification continued, but decelerated. However, other factors pulled in the opposite direction: lower fleet turnover in mature markets meant that fewer inefficient cars were replaced with new cars, and the market maintained its relentless shift towards large vehicles with relatively lower fuel economy.

To quantify some of these factors, electric car sales rose by 0.1 million in 2019 while the passenger car market as a whole contracted by around 4 million sales worldwide, or 5%. Globally, the electric cars sold in 2019 are expected to reduce transport oil demand by around 50 kb/d. On top of this, the 155 000 electric buses and other commercial vehicles registered in 2019 could offset a further 10 kb/d. It is hard to quantify the impact of fewer total car sales on oil demand, because we do not yet know the balance between delayed replacements of vehicles and slower growth in overall demand for car travel. However, a rough estimate suggests that fewer sales could have meant foregoing a 15 kb/d reduction in oil demand that would have arisen through fuel economy, as more old cars were replaced with new around the world. The replacements of older cars in 2019 likely avoided up to 150 kb/d of oil demand but this does not compensate for the annual increases of over 500 kb/d of road transport fuel demand on average since 2014, an increase that has been mostly due to putting more cars on the road.

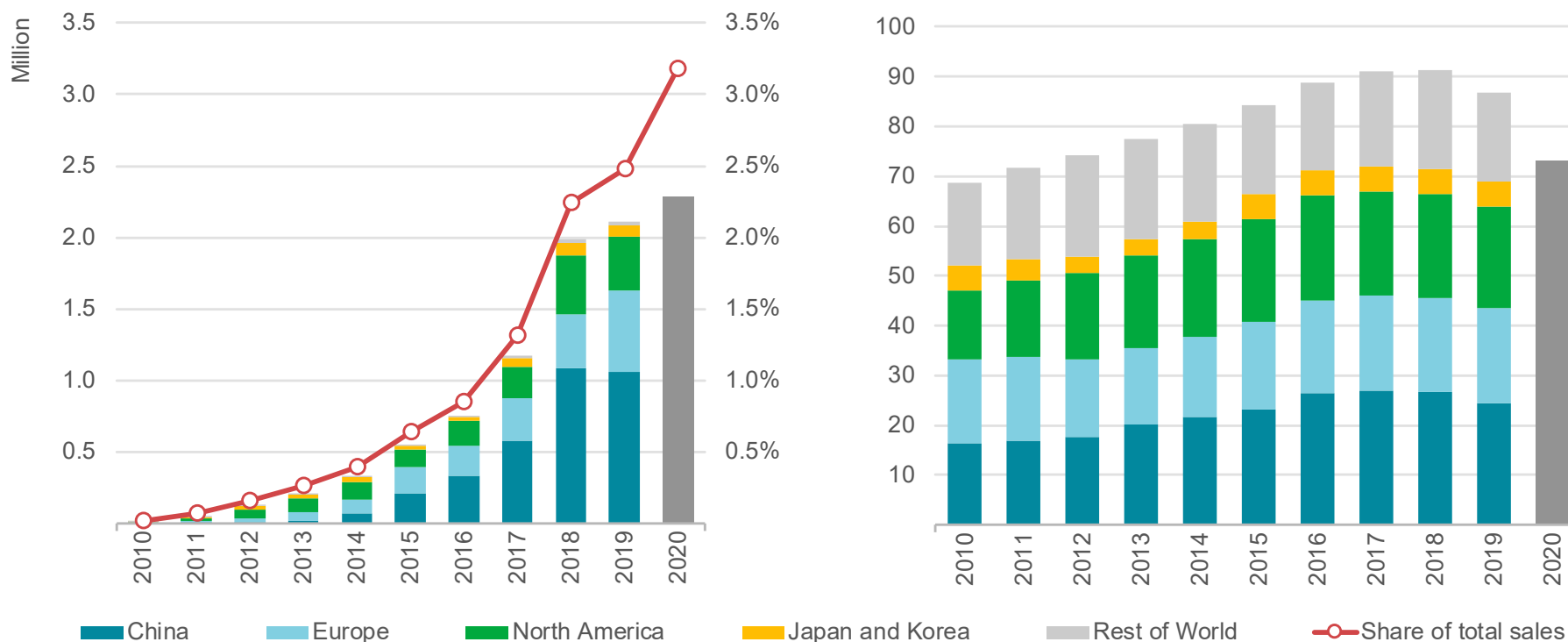
These amounts of avoided oil demand growth would have been larger, however, had there not been a dramatic shift towards bigger and heavier cars. This shift has led to a doubling of the share of SUVs in car sales over the last decade. As a result, there are now well over 200 million SUVs on the road globally, up from about 35 million in 2010. SUVs account for 60% of the increase in the global car fleet since 2010. In 2019, their share in total car sales topped 40% for the first time, compared with less than 20% a decade ago.

This trend has been universal and unrelenting. Today, half of all cars sold in the United States and over 35% of the cars sold in Europe are SUVs. Oil prices and tax policies have not put off consumers in these regions from buying cars with higher operational costs. In China, as elsewhere, SUVs are often considered symbols of wealth and status. In India, sales are currently lower, but consumer preferences are changing as more and more people can afford SUVs, and their share is rising. Similarly, in Africa, the rapid pace of urbanisation and economic development is strengthening demand for premium and luxury cars.

On average, SUVs consume about a quarter more fuel per kilometre than medium-sized cars. The higher share of SUVs was responsible for around 500 kb/d growth in oil demand from passenger cars between 2010 and 2019. While this was more than offset by fuel economy improvements in other car segments, total savings would have been larger without the higher SUV sales. In some countries, SUVs are not included in the same fuel economy standards as smaller cars, and unless policy makers take into account the shift to SUVs, then this counterbalance cannot be assumed in the future.

Electric vehicle sales growth stalled in 2019, with a drop in Chinese purchases, but the share of EVs continued to climb as the wider vehicle market contracted

Global electric passenger light-duty vehicle sales and market share (left) and total light-duty vehicle sales (right)



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Notes: Includes passenger cars and passenger light trucks. Includes plug-in hybrids, battery EVs and fuel cell EVs. Share of total sales represents the total sales of EVs in countries listed in IEA *Global Electric Vehicle Outlook* as a percentage of total passenger car sales in those same countries. The 2020 estimates are based on the assumptions of a gradual global economic recovery and cautious consumer spending behaviour over the rest of 2020. This accounts for government measures in place at the time of writing, notably in China.

Sources: IEA (2020e); IEA (2020f); Marklines (2020).

Lower purchase incentives lowered Chinese demand for electric cars in 2019, while European sales grew strongly. So far in 2020, Covid-19 reduced Q1 car sales, with electric cars down 9%

The year 2019 was turbulent for the auto industry, but this is likely to appear mild in comparison with 2020. Electric cars (including passenger battery EVs, plug-in hybrids and fuel cell EVs), for which sales grew nearly 70% per year between 2011 and 2018, are strongly affected by these trends, as well as changes to policy support in key markets.

By the end of 2019, electric car sales growth had slowed to its lowest rate since 2011, with total registrations of 2.1 million, just 6% higher than 2018. However, electric car sales outperformed the car market as a whole, as total car sales growth slowed in all major regions and turned negative in China and the United States in 2019. In China this reflected a sluggish economy, low consumer confidence and high household debt. The US market is shaped by replacements of existing cars, and the sales boom in the prior five years meant that fewer consumers needed to upgrade their cars despite the relatively strong economy. In Europe, sales growth would have been flat but for a spike in December after EU fuel economy rules were clarified.

Changes to purchase incentives also had major impacts. The maximum subsidy under China's New Energy Vehicle scheme was halved in July 2019, to USD 3 700, with an immediate effect: EV sales in July and August were 10% lower than in those months in 2018. At 1.1 million, China's full-year sales were 2% lower than 2018, but still represented half of all sales worldwide. National-level purchase incentives were to be phased out in 2020, but ambitious EV quotas for automakers and other policies were expected to keep sales rising.

EV sales also declined in the United States, by 10% to 330 000. This was partly a rebalancing after the bump in 2018 sales that accompanied the launch of the Tesla Model 3. In addition, the US market was weighed

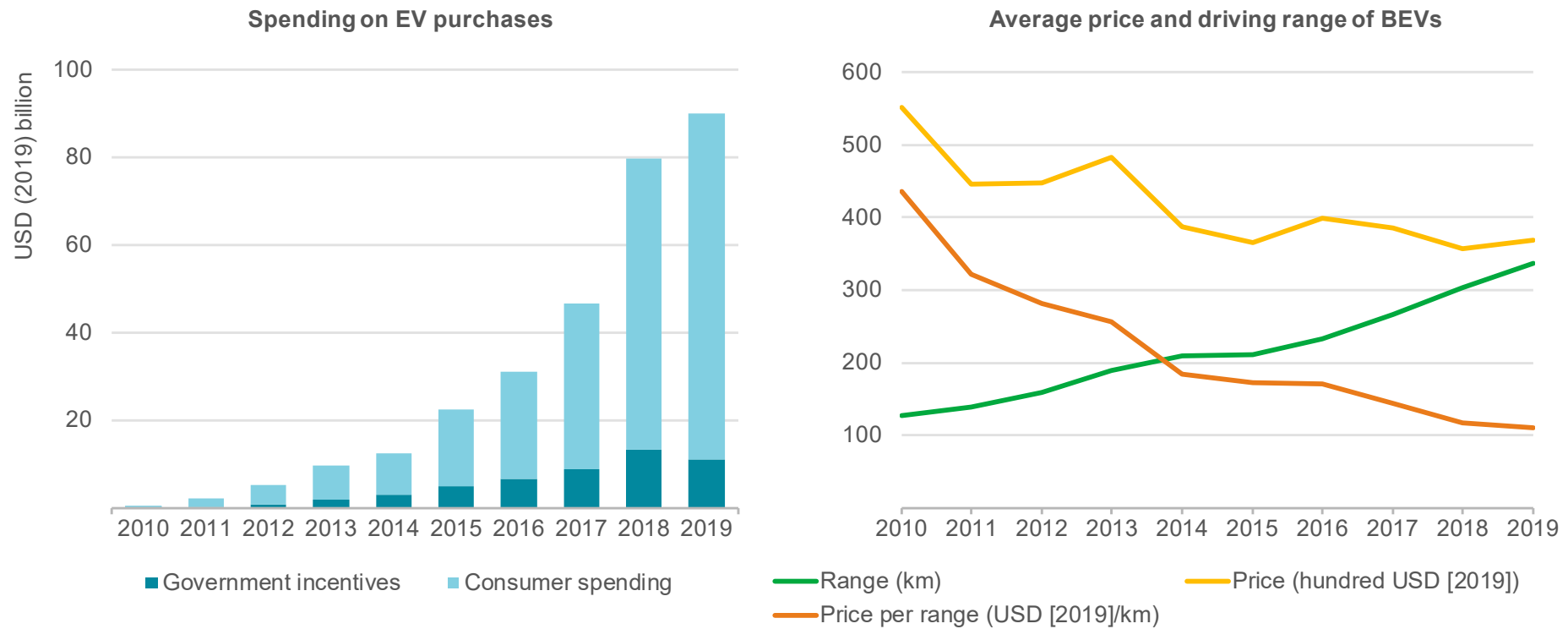
down in 2019 by the reduction of tax incentives for Tesla and GM models and uncertainty around the future of fuel economy regulations.

Europe was the only major region where electric car sales maintained their 2018 growth rate, rising 48% to over half a million for the first time. This trend accelerated into April 2020 as EU fuel economy standards tightened and Germany raised its purchase incentives. Carmakers may focus EV sales on Europe in response to a weaker outlook for US fuel economy regulations, pushing EU sales closer to the level in China.

Despite weaknesses in the global car market, more robust growth of electric car sales had been expected around the world in 2020. However, Covid-19 related lockdowns severely depressed auto sales in Q1 and Q2 and the industry has been particularly affected by the lost revenue. At the time of writing, a drop in global car sales of around 15% in one year is forecasted, which is dramatic in comparison with the 10% drop over two years that followed the 2008 financial crisis. Whether electric car sales follow the scale of this drop depends largely on government policy. In the first quarter of 2020, sales of electric cars were 9% lower year-on-year, compared with around 25% for the market as a whole. Some analysts, citing concerns about mining disruptions for battery inputs and the possibility that carmakers will delay scale-up of electric cars, suggest a significant fall in EV sales in the absence of new policy support (WoodMac, 2020). However, in April Chinese authorities delayed further subsidy cuts to 2022 and some local incentives were increased. Continued policy support, especially in Europe, underpins the IEA view that 2020 will see a year-on-year rise in EV sales, including a new record for the share of EVs in total car sales (IEA, 2020f).

Total spending on electric car sales rose 13% in 2019 – a rate much slower than in 2018 – as China cut back purchase incentives and average vehicle prices remained steady

Global trends in the electric passenger light-duty vehicle market



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Notes: Government spending includes direct and tax expenditures on battery-electric vehicles (BEVs) and plug-in hybrid EVs. Spending is inclusive of sales taxes. Government incentives assigned per model in each year based on national policy documents and include tax incentives and transfers to consumers or manufacturers to reduce purchase prices. Non-purchase incentives, such as lower road taxes or parking fees, are not included. Right chart shows averages weighted by sales per model. Ranges converted to Worldwide Harmonised Light Vehicles Test Procedure (WLTP).

Sources: IEA calculations based on IEA (2020d); IHS Markit (2018); and EV Volumes (2020).

The government share of electric vehicle purchase costs in 2019 was the lowest to date, potentially signalling a shift to a more sustainable market based on private spending

Encouraged by continued government support, global spending on electric car purchases grew to USD 90 billion in 2019, a 13% increase compared with 2018. Of this, USD 60 billion was on battery-electric cars and the remainder on plug-in hybrids. The rise in spending was lower than in 2018, when around USD 35 billion was added to the global electric car market in just one year, but higher than the growth in numbers of cars sold.

Spending rose faster than sales because of an increased share of global sales from the European market at the expense of China, where sales contracted under a slowing economy and reduced policy support. On average, prices for electric cars are higher in Europe than China, with BEVs 50% more expensive on average globally.

Electric car prices have been relatively stable since 2016, as savings from improvements in cost per unit of battery capacity have been passed on to consumers as additional range, not cheaper cars. The average range of a BEV sold in 2019 surpassed 330 km. Longer ranges are incentivised by policy in some countries. In China, purchase incentives for BEVs with driving ranges below 150 km were phased out in 2018, and ranges below 250 km became ineligible in 2019. Looking at the average car price as a function of its range shows that by this metric, the EV value proposition for consumers improved by 12% compared with 2018 and 36% compared with 2015.

Another reason that average prices have been stable is the higher share of large vehicle sales, including luxury sedans and SUVs. A partly offsetting factor stems from the lower share of plug-in hybrid sales, which are generally pricier on a like-for-like basis due to the

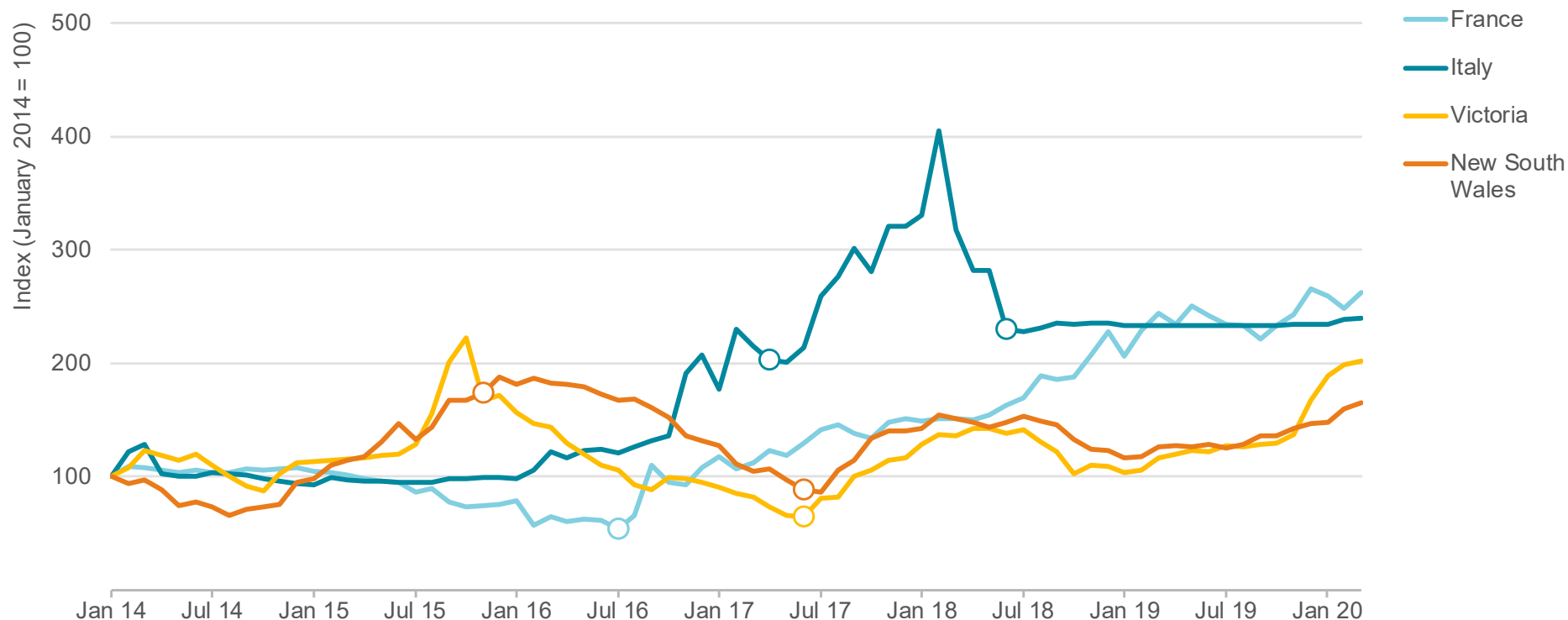
need for two drivetrains. Their share fell from 50% in 2012 to 27% in 2019, reflecting the higher ranges and availability of BEVs. Electric car markets are increasingly tilted towards bigger cars. While electric versions of SUVs can be more attractive – due to higher fuel savings and manageable upfront price for buyers of larger cars – the overall costs of electrifying a fleet of bigger cars would be higher for governments and consumers alike.

As a share of total spending, the contribution of government support declined to 12% after rising slowly for several years. In other words, roughly USD 7 of consumer spending are generated for every dollar spent by governments. By correlating vehicle prices, sales data and support schemes to estimate the value of government purchase incentives (including tax breaks), we estimate that public spending amounted to USD 11 billion. This is USD 2 billion lower than in 2018 despite sales being 7% higher. Reasons include the lower level of subsidy in China and the expiry of US tax credits for Tesla and GM.

The ability of governments to reduce their share of total spending will be a key test of the sustainability of the electric car market in coming years. Unless government incentives adjust as the market increases, considerable pressure will be placed on public budgets. Between 2012 and 2017, the government share of total EV spending generally rose but there are signs it is declining as policies such as standards, regulations and mandates shift costs from the public sector to consumers and manufacturers. This trend will likely accelerate as electric cars become more competitive. However, in the immediate future the proposed inclusion of support for EVs in post-crisis stimulus packages, as well as low oil prices, may put this development on hold.

White certificate markets, which support a growing share of energy efficiency investments in several countries, broadly stabilised in 2019 and Q1 2020

Trends in prices for white certificates for energy efficiency in four markets around the world



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Notes: France data are a weighted average of fuel poverty certificates and classic certificates, weighted by volume. Dots indicate major policy interventions to change the market rules. These include (from left to right): changes to the eligibility of lighting projects in New South Wales, Australia; reservation of 25% of the French market for fuel poverty certificates; tightening of eligibility criteria in Italy; changes to eligibility of lighting projects in New South Wales and Victoria, Australia; cap on certificate prices in Italy.

Sources: IEA calculations based on Emmy (2019); GME (2019); and TFS Green Australia (2018).

White certificates provide an additional source of remuneration for efficiency projects, but their effectiveness in spurring investment depends on appropriate market design

After recent volatility in white certificate markets, price trends in 2019 and early 2020 have been relatively stable, with some sharp growth in Victoria, Australia. In France, certificate prices climbed to over EUR 8/kWh, or 30%, during 2019.³ Increasing price stability following policy changes in previous years indicates a maturing of market design from which other jurisdictions could learn. There are over 50 different energy obligation systems that generate certificates around the world, most of which do not have a marketplace for trade.

For more than 15 years, white certificates have allowed energy savings from efficiency projects to be traded by obligated parties, generally final energy suppliers, such as electricity and gas retailers. Tradable markets for energy efficiency reward energy suppliers for undertaking the most cost-effective projects. They provide a financial incentive that helps to decouple their revenues from demand for their core energy products and can also support efficiency investment by third-party providers, including energy service companies (ESCOs). However, market design is more challenging than in other areas of energy.

Regulators generally have limited advance knowledge about the costs of energy efficiency projects and the volumes of projects available at different cost levels. Furthermore, certification systems require sensitive assumptions about demand counterfactuals and additionality. Regulators face a challenge of balancing the robustness of the framework (to avoid fraud, gaming or double counting) against the level of administrative burden that may affect political support. In some cases, incentives have

driven activity among consumers that were not the anticipated beneficiaries, which were low-income households in France or industrial consumers in Italy. Policy makers have made corrective market interventions to maintain incentives to invest and limit costs to consumers, which has sometimes resulted in price volatility.

The French market is in the middle of the 2017-21 trading period, in which targets have increased.⁴ The rising price trend reflects projects higher on the cost curve, e.g. as bulk light bulb replacement opportunities are exhausted. Still, the outlook is clouded by ongoing discussions about the upcoming period and post-2023, when new targets are set. In Italy, a price cap was introduced in 2018 in response to the peak that followed a tightening of eligibility criteria. Prices did not fall below the cap of EUR 250/toe in 2019. In the two Australian markets of Victoria and New South Wales, prices rose smoothly following adjustment in 2018 to a revaluation of lighting projects. In Victoria, they have rallied in recent months as newly proposed regulations anticipate the phase-out of these low-cost efficiency projects.

In 2020, prices are likely to be positively impacted by Covid-19 related restrictions as fewer certificates are generated, as well as ongoing policy processes. Obligations like this may also provide a means for governments to co-ordinate the delivery of energy efficiency stimulus goals in co-operation with large energy companies.

³ French certificates represent a saving over the lifetime of the intervention, beyond a counterfactual of 4% demand reduction.

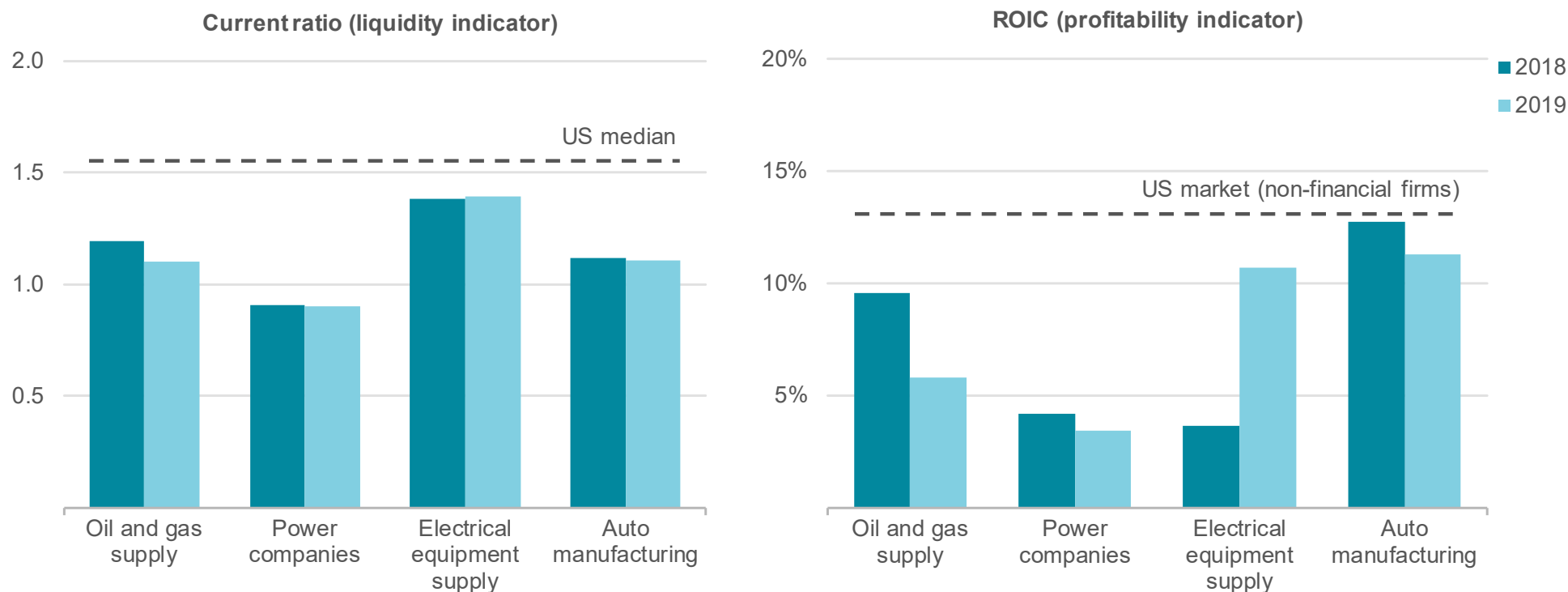
⁴ The share of certificates to come from fuel poverty homes was raised for this fourth period, the end of which was extended by one year to the end of 2021.

Energy financing and funding

Cross-sector trends in energy finance

Ahead of 2020, varied financial indicators for energy-related companies

Liquidity and profitability indicators for top-listed energy-related companies



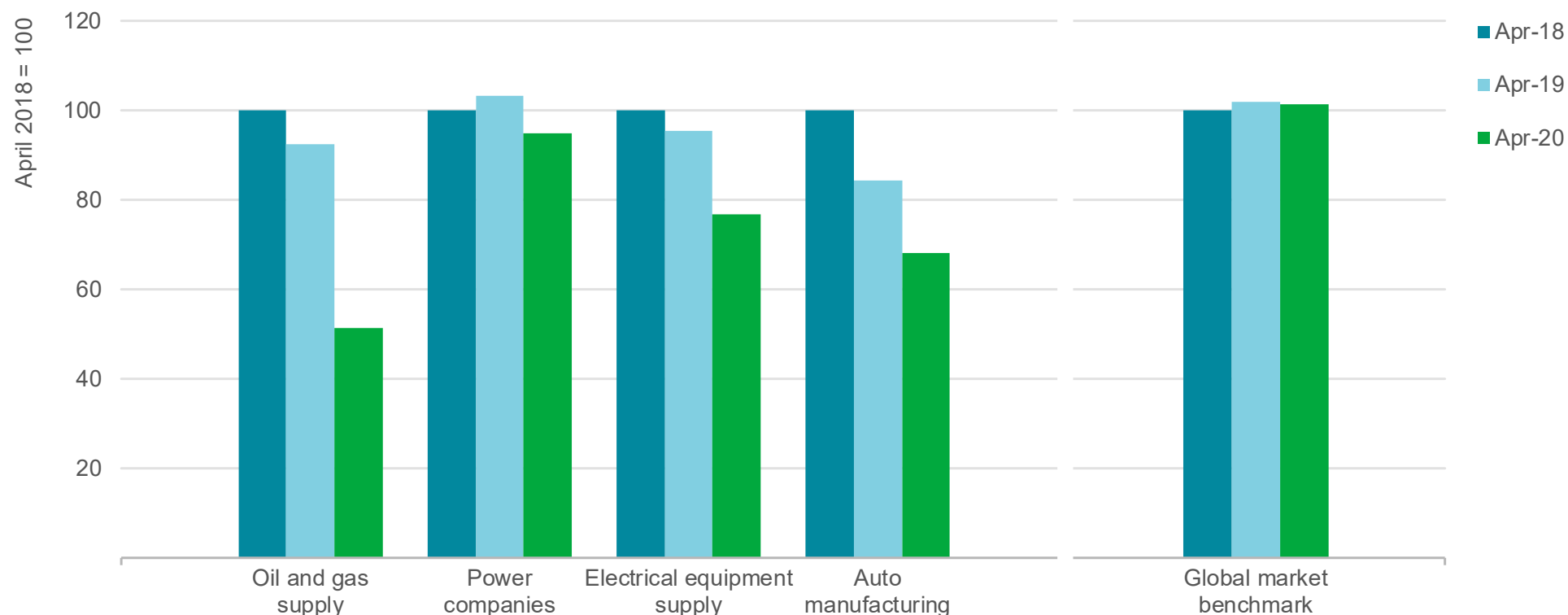
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Notes: Current ratio = current assets divided by current liabilities. ROIC = return on invested capital. Includes top 25 listed companies based on sales (top 10 for electrical equipment and automotive), but excludes those in China and Russia.

Sources: IEA calculations based on Thomson Reuters Eikon (2020) and Damodaran (2020).

Equity market pressures have intensified for energy-related sectors in 2020, but more so in those exposed to fuel supply and consumer goods

Market capitalisation for listed energy-related companies (top companies based on sales), as of the end of April



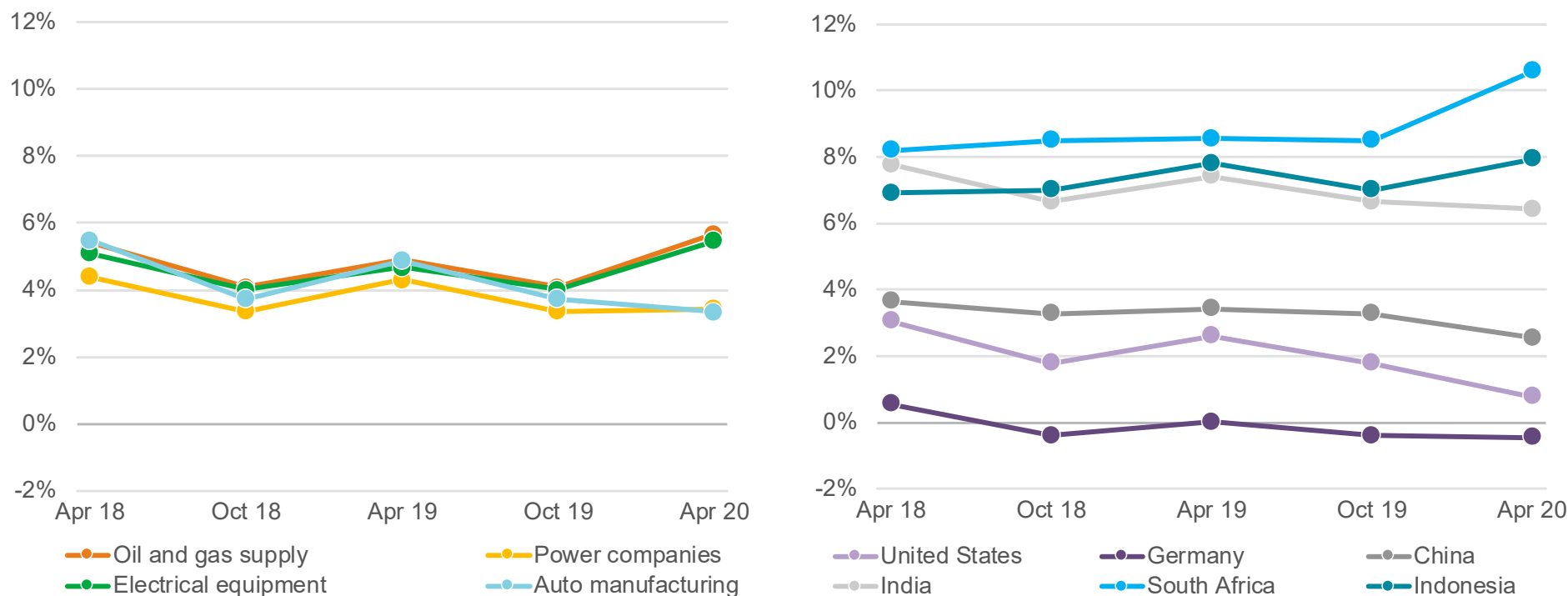
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Notes: Includes top 25 listed companies based on sales (top 10 for electrical equipment and automotive), but excludes those in China and Russia. Market capitalisation is measured at the end of April for each year. Global market benchmark = FTSE All-World equity index.

Source: IEA calculations based on Thomson Reuters Eikon (2020).

Borrowing costs have risen for a number of companies, even as benchmark rates fell in the United States and Europe, and a number of emerging economies face tighter credit conditions

Weighted average cost of long-term debt for top energy companies (left) and government 10-year bond yields (right)



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Note: Includes top 25 listed companies based on sales (top 10 for electrical equipment and automotive), but excludes those in China and Russia.

Source: IEA calculations based on Thomson Reuters Eikon (2020).

Emerging financing and funding pressures raise new risks to energy investment...

Recent events have brought a repricing of risk across the global economy and to the energy sector in particular. Energy investments face new risks from both a funding – i.e. how well project revenues and earnings can support new expenditures on corporate balance sheets – as well as a financing perspective – i.e. how well debt and equity can be raised to supplement corporate and government funds.

These are most apparent from the estimated declines in revenues facing both the oil and gas and power sector in 2020, as well as equipment and goods suppliers (see Overview), exacerbated by financial market volatility and a slowdown in project finance transactions and mergers and acquisitions. The cost of money has risen for most actors save for mature market sovereigns, whose bond yields have fallen. The ability to price and structure financial deals remains challenging due to strong market volatility as well as the physical situation of industry professionals. Near-term liquidity constraints and growing risk of defaults across the economy also cast uncertainty, with many companies and investors opting for capital discipline over financing new transactions.

There are questions over how short-term market volatility will affect the industry landscape and investment decisions. Like the wider economy, the financial conditions for energy-related companies have changed in 2020, in particular with top companies experiencing falls in market capitalisation steeper than those of equity benchmarks. While falling share prices more directly impact investors, they provide a signal of expectations for profitability and increase the cost of issuing equity.

In the near-term, the challenges concern liquidity – sufficient cash flow to keep businesses operating and meeting obligations with customers and suppliers. Shifting market fundamentals and uncertainty over the

timing and nature of economic recovery is also pressuring profitability, which shapes future funding capacity. Coming into 2020, indicators for energy-related industries trailed market benchmarks in these areas. Early observations suggest higher risks around certain segments.

Over the past two years, the market capitalisation of the top-listed oil and gas companies declined by nearly 50%, with most of the fall coming in the past year, as investors reassessed risks and profitability expectations in the face of lower oil prices, emerging oversupply and uncertainty over how well companies can position themselves in a changing market environment. These risks are also reflected in an increase of volatility compared with the wider market, as expressed by a higher beta, which was rising even before the recent crisis took hold.

For some segments, such as US shale producers, which rely on debt markets to finance operations, the knock-on effects from much lower oil prices have resulted in much higher borrowing costs and near-term liquidity constraints for a number of companies. For better capitalised players (e.g. the Majors) financial developments have forced companies to cut capital spending; dramatically re-evaluate investment plans, and in some cases dividends; and look to debt markets to help fund shareholder commitments (see “Sectoral trends” section below).

The financial situation is varied for the power sector, where the top-listed companies have seen a loss in market capitalisation of only around 5%. Some buffer is provided by the more predictable revenues for utilities from regulated networks and renewables, where investments are increasingly focused, while many power producers in competitive markets have hedged some merchant exposure a year ahead (Rack, 2020). Renewable developers also came into 2020 with improving performance.

... but financial markets can also amplify supportive factors for energy investment

That said, declines in power demand, uncertainties over future pricing for wholesale market generators and exposure to gas distribution as part of utility business models raise new funding challenges. Borrowing costs have also risen and utilities face credit risks from non-payment by customers under financial stress. For European utilities that had already seen earnings erode over the past decade in the face of lower demand, the financial picture is more shaky, while US utilities entered the crisis on firmer footing. Some state-owned utilities in emerging economies that borrowed heavily in foreign currency now face ballooning debt obligations, with potentially less relief available from government coffers. Given long capital cycles for power, shifting financial conditions appear to have less of an impact on current capital spending compared with oil and gas (see Power Sector section), but the financial risks vary considerably by market and segment.

Players in the electrical equipment supply chain – which helps to provide everything from turbines to grid components to energy management systems – may face more challenging financial conditions than project developers. With economic uncertainties, some governments and utilities are delaying procurement of power projects, which means reduced order books and cash flow for suppliers, though there may be an opportunity to focus on repowering existing assets and adopting more flexible payment terms. Consolidation pressure on smaller renewables manufacturers with weaker balance sheets may accelerate, while larger players may be able to weather the storm with cost cutting.

Finally, automakers also face a much more uncertain financial picture with a steep fall-off in sales in the first months of the year and a more than 30% loss in market capitalisation, second to that of oil and gas.

This raises questions over the turnover of the vehicle fleet as well as the continued roll-out of more efficient vehicles and EVs, particularly in the face of much lower fuel prices (see Energy End Use and Efficiency section).

The financial markets can play an amplification role for energy investment on both the downside and the upside. While uncertainties abound in the near term, conditions may be ripe for refinancing and acquisitions that can help lower the cost of finance and improve the confidence of developers to invest, knowing that they can quickly recover their capital. Such opportunities have increased in recent years and could now become more attractive for institutional investors searching for yield with risk appetite for assets, such as renewables, energy infrastructure and other capital-intensive technologies with reliable revenue profiles. They may also be reinforced by some of the longer-term preferences expressed in the market for allocating capital towards sustainable finance opportunities. Further discussion of these dynamics are found in the sections below on the “Role of institutional investors in energy investment” and “Sustainable finance and energy investment”.

Private decisions to invest will of course also depend on the evolution of the current crisis and actions taken by governments to support markets. For example, while investors have increased their focus on sustainable finance in recent years, there are questions over the clarity of energy policy signals and alignment of financial policies that would better channel financial flows to real sustainable assets. Moreover, in markets and sectors where investment risks remain relatively high, the risk-taking capacity of public finance institutions may play an increasingly important role.

Have investments in renewables companies performed better than those for fossil fuels?

Despite growing cost-competitiveness, which has supported rising deployment for solar PV and wind over the past decade, renewables investments are not expanding at the rate needed to align with sustainability goals. They would need to more than double over the next decade. That said, decisions to allocate capital towards different mixes of fuels and technologies depend a lot on financial performance, taking into account not just returns, but the level of risk as well.

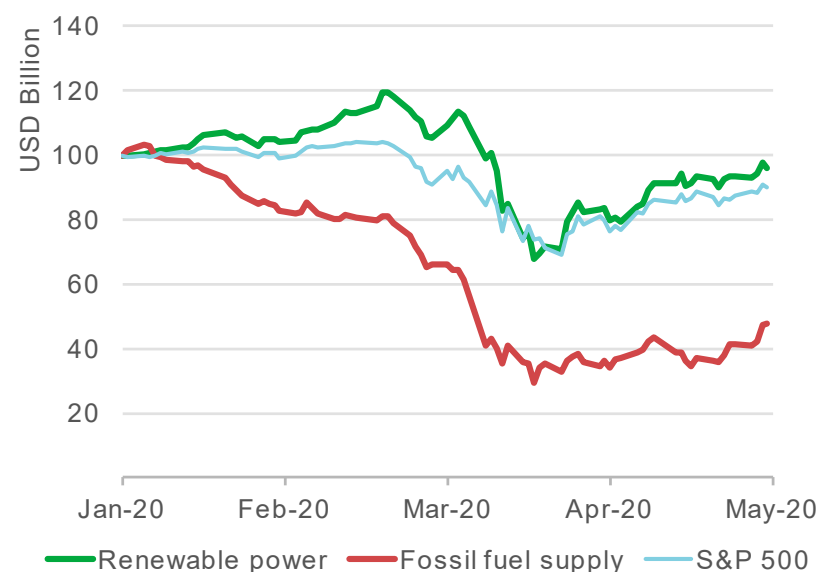
The IEA and Imperial College London are investigating the risk and return proposition available to investors in the energy sector through a series of special reports. The first study focuses on historical financial performance of fossil fuels versus renewable power in listed equity markets of select advanced economies. We constructed hypothetical investment portfolios to compare fossil fuel and renewable power business segments in three geographies: the United States, the United Kingdom, and Germany and France. The methodology described in the report will be extended to other countries and unlisted (i.e. private market) investments in forthcoming work.

The findings indicate that renewables shares in these markets over the past decade offered higher total returns relative to fossil fuels, with lower annualized volatility (a measure of investment risk). Over January-April 2020 renewable power companies held up better than fossil fuel companies during a period of severe stress and volatility.

So why has the apparent financial attractiveness of renewable power in equity markets not resulted in a more pronounced reallocation of investor capital? One reason is that the characteristics of a dedicated renewable power portfolio are substantially different from those of pure play fossil fuel portfolio. These characteristics (such as average market capitalization, dividend pay-out ratio, firm capital structure, and liquidity) matter a lot to large institutional investors.. Additional

measures, and development, may be required to prepare the industry for fully-fledged support from listed equity markets. How quickly this occurs, and whether existing norms in the investment industry will adapt to the funding needs of a relatively new asset class, are key questions for further study.

Total equity return for US and Europe companies by sector

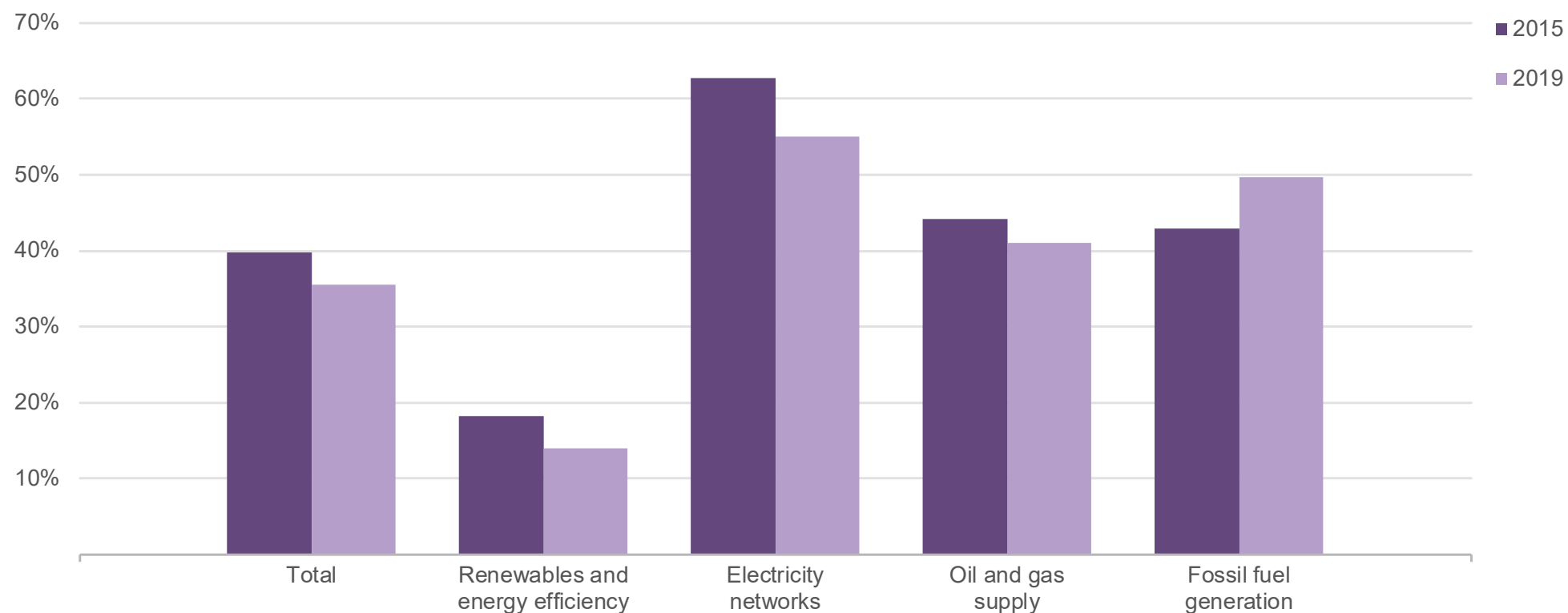


Notes: Includes companies with market capitalisation of at least USD 200 million in the Bloomberg Industry Classification Systems. Fossil fuels = oil and gas (exploration and production, integrated oils, midstream, services and equipment, refining and marketing) and coal operations; Renewable power = project developers and equipment manufacturers, green utilities (>50% of revenues from renewables) and yieldcos.

Source: IEA and Imperial College (2020).

Though somewhat lower since 2015, state-owned enterprises continue to play a big role in energy investment, particularly in fossil fuel-based sectors and networks

The share of government/SOE ownership in global energy investment by sector, 2015 and 2019

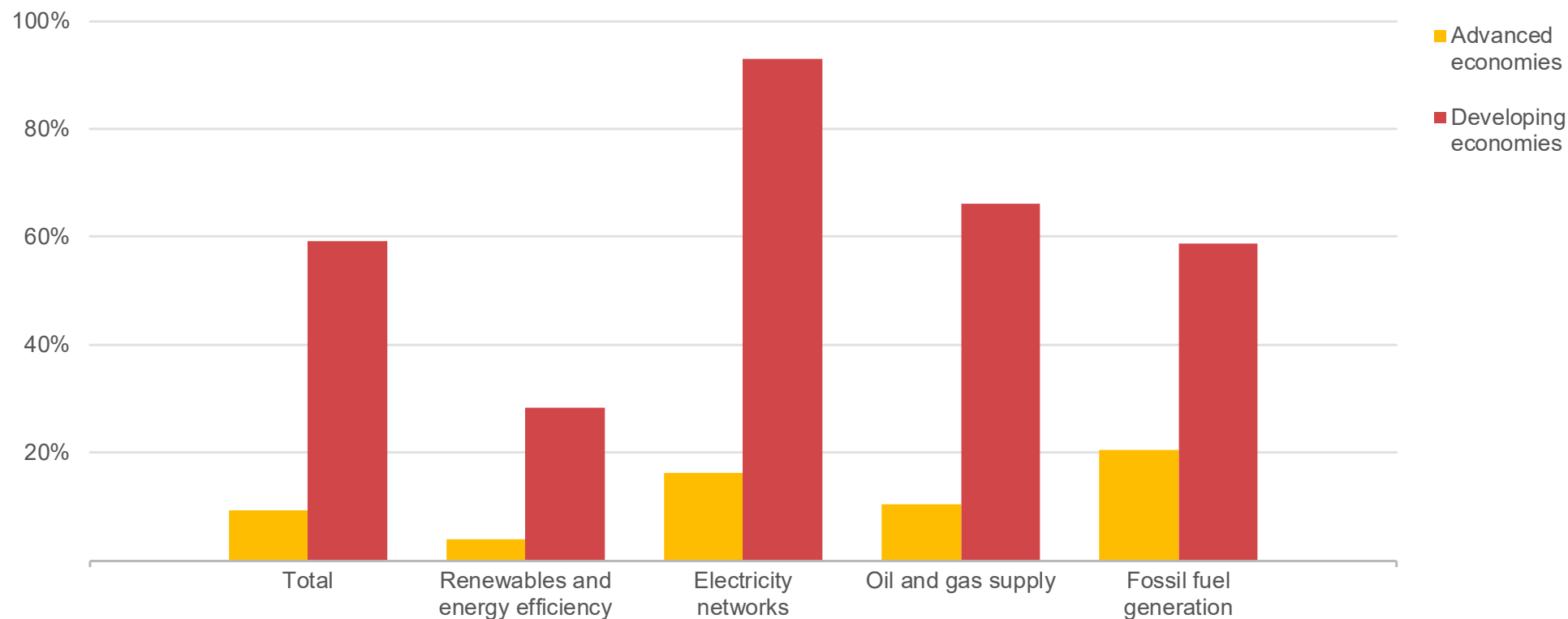


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Note: SOE = state-owned enterprise.

State-backed ownership plays a much greater role in developing economies, where market structures are more regulated and the cost of capital is higher

The share of government/SOE ownership in energy investments by economy type and sector in 2019

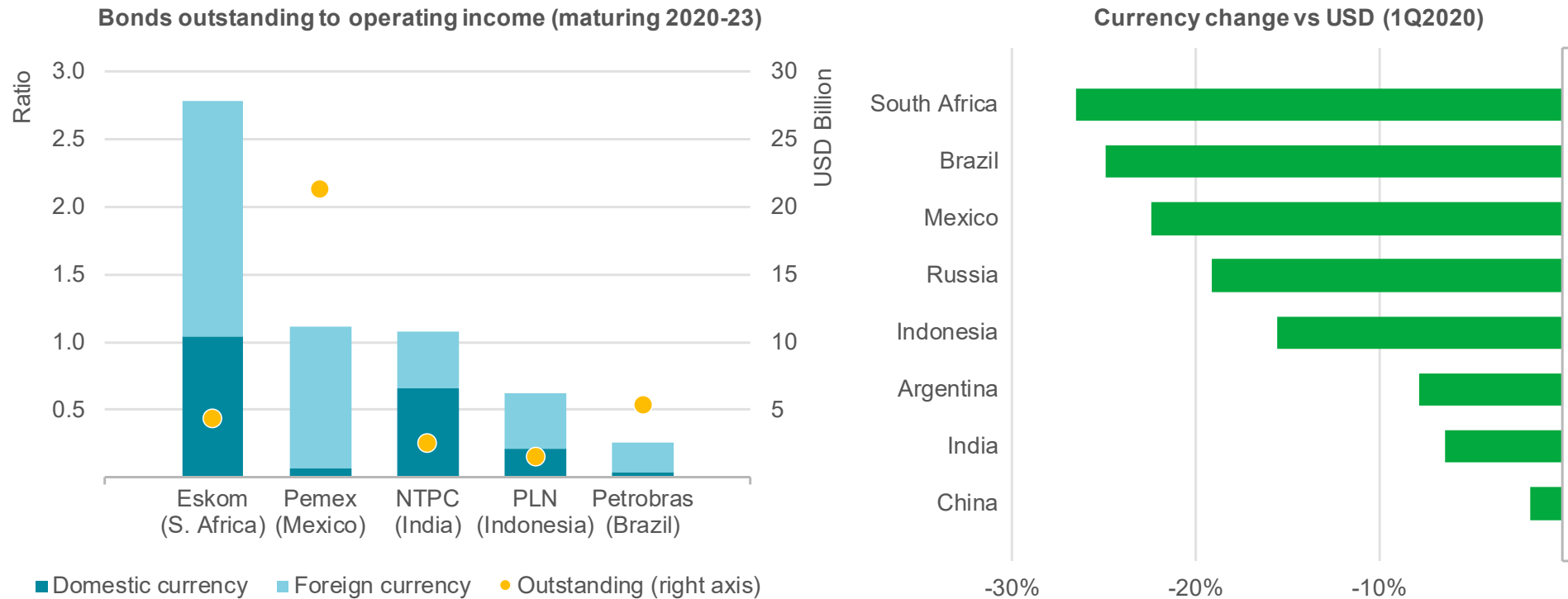


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Note: SOE = state-owned enterprise.

SOEs that borrowed heavily in foreign currency may now face a debt “maturity wall”

Outstanding bonds by currency denomination and recent exchange rate movements for key SOEs and emerging economies



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Notes: PLN = Perusahaan Listrik Negara. Operating income reflects latest annual reported value.

Source: IEA calculations based on Thomson Reuters Eikon (2020).

Weakening SOE finances raise investment risks, and uncertainties over the role of state actors

The share of private-led energy investment, in terms of ownership, has increased since 2015. There has been a growing role for renewables, where private entities own nearly three-quarters of investments; energy efficiency, which is dominated by private spending; and private-led spending in grids and battery storage. But state-led investments have remained relatively robust in certain sectors, such as oil and gas and fossil fuel-based generation. Overall, the SOE share of energy investment was 36% in 2019, down from nearly 40% in 2015.

SOEs account for nearly 40% of power investments, though this share has fallen since 2015, from lower spend by Chinese SOEs in coal-fired generation and networks. In some emerging markets outside China, the role of SOEs in power investment increased, with more resilient investment in fossil fuel generation by SOEs, compared with private actors, notably coal plants in India and South Africa and gas plants in North Africa. SOE investment in coal plants in Poland also increased.

Electricity sector investment by the private sector and consumers declined less than that of SOEs over 2015-19, mainly due to more resilient investment in renewables and a higher share of grid spending in markets with investor-owned utilities. This was reinforced by a rise in distributed solar PV and an increase in consumer spending on energy efficiency, helping to boost the total private share. Notably, in emerging economies, private actors play a predominant role in renewables investment (except hydropower, where state players dominate), but their projects typically sell to state-owned utilities.

In upstream oil and gas, the share of NOCs in investment remained over 40% in 2019, though spending in the Middle East and Russia, where NOCs dominate, increased less than in other parts of the world, notably in the United States and in shale, where private companies are

more important. This share is still higher than before the oil price collapse in 2014 as large private oil and gas companies, including the major oil companies, cut back spending more heavily in 2015 and 2016, a trend likely to be reinforced with the downturn in 2020.

Given an expected downturn for global energy investment in 2020, additional questions are emerging over how the role of NOCs and SOEs will evolve. Private actors, at least in oil and gas, have borne the brunt of capital cuts thus far, and SOEs may also be a vehicle for some governments to carry out fiscal stimulus measures. Still, some indebted and poorly performing NOCs are also being hit very hard by the current crisis, with knock-on effects on host governments that rely on oil and gas revenue to provide essential services (see Fuel Supply section).

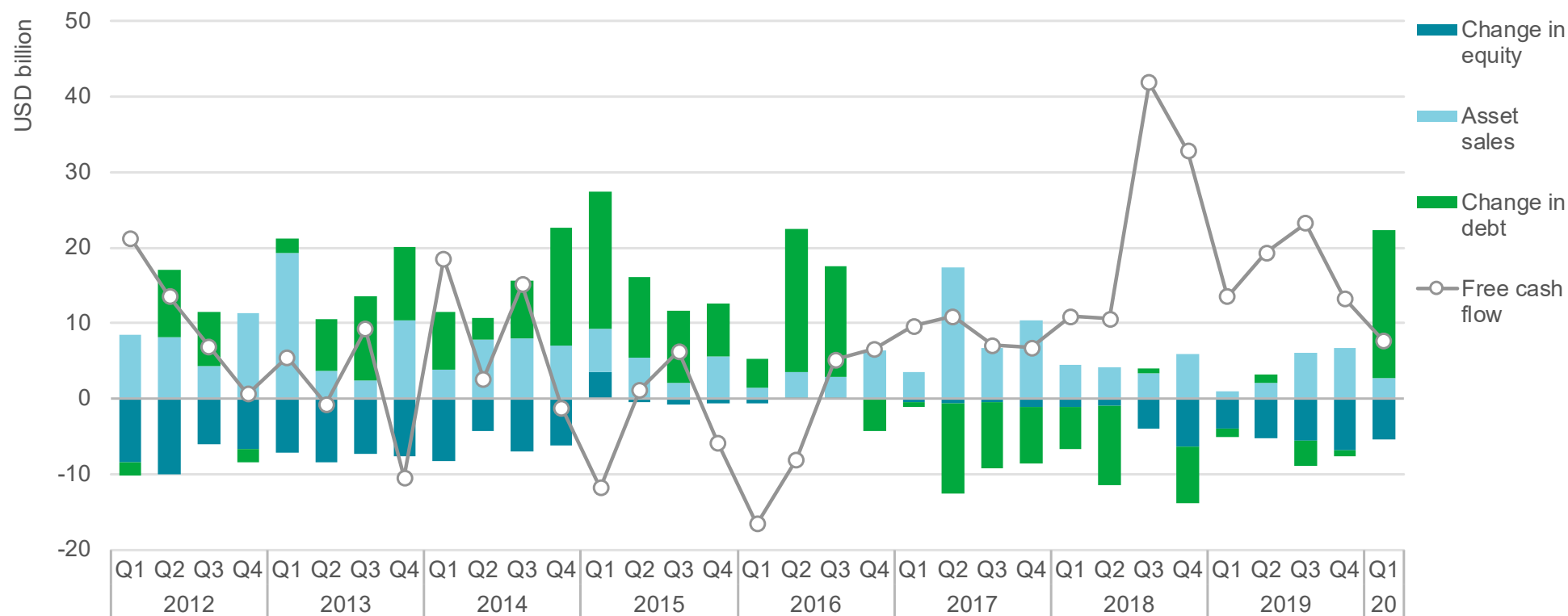
In 2020, a repricing of country risks in some developing economies led to rising government bond yields and falling currencies. SOE financing is often tied to the sovereign entity guaranteeing the debt, and so sharp declines in emerging market bond prices means rising financing costs. South Africa has lost its last investment grade rating on its credit. Compounding the situation, a number of SOEs (e.g. Eskom, Pemex, PLN, Petrobras) have borrowed heavily in foreign currency and now face debt repayments some 15-30% higher in domestic currency terms, alongside more uncertain revenues from changing market conditions.

In the near term, governments may find themselves stepping in to shore up SOE finances, particularly through providing liquidity, refinancing and foreign exchange reserves to meet growing debt challenges. But reduced fiscal capacity and higher borrowing costs from the crisis may also hamper their ability to respond.

Sectoral trends in energy finance

Over time, oil and gas majors improved their financial position by cutting costs, deleveraging and boosting free cash flow, but trends have shifted sharply in 2020

Majors' indicative sources of finance and free cash flow



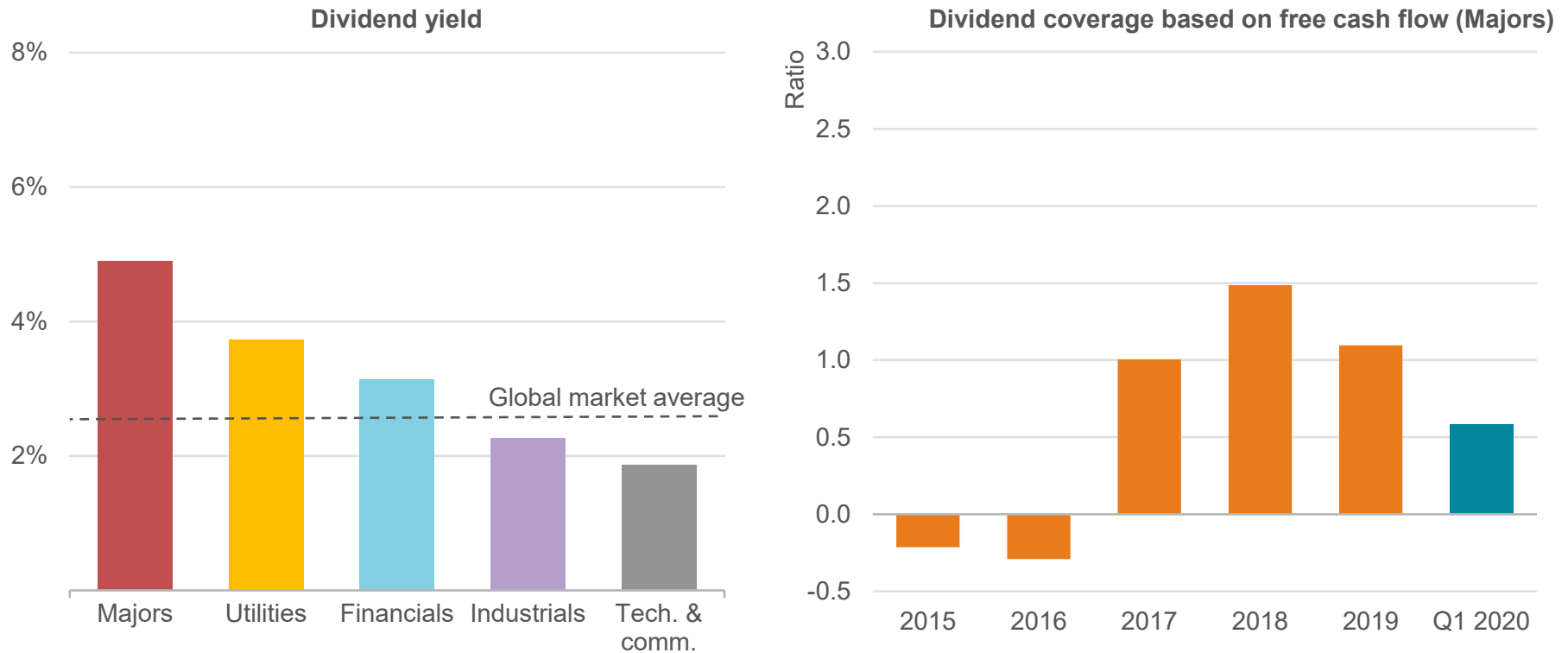
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Notes: Free cash flow is cash flow from operating activities less capital expenditure. It excludes changes in working capital. Majors = BP, Chevron, ConocoPhillips, Eni, ExxonMobil, Shell and Total.

Sources: IEA calculations based on Bloomberg (2020) and Thomson Reuters Eikon (2020).

High-dividend yields and share buybacks have been part of the Majors' financial strategy, but there are questions over these practices in a changed market environment

Dividend yield for Majors and globally listed companies by selected sector (2015-19) and dividend coverage ratios for Majors



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Notes: Tech. & comm. = technology and communications. The charts include all listed companies in the world with over USD 10 billion of market capitalisation. The dividend yield is the average weighted with market capitalisation in each year. The dividend coverage ratio is defined as free cash flow divided by dividends paid.

Sources: IEA calculations based on company filings and Bloomberg (2020).

In 2020, companies face a new stress test in finding the right balance between delivering oil and gas, maintaining capital discipline, returning cash to shareholders and investing for the future

Companies across the oil and gas sector now face an unprecedented stress test – in their business strategies, operations and financial models – from a sharp demand shortfall from the current economic crisis and a supply overhang (see Fuel Supply section). The sector as a whole faces the prospect of a smaller and more competitive space within which to operate, though the financial implications and strategies vary strongly by type of company. Here we discuss the choices faced by oil and gas Majors in balancing investment priorities with new financial pressures – to weather the current downturn and position future energy portfolios. The situation of US Independents is also treated below.

By the end of 2019, Majors had greatly improved financial performance relative to the previous oil price downturn, employing a combination of cost-cutting and activity delays, careful project selection, asset sales, and paying down debt. Companies also looked to the oil services and equipment sector to lower margins, which supported a reduction in upstream costs some 20% below 2014 levels. However, this position has reversed sharply in the first quarter of 2020, with free cash flow reverting back to 2017 levels and companies significantly increasing debt issuance to cover obligations. The financial position is likely to worsen as the full brunt of sharply declining revenues is felt through the course of the year. Moreover, there is relatively little scope this time around for further cost-cutting as most of the available savings have already been made.

At the same time, the Majors have also faced growing pressure from investors, reflecting near-term economic stress, but also growing climate risk concerns by the financial community (see below).

Many Majors have diversified spending into non-core areas: renewables and other clean energy technologies now account for up to 5% of their capital expenditure, and they are also acquiring existing non-core businesses, for example in electricity distribution, electric vehicle charging and batteries, while stepping up research and development activity. However, these areas are not at the scale or profitability to provide much of a financial buffer in the current crisis.

Providing high-dividend yields and share buybacks have historically been features of their financial strategies and ways to keep investors in the fold. The Majors took on additional debt in the 2014-16 downturn to continue to pay cash dividends, and they also offered payment in additional shares (so-called scrip dividends), and over 2018-19 they bought back over USD 30 billion of equity.

But in today's market, traditional financial strategies may now be less effective. Equity returns for the majors underperformed the broader market over 2015-19, and in the first quarter of 2020 declined sharply. Dividend coverage ratios have declined to low levels. Some companies have taken the dramatic step of cutting dividends – to date, Shell and Equinor (an NOC) have announced two-thirds cuts to quarterly payouts. Several Majors, including Chevron, Eni, ExxonMobil and Total, have announced the suspension or paring of share buyback programmes. Recently, several companies raised over USD 30 billion from debt markets to shore up liquidity and maintain commitments to shareholders. While the Majors are uniquely positioned to exercise this option compared with smaller companies, some have witnessed credit downgrades that may make borrowing more expensive over time.

Oilfield service and equipment providers face huge financial challenges

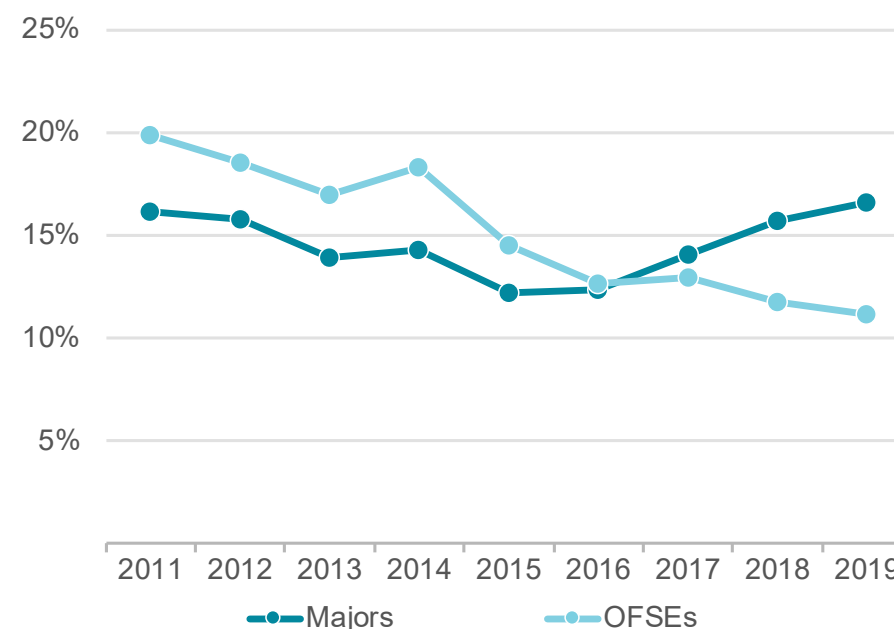
The financial performance of oilfield service and equipment (OFSE) providers, already weakened over the past five years, is seeing a new wave of challenges as producing companies cut costs in reaction to the current downturn. During the oil price decline in 2014-16, profit margins for service providers shrank from relatively comfortable levels and declined below that of the Majors as operators shelved projects and renegotiated contracts. Production companies adjusted design strategies, moving away from bespoke to supplier-standard offerings that could be delivered for less cost and with shorter lead times.

This trend fed into a period of increased industrial consolidation, including mergers and acquisitions and notable bankruptcies in several sub-sectors. Larger players took advantage to diversify their portfolios across value chains with Schlumberger acquiring Cameron, Technip merging with FMC, and Baker Hughes and GE combining forces. The engineering, procurement and construction sub-sector was particularly affected, marked by historically high debt ratios, restructuring and government bailouts (e.g. Daewoo Shipbuilding and Marine Engineering [DSME]). Additionally, contracting strategies have trended to putting increased financial risk onto contractors and shortening contract lengths, resulting in service companies' reduced ability to hedge income far into the future.

Supply chain challenges manifested themselves early in the current pandemic, and service companies quickly adjusted staffing rotations and supply options where possible. OFSEs, particularly those exposed to the US shale market and drilling cutbacks, have announced capital expenditure cuts upwards of 31% in 2020. They have supplemented these cuts with cash saving measures, including stopping or reducing dividends, salary cuts, and the furloughing or laying-off of staff.

While already under pressure from the previous downturn, the current market situation may further reduce diversity among service providers. Baker Hughes announced debt restructuring and Diamond Offshore Drilling filed for bankruptcy while Weatherford International was delisted. They may not be the last companies to do so as the dynamic landscape of the service sector evolves in the downturn.

EBITDA margins by oil and gas company type

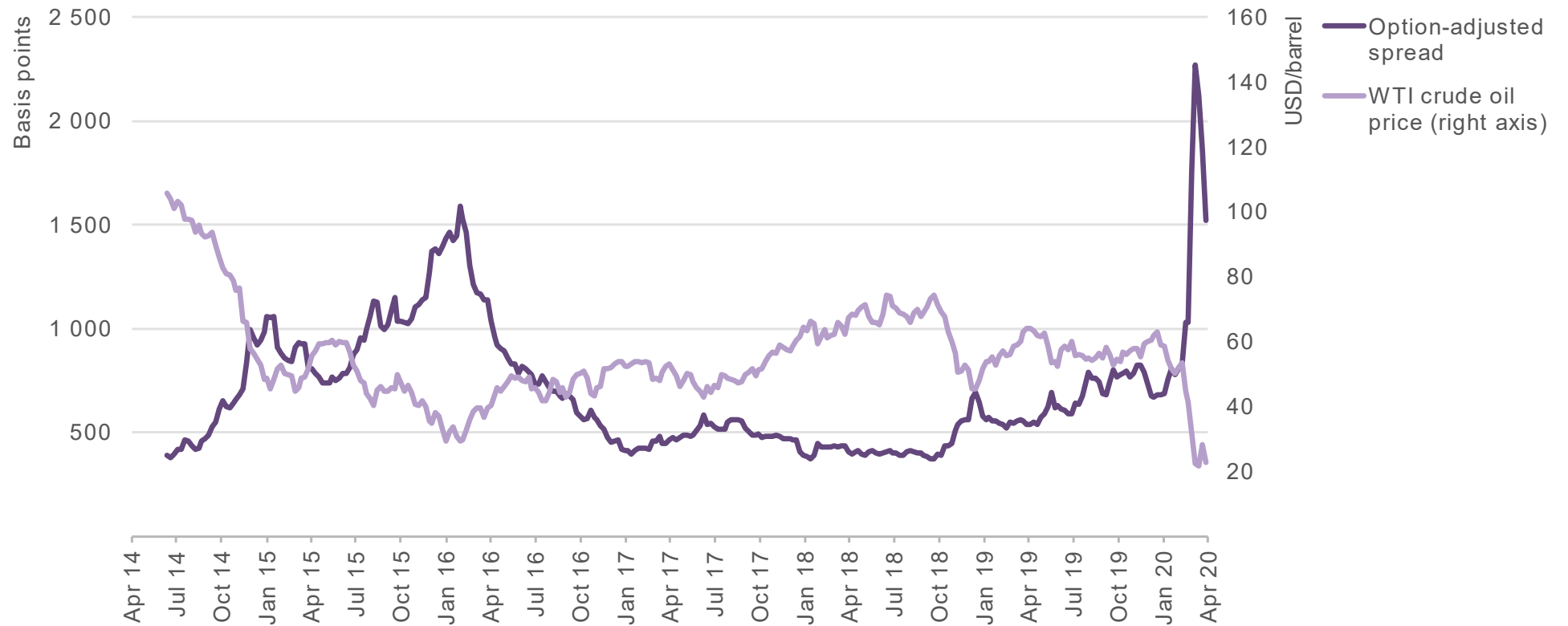


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Note: EBITDA = earnings before interest, taxes, depreciation and amortisation.

US shale producers now face more extreme near-term funding challenges

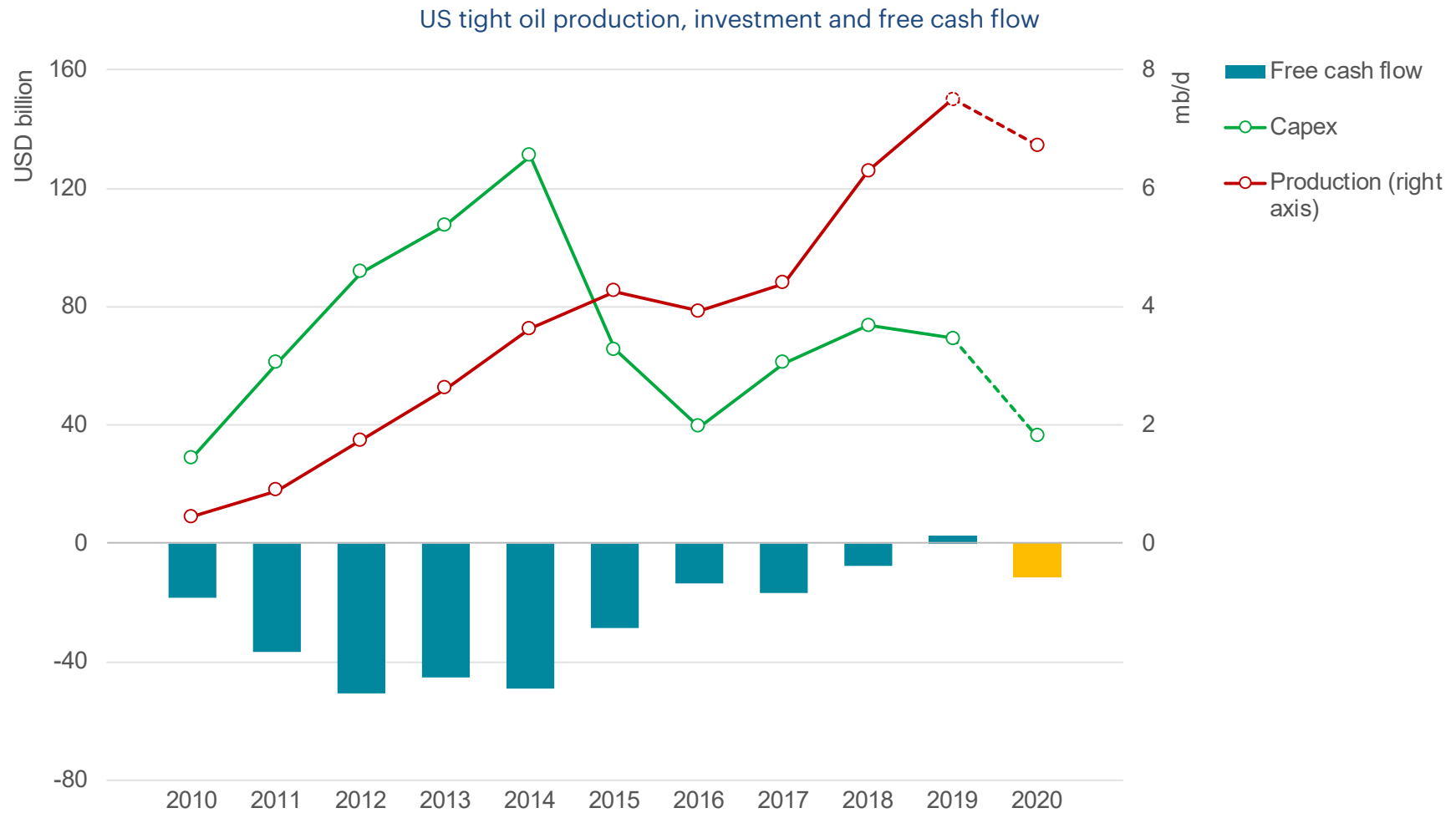
Option-adjusted credit spread for US high-yield energy sector corporate bonds and crude oil price



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Source: IEA calculations based on Bloomberg (2020).

Shale fundamentals are set to reverse sharply in 2020



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Sources: IEA calculations based on company filings, Rystad Energy (2020), and Bloomberg (2020).

Investment cuts, financial restructuring and a changed industry landscape for independents

The small and medium-size independents that make up the US shale sector are among the most financially exposed to the current economic crisis and the supply shock in oil markets. They face a short-term credit crunch and also have reduced scope to increase productivity by cutting costs compared with the past.

For the shale industry, at an oil price of USD 30/bbl or less, the outlook for many highly leveraged companies looks bleak (see Fuel Supply section). Despite improving finances and efforts to pay down debt over the past four years, which resulted in reduced risk premiums, the sector's exposure to high-yield bonds and a subsequent run-up in credit spreads in that market effectively closed a vital funding channel in early 2020. Companies are trying to extend bond maturities and keep revolving credit facilities open, but banks are also cutting exposure. A number of players have announced credit downgrades, bankruptcies, redefinition and debt restructuring as reassessments of reserved-based lending and cash flow expectations continue.

In 2020, the free cash flow position of shale companies is set for its worst year since 2015. Companies have announced significant cost-cutting and capital reduction measures. For example, Occidental Petroleum, with its heavy debt load since acquiring Anadarko Petroleum in 2019 for USD 38 billion, announced capital expenditure cuts of 54%, in addition to operational cost and dividend reductions. But opportunities to extract greater operational efficiency, as was achieved in the past by working with OFSE companies, are more limited in the current crisis.

Shale bankruptcies have continued from last year, with exits at a similar level to the immediate aftermath of the 2014-15 downturn, indicating

persistent financial distress (Haynes and Boone, 2020). One of the larger independent players Whiting Petroleum filed for bankruptcy in April, and others have been early to announce restructuring in 2020 as the process continues across much of the sector.

Efforts to find the most productive areas of shale basins, adopt new technologies and expand infrastructure enabled US shale companies to double production over the past five years while continuing improving capital efficiency 40% since 2015. But the ferocity of the crisis in 2020 has been well beyond the contingencies that the industry had planned for. In addition to the price risks (against which many players had hedged), the industry was also faced with acute logistical difficulties as demand plummeted in April and available storage filled up.

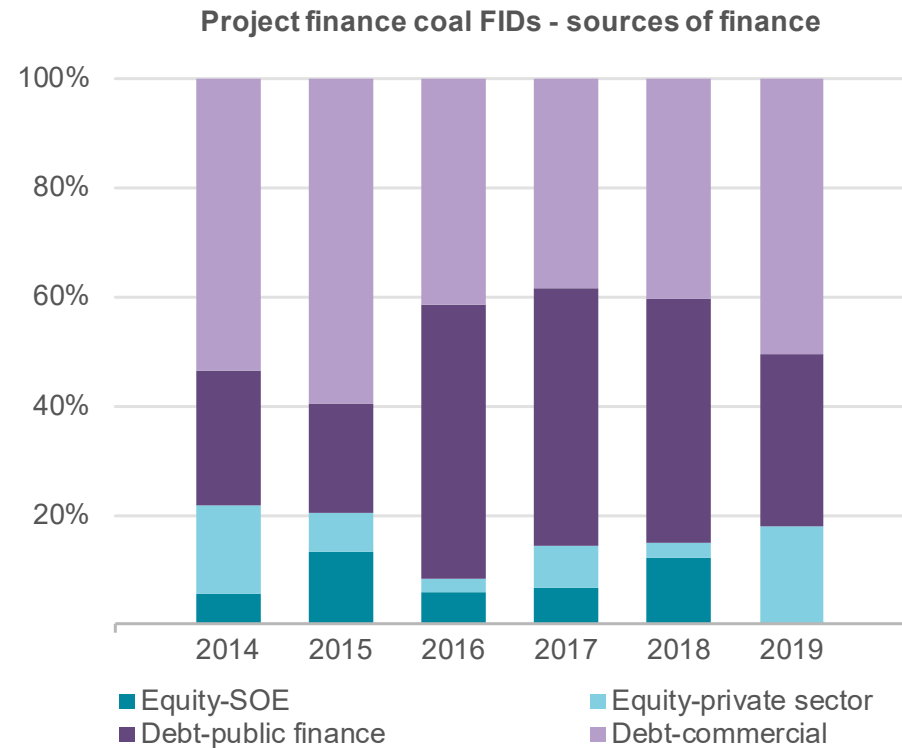
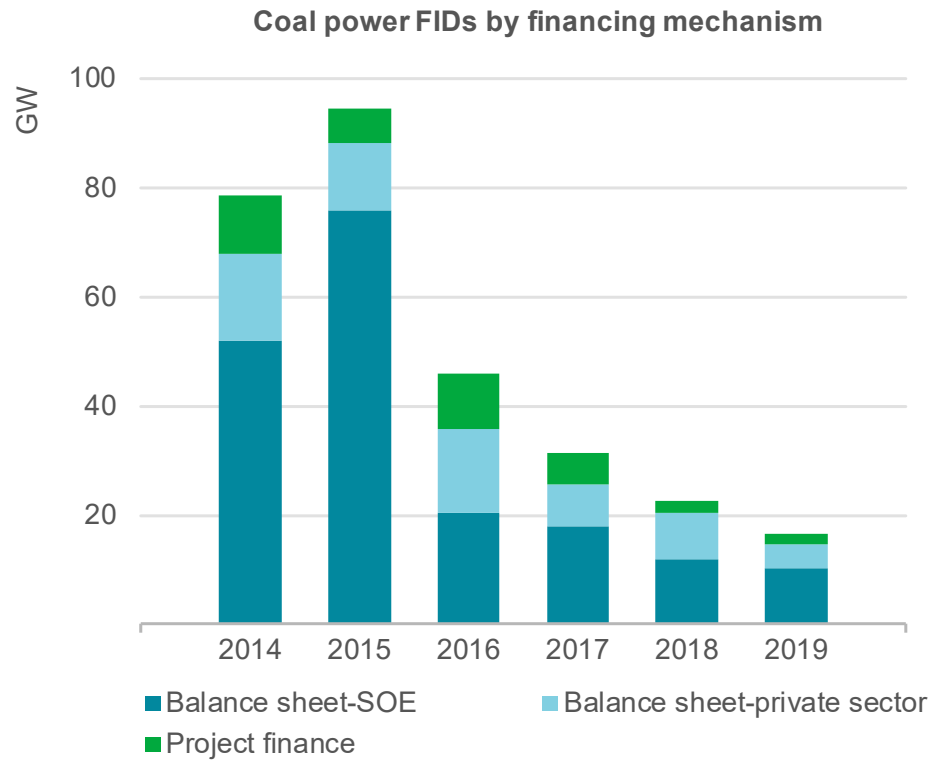
Due to the steep nature of unconventional well declines, often on the order of 60% in the first year, activity reductions are set to result in production losses, especially as they are accompanied by widespread well shut-ins.

The shock of 2020 does not spell the demise of shale or of independent operators, particularly given the sector's ability to ramp up quickly with higher oil prices, but will likely result in a dramatic restructuring of the industry landscape, including consolidation among players with well-located resources.

Looking beyond 2020, and even if oil prices recover back to 2019 levels, investment and the journey towards a more sustainable business model may depend on companies considering further innovation or efficiencies to reduce costs, or improve ultimate recoveries.

Coal power investment decisions continued to fall, and depend mostly on state-backed finance

Final investment decisions for coal power



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Sources: IEA calculations based on McCoy Power Reports (2020) for FID capacity levels and IJ Global (2020) and World Bank (2020) for sources of project finance.

As commercial actors announce new restrictions, coal power finance relies on fewer sources

Coal power FIDs have plummeted in recent years – stemming from excess capacity and declining utilisation rates in some markets (e.g. China, India), and increased renewables and (in China) gas role in the energy mix. At the same time, the pool of capital for new developments has shrunk and financing terms have become more strict. Well over 100 financial institutions globally have announced restrictions on financing coal (IEEFA, 2020).⁵ Yet a large construction pipeline persists, facilitated by availability of state-backed equity, debt and guarantees, as well as long-term contracts in some Asian markets.

Since 2016, state-backed sources (including SOEs and public financial institutions) have accounted for over 60% of the financing of new coal power. The majority of this stems from SOEs building new plants on balance sheet in China, but also in India and Indonesia. A mix of private actors (power companies and industrial companies) have also taken investment decisions in these markets, as well as in other emerging Asian countries, Japan, Korea and the Middle East.

Some challenges have emerged for SOEs in the largest markets. Chinese power companies are increasingly burdened by heavy debt levels, and India's thermal generation has come under increased financial stress with slowing demand and insufficient reforms to the distribution sector. Developments in 2020 exacerbate these trends. In Indonesia, the state-owned utility – already facing financial challenges – has seen debt burdens rise from a combination of currency depreciation and a large share of borrowing in foreign currency. It remains to be seen how changing financial dynamics will affect expansion plans, and in some cases power companies may choose to retire less efficient assets. In China, companies have shelved a number

of smaller plants in recent years, while local economic and employment factors provide incentives to continue investing in new ones.

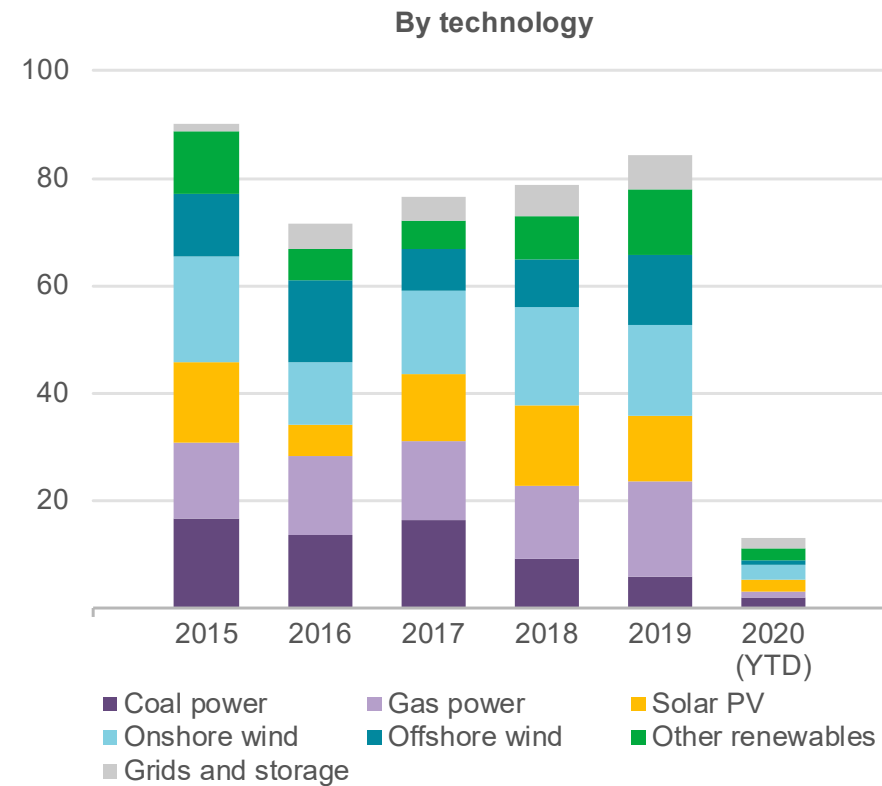
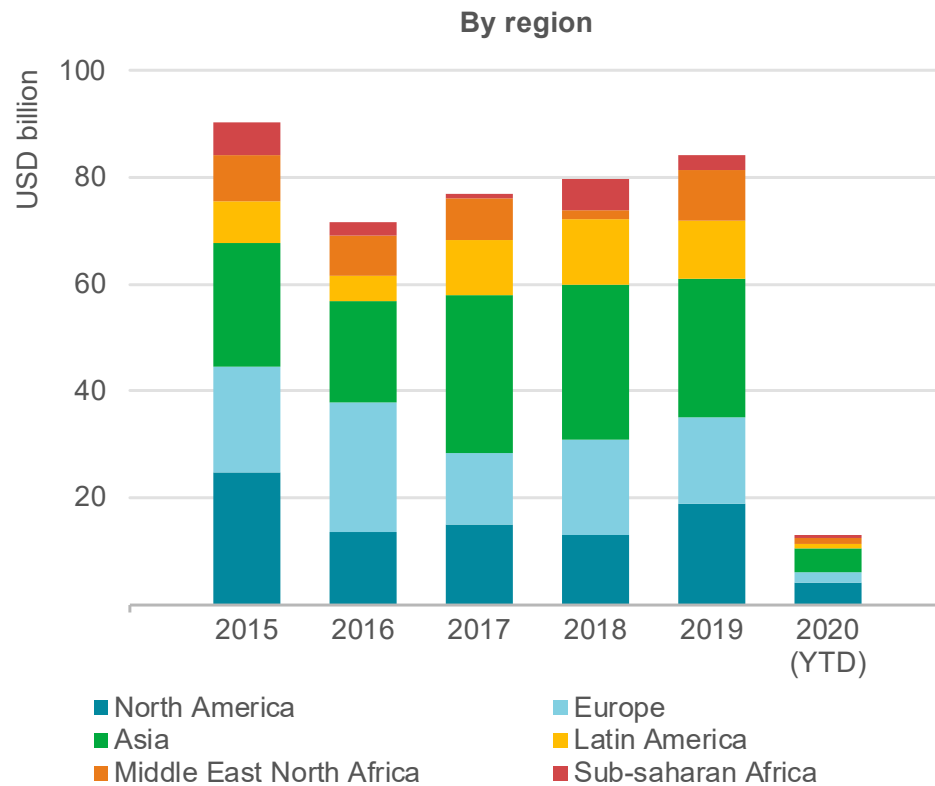
Project finance structures have accounted for a fifth of coal power FIDs, and state-backed sources of finance made up over half of these deals since 2016. Transactions have been highly leveraged over 80% debt. The three largest debt providers globally (who also provide guarantees), accounting for 35% of project debt, have been development banks and export credit agencies from China and Japan. A mixture of commercial banks from Asian countries, Chinese policy banks, and export credit agencies from India and Korea have also featured among recent major lenders.

Several commercial debt providers that were still financing in 2019 have signalled intentions to step back from the sector. Two major Japanese banks – Mizuho and Sumitomo Mitsui – announced restrictions to lending for new coal plants in April of this year. Mizuho's announcement came in the wake of a shareholder motion filed against the bank (the first climate-related resolution faced by a publicly traded company in Japan), pointing to the influence of investor pressure. All this raises questions over the degree to which public sources may continue to fill the gap. Through March, only one new coal power FID based on project finance emerged for 2020, in Pakistan, though all project approvals were over half that for 2019 (see Power Sector section).

⁵ See chapter 5 of IEA (2019b) for fuller discussion on coal divestments.

Following several years of renewed growth, and a shift towards renewables, power sector project finance transactions have fallen sharply in 2020

Project finance transactions for power, by year of financial close



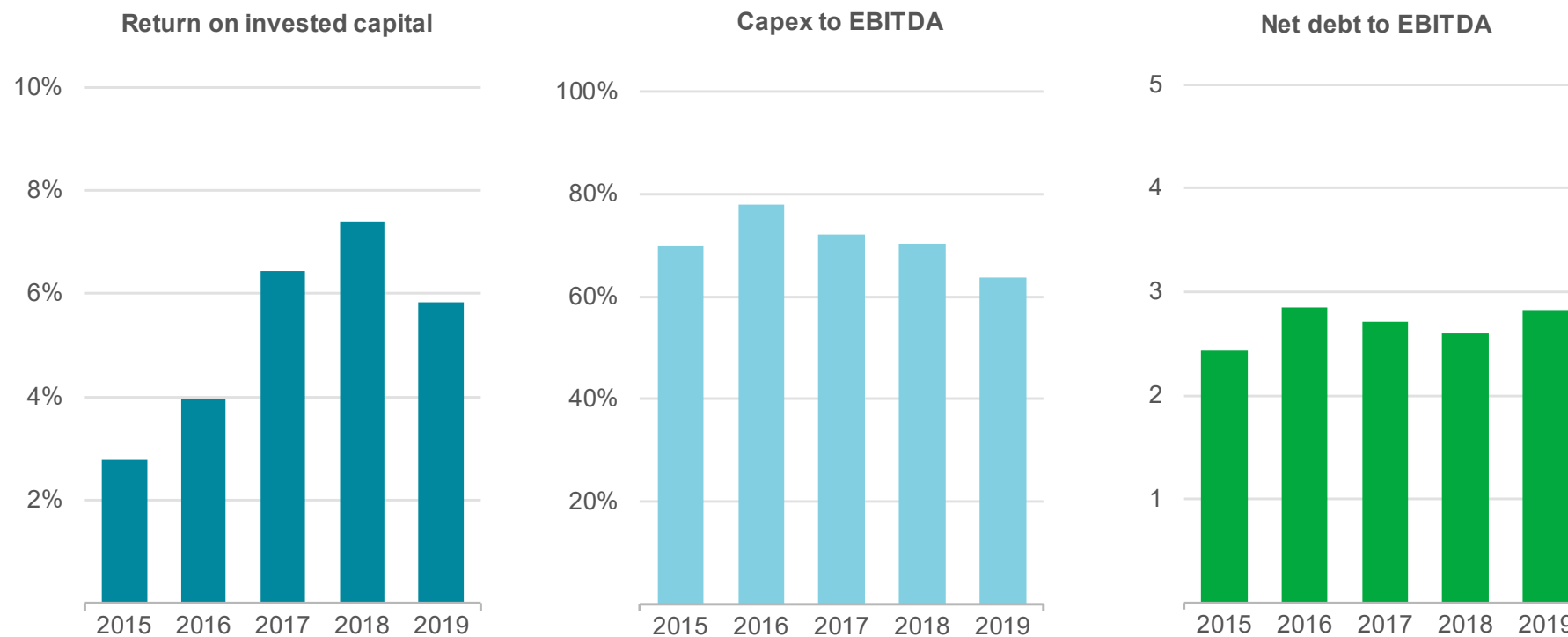
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Notes: 2020 (YTD) = year to date January–April. Includes disclosed transactions.

Source: IEA calculations based on IJGlobal (2020).

Ahead of 2020, the largest developers of renewable power had broadly improved profitability, with manageable leverage, but capital expenditures have not grown in line with earnings

Financial performance metrics for top 30 listed renewable power project developers (excluding Chinese companies)



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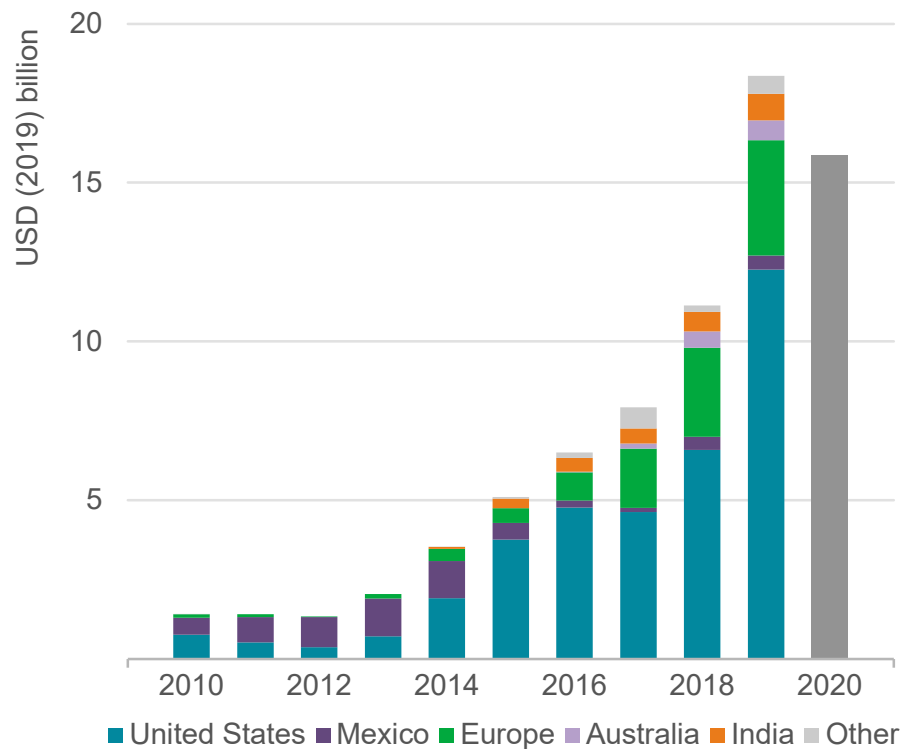
Note: Includes the top 30 listed project developers (including utilities, independent power producers and manufacturers) by capacity, excluding those in China and hydropower.

Source: IEA calculations based on Thomson Reuters Eikon (2020).

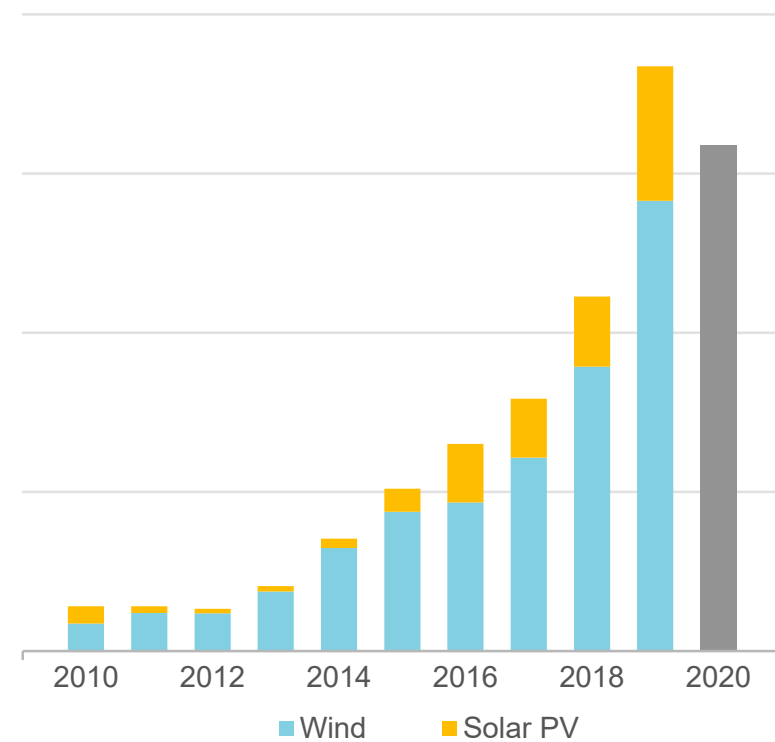
Over 10% of utility-scale solar PV and wind investment is now based on corporate PPAs, but associated capital spending is likely to decline for the first time in 2020

Renewables investment based on corporate power purchase agreements

By geography



By technology



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Notes: PPA = power purchase agreement. 2020 spending is estimated based on observed FIDs in the first four months 2020 and assessed project pipelines.

Potentially greater near-term reliance on developer balance sheets to fund renewables projects

Most of renewables investment is carried out on the balance sheets of developers; in recent years project finance transactions (including non-recourse bank debt) have grown, especially for utility-scale solar PV and wind, following a dip in 2016. Such project finance transactions rose to over USD 50 billion in 2019, reflecting ongoing risk management efforts for renewables. In 2020, transactions fell to low levels, placing increased importance on developer balance sheets to fund new projects.

As costs have declined and policies have supported deployment, the largest developers of renewables have become more profitable with returns on invested capital rising, though with slowing momentum in 2019. Leverage levels (net debt to EBITDA ratio) have edged up but remain manageable (below 4-5), indicating adequate liquidity and credit positions. Still, capital expenditures have not grown in line with earnings, suggesting that companies may be increasing holdings of cash, relative to investing, in the face of policy and market uncertainties in some areas. Despite supportive conditions heading into 2020, with the recent downturn some developers face the prospect of lower earnings, rising debt, pressure to increase capital discipline and payment and project delays in some markets (see Power Sector section). There are also questions over pricing of external finance, such as tax equity in the United States.

Government and market responses will likely influence the financial position of the industry, as well as the reemergence of project finance markets. Renewables investment largely depends on policies and contracts that help manage price risks and there continues to be a global movement towards long-term contracts awarded via competitive auctions (IEA 2019a). But with evolving policy conditions in competitive power markets, developers and financiers are increasingly required to

have strategies, beyond subsidies, for solar PV and wind projects to manage revenue risks and merchant pricing exposure (IEA 2019d).

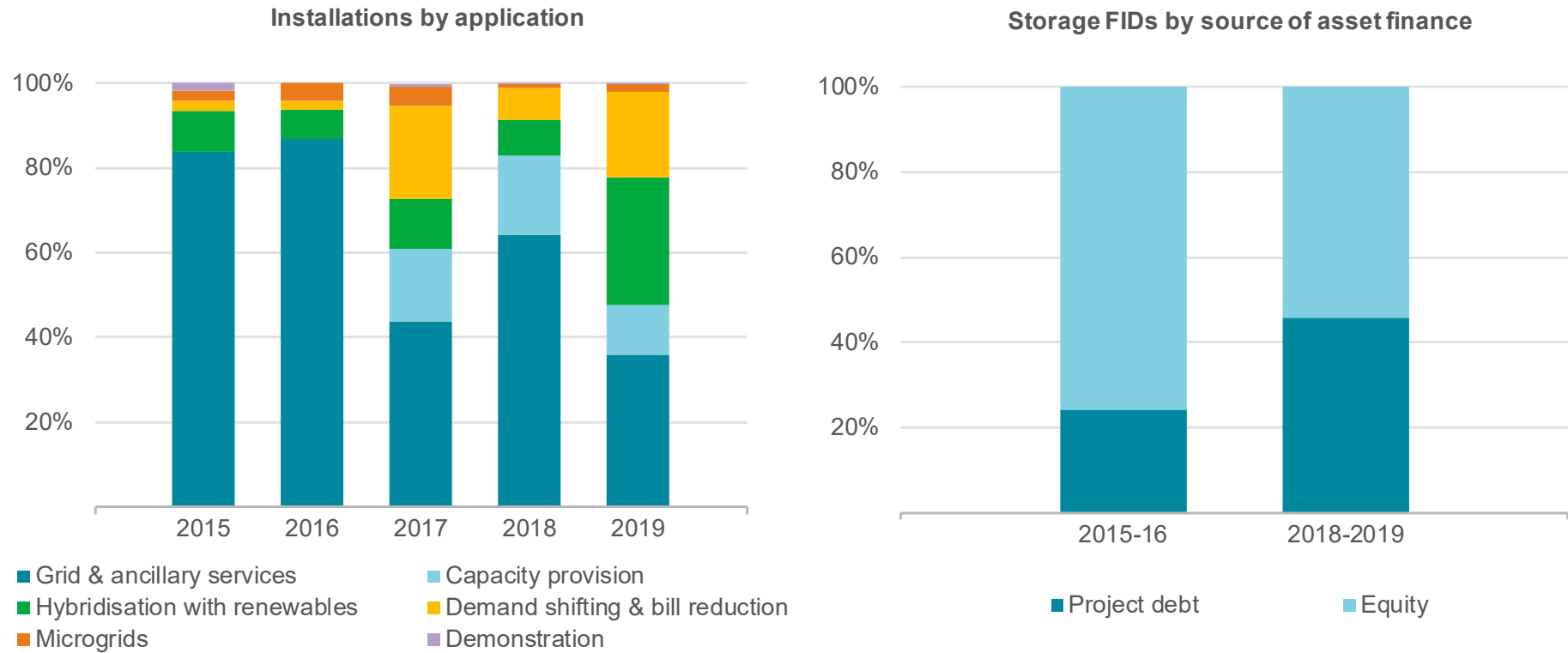
Corporate PPAs have emerged to fill this role, and with associated investments over USD 18 billion in 2019, were the largest commercial arrangement for renewables to manage market risks. Two-thirds of activity was in the United States, where corporate PPAs complement tax credits that are being reduced over time for new plants. Investment rose in Europe, where five deals linked to offshore wind were made in 2019 (Belgium, Germany and the United Kingdom), Sweden led onshore wind, and Spain has emerged as the largest solar PV market. India was the third largest geography, reaching over USD 0.8 billion. Companies signing PPAs continued to diversify from IT players (e.g. Google, Facebook, Amazon, Microsoft) to consumer (Wal-Mart, Starbucks) and resource actors (e.g. BHP Group, ExxonMobil).

Corporate PPAs may become more important as a tool to manage market risk and as non-energy corporations increase ambition to directly source renewables. Still, there are questions over how the PPAs (which are moving towards shorter tenors) evolve to satisfy more buyers, and provide adequate risk management amid changing market conditions. Further effort is needed to scale them in emerging economies, where frameworks have been less accommodating.

In 2020, spending on corporate PPA projects is likely to decline with lower power demand and prices, and credit and profitability issues among corporates. While they remain economically attractive (a recent deal in Spain was struck at less than USD 40/MWh) and provide diversity in terms of procurement options, off takers may also become less able to enter into long-term contracts under current market uncertainty.

Applications and services related to grid-scale battery storage installations have diversified...

Battery storage projects by application (left) and electricity storage FIDs and type of finance (right)



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Notes: Sources of asset finance are based on disclosed transactions for energy storage and some projects are hybridised with renewables capacity; a small amount of reported guarantees are included in project debt.

Source: IEA calculations based on Clean Horizon (2020) for applications and Clean Energy Pipeline (2020) for type of finance.

...while equity finance for storage predominates, the contribution of project debt has grown over time

Stationary battery storage investment has risen above USD 4 billion (see Power section), supported by targets and policies that pay for the value of storage, but financing new projects can be a challenge, given the diversity and complexity of business models.

Grid-scale storage depends on the ability to monetise revenues from various services to consumers and system operators, as well as from avoided grid investment. Applications have diversified over time; in 2019, installations were mostly based on expectations to provide grid and ancillary services and support renewables integration (through hybridisation allowing variable renewables plants to operate more like dispatchable power). A smaller share went to demand shifting and bill reduction, followed by capacity provision. Project revenues often come from a combination of contracts and regulated and market pricing. Private-sector actors have financed most projects. But commercial debt remains limited for projects with short contract periods or based solely on wholesale market sales.

Uncertainties over these revenues can make it difficult to secure financing in some markets, particularly project debt from banks, and there are not enough standalone battery storage projects with cash flows and scale attractive enough to take advantage of available capital. Developers tend to favour projects with short payback periods. For projects taking FID over 2015 and 2016, most finance was estimated to come from equity sources, predominantly the balance sheets of developers. The contribution of debt has recently increased for projects taking FID in 2018 and 2019, with lending on the rise particularly in Australia, the United States and some European markets. This likely reflects availability of suitable price contracts, some increased comfort of banks with the risks, and efforts of developers to improve due diligence and structure projects that satisfy cash flow and reserve requirements.

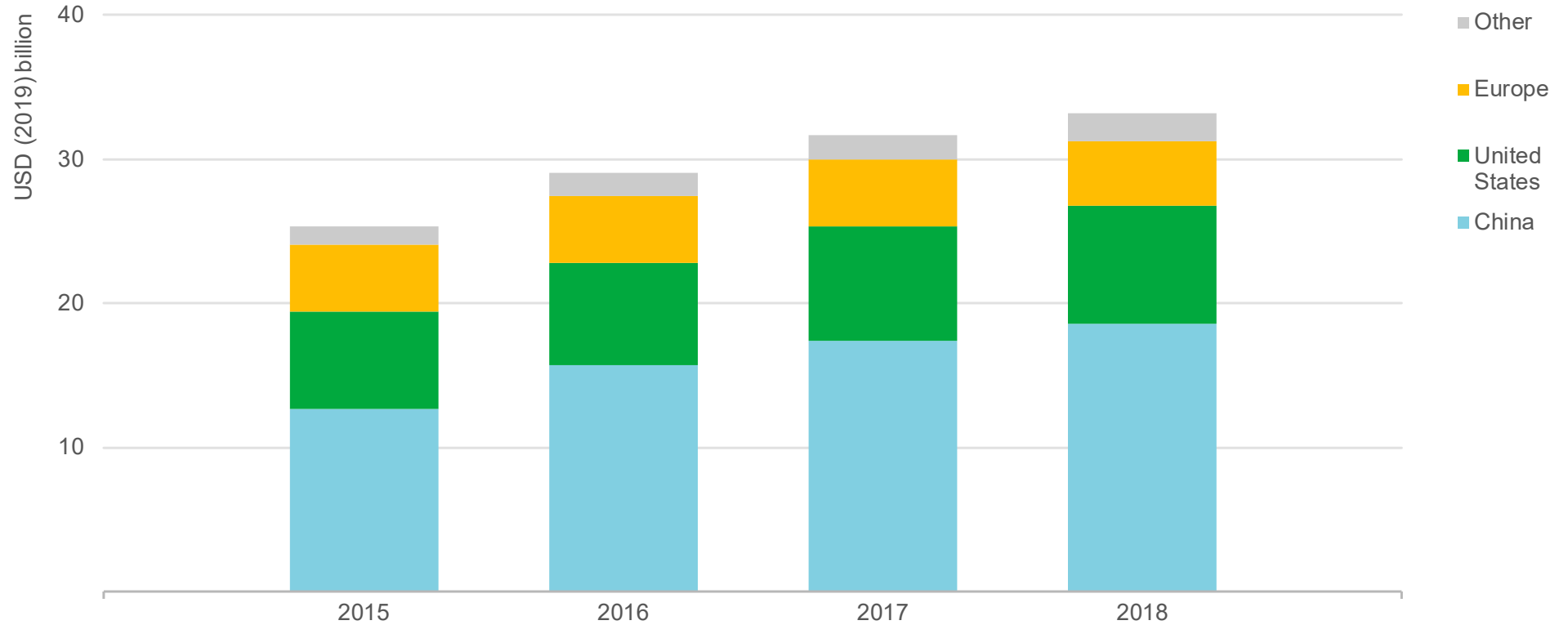
Public sources of finance have played an instrumental role in facilitating investment decisions in some markets. For example, in Australia, most projects have benefitted either from debt provided by the Clean Energy Finance Corporation and Australian Renewable Energy Agency (ARENA) or equity from Australian state governments and ARENA. The European Investment Bank (EIB), European Bank for Reconstruction and Development and the World Bank have been active in providing debt (and technical assistance) around the world. State-backed finance is also important for electricity storage outside of batteries – in 2019, two sovereign wealth funds – GIC in Singapore and the Abu Dhabi Investment Authority – provided equity for a pumped-hydro project taking final investment decision in India.

In contrast to the financing models for grid-scale storage, behind-the-meter storage is more linked to that of distributed solar PV. Most such installations are financed from the balance sheets of consumers and companies, often supplemented by loans, or through equipment leases and PPAs, where third parties (e.g. energy service companies [ESCOs], see below) install and retain ownership of the asset. Both models depend on significant upfront capital, which is recovered through electricity bill savings and other remuneration.

In general, the financing case depends on the contractual backbone for revenues, consumer credit quality and local factors (e.g. electricity pricing reflecting the time value of storage). In Germany, development bank KfW has provided concessional finance to installations integrating battery storage, and several aggregators have emerged offering solar PV and battery systems on a PPA basis. In emerging economies, credit for consumers and small companies is more constrained and electricity tariffs tend to be distorted more by subsidies, making financing distributed assets more challenging there.

The ESCO market grew by 5% in 2018, though remains geographically concentrated

Energy service company market revenues, by geography



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Note: Market size is defined in terms of energy performance contract revenue.

Source: IEA (2020g).

Revenues may suffer in 2020; supportive policies and financing are key to continued benefits

ESCOs provide efficiency and distributed services that are funded primarily by energy savings. Their contracting, financing and payment models enable consumers (mostly commercial and industrial actors) to overcome the upfront capital burdens of investing in energy assets that may not be part of core business.

The latest IEA survey shows that global ESCO revenues reached USD 33 billion in 2018, up 5% from the prior year and 31% since 2015. Much of this growth has occurred in China, the largest market by far, but as the Chinese market has slowed so has global growth.

Outside China, the other major markets of Europe and the United States have been relatively stable. In Europe, the role of ESCOs varies substantially by country, reflecting differences in how EU energy efficiency directives have been implemented. Markets that have grown significantly include Belgium, Denmark, Italy, Slovenia and Ukraine, while the German market, one of Europe's largest, has stagnated. Recent clarification of accounting rules for energy performance contracts in 2018, allowing governments to record them off their balance sheets, have yet to boost activity.

Other markets in Asia have also grown. New partnerships such as the Asia Pacific ESCO Industry Alliance seek to promote knowledge sharing and private investment. Korea's expanding market is supported by the government's Energy Use Rationalization Fund, offering loans of up to USD 18 million. Korean ESCOs have also adopted new ways to renew their capital, with businesses selling accounts receivables to third parties at a discount in exchange for upfront cash. In Southeast Asia, ESCO development can be inhibited by electricity subsidies and regulatory barriers. Thailand's ESCO Fund, providing equity and

equipment leasing, and Energy Efficiency Revolving Fund, providing low-interest loans for bank on-lending, have helped boost activity there.

Government policies and procurement remain key drivers of ESCO activity. Many ESCOs are public entities or backed by governments, meaning they could function as effective conduits of public funds to stimulate local spending and employment in ways that deliver long-term structural benefits. Around half of global ESCO revenues come from public sources, with shares as high as 85% in the United States and 70% in Europe. In the United States, contracting by municipalities particularly benefits from financing through tax-exempt bond issuance. In China, policy incentives have driven ESCO engagement much more with private actors, which account for 90% of revenues.

Globally, most customers continue to pay for ESCO services on the basis of energy performance contracts that deliver guaranteed energy savings. These contracts are complemented by new financing approaches in some markets. In some US states, property-assessed clean energy financing, which links capital recovery to tax obligations, has helped facilitate securitisation of efficiency and renewables (see below) while some ESCOs are now looking to monetise energy savings in wholesale power markets with Pay-for-Performance contracts.

The current downturn creates new economic challenges for ESCOs, especially smaller players, which may spur consolidation. Demand for interventions to raise buildings efficiency will likely fall due to restrictive measures (see Energy end use and efficiency section). Lower electricity and gas prices may sap incentives for contracting, while supply chains may also be disrupted. That said, buildings efficiency was highlighted in the European Green Deal; as such, ESCOs may also function as a vehicle for some recovery efforts.

Community aggregators: A new model for funding renewables, efficiency and DERs?

Community choice aggregators (CCAs) – municipal-level entities that procure bulk power, including from ESCOs, for consumers – have emerged in some areas as an alternative to the traditional utility retail model. They are most prominent in California, where regulators have designated them as load-serving entities responsible for meeting long-term renewables and zero-emissions goals, and where the revenue share of full-service utilities has fallen to 80%, from 95% a decade ago.

Stakeholders see CCAs as a new market to express local preferences for procuring renewables and demand services, with more say over tariffs, and as a funder of investment in distributed energy resources (DERs) such as solar PV, batteries and demand-side response, facilitating more flexible loads that can serve system integration goals.

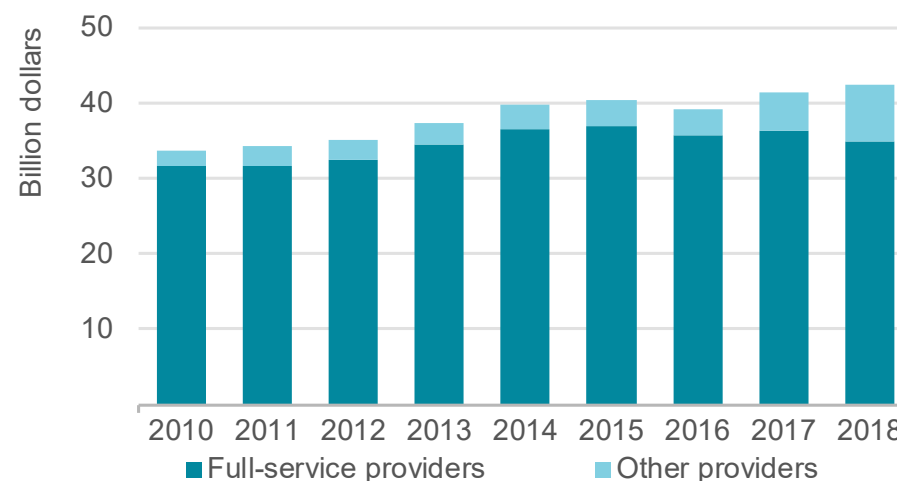
However, there are challenges to realising this vision. As they are new and smaller than utilities, CCAs often lack credit ratings and a financial track record that enable financing and negotiation of contracts to support new procurement. They also still rely on utilities to manage system operations and balancing, transmission of power, and often billing services. And with more customers flocking to CCAs, California regulators and utilities face the growing challenge of managing tariffs and charges in a way that would help fund fixed investment in the grid.

Looking ahead, some features of CCAs, such as the ability to target projects that can cater to local system needs and to form regional co-operatives, may help the integration and financing challenge. Further solutions may also come from more sophisticated contractual arrangements that value storage and demand response, as well as use excess solar PV generation for managing EV charging (Trabish, 2019). But there are also larger questions over the scalability of this model

under current investment frameworks – while retail competition is present in 17 US states, only 8 of them allow CCAs.

Outside of the United States, aggregators are growing in competitive markets in Europe, Australia and Japan. In Europe, their portfolios have diversified beyond renewables, to include behind-the-meter storage and demand response; they often provide capacity to utilities or within ancillary services markets. The rollout of smart meters and digital management systems is critical to enabling this functionality (see Power Sector section). In addition to utility-led programmes, third party investments are emerging, sometimes backed by public finance. The EIB provided a loan, with an EU guarantee, in 2020 to an aggregator to support deployment of “smart boxes” to support demand side management.

Electricity sales revenue in California by type of provider



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Role of institutional investors in energy investment

Institutional investors represent a potentially large source of finance for energy investments

With over USD 100 trillion under management, institutional investors – including asset managers, infrastructure funds, insurance companies, pension funds, private equity and sovereign wealth funds – are a large potential source of finance for the energy sector (Arezki et al., 2016).

Past editions of *WEI* have noted that 90% of energy investments are financed on a *primary* basis from the balance sheets of companies and consumers, with a smaller role for project finance (mostly loans from banks). But such mechanisms also depend on having a robust interconnected system of *secondary* financial sources and intermediaries, diverse investment vehicles to facilitate flows, and clear signals for investment, based on profit expectations and risk profiles (IEA, 2019b). Although a number of well-capitalised industry players (e.g. some integrated oil and gas, utility and state-owned companies) are able to make investments from retained earnings alone, there are economic benefits to tapping into wider pools of finance, at a lower cost of capital, and especially in an era of lower interest rates. Moreover, banks often face limits on their lending, particularly with regulatory constraints emerging in recent years, such as Basel III.

Institutional investors provide finance through three main channels:⁶

- companies – listed equities shareholding, bonds purchase
- projects – equity stakes in assets, bonds purchase
- funds or pooled investment vehicles based on energy assets.

They have long played a role in fundraising by companies, but an emerging question for policy makers is the extent to which investors

can more directly help finance growing investments ahead, especially in clean energy sectors. Addressing this question in quantitative ways remains challenging, as the relationship between capital expenditures and financial flows is not well understood (EU TEG, 2019). Moreover, understanding the impact of investors on decision-making involves more qualitative factors, including corporate stewardship and recent initiatives by some public and private actors to align financial markets with calls to manage climate-related risks and energy transition goals.

The objective here is not to provide a full accounting, but to track investor and capital market trends in three main channels:

- shareholding in the top energy companies
- acquisitions and refinancing of energy projects
- financial flows to pooled vehicles (securitisation and yieldcos) for clean energy.

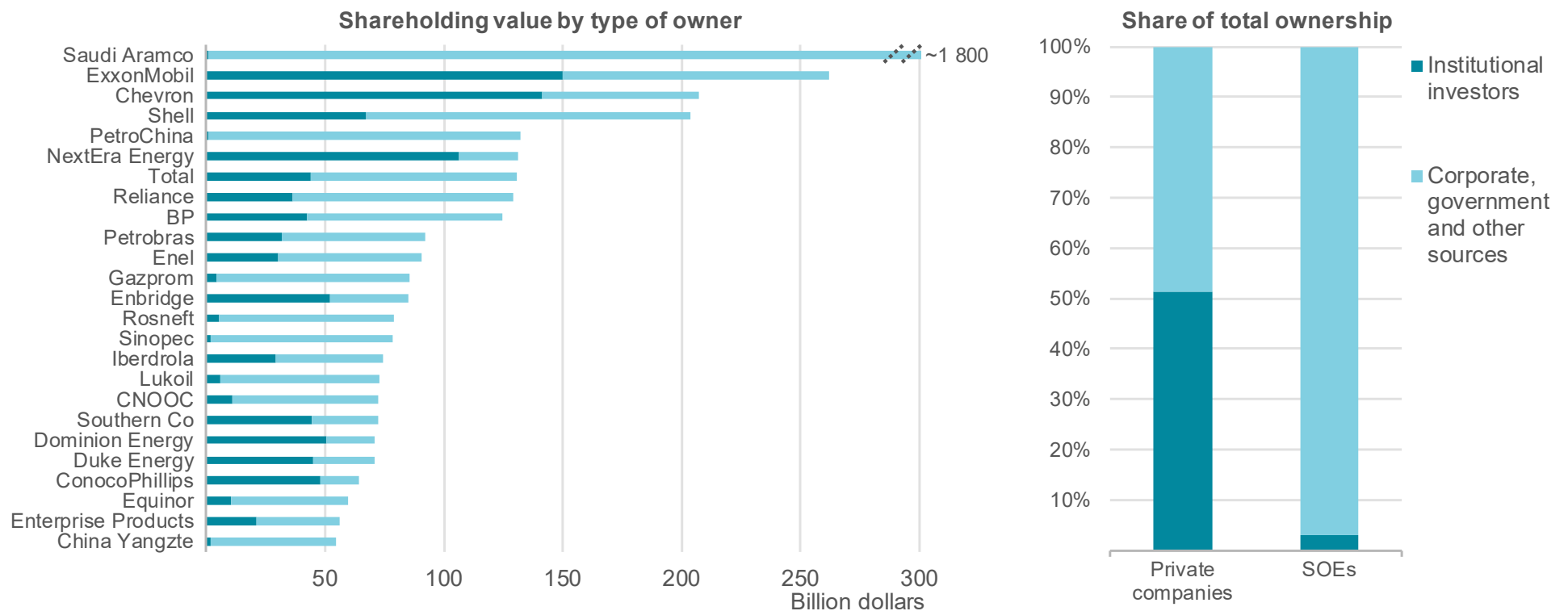
The section after assesses from a broader standpoint a related trend – the recent dramatic rise of sustainable finance, and related regulatory developments, and how this trend also relates to energy investment.

The events of 2020 illustrate how rapidly financial markets can shift. The risk management practices of investors may adjust to liquidity issues and changing risk profiles of real assets. While this analysis takes a longer view, volatility casts uncertainty over some trends.

⁶ See Nelson and Pierpont (2013) and Kaminker and Stewart (2012) for further discussion of this framework and related financing vehicles.

Institutional investors account for a quarter of ownership in top-listed energy companies, though they play a much greater role in ownership of private companies compared with SOEs

Role of institutional investors in the ownership of the top 25 listed energy companies (ranked by market capitalisation in February 2020)



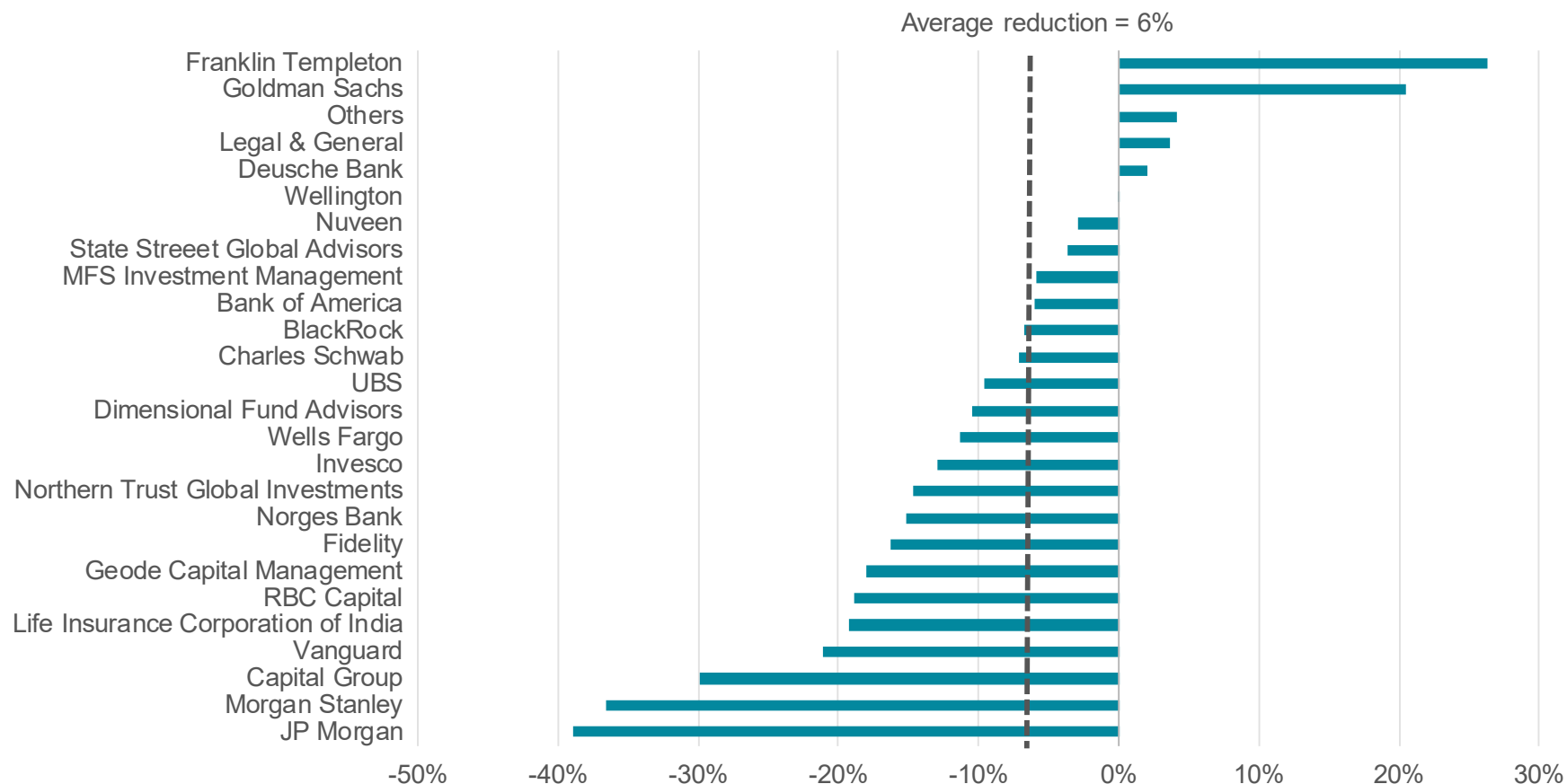
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Notes: Institutional investors include asset managers, infrastructure funds, insurance companies, pension funds, private equity and sovereign wealth funds. Reflects market values as of mid-February 2020.

Sources: IEA calculations based on Thomson Reuters Eikon (2020) and Bloomberg (2020).

Before the downturn in financial markets in early 2020, investors had reduced equity positions in the top energy companies during 2018 and 2019

Change in shareholding position by institutional investors in the top 25 listed energy companies, 1Q 2018 to 4Q 2019



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Note: Top 25 listed companies excludes Saudi Aramco, whose initial public offering took place in 4Q 2019.

Source: IEA calculations based on Thomson Reuters Eikon (2020).

The energy investment implications of shareholding depends not just on buying and selling, but the extent to which investors become more engaged owners

Institutional investment in energy most commonly comes in the form of traded securities on equity and debt capital markets. Among the top 25 listed energy companies, by capital expenditure, investors accounted for nearly USD 1 trillion, or 25%, of the market value of these firms, as of early 2020. Excluding Saudi Aramco, whose initial public offering took place in late 2019, the capital markets represented nearly 40% of ownership. Institutional shareholding of listed equities varies by type of company, and investment opportunities tend to be more prominent with firms without recourse to government funding. For the private-sector energy companies, investors account for over half of shareholding, while for SOEs the share is less than 10%.

Over 80% of institutional capital for these companies comes from asset managers and brokerages, the largest holders of which include BlackRock, Vanguard, the Capital Group and State Street Global Advisors. While difficult to quantify, the investment strategies of the largest asset managers include a sizeable component of passive funds that follow established broad indices, compared with funds based on active strategies, where asset managers more frequently buy and sell shares. Pension funds and insurance companies, which typically employ active strategies, but with long time horizons, accounted for less than 10%, followed by sovereign wealth funds.

The first quarter of 2020 was marked by extraordinary movements in financial markets, with the market value of oil and gas companies, in particular, falling precipitously on the back of economic risks from the coronavirus, and prospects of a near-term oil supply glut. Even before these events, however, there was some evidence of investors pulling back from the largest energy companies. From the start of 2018 to the

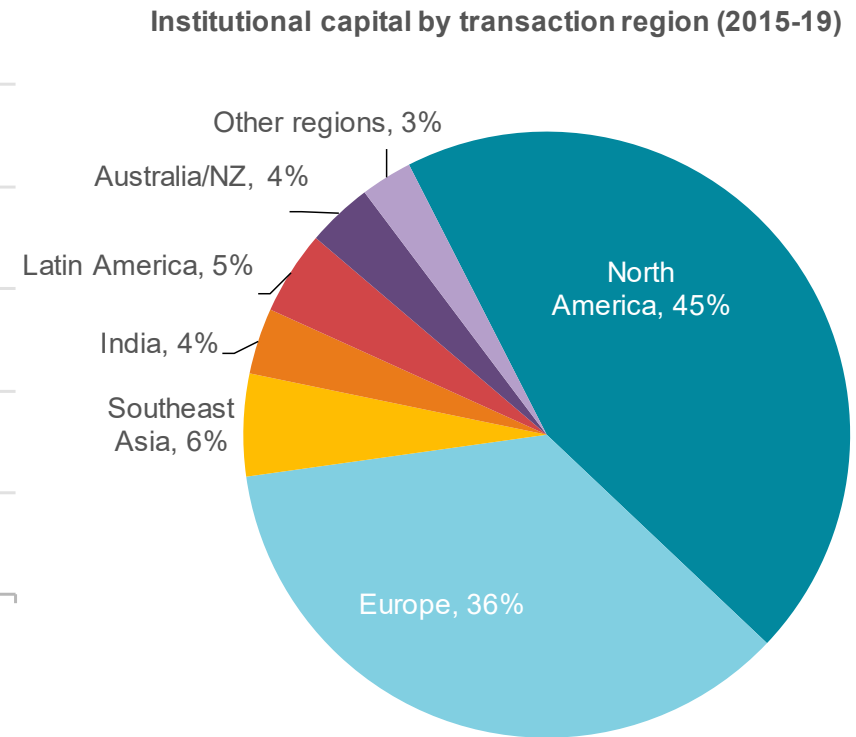
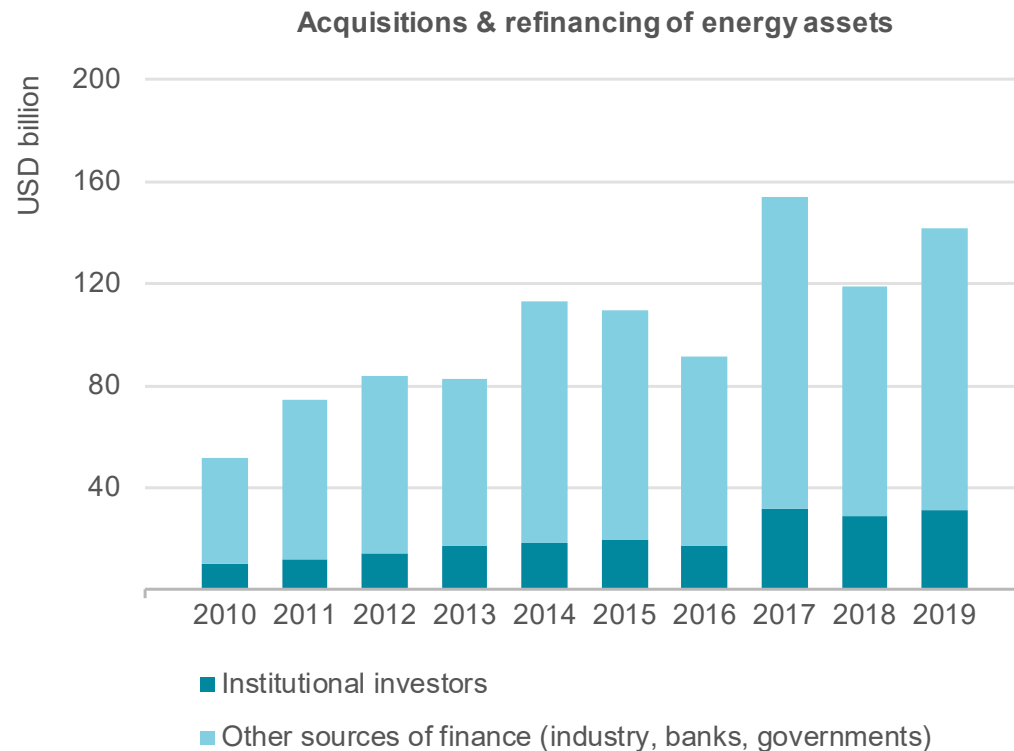
end of 2019, institutional investors pared shareholding in this group by around 6%. Share buybacks by some companies (e.g. oil and gas majors) during the past two years likely had influence on this, and there is considerable divergence in holdings among companies, partly reflecting investor uncertainty over how well some large players in the energy industry can position themselves in a changing market environment. The pullback included investors with sizeable passive holdings – as indices rebalanced, due to changing market prices and weightings, so did passive investor positions.

The energy investment implications of investor shareholding has both financial and corporate governance components. The buying and selling of shares is integral to corporate fundraising activities and the cost of capital, which can influence the selection of projects based on evolving risk and return requirements of investors, who have fiduciary duty to prudently manage the financial assets of their beneficiaries.

A larger question is the extent to which normally passive investors may become more active, seeking to wield more influence over energy companies in terms of strategy and decisions over capital expenditures and dividends. Stock ownership allows investors to vote on company issues and the selection of the board of directors at annual shareholders meetings. Already, some investors are taking stronger action to engage energy companies on sustainability issues (see below) and one indicator of change is the near-doubling of stewardship teams of major asset managers between 2017 and early 2020 (Mooney, 2020). Further monitoring is needed to assess investor commitments and industry impacts in this area, particularly amid the current economic downturn.

Institutional investors now fund nearly a quarter of a growing market for energy project acquisitions and refinancings, with activity concentrated mostly in mature economies

The role of institutional investors in energy project acquisitions and refinancing



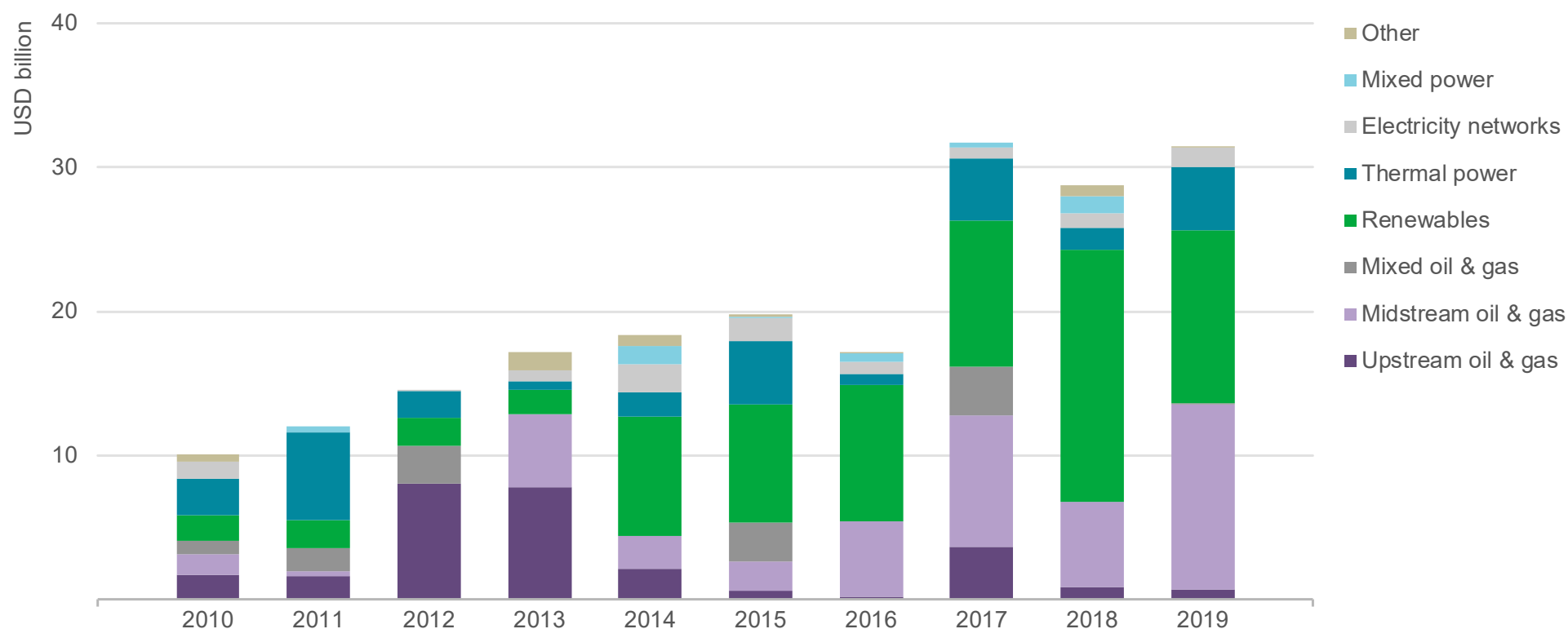
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Notes: Includes disclosed transactions. Debt includes loans and the purchase of commercial bonds. Institutional investors include asset managers, infrastructure funds, insurance companies, pension funds, private equity, other private investors and sovereign wealth funds. NZ = New Zealand.

Source: IEA calculations based on IJGlobal (2020).

Most institutional investment for energy projects has gone towards acquiring and refinancing assets with perceived reliable cash flows, particularly renewables and energy infrastructure

Institutional investor finance for energy project acquisitions and refinancing, by sector



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Notes: Includes disclosed transactions. Institutional investors include asset managers, infrastructure funds, insurance companies, pension funds, private equity, other private investors and sovereign wealth funds.

Source: IEA calculations based on IJGlobal (2020).

After record project refinancing and acquisitions the past three years, will activity slow in 2020?

At more than USD 140 billion in 2019, the market for acquisitions and refinancing of energy assets (primarily large-scale energy supply and infrastructure projects) has more than doubled over the past decade, fuelled by ongoing industry restructuring in the oil and gas and power sectors and facilitated by accommodative financial conditions. While refinancing of existing assets does not directly add new projects to the mix, it plays an important role in energy investment by creating opportunities for developers to recycle their capital, reduce financing costs and improve confidence to undertake new projects (see below).

Institutional investors have played a growing role in this market, accounting for over USD 30 billion, nearly a quarter of transactions, up from less than one-fifth in 2010, driven by an ongoing search for yield in a low interest rate environment, and growing interest in ways to directly invest in low-carbon energy projects to meet sustainability goals (see below). Finance has come through both debt and equity channels, though in the past five years, their provision of project debt and purchase of project bonds has risen, in part due to the shifting nature of transactions to power- and infrastructure-related assets.

During the past five years, over 80% of acquisitions and refinancings by institutional investors have come in geographies with relatively liquid and deep capital markets (i.e. North America and European countries), with the United States alone accounting for one-third. Financing activity has remained more limited in emerging economies, where investment risks are higher and capital markets are less developed, though transactions in India and in Brazil, where the government has promoted tax-exempt local infrastructure bonds, picked up the past three years; in China there is a lack of disclosed transactions, which makes assessing the true level of activity more challenging.

There has been a shift by investors from the refinancing of upstream oil and gas in the first half of the decade towards renewables, which offer relatively predictable cash flows from long-term contracts. The investor portion of renewables transactions was around USD 12 billion in 2019 (from a record USD 17 billion in 2018), led by offshore wind. Interest in oil and gas infrastructure (pipelines and LNG) projects has also grown, supported by master limited partnership structures in the United States offering tax pass-through benefits, and in power and heating networks with remuneration typically based on regulated rates of return.

In 2019, the largest deals with investor participation included refinancing of the 588 MW Beatrice Offshore Wind Farm (United Kingdom); acquisition of the Veja Mate Offshore Wind Farm (Germany); refinancing of the Sabine Pass LNG and Creole Trail pipeline (United States); and acquisition of Energias de Portugal's (EDP's) hydropower portfolio (Portugal). Early indications from 2020 suggest that investors with cash to deploy are becoming more disciplined and awaiting clarity on price discovery in financial markets. That said, financing existing assets with reliable cash flows, such as renewables, may remain attractive in the face of market volatility.

Looking ahead, there is considerable scope for more investor participation, particularly in renewables, where their refinancing activity is equivalent to about 5% of annual capital expenditures. Scaling up project-based institutional finance depends on policies that support cash flow profiles aligned with investor risk-return profiles and reduced barriers to participation as well as investor efforts to build in-house skills and manage scale and liquidity issues associated with direct investments. This is an area ripe for further work.

Can refinancing and acquisitions facilitate exit opportunities and economics for renewables?

While investor capital for refinancing and acquisitions does not directly support new project development, it can have a powerful indirect effect. Investors provide an exit opportunity for developers, allowing them to swiftly recover their capital and reinvest this in new projects.

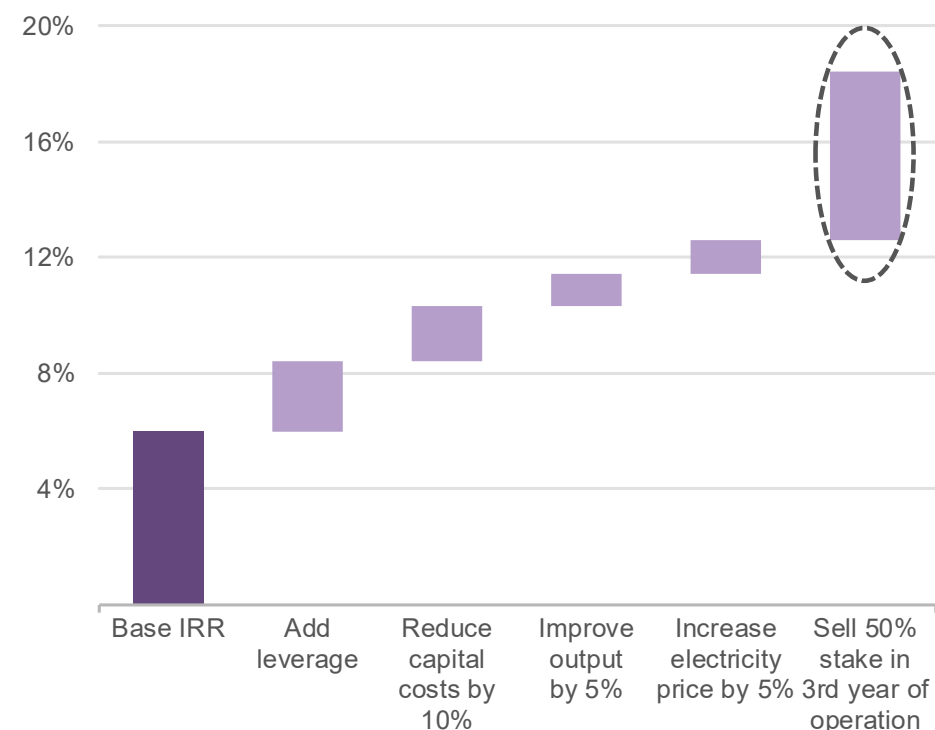
There are also economic benefits. Some renewables developers have been able to enhance their equity returns through a combination of improving project output, reducing capital costs and employing greater leverage from banks. Moreover, selling operating projects – which can match the lower risk and return requirements of investors – provides an underutilised means to enhancing returns. For an indicative onshore wind project in Europe, selling a 50% stake of the investment to an institutional investor with a return expectation of 5% can help boost equity returns for the developer from single- to double-digit rates.

These economic benefits can also support more affordable deployment of renewables. Substitution of institutional capital for a part of the original equity reduces the lifetime cost of capital for projects and can enable developers to bid for power purchase contracts at lower electricity prices, while maintaining the same level of expected returns. For example, analysis by the Development Bank of Japan suggests that a 2-3 percentage point reduction in the weighted average cost of capital (from refinancing and acquisitions by institutional investors) could translate into a nearly 15% reduction (from JPY 36/kWh) of feed-in tariff levels for offshore wind in Japan (Yasuda, 2019).

Creating such opportunities requires confidence over potential exit opportunities when developers evaluate the financial case for investing in a new project. Greater participation of investors in renewables investment could be a factor in reinforcing these expectations. That said, this model can also entail risks for developers in a changing

interest rate environment when return expectations shift for investors between the period of project development and sale.

Enhancing equity returns (onshore wind example)

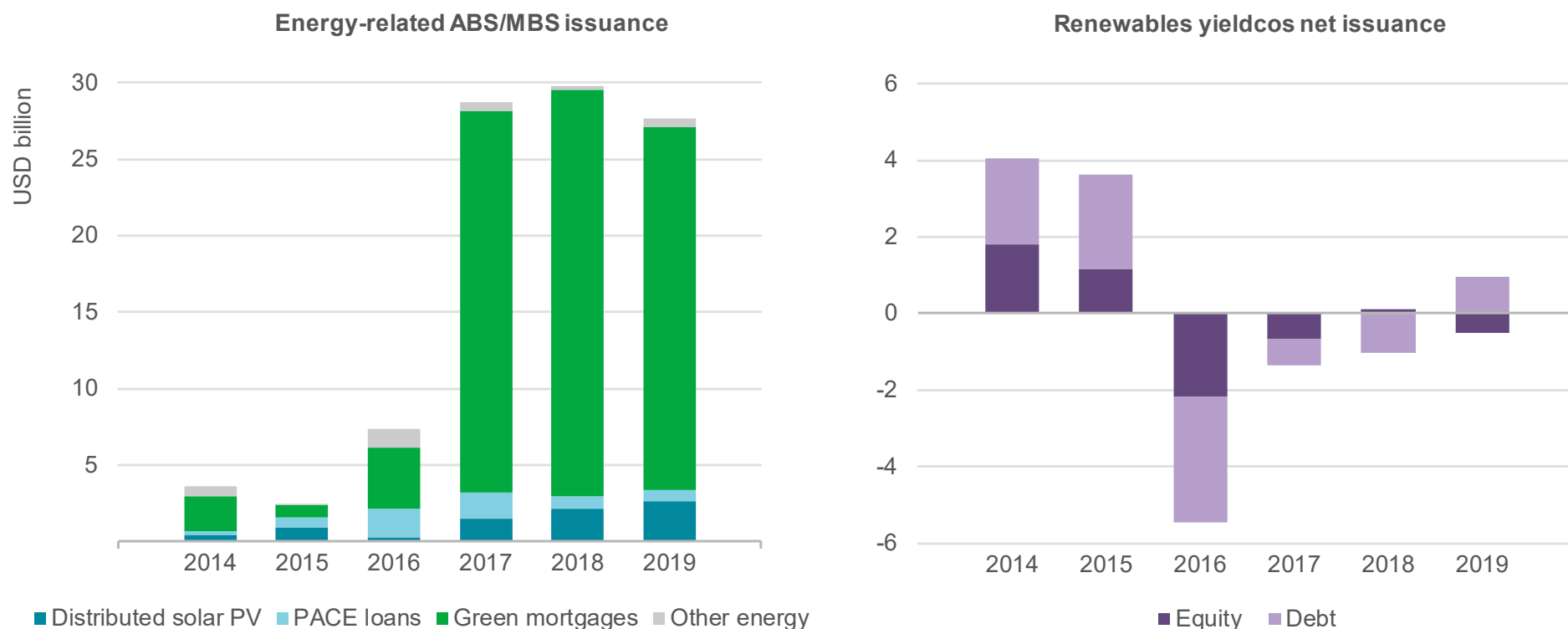


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Notes: IRR = internal rate of return; analysis is based on an indicative onshore wind farm in Europe with capital cost of USD 1 800/kW, capacity factor of 22%, added leverage of 60%, and 50% equity stake acquired by an institutional investor with return expectations of 5%.

Among pooled investment vehicles, securitisation of energy-related assets has picked up, led by green mortgages, while growth in yieldcos has been more lacklustre

Issuance of pooled investment vehicles based on clean energy assets: securitisation (left) and yield companies (right)



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Notes: ABS = asset-backed securities; MBS = mortgage-backed securities; PACE = property-assessed clean energy. "Other energy" includes issuance based on electricity networks, utility-scale renewables and thermal power.

Source: IEA calculations based on Thomson Reuters Eikon (2020).

Policies that help manage cash flow risks for efficiency and renewables help assets connect to low-cost institutional capital, though issuance remains small relative to the wider market

Institutional investors can direct capital towards a universe of project funds and pooled vehicles (i.e. those that aggregate a portfolio of assets) based on energy investments, but it can be challenging to assess their links to real assets. One mapping in Europe tallied over EUR 20 billion in green funds, but their energy composition is not entirely clear (Novethic, 2017). Some dedicated funds have emerged around clean energy (e.g. storage and efficiency funds launched in 2019 by SUSI Partners), but a number remain unlisted.

Securitisation and yieldcos aggregate portfolios of loans, receivables or projects from the balance sheets of banks and developers. These portfolios are then issued as listed securities. They are well suited to directly refinancing small-scale assets (e.g. efficiency, distributed solar PV), whose transaction sizes would not attract investor capital, and can also work for larger projects. By pooling assets, these vehicles diversify and spread risks across investors, enabling a lower cost of capital.

Securitisation of energy into listed debt securities has accelerated in recent years, though dipped in 2019 to under USD 28 billion. Over the past three years, three-quarters has come from issuance of green MBS (loans to properties making demonstrated efficiency or renewables investments) by Fannie Mae (US agency which purchases loans from other lenders), though increased competition in the mortgage market has slowed its activity. ABS based on leases and loans for distributed solar PV and efficiency/renewables investments made under PACE payment mechanisms (i.e. tax liens) were over USD 3 billion in 2019. Most securitisation is in the United States, but energy assets account for only 1% of the USD 2.5 trillion of ABS/MBS issued there in 2019.

Securitisations of clean energy depend on underlying cash flows of many small assets; policies often help to manage credit risks and enhance technical and legal standardisation. Fannie Mae provides guarantees for its mortgages, and US-based solar PV securities are largely based on revenues under net metering schemes. PACE programmes (available in 20 US states) provide a standard framework and link loan repayments to tax obligations, encouraging lenders to provide loans on better terms; there is now a movement to develop PACE in Europe. Some state-backed Green Banks are now facilitating securitisation in their local markets (Green Bank Network, 2019).

There is some evidence such assets can have credit risk advantages (see below). The ability to refinance through securitisation can also encourage banks to develop clean energy financing products – e.g. Barclays in 2018 launched a green mortgage product which offers a 10 basis point discount to traditional loans. So far, securitisation has been used on just a few large-scale projects (e.g. gas power, networks), but Singapore recently launched a USD 2 billion platform to encourage infrastructure refinancing via this mechanism.

Yieldcos – listed equity vehicles holding multiple operational renewable energy projects (which can also be suitable for efficiency), typically benefiting from power purchase contracts – saw a boost in fundraising over 2014-15. But experiences have considerably varied by market, with differences in how assets are aggregated and capital is structured impacting financial performance (Donovan and Li, 2018). These structures also may not offer suitable diversification, with the parent operator common to all assets. This has called into question some of their cost of capital benefits, so far, relative to traditional utility finance.

Lower credit risk from asset-backed securities based on clean energy and efficiency?

An important question for investors and policy makers looking at securitisation pertains to whether clean energy assets can manage cash flow risks better than other options, enabling lower cost of capital.

Some evidence comes from the ratings of ABS based on PACE financing. Residential properties with a PACE assessment had lower tax delinquency rates than benchmarks, and loan prepayment rates had come in higher than original assumptions, which were credit-positive factors for a new asset class (Nocera et al., 2018). Part of this performance may stem from the type of homeowner who invests in efficiency and renewables upgrades, but it likely also reflects the payment security provided by the PACE mechanism itself.

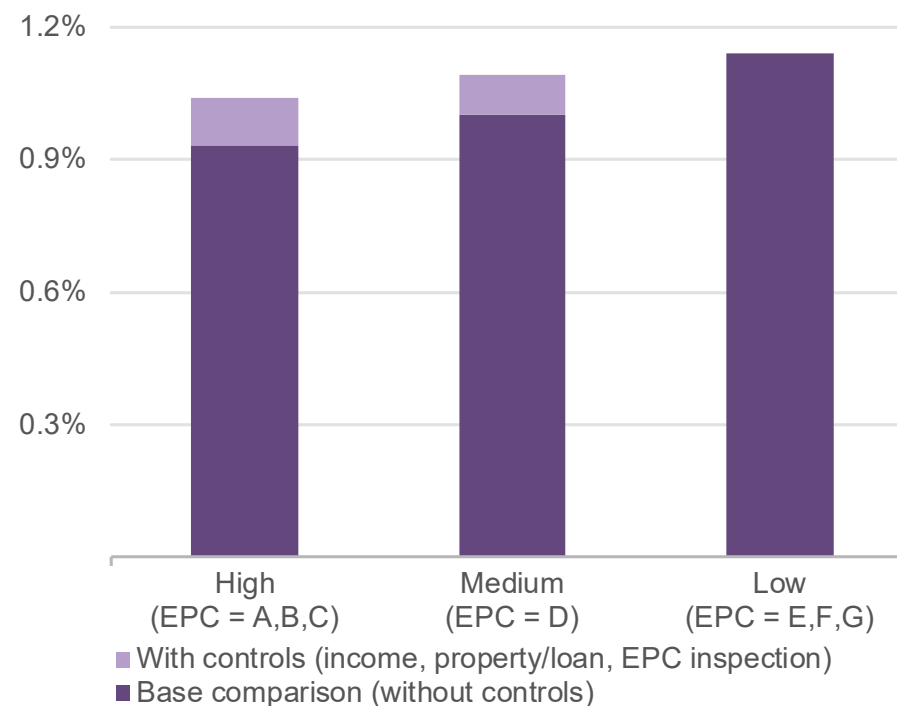
It is further possible that energy savings from efficiency projects can enhance property values and translate into lower credit risk for mortgages. A recent Bank of England study of UK residential mortgages found that those properties with high degrees of energy efficiency (as classified by energy performance certificates [EPC]) had somewhat lower default rates than low-energy-efficient properties, even when controlling for household income levels and other factors.

These pieces of evidence suggest there may be financial performance benefits for clean energy and efficiency, also reinforced by socio-economic factors and policies. This has implications for financial regulator discussions in Europe on the capital treatment of assets based on environmental attributes, which can further impact energy project economics. In 2020 the Central Bank of Hungary instituted a preferential capital requirement programme for banks if they apply an interest rate reduction of 0.3% on mortgages to improve the energy efficiency of the underlying property or refurbishment loans (mortgage rates were 4-5% in 2019). The EU Energy Efficient Mortgages Initiative is

developing a pilot scheme that has demonstrated lower default risks from mortgages based on energy-efficient homes in the Netherlands.

Still, it is not clear that green debt always outperforms conventional bonds (see below) and regulators lack an empirical track record. Further analysis is needed, including data collection at asset level and translation of performance metrics into credit model parameters.

UK mortgage default rates based on energy efficiency level



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Source: Adapted from Guin and Korhonen (2020).

Can securitisation also help to ease financial burdens from unprofitable assets?

As the roles of renewables and efficiency rise in the energy system, some regulators are looking at financing strategies for managing turnover of the existing capital stock, particularly regulated coal and gas assets with changing utilisation that makes them less economic.⁷ In addition to traditional utility finance tools – e.g. accelerated depreciation and adjustments to equity returns – the practice of securitisation features as a way to refinance obligations and take advantage of the lower cost of capital for debt compared with the equity that makes up part of the utility cost of finance.

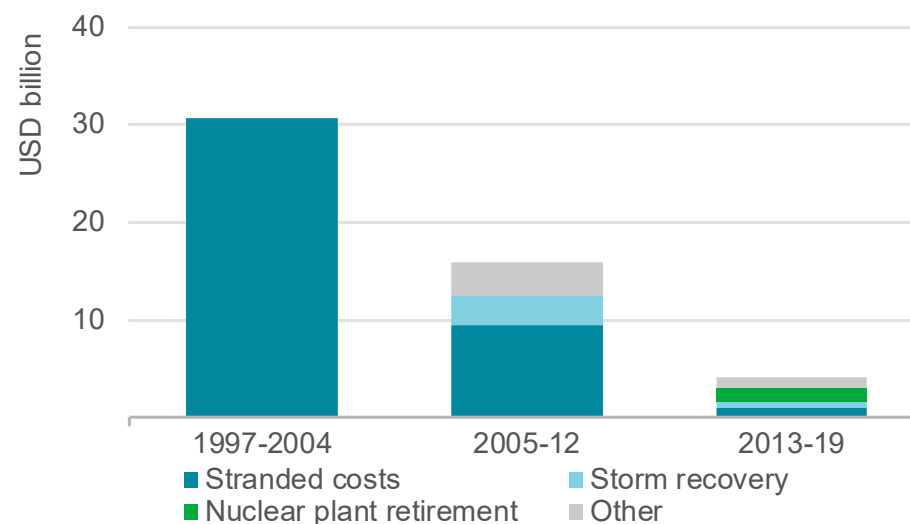
Since the mid-1990s, US utilities have securitised over USD 50 billion of assets, mostly before 2005 in the wake of state-level deregulations, with 80% of the use of proceeds going to diverse stranded costs and storm damages. In 2016, securitisation funded retirement of a nuclear plant, though little activity has followed.

To obtain a high credit rating, such securities need to be backed by regulatory guarantees. While this places a burden on ratepayers, it can be more affordable than other financial options for early retirement. Refinancing with debt can also mean a haircut for equity investors and may be less attractive for the utility (e.g. versus depreciation). In this light, some utilities are looking at securitising and then reinvesting the proceeds from unprofitable coal power generation into renewable power (“steel-for-fuel”), to create a new equity return and support transition goals (Lehr and O’Boyle, 2018).

Overall, the question of “who pays” for assets with changing utilisation profiles is not easy and securitisation may require special regulatory conditions put in place to make it possible. As electrification increases

in the global energy system and decisions for gas networks consider their potential to deliver different types of gas in a low-emissions future, securitisation may be also looked upon in some markets – among other options – for helping to manage energy infrastructure.

Securitised bonds issued by US utilities by use of proceeds



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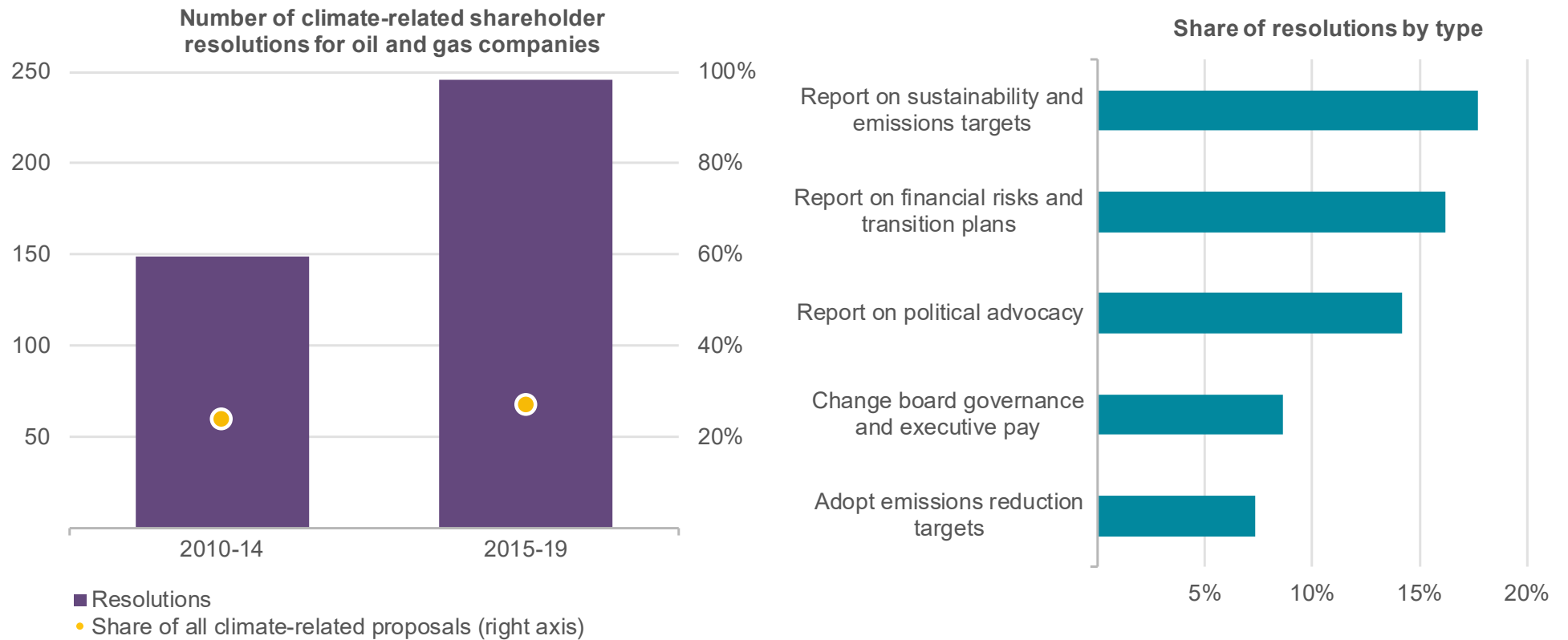
Source: IEA calculations based on Saber Partners (2019).

⁷ See IEA (2019b) for technology option analysis for coal power, gas grids.

Sustainable finance and energy investment

There is growing interest by capital markets in sustainability, marked by three broad trends: first, investor pressure is focusing corporate attention on climate-related risks

Investor engagement with oil and gas companies on climate-related issues

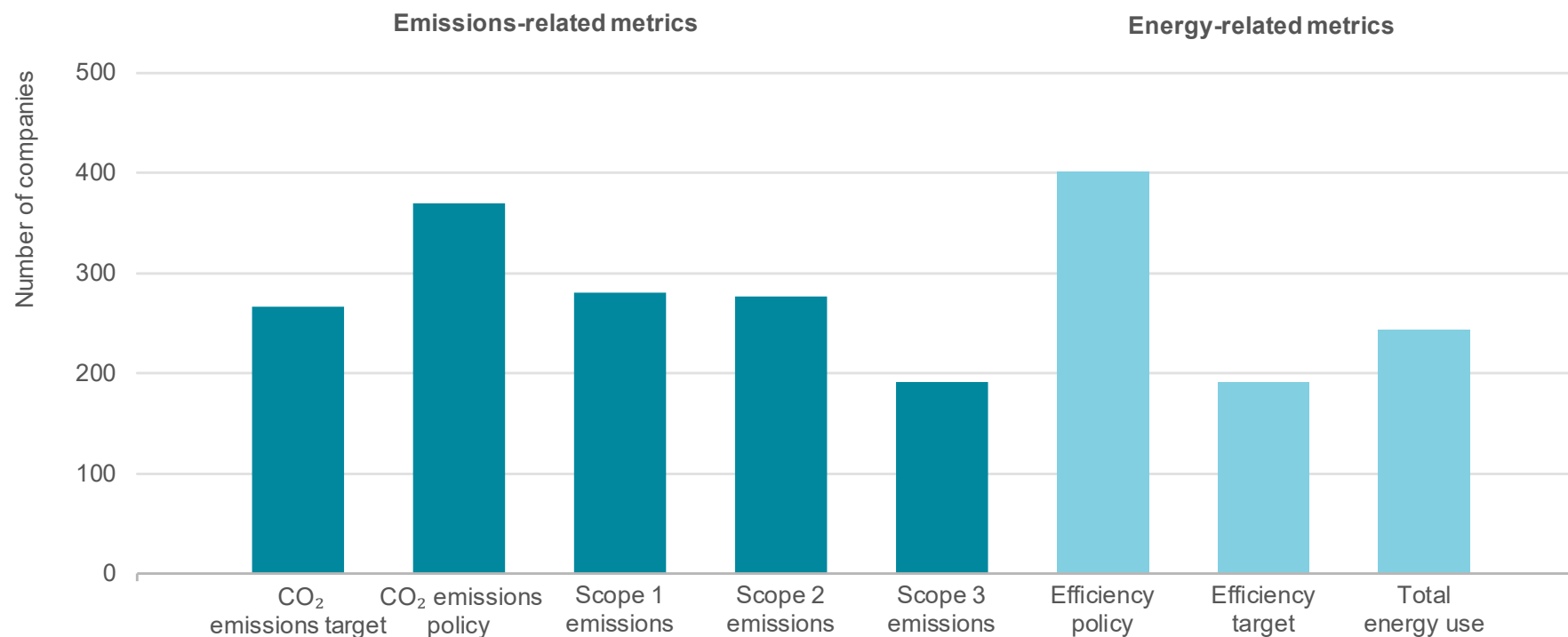


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Source: IEA calculations based on Ceres (2019).

Second, there is a growing need to identify and evaluate financial risks posed by the energy transition, though the quality and comparability of disclosed data remain incomplete

Number of companies in the S&P 500 reporting energy- and emissions-related metrics



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Notes: S&P 500 is a stock market index of 500 large companies listed in the United States. Scope 1 greenhouse gas emissions come directly from company operations; scope 2 emissions arise from the generation of energy that is purchased by companies; scope 3 emissions occur during the use of a company's products and are more challenging to estimate.

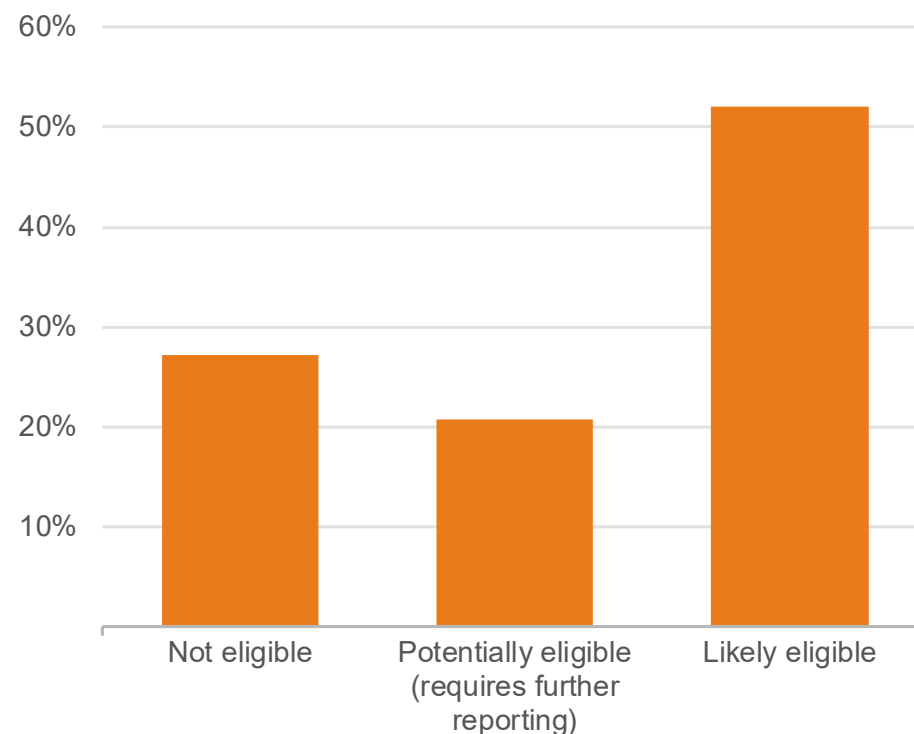
Source: IEA calculations based on Thomson Reuters Eikon (2020).

Third, there are new efforts to better classify sustainable investments and avoid greenwashing, but market approaches differ and applying taxonomies may require new data and interpretation

Select sustainable finance taxonomy and certification initiatives

| Initiative | Reporting compliance | Effective |
|---|----------------------|-------------------|
| Canada Green Taxonomy | Voluntary | Under development |
| China Green Industry Guidance Catalogue | Voluntary | 2020 |
| EU Taxonomy of Sustainable Economic Activities | Mandatory | 2021 |
| Malaysia Green Taxonomy | Voluntary | Under development |
| MDB Common Principles for Climate Mitigation Finance Tracking | Mandatory | 2012 |
| ISO Technical Committee 322 on Sustainable Finance | Voluntary | Under development |

Indicative eligibility of capital expenditures under the proposed EU Sustainable Finance Taxonomy for the top 5 European utilities



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Note: MDB = multilateral development banks; ISO = International Organization for Standardization; the chart on the right depicts the top 5 European utilities by 2019 capital expenditures, with capital expenditure eligibility estimated based on review of corporate financial reporting.

Broad push for sustainable finance, but will recent financial market volatility affect momentum?

In recent years, there has been a broad push by investors and policy makers across three areas to align decision-making in the financial sector with improving sustainability in the real economy. This creates opportunities and challenges for the allocation of capital in the energy sector, as well as the engagement of investors with energy companies.

First, investor pressure is focusing corporate attention on climate-related risks through engagement and divestment movements. Over the past decade, climate-related shareholder resolutions, which commonly seek to improve disclosure or align the strategies of companies with a more sustainable pathway, have strongly increased, especially for oil and gas companies. Meanwhile, burgeoning investor collaborations, such as the Climate Action 100+, increasingly seek to facilitate corporate engagement on sustainability. Earlier this year, the world's largest asset manager, BlackRock, announced new disclosure requirements, climate-related engagement and criteria for its investments. More banks, pension funds, insurance companies and investors are limiting exposure to certain types of fossil fuel projects; the primary focus has been on coal, but restrictions are increasingly seen on some oil and gas projects.

Second, there is a growing need for financial institutions to identify and evaluate the financial risks associated with energy transition. Doing so requires better corporate disclosure on energy and environmental performance, as well as assessment tools. Some jurisdictions (e.g. France) have already mandated investors to report the sustainability of their portfolios, while recommendations of the Task Force on Climate-Related Financial Disclosures and those by central banks (e.g. from the Network on Greening the Financial System) have encouraged voluntary reporting and risk analysis. But metrics are incomplete – for example, less than 60% of S&P 500 firms report any

emissions data. Sustainability disclosure and accounting standards remain fragmented, with several frameworks in existence (Gibbs, Portilla and Rismanchi, 2020). There is also lack of agreed benchmarks (e.g. scenarios) to assess reporting consistency with climate objectives over different time horizons.

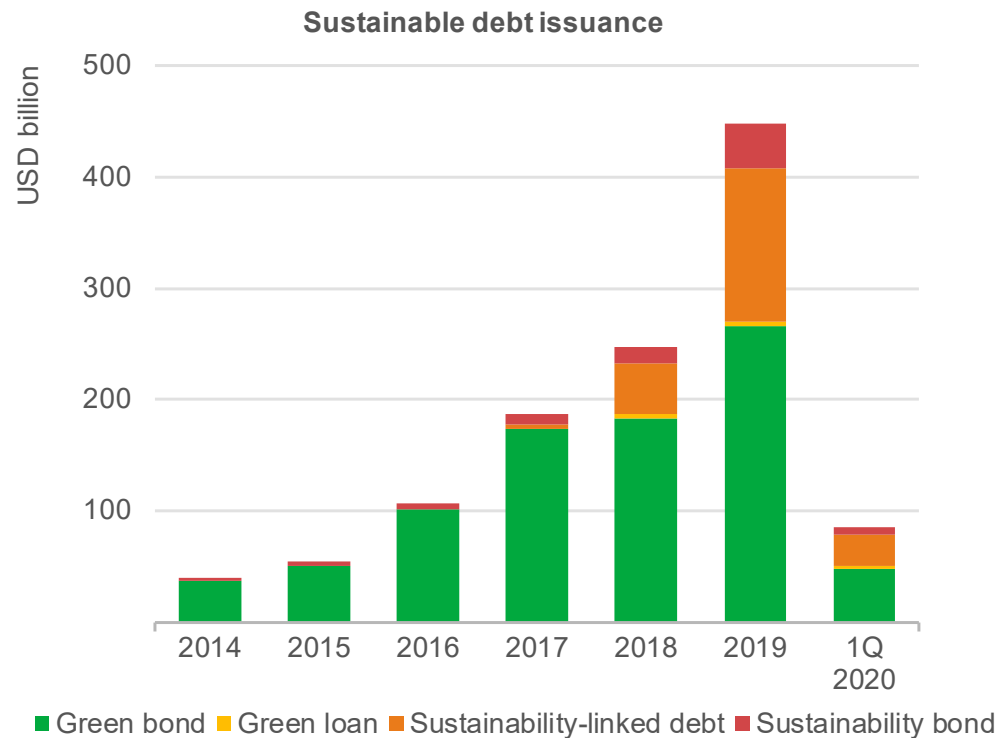
A number of initiatives to classify sustainable investments have emerged, as a way of clarifying financial decision-making. The most comprehensive framework has come from Europe, where the proposed EU Taxonomy is set to require investors to report from 2021 portfolio alignment based on sustainability criteria for 70 different economic activities. Applying the taxonomy will require better financial data and analyst interpretation – an indicative look at Europe's top utilities suggests that current company reporting does not yet provide the granularity needed to always map criteria onto key financial metrics such as capital expenditures and sales. A new EU Climate Benchmark regulation seeks to provide transparent measures for investors to compare the financial performance of their own strategies.

There are also challenges in agreeing what is meant by “sustainable” in different markets around the world. Other taxonomies are emerging in Canada, China and Malaysia, which seek to base criteria on local conditions and varied pathways for energy transition.

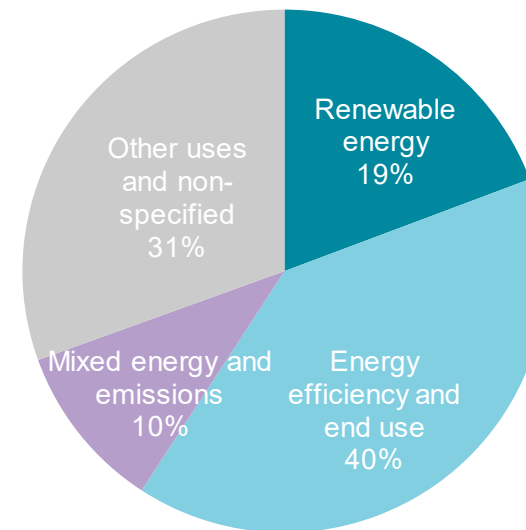
How might recent market volatility affect momentum? The financial crisis of a decade ago may have helped to refocus investor attention on sustainability (IFC, 2009). The European Union continues to push forward on consultations related to its Action Plan on Sustainable Finance. While sustainable finance flows (see below) have slowed, as investors reassess exposure across all asset classes, such instruments may also play a role in the financial and fiscal policy responses.

Higher and more diverse sustainable debt flows, with most intended uses towards clean energy

Sustainable debt issuance (left) and intended use of proceeds from bonds issued in 2018-19 (right)



Intended use of proceeds (2018-19 issuance)



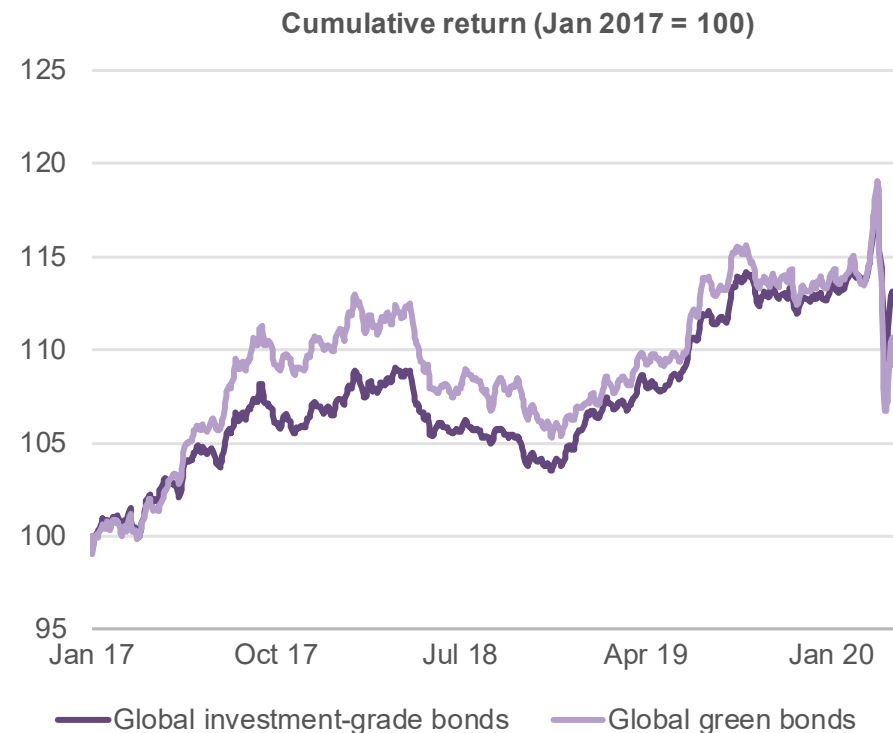
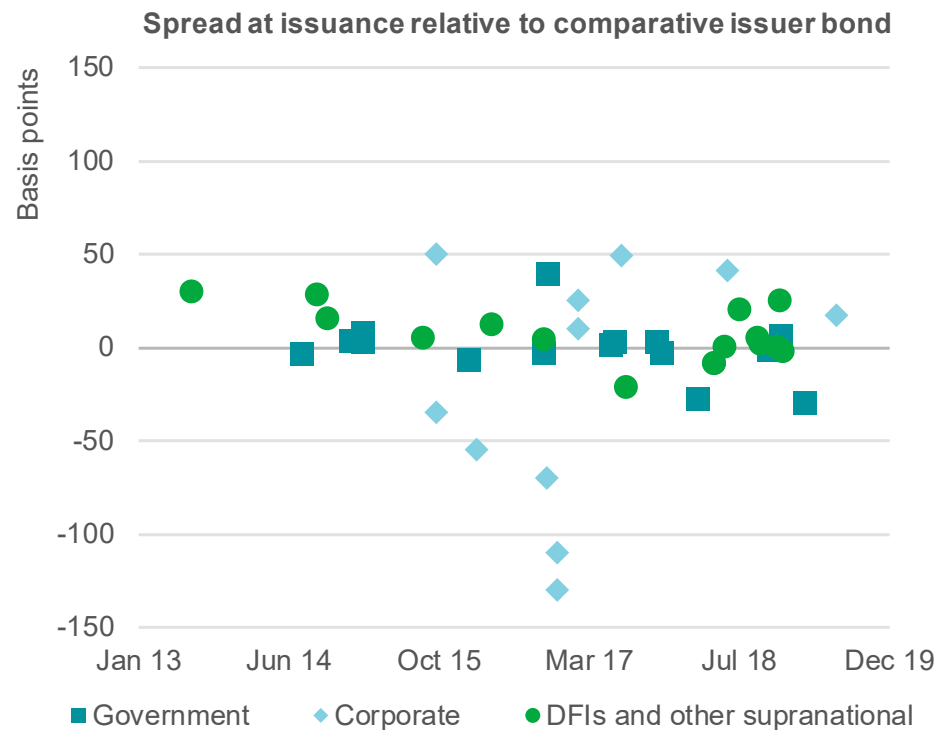
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Note: 1Q = first quarter.

Sources: IEA calculations based on BNEF (2020); Thomson Reuters Eikon (2020); Environmental Finance (2020).

Do green bonds offer additional financial benefits to energy project developers and investors?

Green bond issuer costs compared with conventional bonds (left) and annual returns (right)



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Note: DFI = development finance institution.

Sources: Calculations based on IMF (2019) for spreads and IIF (2020) for returns.

Sustainable finance flows have grown rapidly, but at a rate far outpacing clean energy capex

Among listed investments, sustainable debt securities – including labelled green bonds, green and sustainable loans, and sustainability-linked debt – may provide investors the clearest route to capital allocation for clean energy and other green activities.⁸ They may also be particularly suited for small-scale renewables and efficiency investments, which are difficult for investors to fund directly. These advantages stem from labelling and certification (under frameworks such as Green Bond Principles, and more specific evaluations, e.g. Climate Bonds Standard). Still, frameworks are not always harmonised across markets, and as labelled securities grow beyond green bonds, their impact and uses become more complex to evaluate.

In 2019, sustainable debt issuance was nearly USD 450 billion, up from near USD 250 billion, though it remains a fraction of overall debt issuance at just over 5%. So far in 2020, issuance has proceeded at a slower pace, on an annualised basis, reflecting wider market volatility. Green bonds, whose labelling corresponds to projects and activities defined in the bond, represented 60% of 2019 issuance, led by government actors (US agency Fannie Mae, German development bank KfW, and Dutch and French governments). Financial institutions, which mostly use proceeds for on-lending, were the largest issuers, but corporations (especially power) grew fastest. Sustainability-linked debt, based on performance rather than activities, rose to 30% of issuance.

With over 80% of issuance from the United States, Europe, China and mature markets, there is scope for green bonds to play a greater role in financing companies and projects in emerging economies, where there are higher credit constraints and investments rely more on balance

sheets. So far, the Philippines and India have led activity, with green bonds issued by large conglomerates, mostly to finance renewables.

Since 2014, overall sustainable debt issuance has grown over tenfold. This pace has far exceeded that for new capital expenditures in renewables and efficiency, which have remained relatively stable over the period (see Power sector and Energy end use and efficiency sections). These securities have so far had more of an impact on improving funding for existing programmes, refinancing assets and facilitating sustainability dialogue between investors and companies. Some mismatch may stem from availability of opportunities that meet liquidity and asset allocation requirements for investors, but it may also represent the different speeds at which sustainability efforts are proceeding in the financial markets compared with policies and decision-making for new capital formation for real energy assets.

There is also debate over the financial benefits – i.e. do sustainable instruments lower the cost of capital or enhance returns, improving the affordability of clean energy investments? So far, credit risk profiles and issuance costs are broadly comparable to that of conventional instruments, though there are periods of outperformance. In the first quarter of 2020, returns for green bonds were in line with that for global investment-grade bonds. New types of instruments are now seeking to better tie financial performance to environmental outcomes – e.g. interest rates for a USD 2.5 billion Enel bond issued in 2019 are tied to goals for renewables capacity and emissions levels.

⁸ Sustainable debt straddles three investment channels (corporate, project, pooled vehicles), providing an information signal in established routes of financing.

Transition bonds: Funding energy transition for legacy actors, or incremental improvements?

Labelling and standards for green bonds give investors confidence that proceeds will be used for sustainable aims. Still, this can exclude actors with businesses based on fossil fuel supply or consumption as well as environmental activities that fall under so-called “shades of green”.⁹ Such areas still play an important role in achieving climate aims. For example, meeting climate change goals requires significant reductions in methane emissions for upstream oil and gas.

Transition bonds are being marketed to help issuers, such as oil and gas companies or energy-intensive industries, fund improvements in sustainability, despite the relatively high carbon footprint of these actors. The market remains small for now, but as investors and banks reassess climate-related risks, such instruments may help to fill potential financing gaps for the project developers and provide more nuanced approaches to capital allocation by the financial community. For example, oil and gas major Shell recently signed a USD 10 billion credit facility where interest payments are linked to progress in emissions reductions. In shipping, a difficult-to-decarbonise sector, Teekay Shuttle Tankers is seeking to raise funds for emissions reductions through new vessels that can use LNG and propane mixes as fuel (Fjell, 2019).

At the same time, transition bonds may not provide the transparency, benchmarking or level of improvement that some investors with strict sustainability criteria apply to capital allocation. And they may not fit within tightening criteria for green bonds, such as under the proposed EU Taxonomy. Some stakeholders have suggested that transition bonds may increase the risk of corporate greenwashing by focusing on incremental improvements rather than long-term climate solutions. In sum, given the complexity of solutions to reach sustainable development

goals and a need to scale up investment for a range of technologies, by a large range of actors, transition bonds are likely to remain a part of financing and policy discussions, though likely with increased focus on guidelines to improve standards and transparency.

Examples of energy-related transition bonds/loans

| Issuer | Amount (USD billion) | Intended use |
|---|----------------------|---|
| Castle Peak Company (2017) | 0.5 | New combined-cycle gas turbine power plant in China |
| Cadent (2020) | 0.535 | Retrofit gas distribution network to reduce methane leakages and trial hydrogen distribution |
| Crédit Agricole (2019) | 0.11 | Financing coal-to-gas switching in power and oil-to-gas switching in maritime shipping |
| European Bank for Reconstruction and Development (2019) | 0.55 | GreenTransition Portfolio: e.g. efficiency in cement, chemicals, steel manufacturing; electricity grids; buildings renovation |
| Shell (2019) | 10 | Emissions reductions |
| Snam (2019) | 0.5 | Biomethane, energy efficiency, methane emissions reduction |

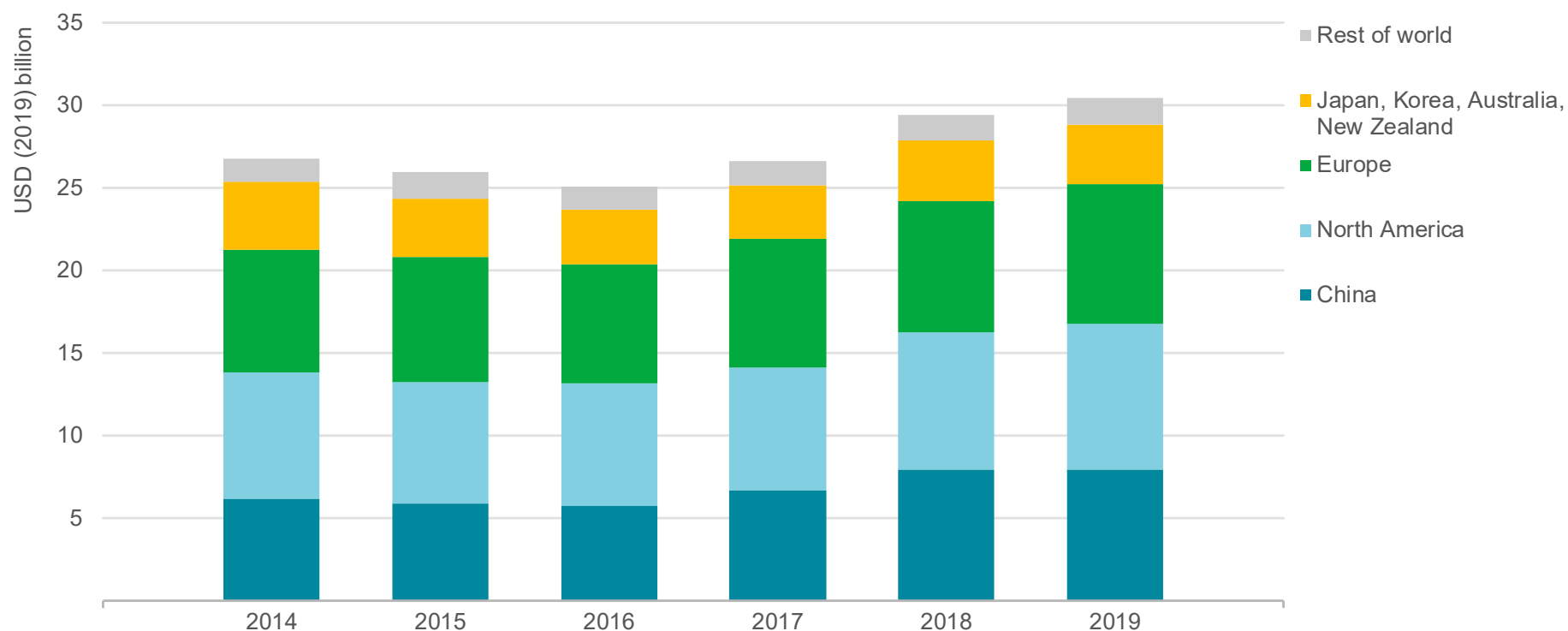
⁹ See CICERO (2015) for a bond framework based on shades of green.

R&D and technology innovation

Investment in energy R&D

Government energy R&D spending grew by 3% in 2019, with robust expansion in Europe and the United States alongside steady spending in China as the 13th Five-Year Plan nears its end

Spending on energy R&D by national governments and the EU



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Notes: R&D = research and development, and includes spending on demonstration projects (i.e. RD&D) wherever reported by governments as defined in IEA (2011). 2019 is a preliminary estimate based on data available by late April 2020. The IEA Secretariat has estimated US data from public sources. Countries not part of the IEA RD&D statistical sharing exercise in 2019 and 2020 have been estimated from public sources and exchanges with government officials.

Source: IEA (2020h).

At 80%, more public energy R&D went to low-carbon technologies in 2019 than the prior year, but the near-term outlook depends on the inclusion of clean energy R&D in recovery measures

Government energy R&D spending in 2019 grew by 3% to USD 30 billion in 2019, and was mostly directed to low-carbon energy technologies. While the growth rate in 2019 was below that of the previous two years, it remained above the annual average since 2014. It also reflects the multi-annual nature of many government R&D budgets, which follow cyclical trends within budget periods. For example, a main reason for the weaker growth in 2019 was the stabilisation of China's public energy R&D spending, yet this is closely tied to the Five-Year Plan (FYP) framework in China. Certain research programmes, especially those related to coal technologies, have passed their peak spending under the 13th FYP and are now analysing results and planning for the next funding period, from 2021 to 2025. There are indications that low-carbon technologies, including hydrogen, could receive a boost in the next period.

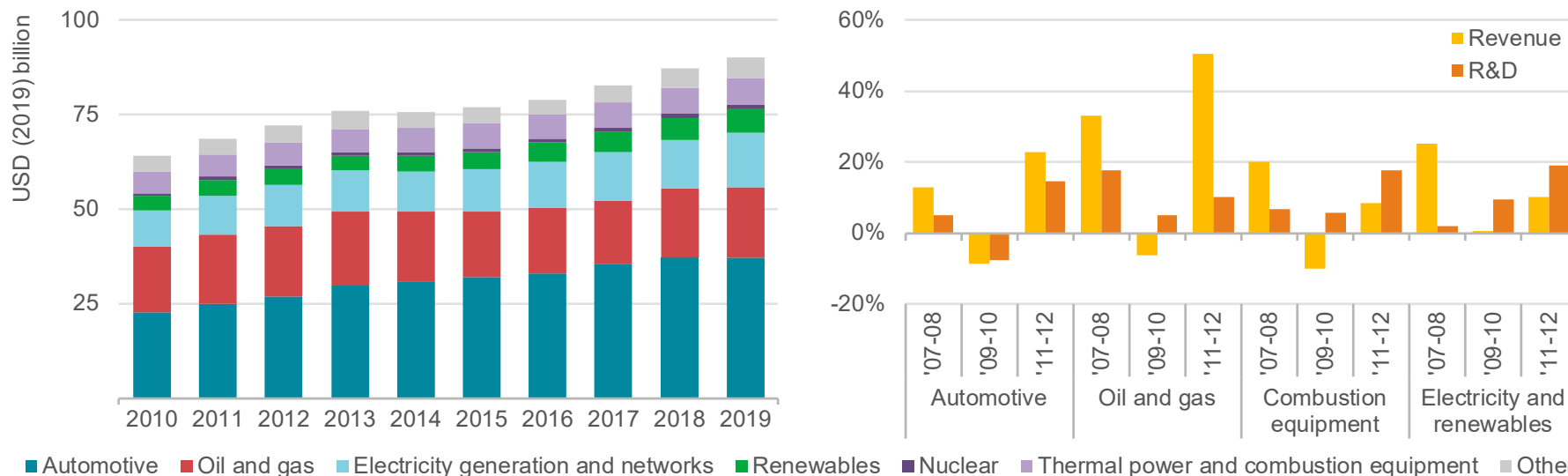
Growth was robust in Europe and the United States; spending on public energy R&D rose by 7% in both economies, above the recent annual trend. Looking ahead, increasing energy R&D has been a central feature of policy discussions in the European Union as part of the European Green Deal and the expanded R&D programme Horizon Europe. In the United States, Congress will decide the level of funding for 2021 by October and this will be influenced by considerations relating to economic health and economic stimulus. Several proposals to increase energy R&D are currently circulating in Washington, including a bipartisan American Energy Innovation Act with provisions to establish new R&D programmes. At 0.06%, Japan has one of the highest ratios of public energy R&D spending to GDP, alongside China, and spending there was constant with respect to GDP in 2019.

In 2019, around 80% of all public energy R&D spending was on low-carbon technologies – energy efficiency, CCUS, renewables, nuclear, hydrogen, energy storage and cross-cutting issues such as smart grids. With 6% growth, spending on low-carbon technologies rose faster than total public energy R&D spending, reaching USD 25 billion in 2019. In China, the low-carbon component of energy R&D grew by 10% in 2019, with big increases in R&D for energy efficiency and hydrogen in particular, driving up the global total. However, to some extent this year-on-year growth in 2019 reflects a slower start to 13th FYP spending compared with fossil fuel technologies, not an unfolding trend. Major governments are increasing energy research investments, as they pledged to do in 2015 under the Mission Innovation initiative.

While it is too early to determine the impact of the Covid-19 pandemic on public energy R&D, the risks are clear. R&D practitioners may find it difficult to execute funded projects in 2020, and public budgets will be under pressure. Experience from the 2008 financial crisis indicates that budgets are likely to be fixed in 2020, most likely seeing reductions in 2022-23. In wealthier countries, cuts may be modest or nonexistent as governments pursue countercyclical R&D policy through stimulus measures. In 2009-11, the American Recovery and Reinvestment Act raised annual energy R&D spending by 75% compared with 2006-08, before it fell back in 2012-14. If global public R&D were raised by 75% in coming years, it would add USD 18 billion of funding. In emerging markets, on the other hand, R&D budgets and value chains are less resilient and the public sector is more dominant. This poses a risk to the development of appropriate clean energy technologies for countries expected to grow their energy sectors most in coming decades.

Corporate energy R&D spending grew 3% in 2019, with little growth in the leading sectors of oil and gas and automotive, both of which could restrain R&D as revenue drops in 2020-21

Global reported corporate energy R&D spending (left) and growth rates for revenue and R&D for selected sectors, 2007-12 (right)



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Notes: “Other” comprises CCUS, electricity storage, insulation, lighting, other fossil fuels and smart energy systems. Corporate energy R&D spending includes reported R&D expenditure by companies in sectors that are dependent on energy technologies, including energy efficiency technologies where possible. Classifications are based on the Bloomberg Industry Classification System. “Automotive” includes technologies for fuel economy, alternative fuels and alternative drivetrains. To allocate R&D spending for companies active in multiple sectors, shares of revenue per sector are used in the absence of other information. All publicly reported R&D spending is included, though companies domiciled in countries that do not require disclosure of R&D spending are under-represented. Depending on the jurisdiction and company, publicly reported corporate R&D spending can include a range of capitalised and non-capitalised costs, from basic research to product development and, in some cases, resource exploration. Compared with World Energy Investment 2019, a small number of companies in countries with highly volatile inflation and exchange rates, including Venezuela’s PDVSA, have been removed from the dataset to avoid atypical annual changes at the global level. Right-hand chart shows average annual growth rates per pairs of years for the top 20 R&D spenders per sector that reported data in each year.

Source: IEA based on Bloomberg (2020).

The push for electro-mobility and cleaner cars has boosted overall corporate energy R&D since 2010, while renewables grew the fastest, at 74%, and oil and gas grew the least, at 9%

Companies active in energy technology sectors over the last decade have increased their total annual energy R&D spending by around 40% since 2010, based on our analysis of the latest available data from annual reports. The total energy R&D spending of this sample reached around USD 90 billion in 2019, 3% higher than in 2018. The multi-year trend traces two periods averaging growth of over 5% (2010-13 and 2015-18), preceded by the global financial crisis and divided by the economic impact of the oil price collapse of 2014, which caused a 10% drop in the R&D spending of oil and gas companies over two years. In each case, the periods of higher growth could therefore have been responses to disruptions. While it is hard to draw conclusions from a single year, the apparent slowdown in 2019 could have reflected a return to the longer-term trend. That issue will not be answered in 2020, however, as the impacts of the Covid-19 pandemic will almost certainly lead to a reduction in corporate energy R&D in 2020-21.

Across the period, companies active in renewable energy technologies represent a particularly bright and resilient story. These companies spent 74% more on R&D between 2010 and 2019, adding over USD 2.5 billion to efforts to improve their technologies, complementing over USD 4 billion spent on renewables R&D by governments.

Automakers – who typically have much higher R&D budgets than energy companies in absolute terms and as a share of revenue – continue to increase their spending as government policies and competitive pressures drive increased focus on energy efficiency and electric vehicles. However, the data suggest they may be facing a balancing act between a weaker outlook for car sales revenue and the need to invest in new vehicles and manufacturing supply chains.

Despite securing a higher share of sales from more profitable cars such as SUVs, the lower margins on EVs – an area of expected strong future growth – means that investments in new production lines are expected to stretch balance sheets. Energy-related automotive R&D is estimated to have stabilised between 2018 and 2019 after several years of growth, and this sector is a key factor in the overall stagnation. This reflects wider cuts to R&D in the automotive supply chain in 2019 that offset growth from the major carmakers. VW Group, for example, increased overall R&D to USD 16 billion, or 7% of revenue. Anticipated cuts to R&D spending in 2020-21 could be a setback to fuel economy improvements that are needed to accompany the shift to larger vehicles (see Energy End Use and Efficiency section) and electrification.

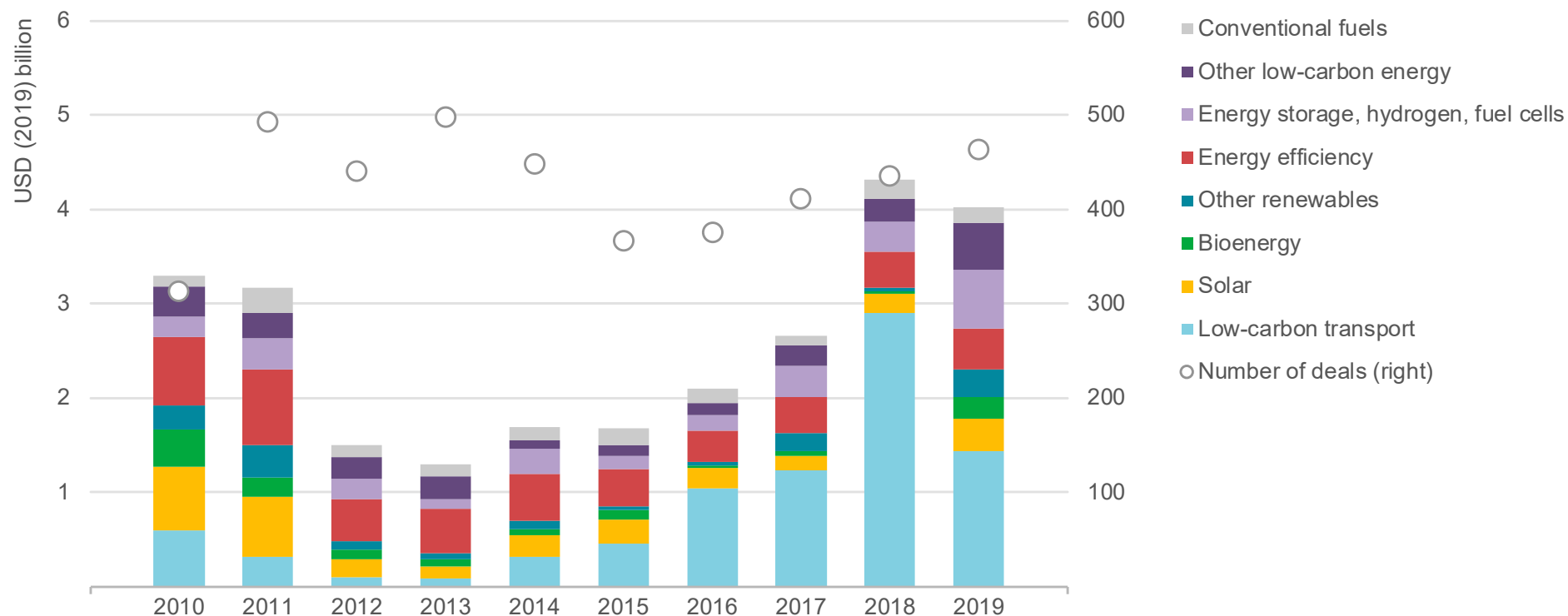
The financial crisis of 2008 and the oil price collapse of 2014 provide some insight into the likely response of companies to the impacts of the Covid-19 pandemic. In 2009-10 the total R&D spending of major sectors held up well relative to revenues, with the exception of the automotive sector. However, the electricity supply and renewables sectors were the only ones not to experience slower growth or cuts to R&D budgets in this period. After 2014, oil and gas company R&D took four years to return to growth and remains below the 2013 level.

While R&D spending is likely to suffer, it can be expected to be much less affected than capital expenditures, as companies seek to retain R&D staff and capabilities, and complete ongoing projects. As in 2009, the outcome will be policy-dependent, with tax incentives and R&D-specific loans being proposed for inclusion in stimulus packages. Still, for the large-scale demonstration of technologies, such as CCUS, cuts to investment could be more damaging than those to R&D.

Trends in investment for technology innovation

Venture capital investment remained robust in 2019, with more diversification of sectors and countries for energy technology start-ups. Storage and hydrogen saw the most growth.

Global early-stage venture capital investment in energy technology companies



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Notes: Includes seed, series A and series B financing deals. Outlier deals of over USD 1 billion that distort the year-on-year trend are excluded; they totalled USD 2.1 billion in 2018 and zero in 2019. World Energy Investment 2019 did not exclude them. Transport includes alternative powertrains and their infrastructure but does not include shared mobility, logistics or autonomous vehicle technology. "Bioenergy" does not include biochemicals. "Other low-carbon energy" includes CCUS, smart grids. "Conventional fuels" includes fossil fuel extraction and use as well as vehicle fuel economy.

Sources: IEA calculations based on Cleantech Group (2020).

While policies in major economies supported VC investment in 2019, private-led scale-up of innovative energy technologies could face major headwinds over the next two years

Total equity investment in energy technology start-ups, including growth equity, by all investor types, stood at USD 16.5 billion in 2019. Of this, early-stage venture capital (VC) (seed, series A and series B), which supports innovative firms through their highest risk stages, is estimated to have been USD 4 billion. These sums are lower than those spent on energy R&D by governments and companies, but this private risk capital plays an important role by enabling market creation and scale-up of the most market-ready technologies. The total reported deal value in 2019 was 7% below that of 2018, but the last two years are well above the decadal average.

Other indicators also show the market is maturing. Compared with recent years, 2019 early-stage VC was spread across more technology areas. While low-carbon transport (mostly EVs and charging) was 35% of this, its share was much lower than in recent years. Time will tell whether this represents consolidation at the end of a period of exuberance marking the start of EV deployment. Other sectors grew significantly, notably energy storage, hydrogen and fuel cells, but also bioenergy and solar. Combined, they largely offset the USD 1.5 billion decline in transport. Higher levels of growth equity, despite lower follow-on deals, provide another indication that investors see storage and hydrogen as having high growth potential. Notable start-ups completing funding rounds included energy storage company Energy Vault (USD 110 million), biomethane producer Bioenergy DevCo (USD 106 million), Jiangsu Guofu Hydrogen (USD 60 million) and battery pack maker Romeo Power (USD 88 million). Among the deals for hydrogen technologies, most were for firms with novel hydrogen production devices, such as pressurised or photocatalytic electrolyzers.

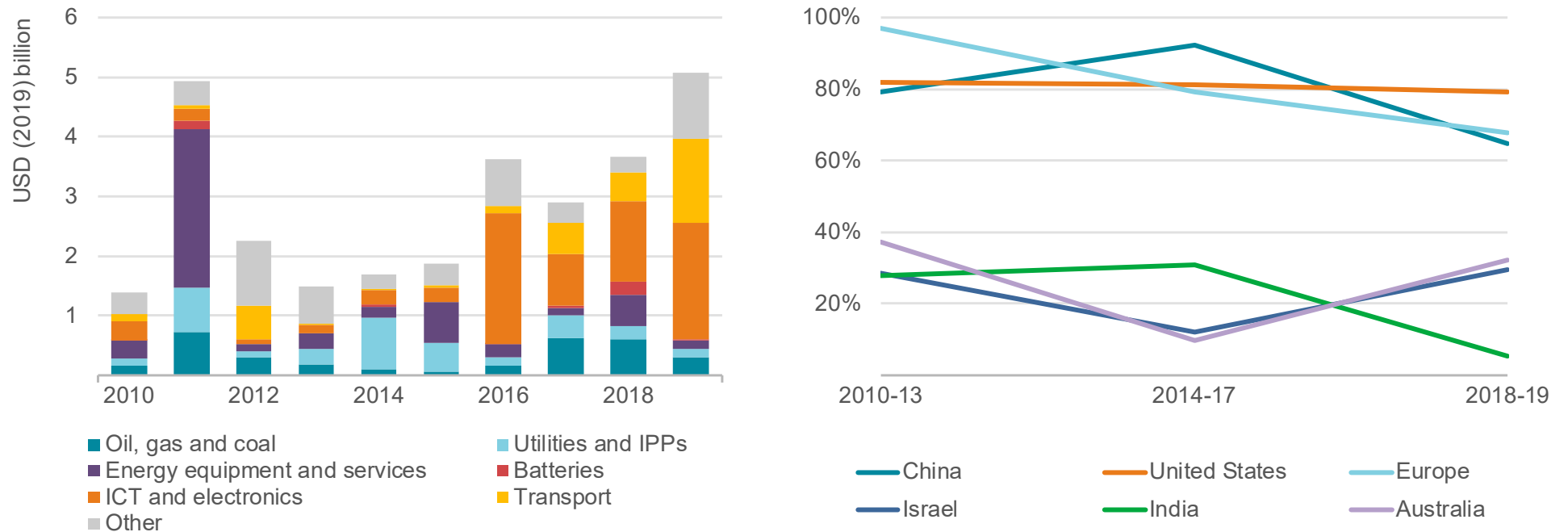
Start-ups receiving funding also diversified geographically. At 19%, Europe had its highest share of reported deal value in four years, while China, at 22%, had its lowest share since 2016. The US share declined to 41% in 2019 compared with 45% in 2018. By contrast, India increased its share to 12% in 2019, from an average of 3% over the previous decade. Notable Indian energy start-ups completing funding rounds included Ola Electric Mobility (USD 250 million), Hero Future Energies (USD 150 million) and Ecozen Solutions (USD 6 million).

The average disclosed deal value for energy tech start-ups was 10% lower in 2019 than 2018, but at USD 12 million, it remains higher than at any point over the previous decade. Deal size is particularly high in China, with start-ups there sometimes raising hundreds of millions of dollars in a single funding round, such as Hozon Automobile (USD 450 million) and Enovate Motors (USD 300 million). However, European and US early-stage VC deal sizes are also at all-time highs. This indicates investor confidence in new energy technologies to play a disruptive and profitable role in the energy sector in the next decade.

While diversification of sectors and geography, plus rising deal value, were good-news stories for 2019, the near-term outlook is very different. Early-stage energy VC deals were still on a par with 2018-19 levels in Q1 2020, but lower activity was evident in China and global declines are expected in Q2-4 due to financial risks, working restrictions and policy uncertainty. When including later-stage deals such as growth equity, which tend to be larger, Q1 2020 activity was 50% lower than in recent years. Some countries have already included support for start-ups in stimulus announcements, including France and the United Kingdom.

Corporate investment in energy start-ups is still led by digital firms, but with a larger role for car companies. Sources of VC funding are slowly diversifying geographically.

Corporate venture capital and growth equity by sector of investor (left) and share of domestic investors in countries' VC activity (right)



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Notes: ICT = information and communication technology; IPPs = independent power producers. "Other" includes all non-stated sectors, among others real estate, hospitality and health. Deals types include grant, seed, series A, series B, growth equity, private investment in public equity, coin/token offering and late-stage private equity. Unless otherwise stated, deal value is shared equally among multiple investors in a single deal. Energy technology companies are defined as per the previous chart.

Sources: IEA calculations based on Cleantech Group (2020).

The globalisation of energy technology VC indicates a maturing sector with corporate and financial investors alike seeking opportunities in funding the best start-ups around the world

Corporate investments in energy technology start-ups, including corporate venture capital, reached a new high in 2019, at around USD 5 billion. The strong annual increase was driven by a small number of very large growth-equity rounds, notably in low-carbon transport. Large corporations continue to see a strategic case for direct investment in innovative, nimble technology players. Companies inside and outside the energy sector are using corporate VC as part of a flexible and open energy innovation strategy.

Traditional energy actors (i.e. fossil fuels, utilities, IPPs, energy equipment and services) account for a decreasing share of investments; about 23% in 2016-19 compared with 49% over 2012 to 2015. The notable spending by electrical equipment manufacturers in electricity storage and EVs, which drove the trend in 2018, was absent. Oil and gas companies accounted for roughly 50% of investments by traditional energy actors but at USD 290 million, their spending was less than in 2017 and 2018. Deals involved start-ups in bioenergy (e.g. Shell investing in Punjab Renewable Energy Systems), CCUS (Chevron in Carbon Engineering), energy storage (Eni in Form Energy), hydrogen (Total in Sunfire) and solar (Equinor in Yellow Door Energy and Oxford PV).

Conversely, the share of non-traditional actors in corporate investments for energy start-ups rose again. The strong investment presence of the ICT and electronics sectors since the mid-2010s was maintained with nearly USD 2 billion in 2019, mostly in low-carbon transport, energy storage and efficiency, including for data centres.

Of the nearly USD 5.9 billion of VC and other equity invested in low-carbon transport start-ups in 2019 in total, USD 3 billion was from

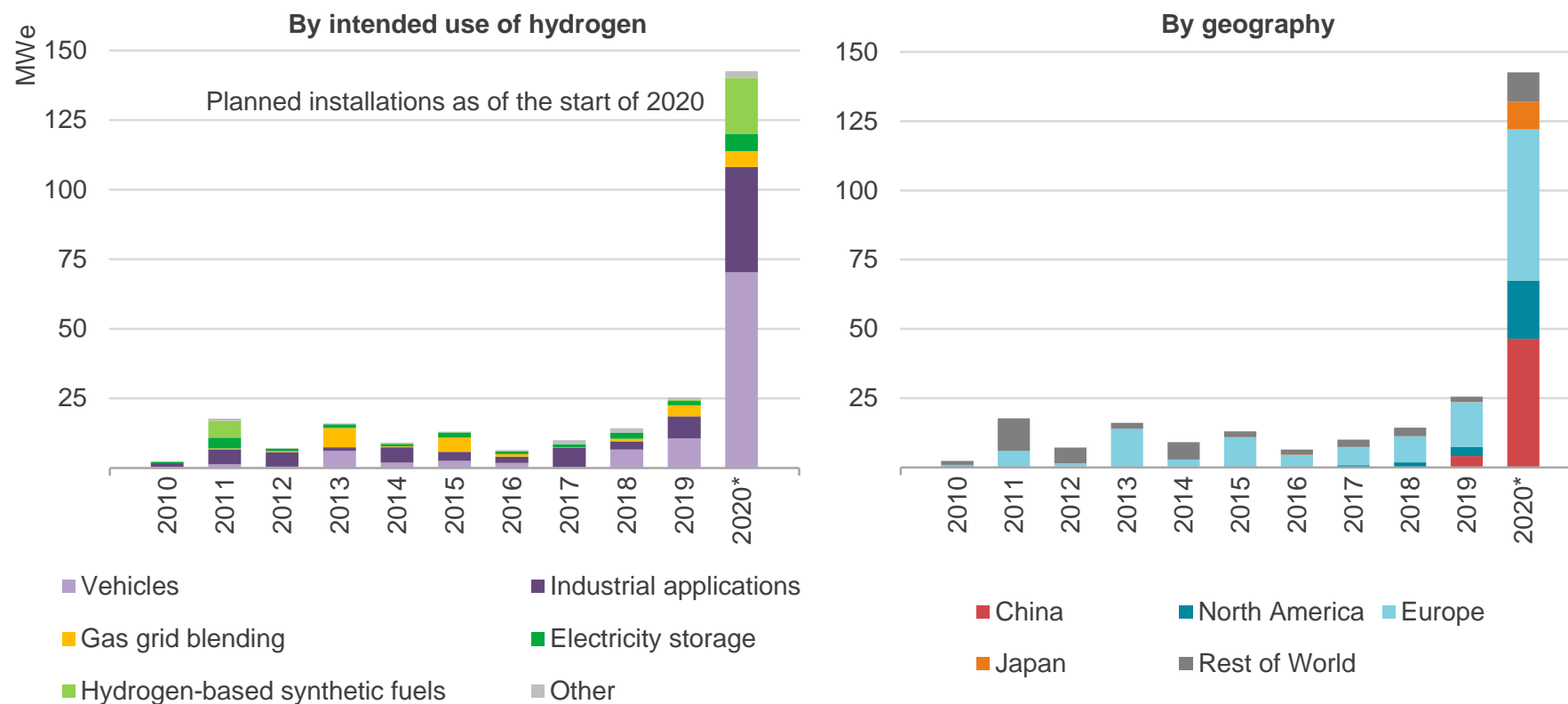
corporate investors, of which USD 1 billion came from the transport sector and USD 1.8 billion from the ICT sector. Electric pickup truck producer Rivian raised over USD 3 billion in 2019 from investors including Ford Motor Company and Amazon. Electric vehicle manufacturer Weltmeister Motor secured USD 450 million in a growth-equity deal led by ICT company Baidu.

A country's VC landscape is defined by its investors as well as its start-ups. For example, four-fifths of the investment in US-based start-ups comes from US investors. This share has declined slightly in recent years, but not as steeply as the share of investment received by Europe-based start-ups from Europe-based investors. That share is now closer to 70%, similar to that of China, which has dipped from over 90% since the middle of the last decade.

While most governments seek to keep the domestic gains from innovation, there are also benefits to attracting overseas finance to local start-ups. World-class start-ups attract investment from all over the world and many VC funds scour the globe for talent. Corporate VC, particularly from multinationals, tends to have a global scope because it seeks opportunities with the best business fit, and often with local market knowledge. The rising share of inward VC in China, Europe and the United States may indicate a more globalised and efficient environment for energy technology entrepreneur finance. Investment in start-ups from Australia, India and Israel comes largely from overseas, reflecting the ability of their entrepreneurs to compete for capital given their relatively smaller domestic VC sectors.

A record capacity of electrolysers to produce hydrogen was added in 2019, supported by vehicles in Europe and industry in China, with a far bigger wave of projects on its way

Capacity of electrolysers for hydrogen production by commissioning year, by intended use of hydrogen (left) and geography (right)



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Notes: 2020 values represent estimates based on successful completion of all projects publicly stating a 2020 commissioning data as of the start of 2020. MW_e = megawatts of electricity input; in some cases this is calculated from hydrogen output volumes if otherwise not stated. Includes electrolysers for the supply of hydrogen for energy purposes or as an alternative to fossil fuels in industry, such as chemical production and oil refining.

Source: IEA (2020i).

But with demand concentrated in hard-hit sectors, a planned 2020 surge faces new challenges

In recent years, capacity additions of water electrolyzers to produce hydrogen have expanded rapidly, from 2 MW_e in 2010 to 25 MW_e in 2019. This activity reflects surging interest in hydrogen as an alternative to fossil fuels in a diverse range of uses, from powering vehicles to storing electricity, refining oil, heating homes, and producing synthetic fuels such as methane or ammonia.

Electrolyzers use electricity to split water into oxygen and hydrogen, which generates no CO₂ emissions at the point of use. The powering of electrolyzers by low-carbon electricity or applying CCUS to hydrogen production from fossil fuels can support low-carbon hydrogen at the point of production. No new CCUS-equipped hydrogen production – each plant equivalent to 100 MW_e to 600 MW_e of electrolyzers – has been added since 2016 but several are planned, mostly in Europe.

Investment has surged in the past two years. Electrolyzers installed in 2019 represent capital expenditure of around USD 40 million, while those in construction may be worth over ten times more. Electrolyzers have grown in scale, from below 0.5 MW_e on average in 2010 to 6 MW_e, and quoted costs for newer designs have halved. A 10 MW_e facility began operation in Japan in March, and a 20 MW_e plant is in construction in Canada, both for vehicles, and potentially industrial uses too. Several hundred MW_e of announced projects seek financial close this year or next; over 600 MW_e could be commissioned through 2021, nearly three times the total additions since 2010. Two electrolyzer factories, 1 GW_e and 360 MW_e, are in construction in the United Kingdom and Norway, with others under development in China.

However, many of these investments could face delays related to Covid-19 restrictions, revised capital expenditure plans and weaker hydrogen demand. The automotive, oil and gas, and steel industries,

among others, may all review the economics of electrolysis hydrogen applications in light of weaker revenues and lower coal and gas prices.

To date, much demand for electrolysis hydrogen – some two to five times more expensive than that from fossil fuels today – has been supported by one-off government initiatives. Project developers expect more predictable demand ahead, arising from industrial emissions reduction commitments (e.g. by oil refiners), and policy incentives that promote clean hydrogen. These factors depend on the evolution of the current downturn, as well as government efforts to include in stimulus measures policies that support demand and supply of hydrogen. In this light, the vehicles sector has been the most dynamic route for hydrogen uptake, based often on hydrogen from natural gas or coal without CCUS. At the end of 2019, 23 350 fuel-cell electric vehicles (FCEVs) were on the road, nearly half registered in 2019 alone, while hydrogen refuelling stations increased by 20% to 460. Most activity has come in Japan and the United States. While blending hydrogen into the gas grid, to deliver low-carbon heat for buildings, is also mentioned in policy debates (see Energy End Use and Efficiency section), just 0.6 MW_e was added for this dedicated purpose in 2019 and 2020.

China represents a major new factor in the development of hydrogen. From minimal levels in 2018, China is aiming for around 150 MW_e in operation by 2021, mostly for mobility, with increased signs of public support. In April 2020, Hebei province approved USD 1.2 billion of projects for hydrogen equipment manufacturing, filling stations, fuel cells and hydrogen production, including electrolysis (Xu and Singh, 2020). Sales of FCEVs climbed from a few units in 2017 to almost 4 400 in 2019; China now leads hydrogen bus and truck deployment.

Will industrial policy help spur venture capital for hydrogen and speed commercialisation?

The landscape of hydrogen technologies and companies is in flux. Industrial uses and the gas grid are becoming more important target markets, China is playing a larger role in technology development, and there is not yet a dominant technology design.

Several countries seek to become technology leaders in hydrogen and are developing policies and financial measures to support strategic investment. This is reflected in the diversity of countries from which the hydrogen start-ups attracting most early-stage VC come.

In addition to a push in China, the Netherlands published a Climate Act in 2019 with specific hydrogen targets and, in May 2020, the Australian government announced up to USD 200 million for a new hydrogen fund (CEFC, 2020). A number of countries, including Portugal, have indicated possible support for hydrogen as part of economic recovery measures, while Germany's national strategy was delayed to accommodate the new economic context.

In 2019, there were more early-stage VC deals for hydrogen start-ups than in any previous year, with over USD 110 million invested in 25 deals. The largest deals were for hydrogen production systems, especially novel technologies, including pressurised electrolyzers, saltwater splitting, anion electrolyte membranes and photocatalytic reactors. Few of these firms are proposing the current market-leading technology of alkaline electrolyzers, or the more expensive, more flexible challenger polymer electrolyte membrane electrolyzers, which are popular for new demonstration projects. This shows that competition between electrolyser technologies is not yet settled.

Among growth equity deals, which tend to involve less technology innovation risk, mobility was a key target market in 2019.

Largest early-stage VC deals in hydrogen start-ups in 2019

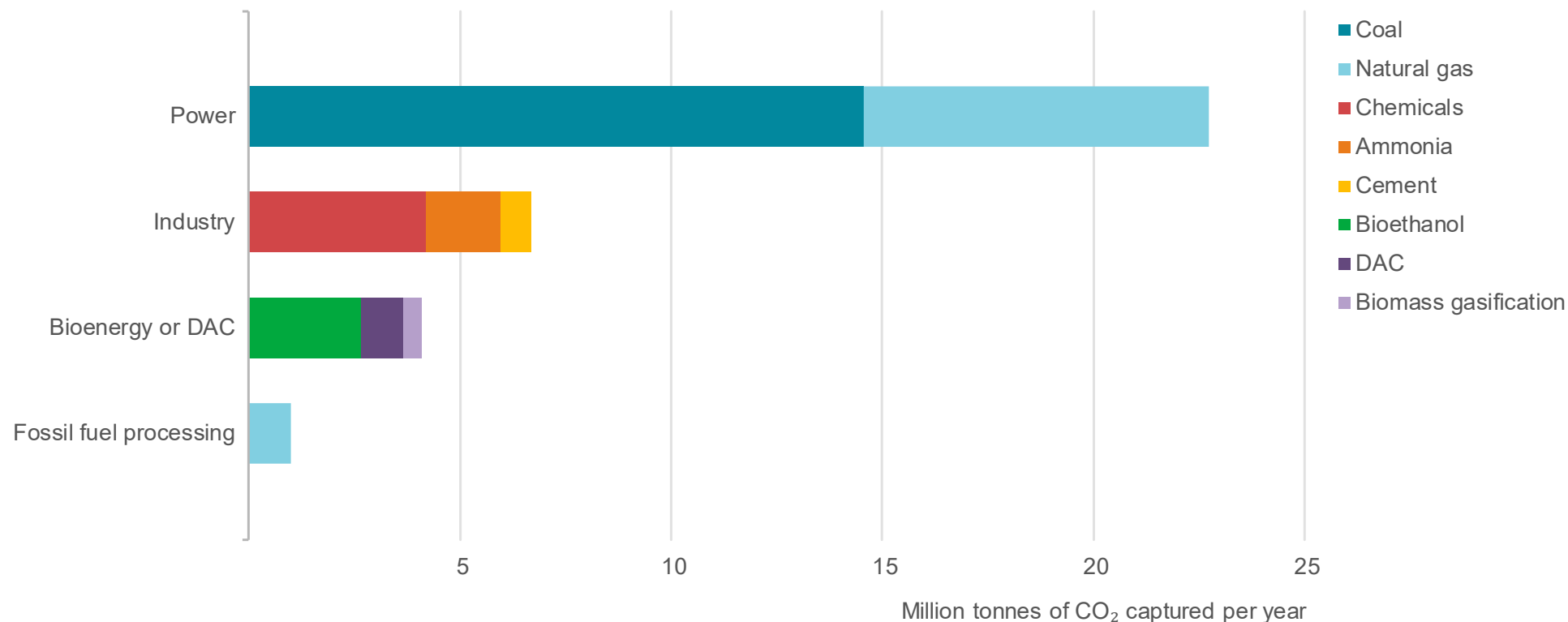
| Company | Offering | USD million | Country |
|-----------------------------------|---|-------------|-------------------------|
| Jiangsu Guofu Hydrogen Technology | Electrolyser, storage, vehicle refuelling | 60 | China |
| Ergosup | Electrolyser | 12.5 | France |
| Joi Scientific | Hydrogen production | 9.8 | United States |
| Szygygy Plasmonics | Hydrogen production from natural gas or ammonia | 9.74 | United States (2 deals) |
| Enapter | Electrolyser | 4.65 | Germany |
| Log 9 Materials | Vehicle fuel cell | 3.5 | India |

Largest growth equity deals in hydrogen firms in 2019

| Company | Offering | USD million | Country |
|-------------------|------------------------------------|-------------|---------------|
| Nikola Motors | Vehicle | 250 | United States |
| Sunfire | Electrolyser, stationary fuel cell | 28.7 | Germany |
| FirstElement Fuel | Vehicle refuelling network | 24 | United States |
| Hydrogenious LOHC | Hydrogen storage | 18.8 | Germany |

While CCUS investment was modest in 2019, new announcements emerged from the United States, where 15 projects seek to enter construction by 2024 to qualify for the 45Q tax credit

Total capacities of 15 announced US CO₂ capture projects targeting final investment decision by the end of 2023



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Notes: DAC = direct air capture. Projects considering multiple CO₂ sources have been allocated to specific categories based on known local CO₂ sources or on an equal basis in other cases.

Sources: calculations based on GCCSI (2020) and company announcements.

80% of these projects plan to sell the captured CO₂ to the oil industry for storage via enhanced oil recovery, but the current market turmoil could threaten their timelines

Capital spending on CCUS projects remained modest in 2019, at under USD 1 billion, mostly on projects that have been under development for several years. The first two CCUS trains of the Gorgon LNG project in Australia began operation, following delays since construction began in 2009. It is now the world's largest dedicated geological CO₂ storage facility (i.e. the CO₂ is not used for enhanced oil recovery [EOR]). It will be able to store 4 Mt of CO₂ per year when the third train starts, which is due in 2020, and if the LNG plant runs at full capacity. Four other CCUS projects are in construction, two in Canada and two in China. While no FIDs have been taken since 2017, in 2020 three oil and gas firms stated a willingness to invest USD 700 million to develop CO₂ storage in Norway by 2024, pending public funding (Equinor, 2020).

Investment signals for CCUS in the United States improved following the extension and reform of the 45Q tax credit in 2017. Companies have since been waiting for regulatory clarification before committing to building, and some of this – on construction criteria – was published in early 2020. Fifteen projects are now reportedly targeting 45Q support, pushing the global number of large-scale projects in development over 30, the highest since 2014. Depending on the size and sector, each project could invest USD 100 million to USD 1 000 million if successful.

Section 45Q of the US tax code provides up to USD 50 (inflation adjusted) per tonne of CO₂ sent to geological storage, or up to USD 35 per tonne used for EOR, for up to 12 years, if the effectiveness of storage is monitored and construction begins by 1 January 2024. Like other production-based incentives, 45Q incentivises investors to identify cost-effective projects developed by any promoter, though the credit is best monetised by bigger players with larger tax burdens.

Alongside 45Q, California's Low Carbon Fuel Standard (LCFS) has emerged as a key complementary policy for projects linked to biofuels production, DAC or EOR. Globally, 45Q and LCFS are trailblazers for DAC support. The 2019 CCUS protocol clarifies how projects can benefit from LCFS credits – which traded at around USD 180 per tonne of CO₂ in 2019 – and requires monitoring of stored CO₂ for 100 years.

Among projects targeting 45Q support, some of the closest to investment decision and operation are those that aim to capture high-purity CO₂ that is currently vented from bioethanol production or natural gas processing. These are among the lowest-cost options for capturing CO₂ and the projects plan to pair this with EOR, which can be the CO₂ storage option that is quickest to bring into operation. It often requires only a connecting pipeline to an existing EOR operation.

However, the current oil price downturn and sharp cuts to upstream investment programmes suggest EOR operators may be reluctant to sign new contracts (see Fuel Supply section). Project sponsors such as ExxonMobil and Occidental Petroleum have cut capital budgets by over 30% in 2020. While some discussion of an extension of the 45Q deadline (beyond 2024) and increasing the value of credits emerged before the crisis, no decisions have been made to adjust the policy.

The largest US announcements are associated with coal and natural gas-fired power plants, with CO₂ capture capacities of 1 Mt to 6 Mt per year. Several of these projects are looking to sell the CO₂ for EOR. Given the likely challenges to securing CO₂ off-take contracts over the coming two and a half years, dedicated geological CO₂ storage options may become more attractive than before.

Annex

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