World Energy Investment 2019

Under embargo until 1:00 a.m. Paris time on Tuesday, May 14.

Message from the Executive Director

The World Energy Investment (WEI) report is the world's benchmark for tracking investment trends across the energy sector. Now in its fourth edition, the report continues to enhance its role as a timely and valued analytical tool - with a new look and feel - to help inform decision making by governments, industry and the financial community alike.

Our latest report emphasises the opportunities for the energy system to attract the scale and types of investment that would align with a more secure and sustainable energy system.

It highlights some notable trends. In 2018, more than two dollars in every ten invested worldwide in energy goes towards powering Asian economies, while another dollar finances oil and gas supply in North America. There have been dramatic efforts to improve business models, cut costs, and attract capital, yielding a more agile upstream industry, more cost-effective renewables investment and new ways to finance energy efficiency and electric mobility.

Nevertheless, several mismatches are emerging between the current trends and the capital needed ahead, requiring a harder look at the risks facing investment across different sectors and countries.

Current market and policy signals are not incentivising the major reallocation of capital to low-carbon power and efficiency that would align with a sustainable energy future. In the absence of such a shift, there is a growing possibility that investment in fuel supply will also fall short of what is needed to satisfy growing demand. And to meet sustainable development goals, more investment is needed in the regions that face the highest economic and financial constraints, such as in sub-Saharan Africa.

Financing our energy future requires policy makers to better understand the risks faced by investors and to design and implement policies that allow for the efficient allocation and management of these risks, which are key determinants of the cost of capital. Where governments – and in some cases, public financial institutions – provide such frameworks, the private sector responds.

All of this requires timely, reliable and authoritative data and analysis. That is why we are releasing *WEI-2019* a full two months earlier than last year, in a modernised digital format that more effectively conveys the key information. This is part of an updated investment portal that synthesises the Agency's key insights on energy investment throughout the year. The *WEI-2019* package represents our latest step in support of the ongoing digitalization of the IEA.

Investment made today in energy infrastructure will leave its mark for decades to come. Achieving the goals of the IEA Sustainable Development Scenario will require a combination of policy and financial know-how to increase the flow of bankable clean energy projects around the world. At the IEA we support sound and sustainable policy making with good data, but also advice, training, and capacity building, to help achieve these aims.

Dr Fatih Birol
IEA Executive Director

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Executive Summary

In 2018, global energy investment stabilised at near USD 1.85 trillion after three years of decline. More spending on oil, gas and coal supply was offset by lower spend on fossil-fuel based generation and renewable power. Efficiency spending was unchanged. Power still attracted the most investment, exceeding oil and gas for a third year in a row.

China was the largest market for energy investment in 2018, but its lead narrowed. The United States and India increased the most over the past three years, but other regions have been less dynamic, reflecting lower oil prices (Middle East), rebalancing between old and new parts of the system (Europe) and financing risks (sub-Saharan Africa).

Energy supply spending has shifted broadly towards projects with shorter lead times, partly reflecting investor preferences for better managing capital at risk amid uncertainties over the future direction of the energy system. Investment purchasing power has risen over time in some sectors. Adjusting for cost declines, renewable power investment is up 55% since 2010, and cost changes have damped the impact of less oil and gas spending since 2014.

Benchmarking today's trends against future needs suggests stepping up energy supply investment in any scenario. But the opportunities and risks vary greatly, depending on the pathway that the world follows.

Today's investment trends are misaligned with where the world appears to be heading. Notably, approvals of new conventional oil and gas projects fall short of what would be needed to meet continued robust demand growth.

There are few signs in the data of a major reallocation of capital required to bring investment in line with the Paris Agreement and other sustainable development goals. Even as costs fall in some areas, investment activity in low-carbon supply and demand is stalling, in part due to insufficient policy focus to address persistent risks.

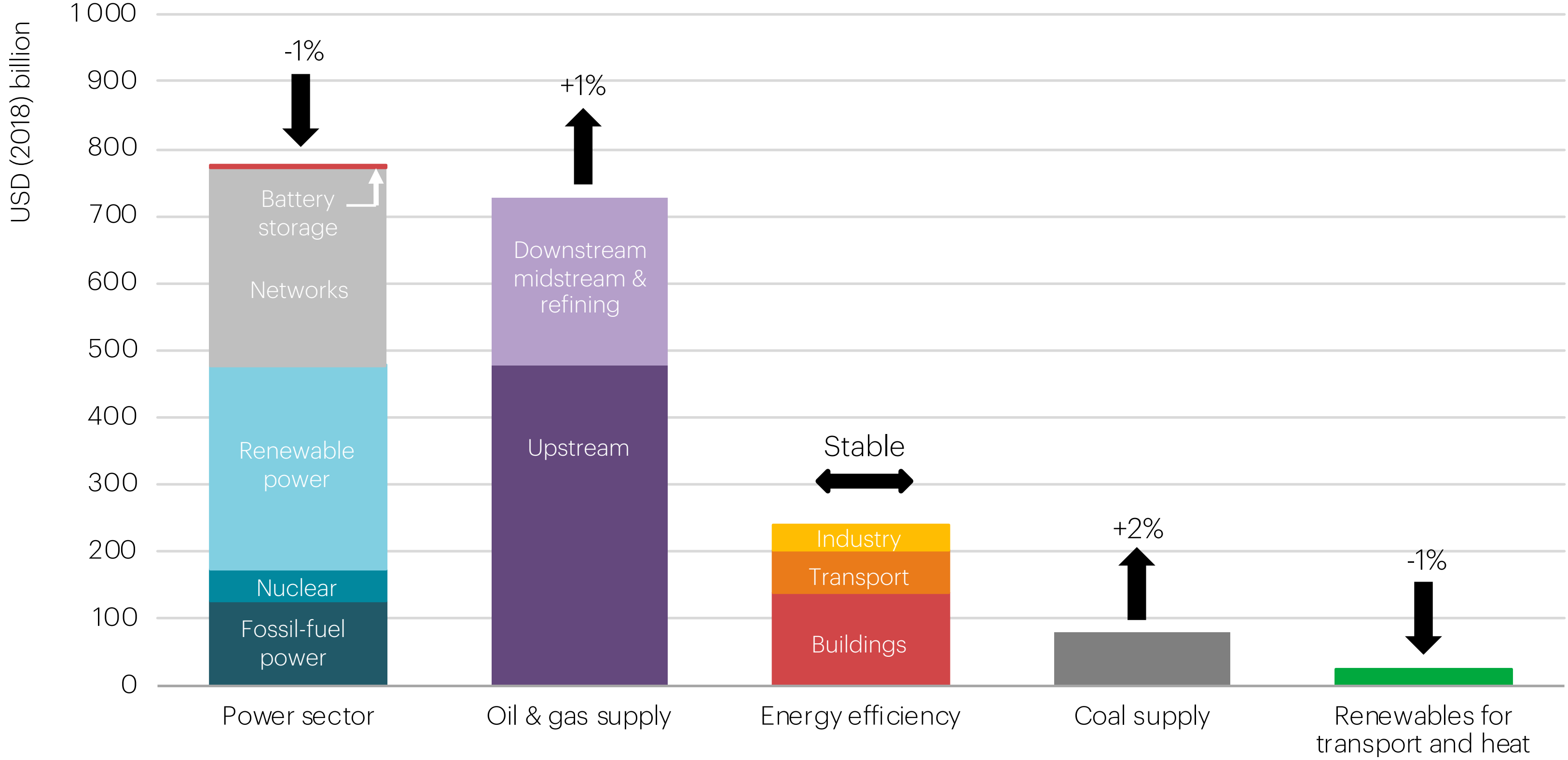
In the Sustainable Development Scenario, the share of low-carbon investment rises to 65% by 2030, but advancing from today's share of 35% would require a step-change in policy focus, new financing solutions at consumer and bulk power levels and faster technological progress, including more RD&D, amid sustained spend on electricity grids.

Overview & key findings

Energy investment by sector

After three years of decline, global energy investment stabilized in 2018

Global energy investment in 2018 and change compared to 2017



Note: Investment is measured as the ongoing capital spending in energy supply capacity and incremental spending on more efficient equipment and goods (in energy efficiency). The scope and methodology for tracking energy investments is found in the Annex of this report as well as at iea.org/media/publications/wei/WEI2019-Methodology-Annex.pdf. Renewables for transport and heat include biofuels for transport and solar thermal heating. Electricity networks include transmission and distribution.

Despite a downtick, power was again the largest sector for investment

Global investment in the power sector compared with oil and gas supply

Investment was driven by higher upstream oil & gas and coal supply spending while that in energy efficiency was stable and renewables spending edged down

In 2018, global energy investment remained relatively stable, at around USD 1.85 trillion (United States dollars), following three years of decline. More spending in upstream oil and gas and coal supply was offset by lower spend on fossil-fuel based generation and renewable power. Investment in energy efficiency was relatively stable.

For the third year in a row, power exceeded oil and gas supply as the largest investment sector. While partly due to shifting costs in both sectors, the trend also reflects the growing importance of electricity, whose demand growth in 2018 was nearly twice as fast as overall energy demand.

A 1% fall in power investment stemmed from less spending on coal power in China and gas power in the United States. Renewables investment edged down, as net additions to capacity were flat and costs fell in some technologies, but was also supported by plants under development. Lower solar PV investment in China was partly offset by higher renewable spend in some areas (e.g. United States, developing Asia).

A 4% rise in upstream oil & gas spending was underpinned by a higher oil price, and a shift to shorter-cycle projects and shale. Spending plans for 2019 point to a potential new wave of conventional projects; for the moment, project approvals are below the level needed to match robust demand.

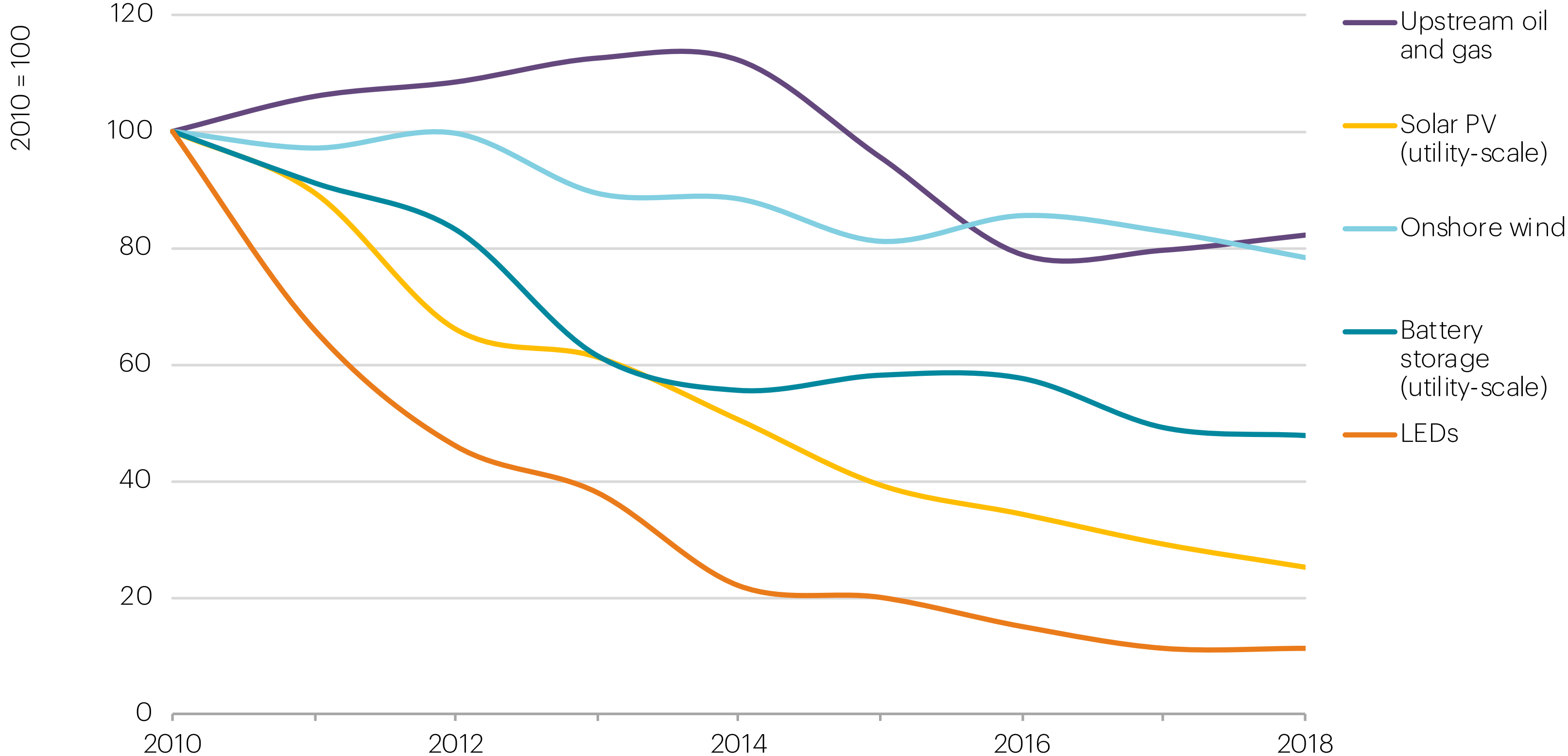
Energy efficiency spending was stable a second year in a row, with limited progress in expanding policy coverage. Despite soaring EV sales, transport efficiency has stagnated, while spending in buildings dipped.

Investment in coal supply increased by 2% – the first such rise since 2012 – although the total remains a long way below the peak levels reached at the start of the decade.

Investment in renewable heat and transport edged down, but spending on new biofuels plants grew.

Changing costs have reshaped the investment landscape in some areas

Capital costs in selected energy-related sectors

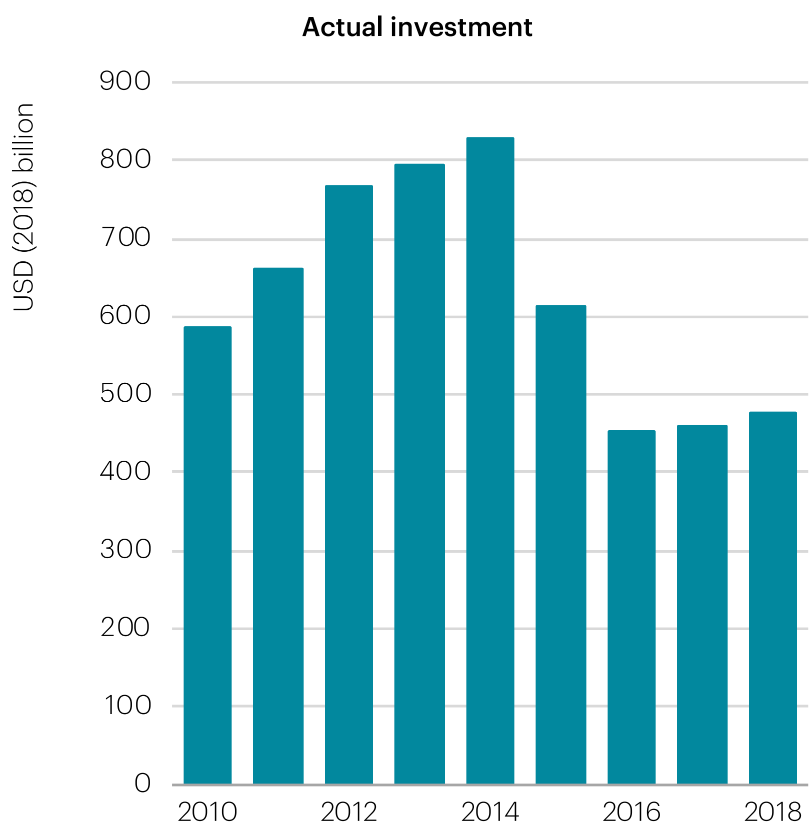


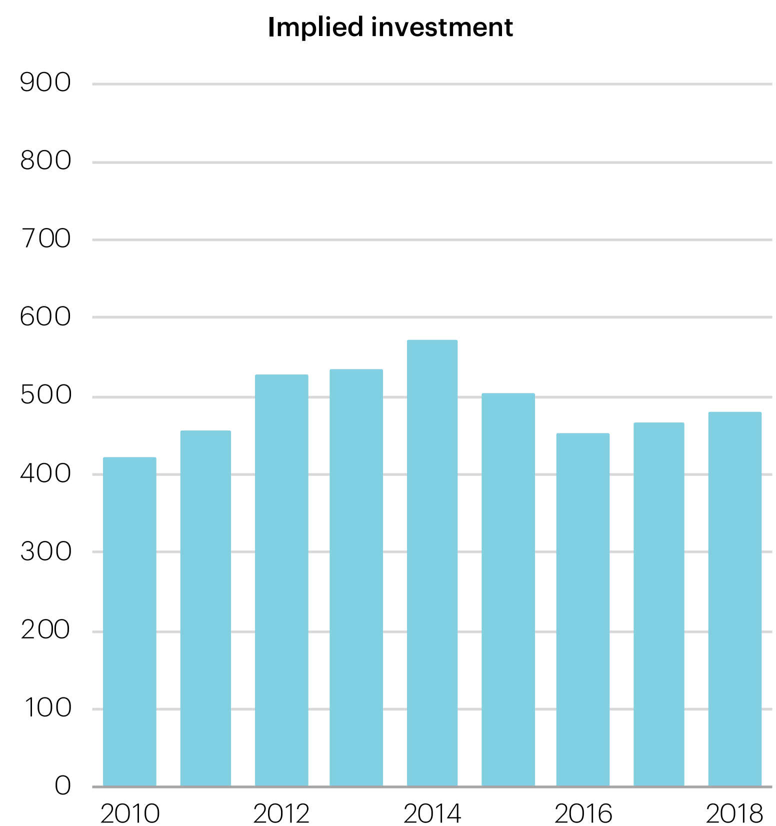
Note: LEDs = light-emitting diodes, PV = photovoltaic. Capital costs reflect global weighted average costs of components or commissioned projects in a given sector.

Source: IEA analysis with calculations for solar PV and wind costs based on IRENA (2019).

Lower costs dampened the impact of less upstream spending since 2014…

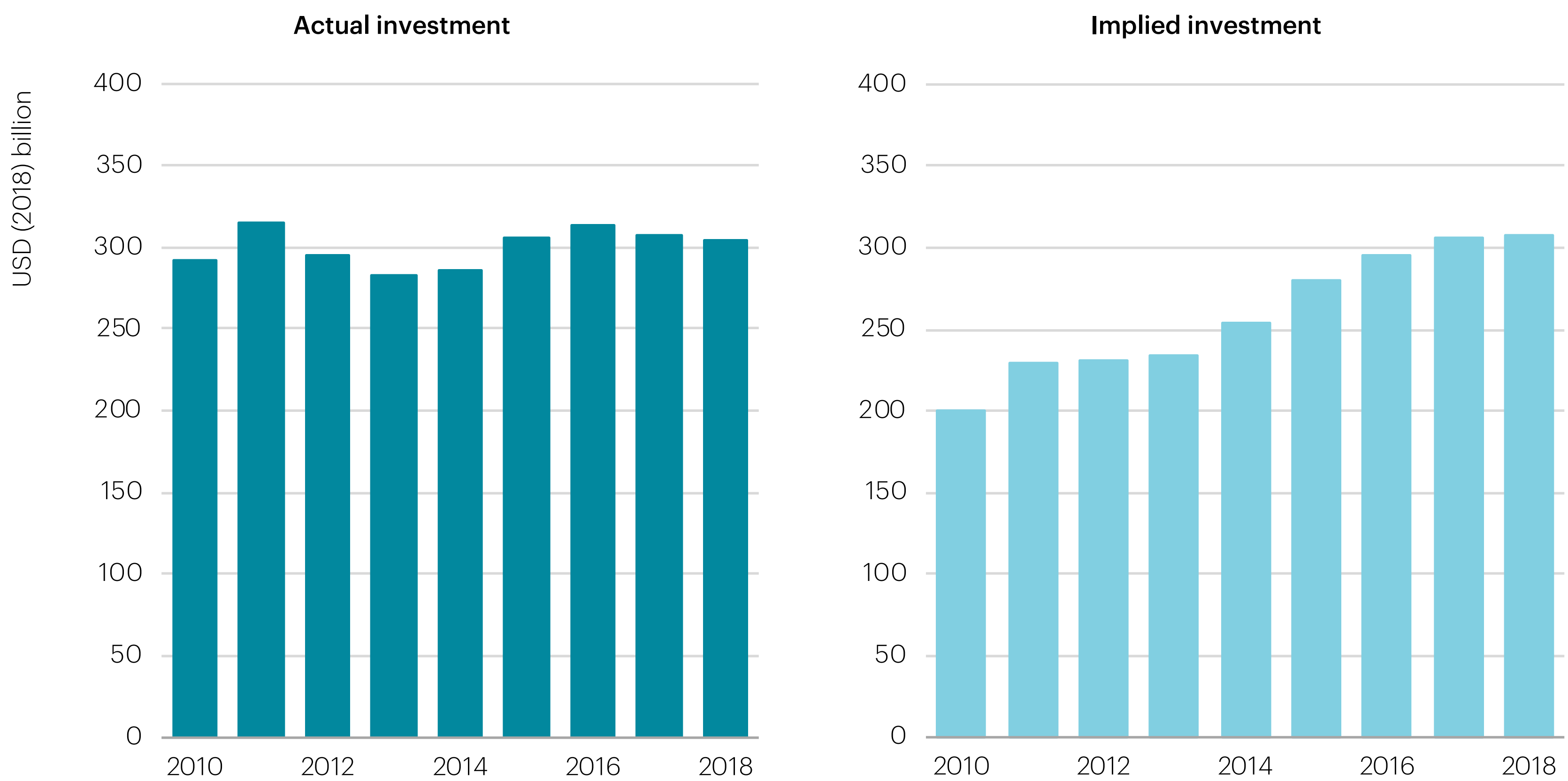
Investment in upstream oil and gas – actual spend vs implied investment at constant 2018 cost levels





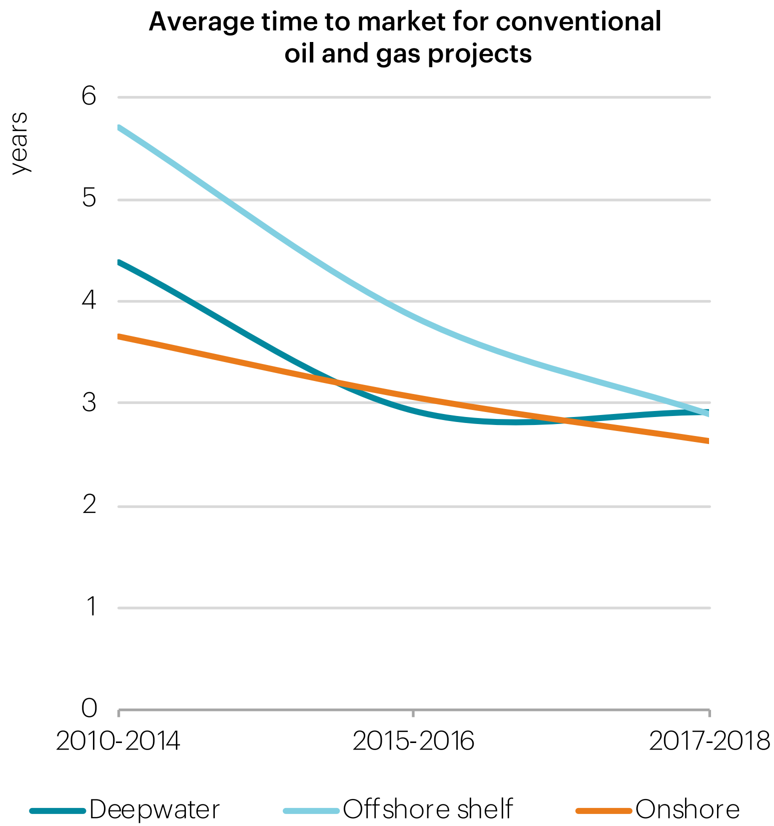
…while adjusted for costs, renewables investment is up 55% since 2010

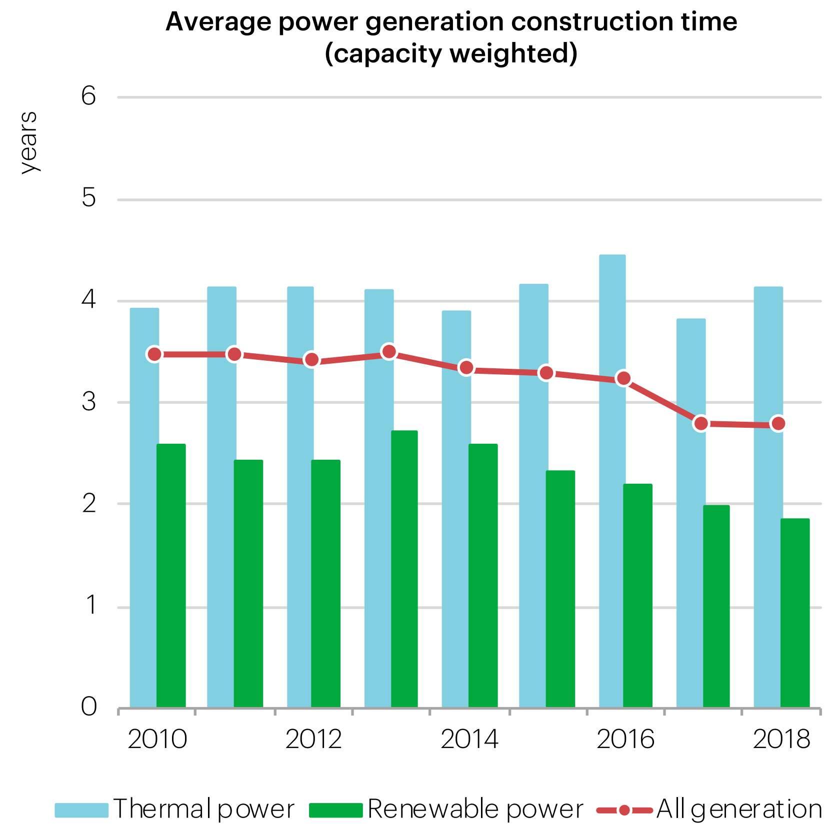
Investment in renewable power – actual spend vs implied investment at constant 2018 cost levels



There has been a broad a shift towards projects with shorter lead times…

Trends in project development and investment timelines for oil and gas supply and power generation





...as industry seeks to limit long-term risks in a changing energy system

In recent years there has been a broad shift in favour of projects with shorter construction times that limit capital at risk. For upstream oil and gas and power generation, the industry is bringing capacity to market on average more than 20% faster than at the start of the decade. This reflects better project management and improved economics for shorter cycle technologies as well as industry competition.

In power, capital cost declines – reflecting technology progress and deployment location – have been most evident in solar PV (-75% since 2010), onshore wind (-20%) and battery storage (-50%). In offshore wind, capital cost declines for commissioned projects have been less dramatic, but rising utilisation rates and lower financing costs have driven prices in auctions to new lows.

After declining 30% over 2014-16, a slight rebound in upstream oil and gas costs in the last two years was lower than the increase in oil prices. With more spending on shale and faster time to market for conventional projects, the industry is now better able to react to changing market conditions.

In oil and gas and renewables, a dollar of investment buys more than in the past. Adjusting investment to 2018 cost levels shows a rising trend in spending activity for renewable power, up around 55% since 2010. For oil and gas, cost reductions have damped the impact of falling investment since 2014.

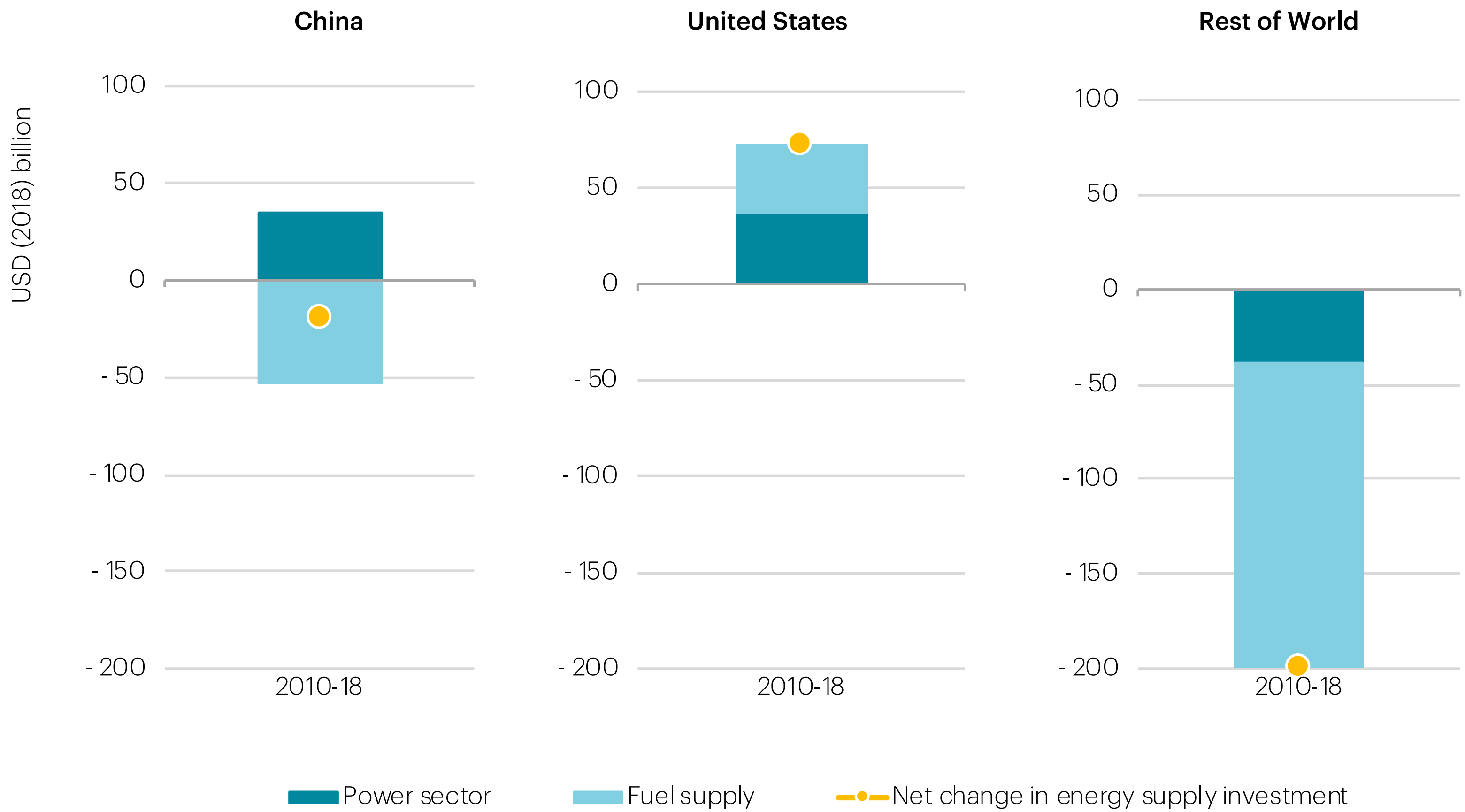
Prices for some efficient goods, e.g. LEDs and electric vehicles, have continued to fall, and many energy efficient investments are already cost-effective with relatively short payback periods. Still, policy, market, and financing-related challenges have acted as barriers to increased spending on efficiency.

Changes are not evident in all areas, with little recent progress in improving costs or project cycles for nuclear; carbon capture, utilisation, and storage; building retrofits; and some large-scale grid projects.

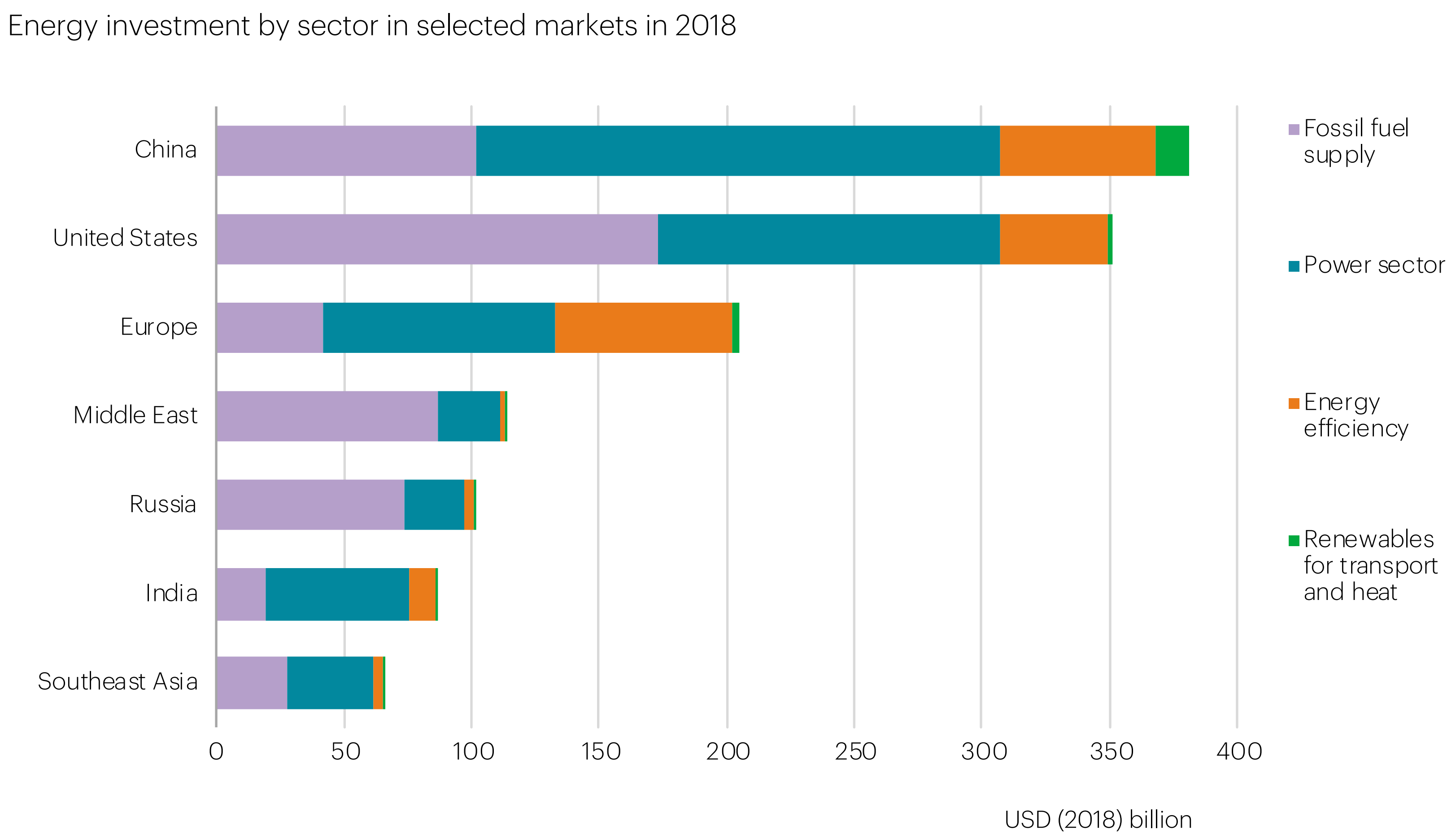
Energy investment by geography

The United States accounted for most growth in energy supply investment this decade

Changes in energy supply investment, 2010-18

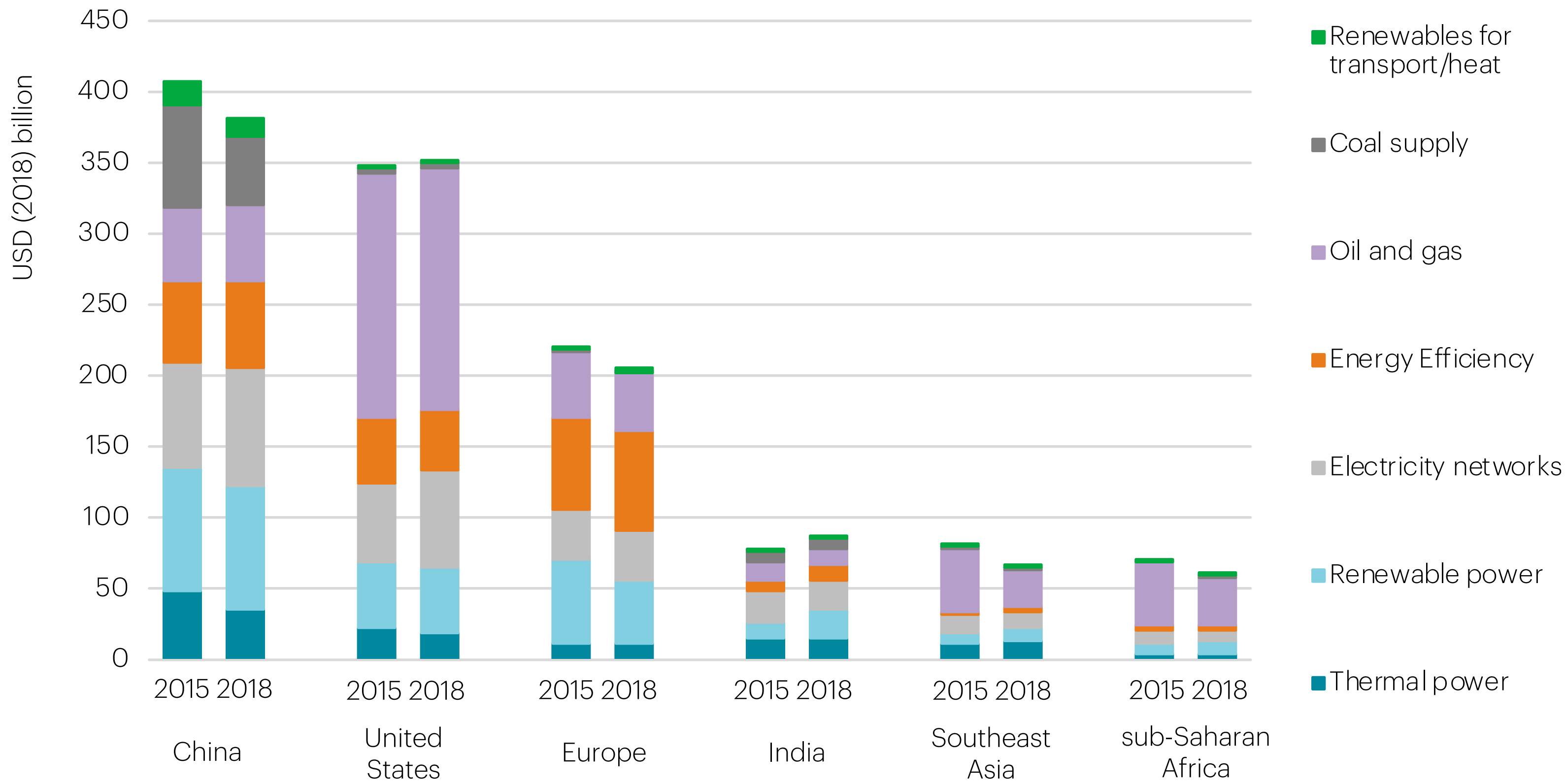


China remained the largest market for total energy investment in 2018



Investment in India has grown the most over the past three years

Energy investment by sector in selected markets, 2015 and 2018



China, the United States & India are driving some key investment trends…

More than two dollars in every ten invested in energy goes to powering Asian economies; another two dollars divides between oil and gas and power in North America. These shares have grown in recent years.

The United States has been responsible for most of the growth in energy supply investment this decade, with increases in both oil and gas, supported by more spending on shale, and in the power sector. While oil and gas spend has moderated somewhat in the past three years (even as it grew strongly from 2017 to 2018), that for electricity networks rose. Compared to 2015, investment in renewable power and gas power remained relatively stable, but at high levels. Meanwhile, investment in energy efficiency has declined over the period.

China remained the largest market for energy investment in 2018, but its lead narrowed. While spending is increasingly driven by low-carbon electricity supply and networks, total investment declined by 7% over the past three years due to lower spend on new coal-fired plants, down over 60%, outweighing relatively high investment in renewable power and nuclear. Energy efficiency spending has risen by over 6% the past three years.

Among major areas, energy investment has risen mostly rapidly in India the past three years, up 12%. In 2018, renewable spending continued to exceed that for fossil fuel-based power, supported by tendering for solar PV, and from 2017 wind, amid uncertain financial attractiveness of new coal power, though spending in coal supply rose somewhat. While transmission spending is expanding, investment in distribution has not grown.

...but each region has its own story, often one of lower spending

Investment growth was stable or declined in other major regions during the past three years. In some areas this reflects a response to lower oil prices (e.g. Middle East), an ongoing rebalancing between old and new parts of the system (e.g. Europe) as well as persistent financing risks that have held back more robust levels of spending to address strong demand growth (e.g. sub-Saharan Africa, Southeast Asia).

Energy investment in the European Union has declined by 7% over the past three years, but the share of spending going towards low-carbon energy has risen to nearly 60%. Energy efficiency has been the lone growth area for spending. Renewable power spending has slowed, in part from falling costs, but accounts for over 80% of generation spending.

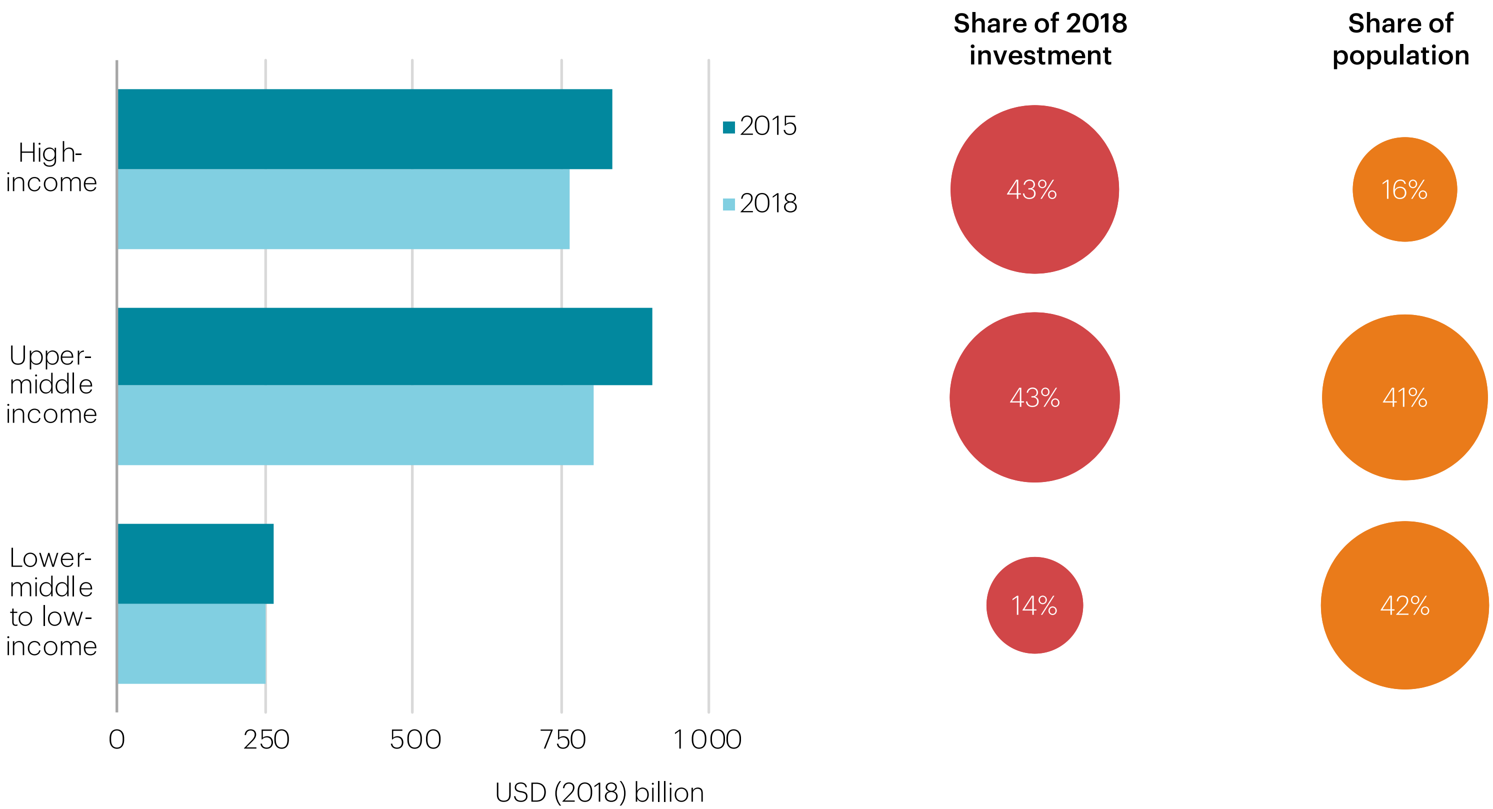
Investment in the Middle East is down by one-fifth over the past three years, one of the largest declines globally, led by a retrenchment in oil and gas spending, which outweighed higher spending on power, particularly in solar PV and gas generation. Some rebound may be on the horizon, with some of the largest national oil companies announcing higher capital budgets for 2019 (see Fuel Supply).

Southeast Asia energy investment is down almost one-fifth since 2015. Most of the fall stemmed from lower oil and gas supply spending while that for renewables and coal power registered increases. Energy efficiency accounts for only around 5% of investment and has not grown significantly.

In sub-Saharan Africa, investment has declined 15% compared with three years ago, with less oil and gas spending offsetting a small increase in renewables. Investment in capital intensive low-carbon technologies remains hampered by insufficient regulatory framework, challenging project development, persistent financial strain for utilities and a limited pool of public finance.

Energy investment was mostly in high and upper-middle income regions...

Energy investment and population by region, classified by current income level



Note: Income categories are defined on the basis of gross national income/capita (current USD) thresholds from World Bank (2019). High-income = > USD 12 055; Upper-middle income = USD 3 896-12 055; Lower-middle to low-income = < USD 3 895.

Source: IEA analysis with calculations for income and population are based on World Bank (2019).

...but a shift towards lower income segments is needed

There is a strong link between income levels and energy investment. Nearly 90% of energy investment in 2018 was concentrated in high- and upper-middle income countries and regions. These areas also tend to benefit from relatively well-developed financial systems (see Financing and funding trends).

High-income countries, with just over 15% of the global population, accounted for over 40% of energy investment in 2018. Investment in this group is down somewhat from five years ago, largely due to lower spending in Europe and Japan, but rose in 2018 with stronger spending in fuel supply and the power sector predominantly in the United States.

Energy investment in recent years has also declined in upper-middle income countries and regions, with an increase in Mexico outweighed by falls in China, the Middle East, Brazil, the Russian Federation, and some Southeast Asia countries. Three years ago, this group comprised over 45% of energy investment, higher than the 43% seen in 2018.

Lower-middle and low-income countries accounted for less than 15% of energy investment in 2018 despite containing well over 40% of the world's population. In recent years, the fastest investment growth within this group has come from India with rising power sector spending, while spending in sub-Saharan Africa has declined, mostly due to less investment in fuel supply.

Looking ahead, the largest investment needs remain concentrated in currently high- and upper-middle income countries and regions, in part reflecting continued investment to replace and upgrade aging assets. However, to meet sustainable development goals, overall spending needs to grow from today's levels and to rebalance towards the fast-growing needs of lower-middle and low-income countries.

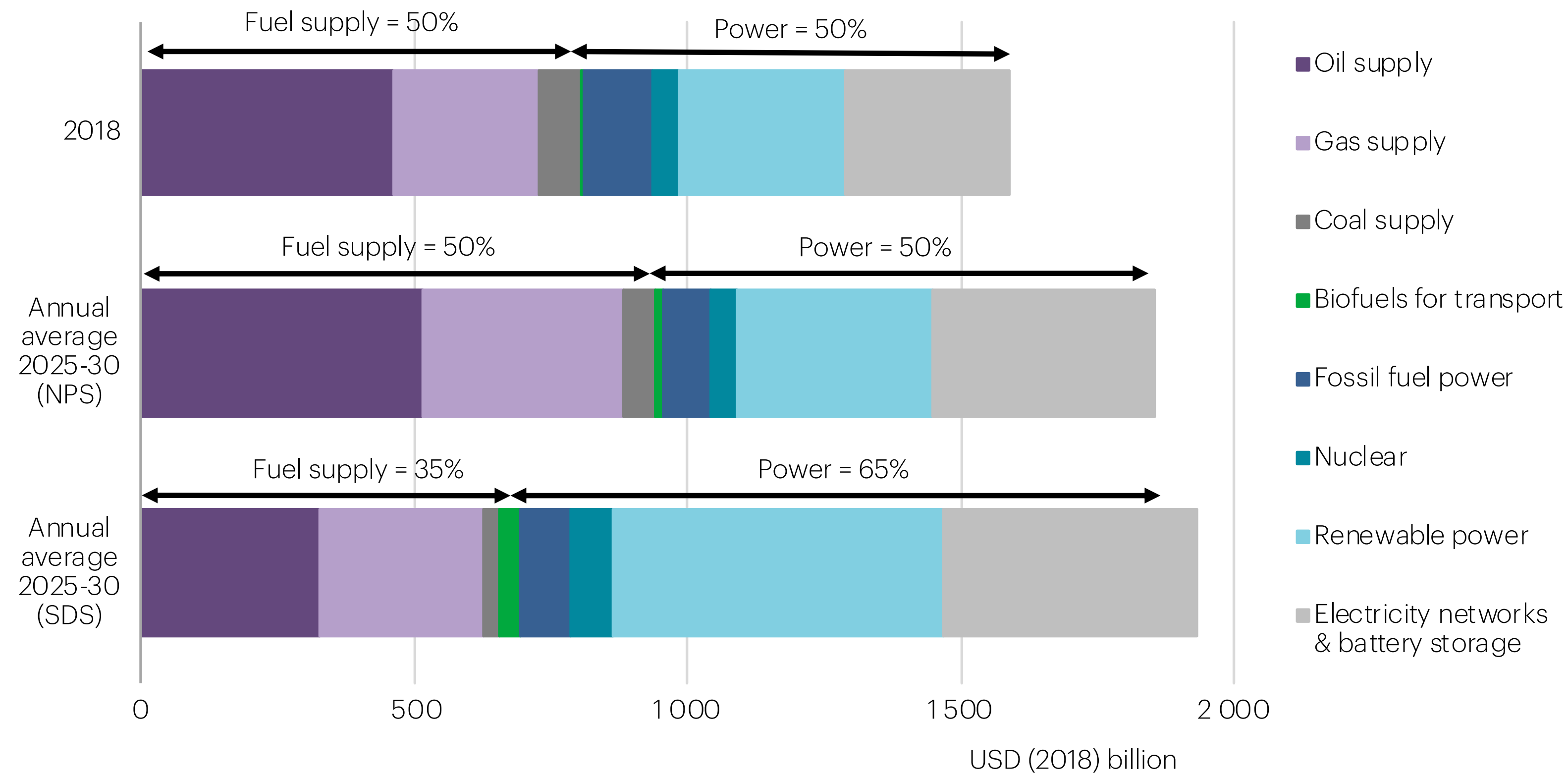
Implications of today's energy investment trends

Is energy supply investment aligned with objectives for energy security and sustainability? (26-30)

Is investment in low-carbon energy enough to meet sustainability goals? (31-34)

Energy supply investment needs to rise under any scenario, but major capital reallocation would be needed to meet sustainability goals

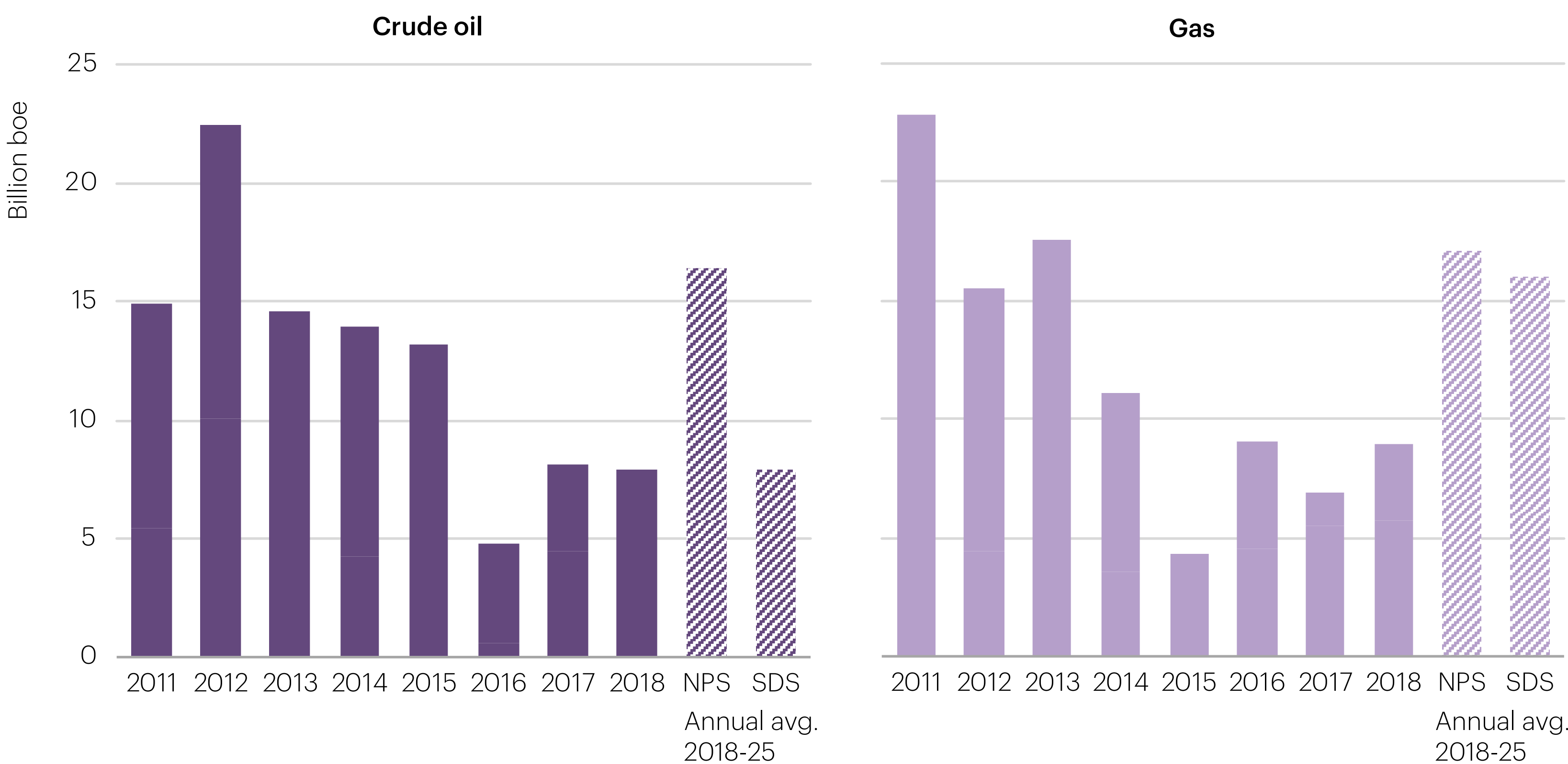
Global energy supply investment by sector in 2018 compared with annual average investment needs 2025-30 by scenario



Note: NPS = New Policies Scenario; SDS = Sustainable Development Scenario. Oil & gas supply includes upstream, midstream and downstream investment.

Continued robust demand growth for oil and gas would require a sharp pick-up in approvals of new conventional upstream projects

Crude oil and gas conventional resources sanctioned

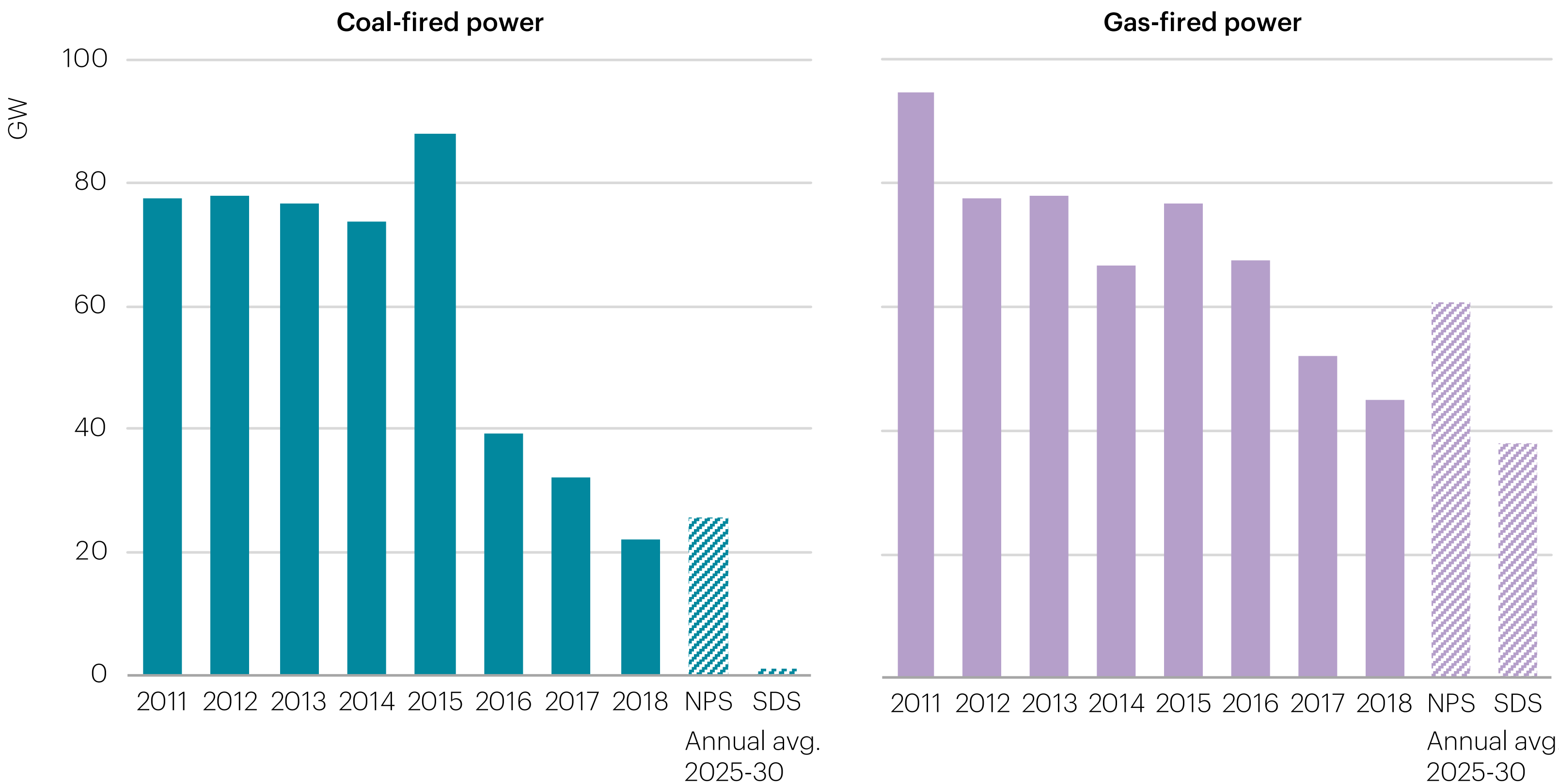


Note: NPS = New Policies Scenario; SDS = Sustainable Development Scenario.

Source: Historical sanctioned resources based on Rystad Energy (2019)

Gas power remains in the mix; while the coal fleet continued to grow in 2018, sustainability goals point to a swift FID phase-out for unabated plants

Final investment decisions (FIDs) for coal-fired & gas-fired generation versus annual average needs 2025-30 by scenario

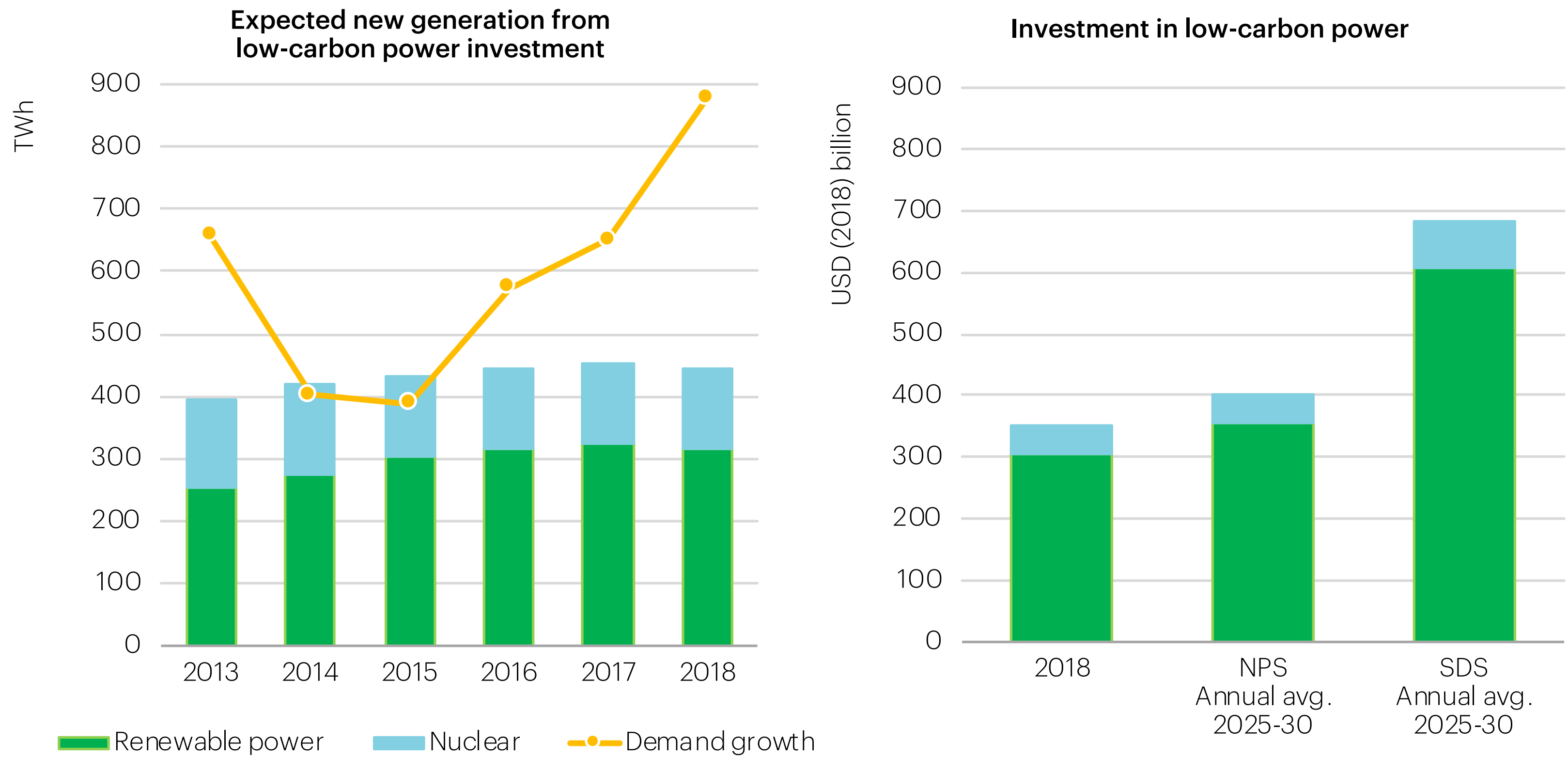


Note: NPS= New Policies Scenario, SDS=Sustainable Development Scenario. FIDs for coal-fired and gas-fired generation capacity in NPS and SDS does not include plants equipped with carbon capture.

Source: IEA analysis with historical FID data based on McCoy Power Reports (2019).

Output from low-carbon power investment is not keeping pace with demand; a doubling of renewables spending is needed in the SDS

Expected generation from low-carbon power investments and annual investment needs by scenario



Note: Generation is based on the expected annualised output of the capacity associated with investment in a given year. TWh = terawatt hour. NPS = New Policies Scenario; SDS = Sustainable Development Scenario.

Energy investment is misaligned with where the world appears to be heading, and also far out of step with where it needs to go

Compared with the annual average investment required for 2025-30 in IEA scenarios, total energy supply investment needs to step up significantly, even with changing costs. But the gaps differ starkly by sector and scenario, reflecting variations in the pathways for energy security and sustainability.

For fossil fuel supply, the lower levels of oil spending seen since 2014 would need to taper further to be consistent with the Sustainable Development Scenario (SDS), i.e. a trajectory consistent with the Paris Agreement. However, investment levels fall well short of what would be needed in a world of continued strong oil demand – as in the New Policies Scenario (NPS).

For gas supply, today's investment falls short of the levels projected in both the SDS and NPS, while for coal supply the opposite is true: current spending comfortably exceeds the levels required by the late 2020s in both scenarios. More spending on biofuels is needed in both scenarios.

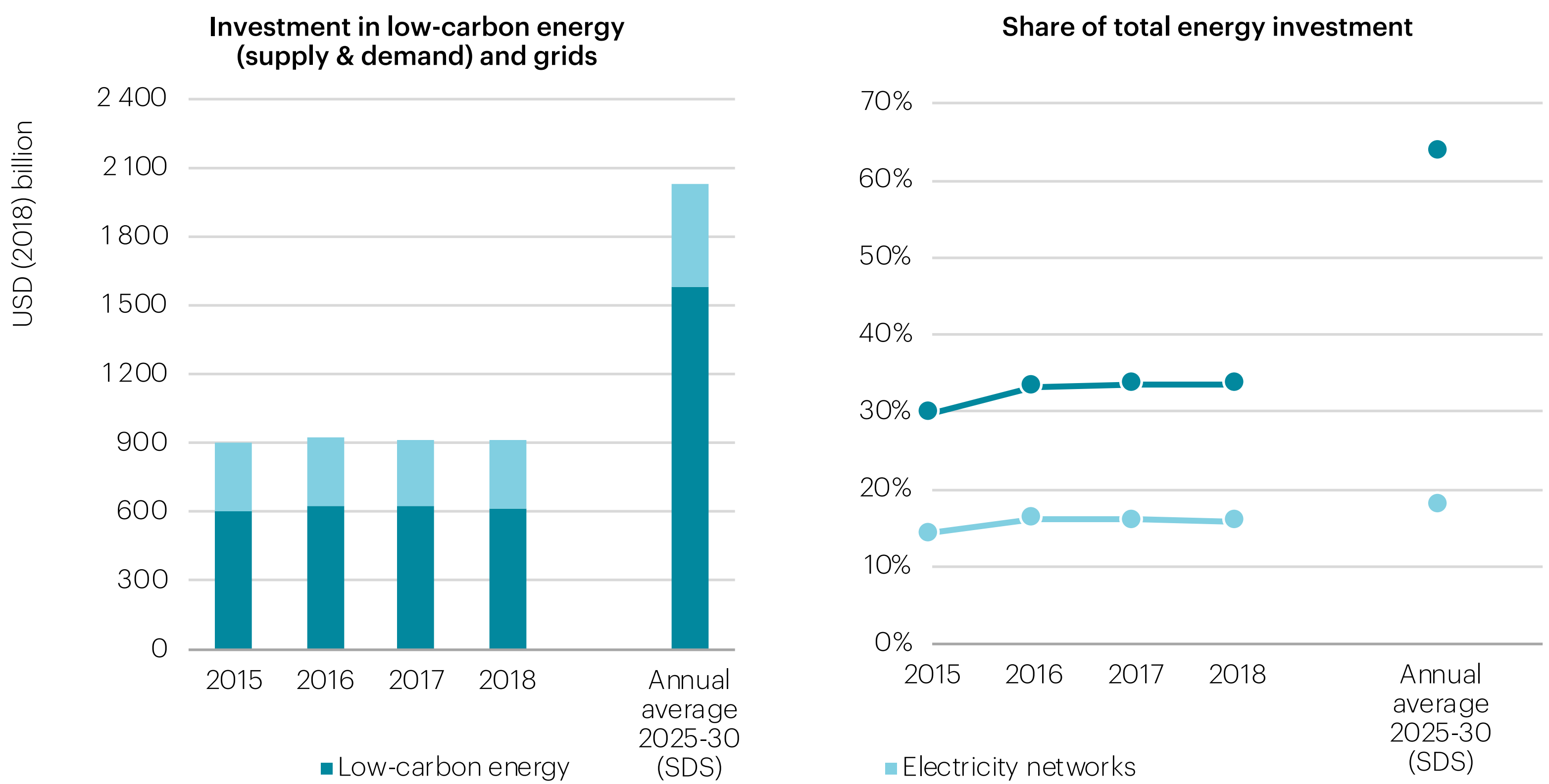
For the power sector, the 2018 investment total is comparable to the projected needs in the NPS but more than one-third lower than required in the SDS.

Both scenarios would require a sizeable reallocation of capital, especially in the accelerated decarbonisation and electrification that marks the SDS, which would require a doubling of renewable power spending, more investment in nuclear and a rising level of spending on electricity networks.

While a shift in spending is required in energy supply, investment needs also rise for demand. Energy efficiency and end-use play increasingly important roles in transport and heat – sectors responsible for over 70% of final energy consumption and over half of global carbon dioxide (CO_2) emissions. The relative lack of policy attention given to these areas points to a broad need for more focus and activity.

Total investment across low-carbon energy – including supply and efficiency – has stalled in recent years and needs a rapid boost to keep Paris in sight

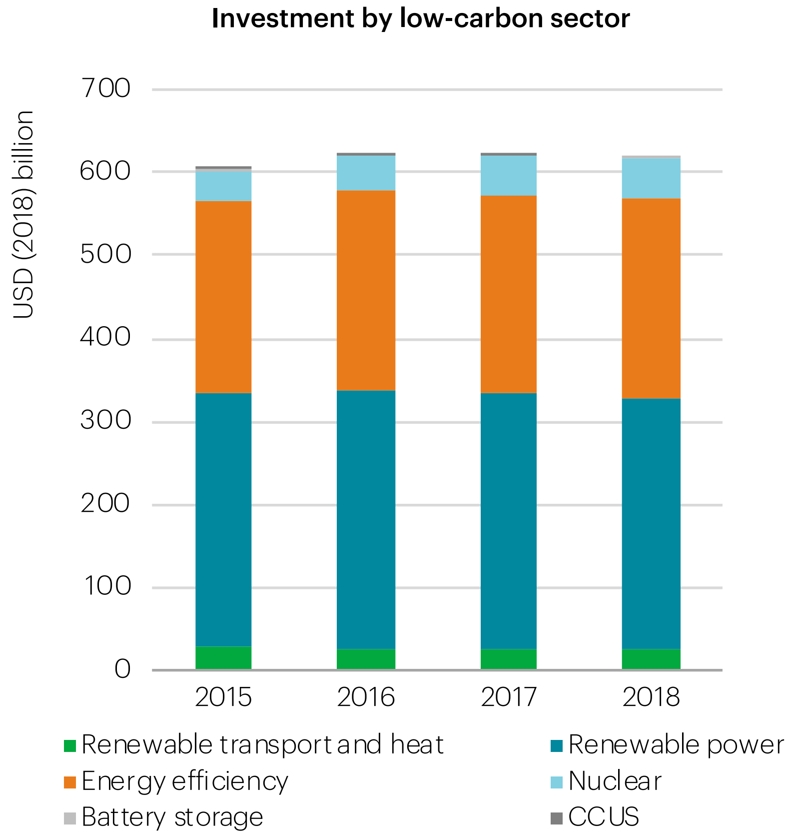
Global investment in low-carbon energy, including efficiency, and electricity networks compared with investment needs (SDS)

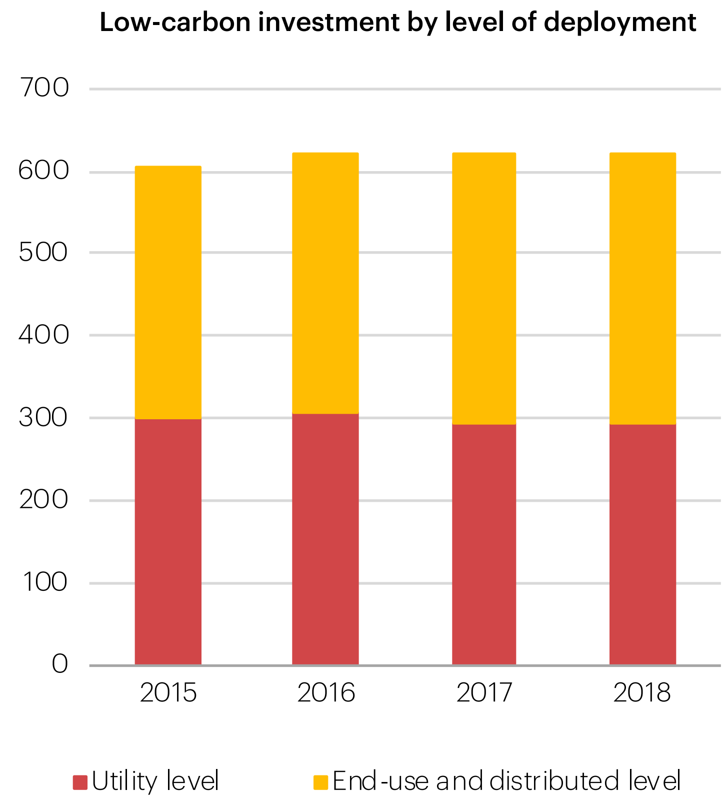


Note: Low-carbon energy investment includes energy efficiency, renewable power, renewables for transport and heat, nuclear, battery storage and carbon capture utilisation and storage. SDS = Sustainable Development Scenario.

The role of efficiency and distributed resources highlight the importance of low-carbon financing solutions at both consumer and bulk power level

Global investment in low-carbon energy by sector and by level of deployment

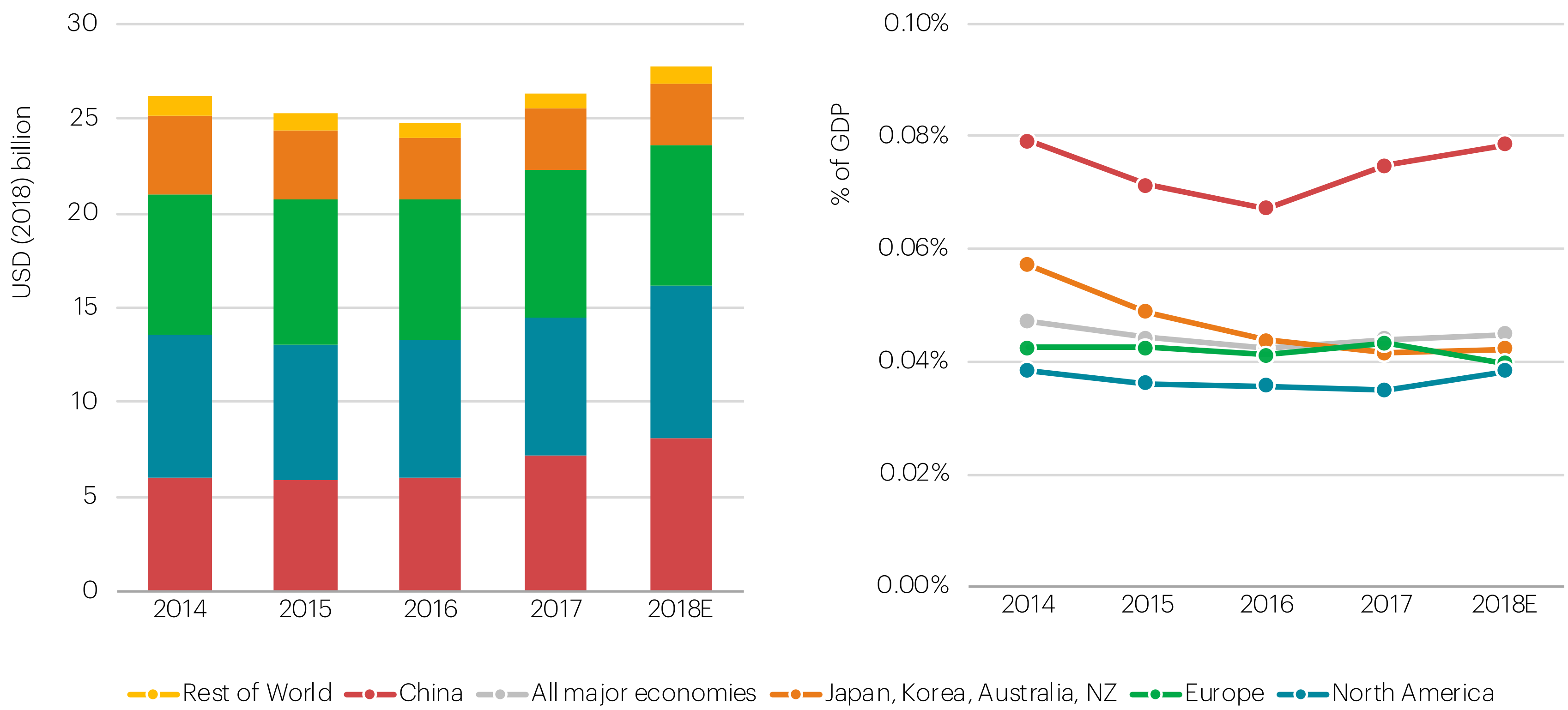




Note: Utility-level assets include plants producing energy for commercial sale. End-user and distributed assets are those typically purchased or deployed at the consumer level. CCUS = carbon capture, usage, and storage.

Government energy RD&D spending is rising, but not keeping up with GDP

Spending on energy RD&D by national governments, with preliminary 2018 data, and as a share of GDP



Note: RD&D = research, development and demonstration, as defined by the IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics, 2011.

A step-change in policy focus, financing solutions and technology progress would be required to get investment onto a sustainable pathway

Investment in low-carbon energy – both in supply and demand – was relatively stable at around USD 620 billion in 2018. Spending growth has stagnated over the past two years, compared with 3% growth in 2016. The share of low-carbon in total energy investment stayed at near 35%. Investment in electricity grids – an enabler for clean energy transitions – has decreased modestly the past two years.

Low-carbon spending in 2018 was marked by unchanged investment in energy efficiency and nuclear, while that for renewable power edged downwards. Battery storage investments grew by almost half, but were the equivalent, in dollar terms, to just over 1% of total grid spending. Spending on renewables for transport and heat declined slightly, with more biofuels investment offset by lower spending on solar heating installations.

Just over half of low-carbon investment was in assets typically purchased or deployed at the end-user level – due to the role of energy efficiency but also distributed energy resources.

This raises a dichotomy in financing energy transitions. Utility-level assets tend to benefit from larger deal sizes and standard structures that attract interest from banks. Investments at end-user level tend to be much smaller and depend on the credit worthiness of consumers and small and medium-sized enterprises, with portfolio aggregation often needed to access larger pools of capital.

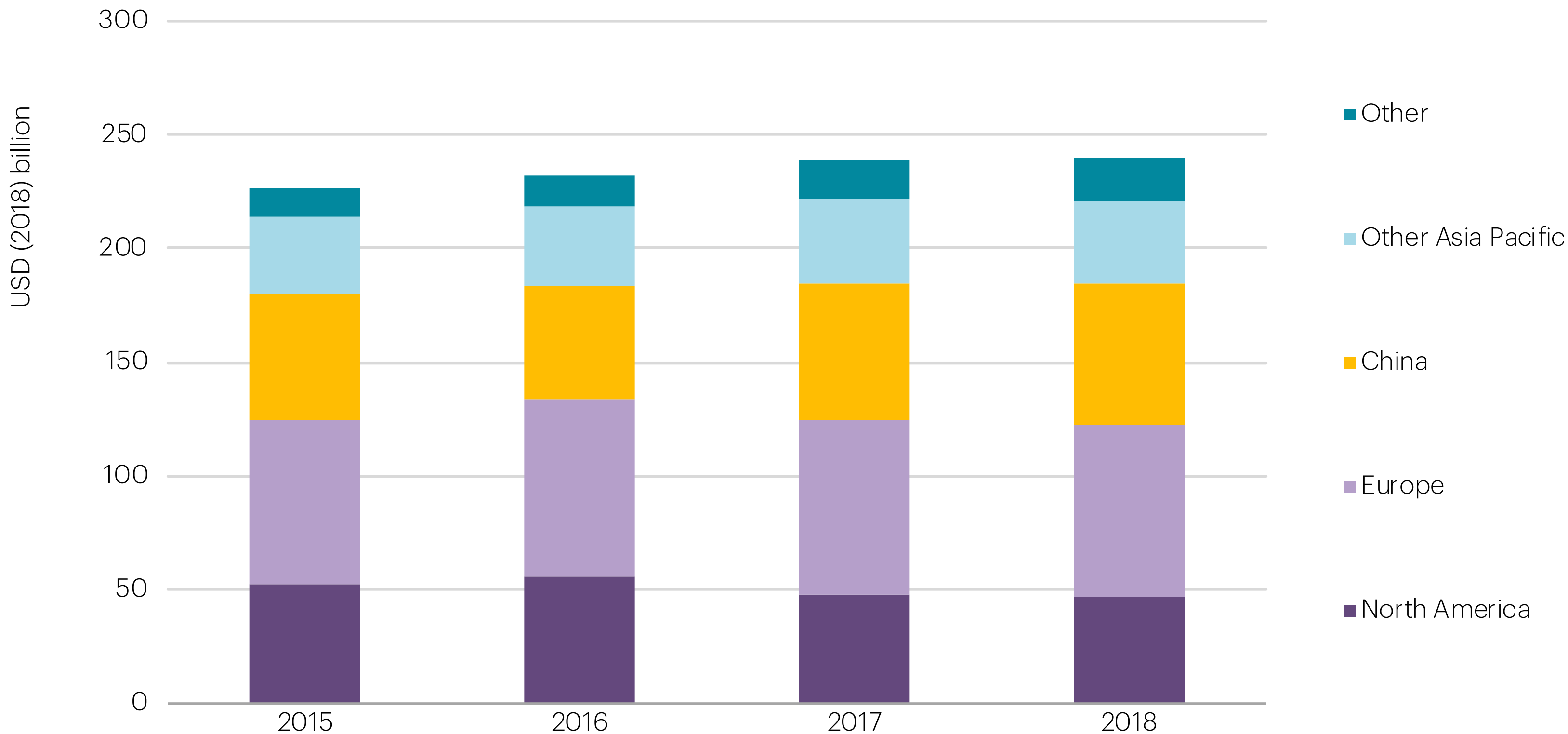
To meet long-term sustainability goals in the SDS, even with changing costs, low-carbon investment would need to grow two-and-a-half times by 2030, with its share rising to 65%. Although the needs in networks are comparatively less, the regulated nature of grids points to a need for sustained policy commitment for appropriate levels of investments that supports growing shares of variable renewables.

Energy end-use and efficiency

Energy efficiency investment

Despite the need for significant increases in energy efficiency investment in the coming years, growth stalled in 2018…

Global investment in energy efficiency by region



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.

...as spending for efficient buildings fell for the first time in four years

A total of USD 240 billion was invested in energy efficiency across the buildings, transport, and industry sectors, the same level as the previous year. This stagnation of energy efficiency investment growth was largely the result of lower spending on energy efficient buildings. Yet energy efficiency investment needs to increase significantly in the near-term to meet global sustainability goals and reduce the overall effort required from energy supply measures.

The buildings sector is still the largest destination of energy efficiency expenditures. However, for the first time since the World Energy Investment started publishing estimates, growth in investment in buildings energy efficiency has faltered. In 2018 it declined by 2% to USD 139 billion.

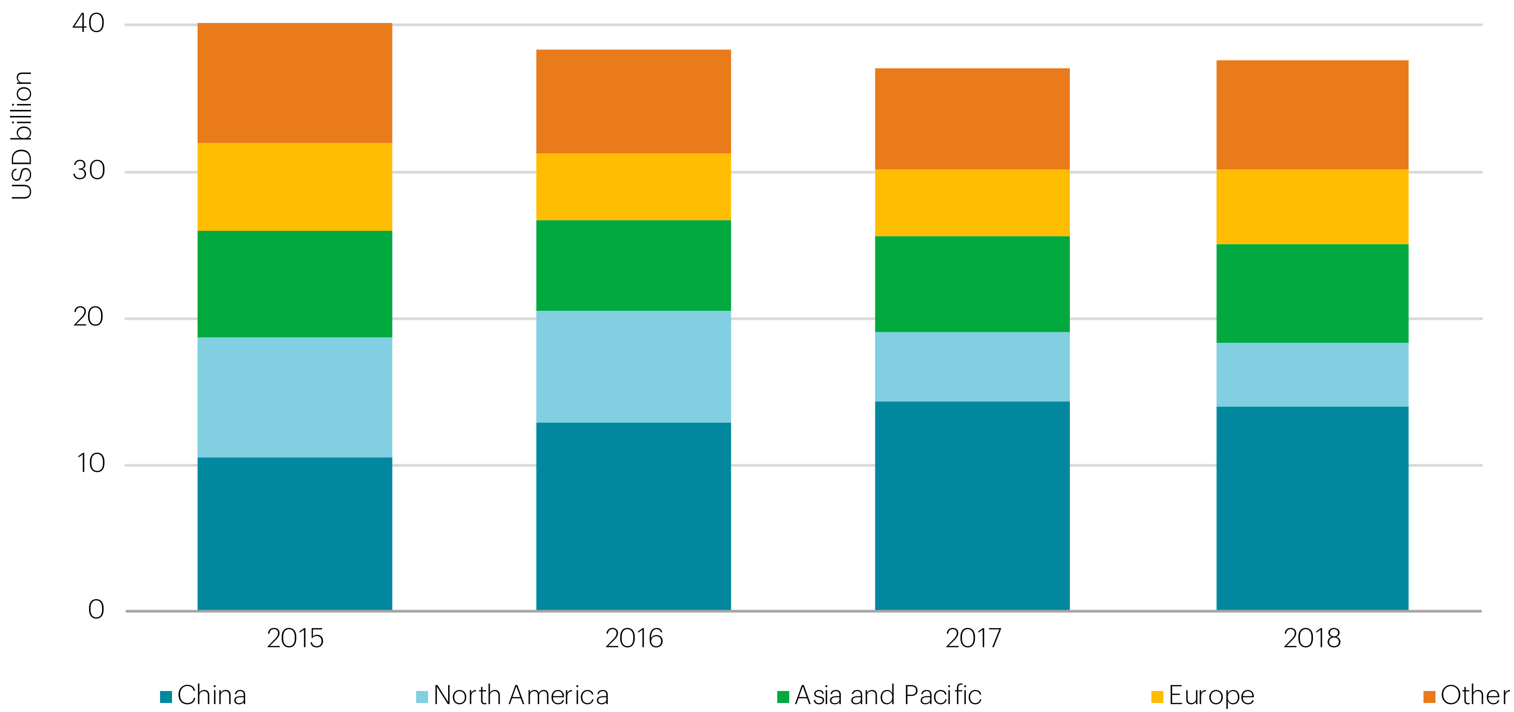
Transport energy efficiency grew modestly between 2017 and 2018, mainly in freight. Global car sales were stable in 2018, with a continued rise in market share by less-efficient light-duty trucks. Heavy-duty vehicle sales rose in Europe, China, and the United States, while new vehicle standards in India (2018) and the European Union (2020) are expected to support more efficiency-related spending.

Due to higher incremental prices of electric vehicles (EV), EV sales growth is having an increasing impact on overall transport efficiency investment. But, as battery prices fall, this price gap is narrowing.

The overall investment trend reflects slower progress for energy efficiency outcomes, with 2018 marking the third consecutive year in which the improvement rate for energy efficiency has slowed. An underlying factor was the static energy efficiency policy environment in 2018, with lacklustre progress on implementing new efficiency policies or increasing the stringency of existing policies.

Investment in industrial energy efficiency remained relatively stable...

Global investment in industrial energy efficiency by region



Note: For the industry sector, the incremental investment includes both an estimate of industry investments in equipment to realise energy intensity gains and investment in energy management systems to unlock system-wide efficiencies.

...as growth in China has offset a continued decline in US spending

Investment in industrial energy efficiency was less than USD 40 billion in 2018. While total investment in industrial energy efficiency has been relatively constant since 2015, the market composition has shifted. The People's Republic of China ("China") represented 37% of the total in 2018, up from a quarter in 2015. North America, which comprised 17% in 2015, was below one tenth of the total in 2018.

This trend reflects the continuing modernisation of the Chinese industrial sector and ongoing efforts to improve energy efficiency, as driven by wide-reaching government mandates. China's active and substantial energy service company (ESCO) industry has also been an important driver, with favourable policies encouraging investment in industrial energy efficiency delivered by ESCOs (see section on Financing and funding trends).

At just over 45%, heavy industry represents a smaller share of global industrial energy efficiency investment than in 2015, when it was nearly half of the total. This largely reflects the continuing slowdown in the construction of new energy-intensive industrial facilities in China, which is the result of ongoing structural change in the Chinese economy, as well as in Europe and North America.

India is an emerging source of industrial energy efficiency investment in the Asia and Pacific region, which grew by nearly 5%. Modernisation of industrial facilities coupled with strong mandatory government policy, through the Perform, Achieve, Trade (PAT) Scheme, are important factors driving greater levels of investment.

In the buildings sector, energy efficiency investment is falling far short of the significant growth needed to meet sustainability goals

Global investment in energy efficient buildings dipped by 2% to under USD 140 billion in 2018. Even as China and the United States remained relatively stable, spending has decreased in Europe, particularly in Germany.

Europe's decline in investment stemmed largely from a significant reduction of government support for energy efficiency measures compared with 2017. In France and the United Kingdom, two of the larger European markets for energy efficiency, investment remained stagnant, while in Germany it fell. While the government budget for grants and loans to energy efficient home construction and renovation was revised down in 2018, it remains a key driver of the large energy efficient building market in Germany.

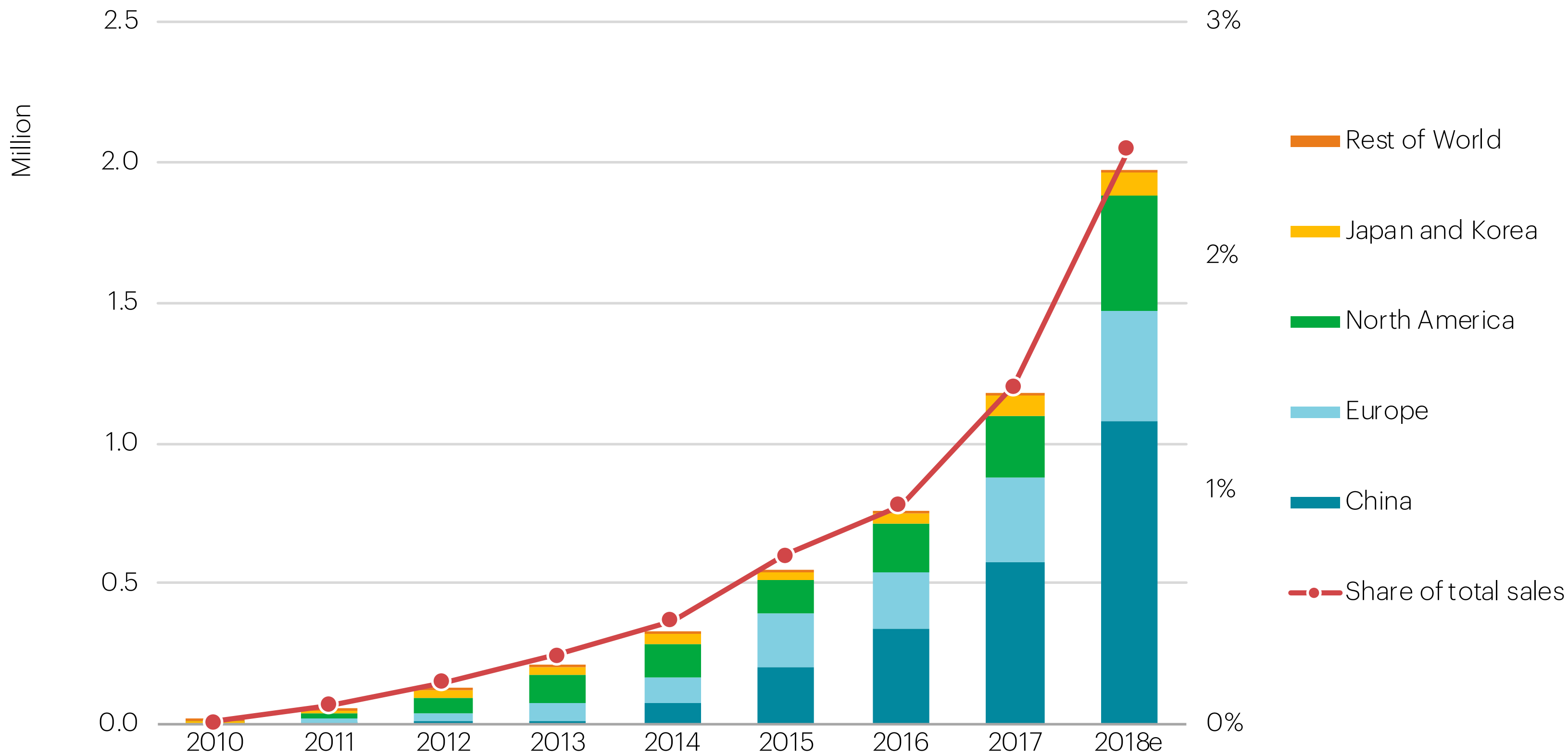
In China, efficiency investment has increasingly tracked the total investment in real estate, as efficiency standards have tightened in recent years. Real estate investment has risen by around 6% per year on average since 2015 to over USD 1.8 trillion in 2018. During this period, residential construction has increased, while non-residential buildings investment has declined. As a result, buildings efficiency spending has risen 33% since 2015 to around USD 27 billion in 2018, though the level remained stable from 2017.

In the United States, total incremental spending on buildings energy efficiency has been broadly unchanged in recent years. Overall investment in construction, however, has risen in the residential and non-residential sectors, with an average nominal growth of 3.8% since 2015, reaching USD 1.4 trillion. Therefore, the share of total construction investment that is dedicated to reducing energy use in buildings in the United States is in decline, and currently stands at just 2%.

Trends in end-use markets

Electric car sales continued to soar, with nearly 70% growth in 2018…

Electric passenger light duty vehicle sales and market share, from the forthcoming IEA Global Electric Vehicle Outlook



Note: Includes passenger cars and passenger light trucks. Includes plug-in hybrids, battery electric vehicles and fuel cell electric vehicles. Share of total sales represents the total sales of electric vehicles in countries listed in IEA Global Electric Vehicle Outlook as a percentage of total passenger car sales in those same countries.

Source: (IEA 2019b, forthcoming).

…China's sales more than doubled, taking the global total to almost 2 million

Global electric passenger car sales reached almost 2 million vehicles in 2018, a nearly 70% increase compared to 2017 and the strongest rate of growth since 2013. The stock stood at more than 5 million at the end of 2018 (details will be available in the forthcoming IEA Global EV Outlook 2019).

China, the world's largest electric car market by far, drove the overall trend. Over 1.1 million electric cars were sold in 2018, similar to the total number of all cars sold in Mexico that year, and comfortably surpassing all the new cars registered in Africa. While electric car sales increased, overall passenger vehicle sales in China declined in 2018.

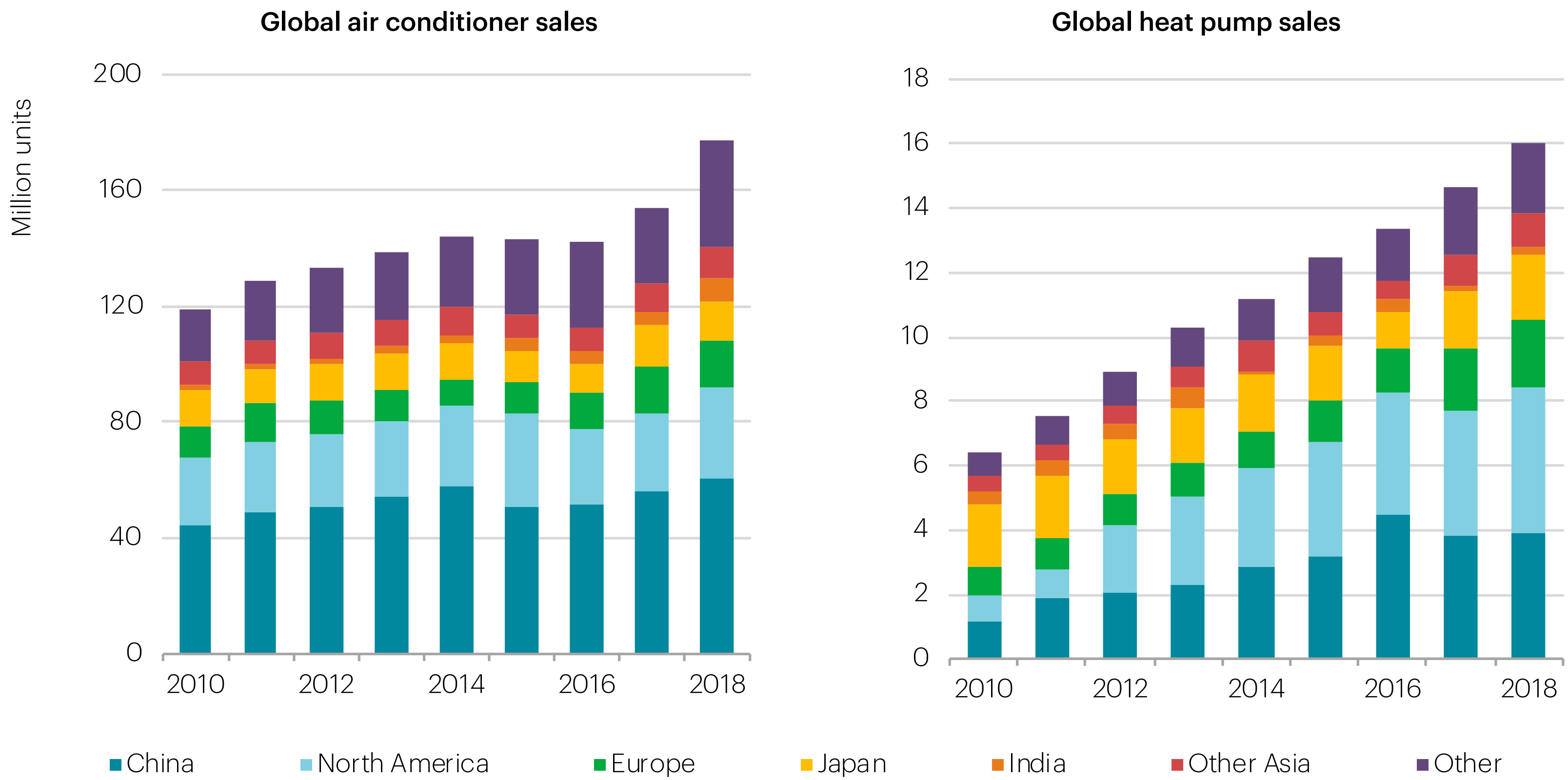
Europe and the United States were the second- and third-largest electric car markets, with sales of 385 000 and 360 000 units, respectively. In Europe, Norway remains the global leader in terms of electric car sales penetration, approaching 50% in 2018, more than 2.5 times as high as the next highest country, Iceland. Norway was also the leader in terms of sales volumes, followed by Germany, the United Kingdom and France.

Sales in the United States rose faster than the rate of the global market, a big increase compared to just 24% growth the year before. This was spurred by the release of the Tesla Model 3, of which 134 000 were registered in 2018. Japan is the only major electric car market where sales decreased.

With 26 million new units in China in 2018, electric two- and three-wheelers still outsell electric cars by more than ten times. Around 92 000 electric buses were added to the global fleet in 2018. Globally, electric cars and buses sold in 2018 are expected to offset 0.1 million barrels per day (mb/d) of transport oil demand growth. Electricity demand from electric vehicles (incl. two- and three-wheelers) sold in 2018 is estimated to be around 12 TWh per year, 1% of 2018 global power demand growth.

Air conditioner sales grew 16% in 2018 to their highest ever level...

Global sales of electrical equipment for building cooling and heating



Note: Heat pump sales are those for primary use in heating, and include air-to-air and air-to-water heat pumps

Source: IEA analysis with calculations partly based on BSRIA (2018) and company and industry association disclosures.

...while Europe and North America sustained the growth in heat pump sales

Global air conditioner sales grew by their largest annual increase, with 16% growth to over 175 million units in 2018. Annual variations in sales are linked to weather patterns and the exceptional growth in 2018 was driven in part by extreme weather and prolonged heat waves.

Much of the growth in air conditioner sales was led by India, North America (especially Mexico), Brazil, the Middle East, and China. China's market remains the world's largest and is not yet saturated.

Rising demand for space cooling is already putting enormous strain on electricity systems in many countries, as well as driving up emissions. Space cooling can represent as much as 50% or more of peak electricity demand on hot days in regions with high air conditioning demand. CO_2 emissions from cooling have tripled since 1990 to 1.1 billion tonnes, equivalent to the total emissions of Japan.

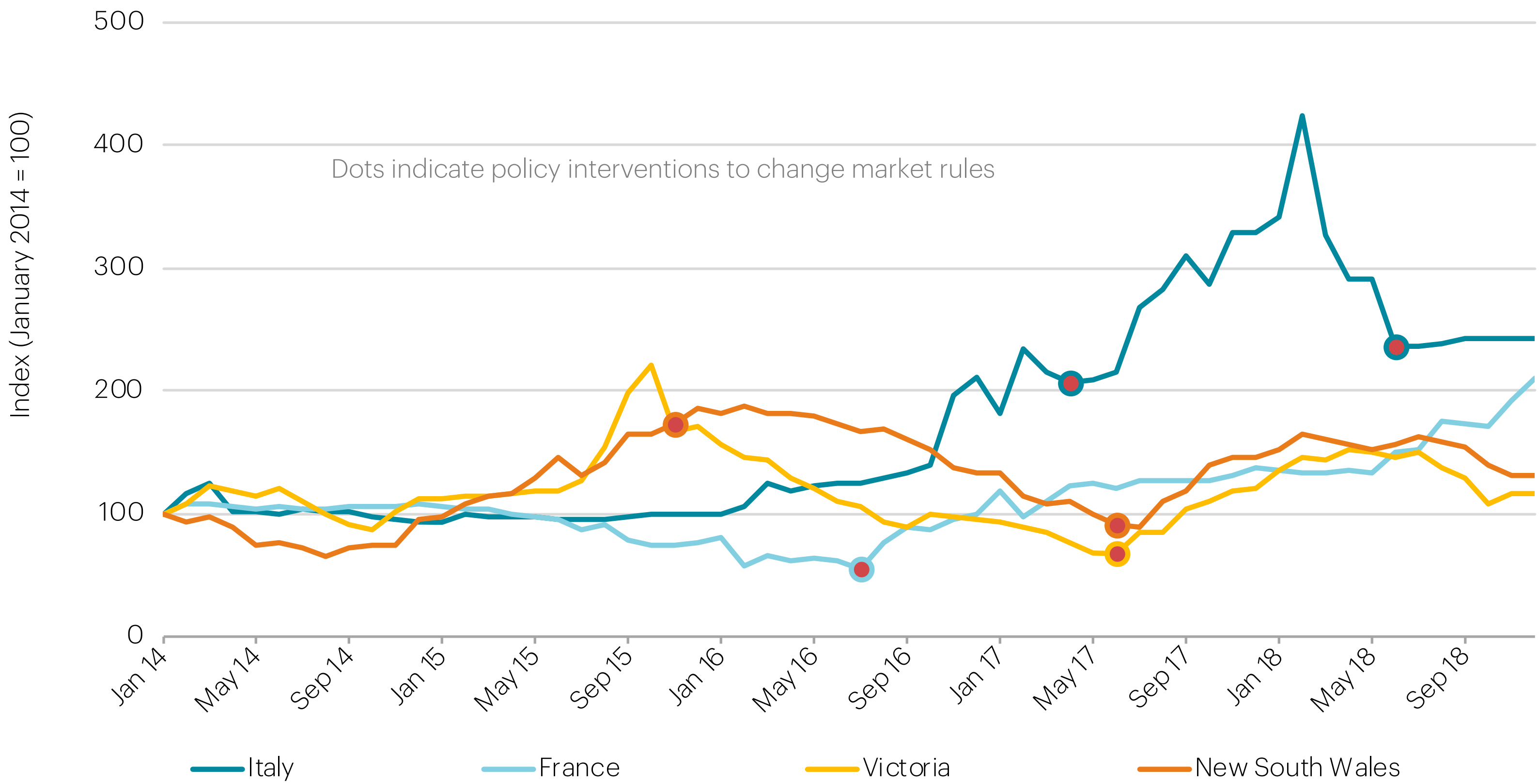
There is huge scope to reduce the gap between the most energy efficient air conditioners on the market and the market average, which is often only half as efficient. Improved regulations and more efficient supply chains could reduce cooling energy consumption by as much as three to five times.

Heat pump sales remain an order of magnitude smaller than air conditioner sales, but maintained nearly 10% annual growth. This was despite a slowdown in China as policy incentives waned. North America became the largest heat pump market again. Overall, heat pumps comprise around 2.5% of the sales of global building heating equipment, but this share is growing.

Since 2016, growth in heat pump sales has been pushed by Europe and Japan. European sales have been boosted by market incentives, including the eligibility of heat pumps to count towards EU renewable energy targets.

Prices stayed volatile in energy efficiency certificate markets in 2018...

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



Note: France data is 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.

Source: IEA analysis with calculations based on EMMY (2019); GME (2019);TFS Green Australia (2018).

…as policy and rule changes continue to shape price trends

Trends in the price of white certificates were mixed across global markets, affecting the returns from eligible energy efficiency projects. White certificates allow energy savings from efficiency projects to be traded in European and Australian markets by obligated parties, generally final energy suppliers, such as electricity and gas retailers. They have been in operation for just over ten years, and policy makers are continuing to learn how to make them more effective.

White certificate prices remain volatile, largely due to policy interventions that change market rules and raise or lower prices. Policy makers intervene in the markets to stop price declines and encourage investment in different project types, for example those with higher social value, or to limit the costs to consumers. One reason behind the periods of low or declining prices is the banking of certificates from low-hanging fruit projects, such as lighting, between trading periods to reduce future liability.

The Italian white certificate market has been through a period of high volatility, which ended in 2018 after the introduction of a price cap in response to a high price peak following a tightening of the project eligibility criteria. Demand for eligible projects and certificates remains strong, with prices not falling below the cap following its introduction.

In the two Australian markets of Victoria and New South Wales, prices in 2018 rose after changes to the relative value of lighting projects prompted clamour for existing certificates, but then fell back.

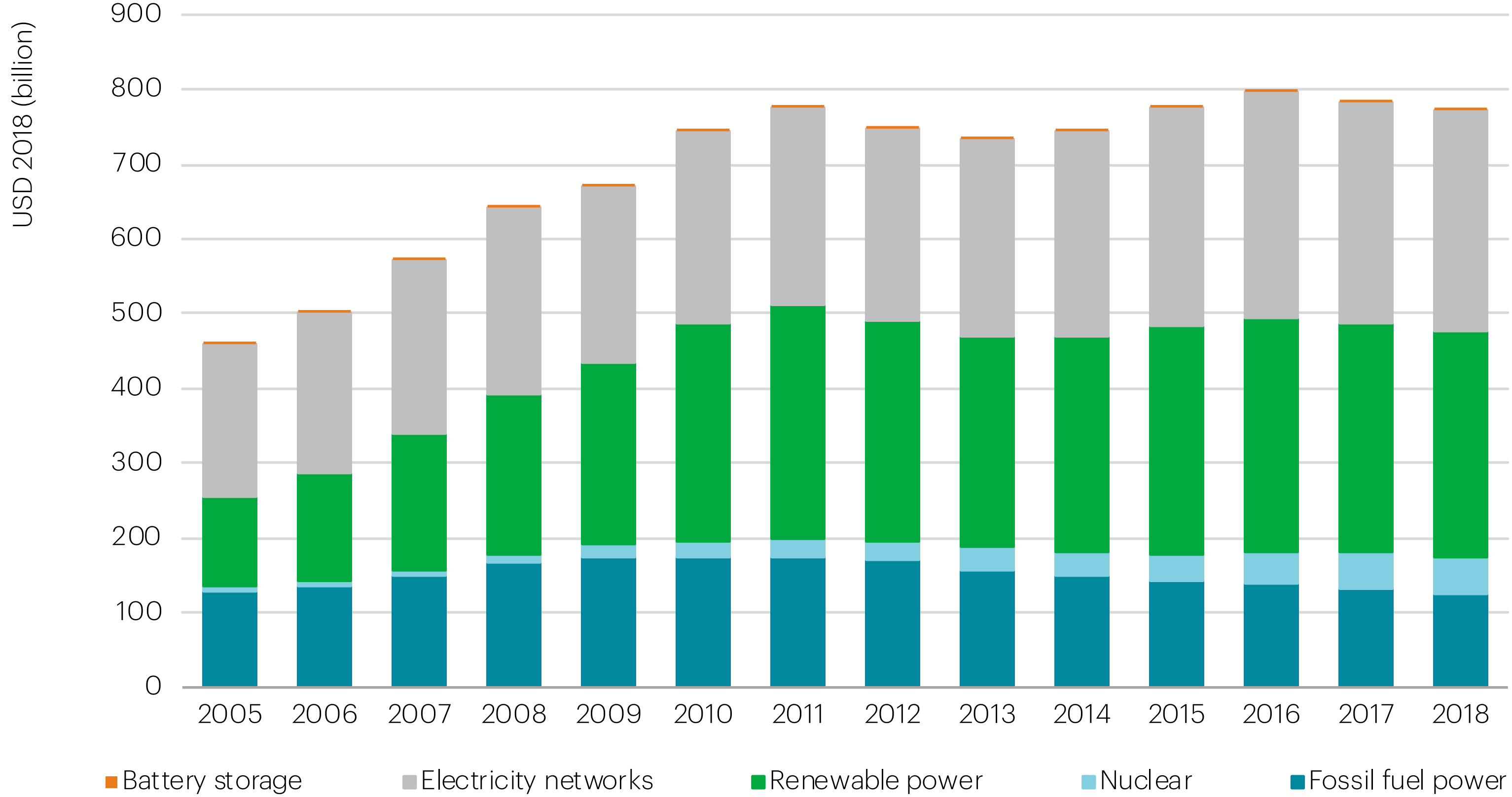
In France, company targets have been increased, and prices for classic certificates have risen faster than those dedicated to fuel poverty projects. Year-on-year price rises can indicate that these markets are moving up the cost curve of efficiency projects, improving returns for eligible projects.

Power sector

Overview of power investment trends

Global electricity investment declined by 1% in 2018…

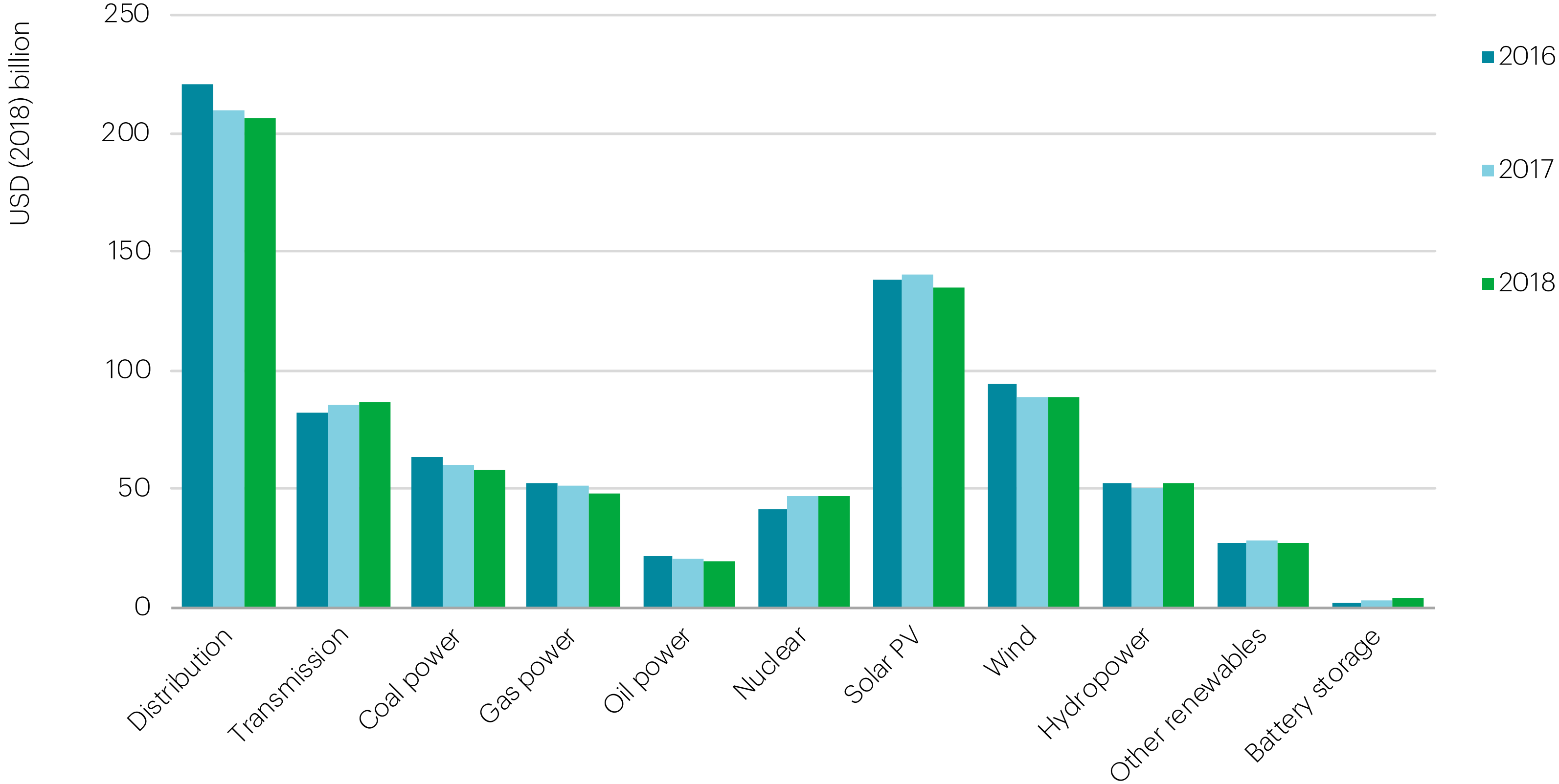
Global investment in the power sector by technology



Note: Investment is measured as the ongoing capital spending in power capacity. The scope and methodology for tracking energy investments is found in the Annex of this report as well as at iea.org/media/publications/wei/WEI2019-Methodology-Annex.pdf.

…due to lower capital spending on coal and gas power, solar PV and distribution

Global investment in the power sector by technology

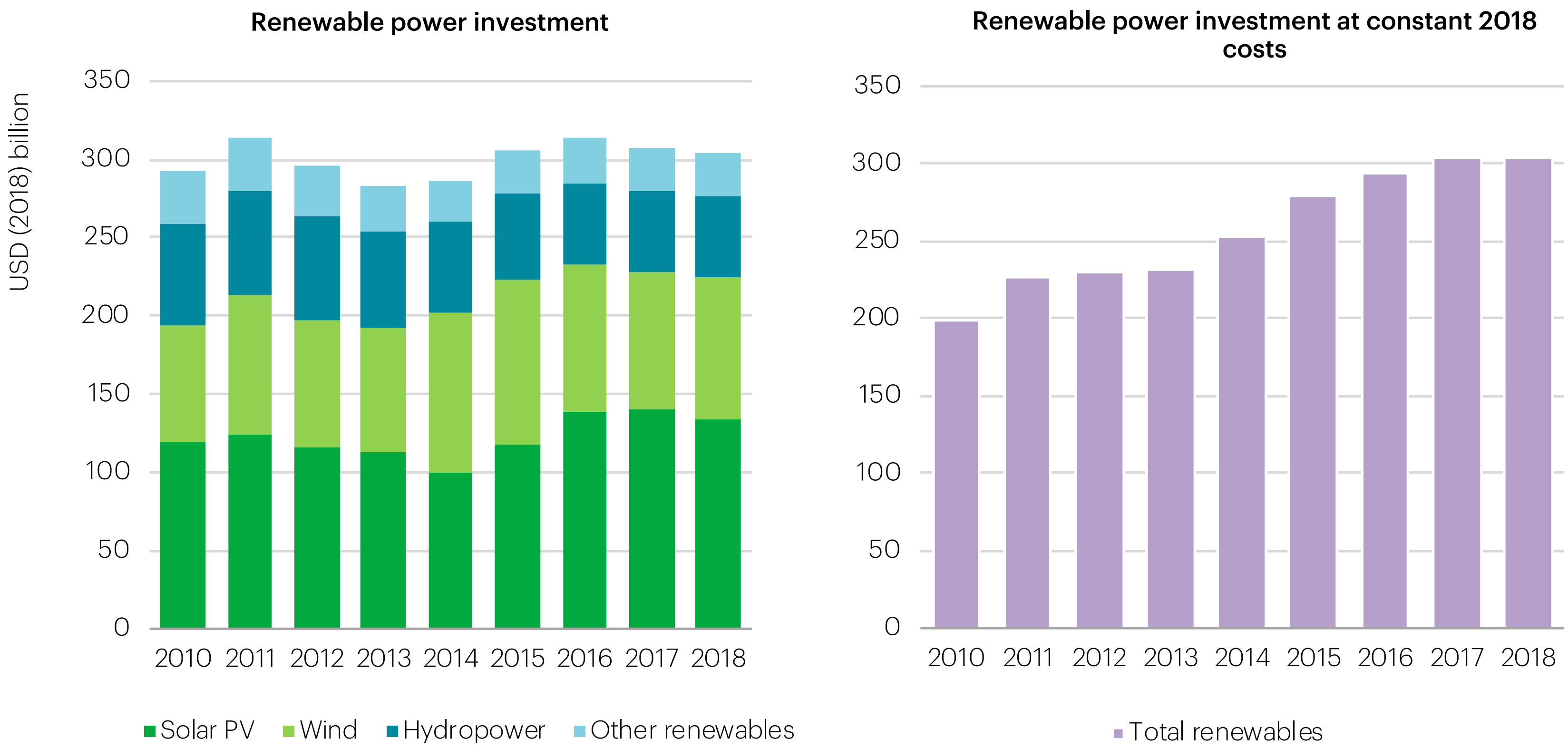


Note: Gas and oil-fired generation investment includes utility-scale plants as well as small-scale generating sets and engines. Hydropower includes pumped hydro storage.

Source: IEA analysis with calculations for solar PV, wind and hydropower based on costs from IRENA (2019).

Total renewable power spending has been relatively stable over time but, after adjusting for cost declines, investment activity is up by 55% since 2010

Investment in renewable power – actual spending vs investment at constant 2018 cost levels



Source: IEA analysis with calculations for solar PV, wind, and hydropower based on costs from IRENA (2019).

Overall, despite a recent dip spending on low-carbon power and grids…

Global power sector investment dipped by 1% to just over USD 775 billion in 2018, with lower capital spending on generation. Investment in electricity networks edged down, although investment in battery storage surged by 45% from a relatively low base.

Investment in coal-fired power declined by nearly 3% to its lowest level since 2004, mainly due to lower spending in China and India. Final investment decisions (FIDs) for new plants declined to their lowest level this century and retirements were at near record levels. Nevertheless, the global coal power fleet continued to grow, due to net additions in developing Asian countries (see below).

After rising to a decade high in 2012, gas-fired power spending slowed, notably in the Middle East and North Africa (MENA) region and in the United States, where a large pipeline of projects has been realised in recent years. Gas power spending in Europe remained near its lowest level this century.

Renewables-based power investment edged down by 1%, as net additions to capacity were flat and costs fell in some technologies, but spending was also supported by plants under development. Despite a generally stable profile for overall investment, a dollar of renewables spending continues to buy more capacity than in the past. Adjusting the time series to 2018 cost levels shows a rising trend over time, with renewables investment activity up by 55% since 2010.

On a cost-adjusted basis, investment activity increases were strongest in solar PV and wind, benefitting from falling costs and higher deployment, particularly versus five years ago, though this trend paused in 2018. The difference in spending and cost-adjusted investment was less evident in hydropower, where additions have slowed and a greater part of development has been in higher cost areas.

...their combined share rose to nearly 85% of power sector spending

Solar PV spending fell by around 4%, while wind investment remained flat. The dip in solar PV was a contributor to the downward movement in renewables investment, largely due to policy changes in China, where the government is seeking to promote more cost-effective and system-friendly investment. Outside of China, renewables spending in the rest of the world grew by almost 5%.

In India, solar PV spending exceeded that for coal power for the first time, supported by government auctions. In the United States, solar PV and wind investment rose almost 15%, supported by corporate procurement, which comprised nearly a quarter of spending (see Financing and funding trends). Offshore plants were one-fifth of wind spending - FIDs in Europe rose to the second-highest level ever.

Nuclear power investment edged up as new grid-connected plants in 2018 grew threefold, 80% of them in China. Construction starts rose to 6 GW none of which were in China, but were much lower than capacity additions. Spending on the long-term operation of existing plants was 13% of the total.

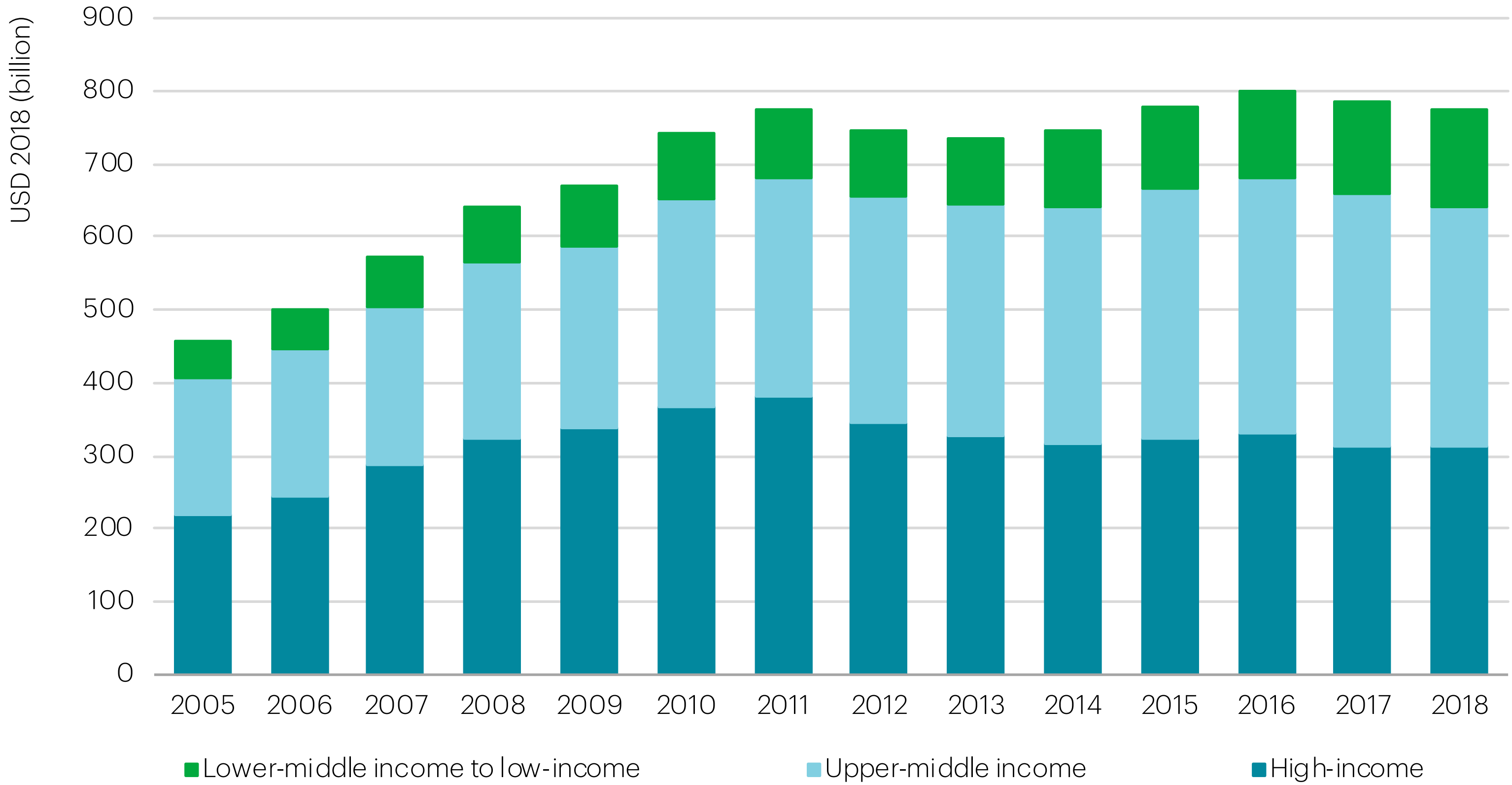
Electricity grids spending dipped by 1% from less investment in distribution, although that for transmission continued to rise. US investment grew strongly while China's dipped. Grid investment in both India and Europe rose by around 5%.

Investment in battery storage rose by 45% to a record of over USD 4 billion in 2018, driven by strong increases in both grid-scale and behind-the-meter batteries, which were the majority of installations.

Overall, low-carbon power generation (renewables and nuclear) comprised nearly three-quarters of generation spending. The share of low-carbon generation plus networks and storage, key enablers for power system flexibility, reached nearly 85% total power spending.

Power investment is shifting towards emerging & developing economies…

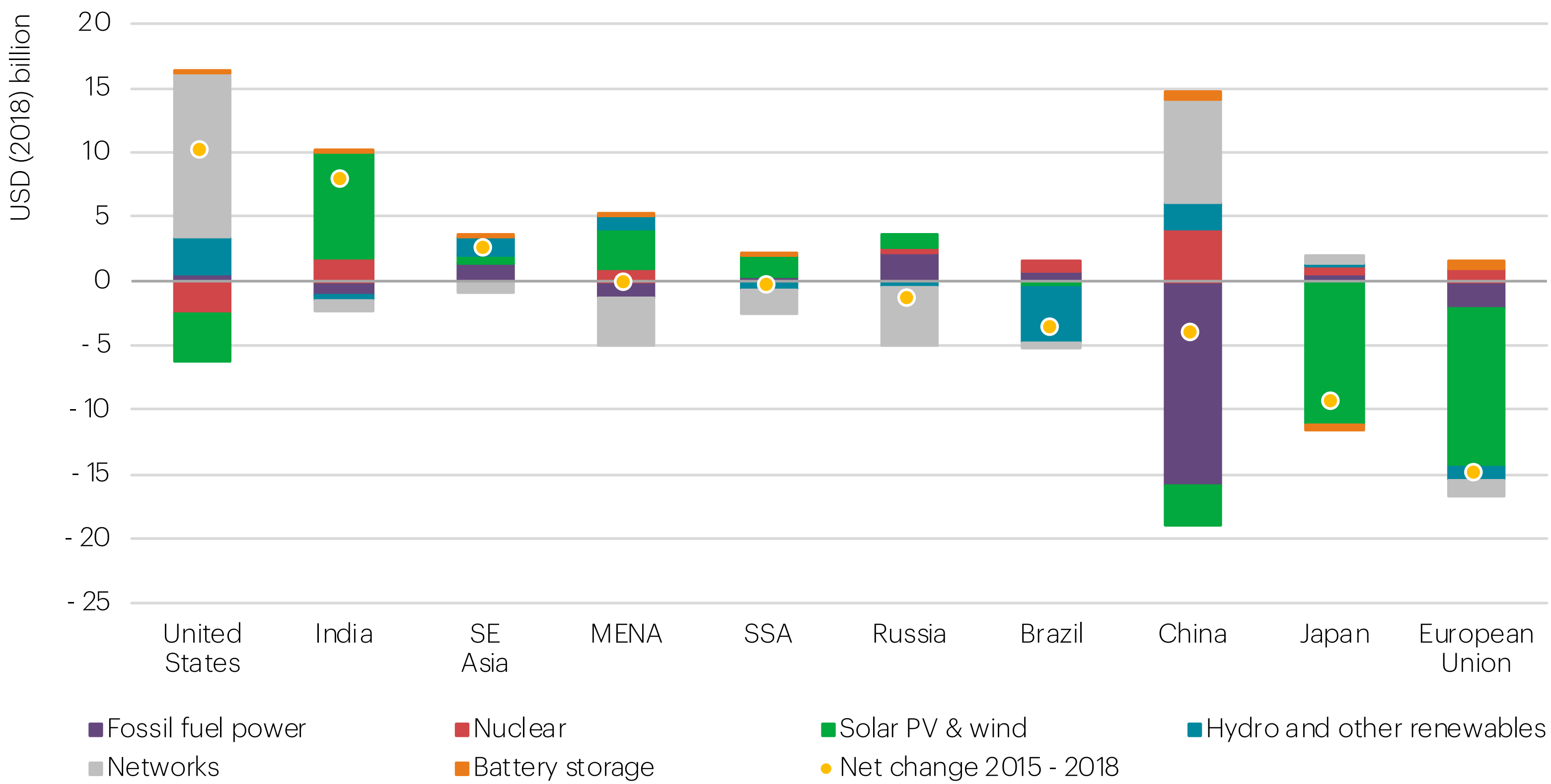
Global investment in the power sector by region, classified by current income level



Note: Income categories are defined on the basis of gross national income/capita (current USD) thresholds by region, as of 2018, from World Bank (2019).

...however, the United States saw the largest growth in the past three years

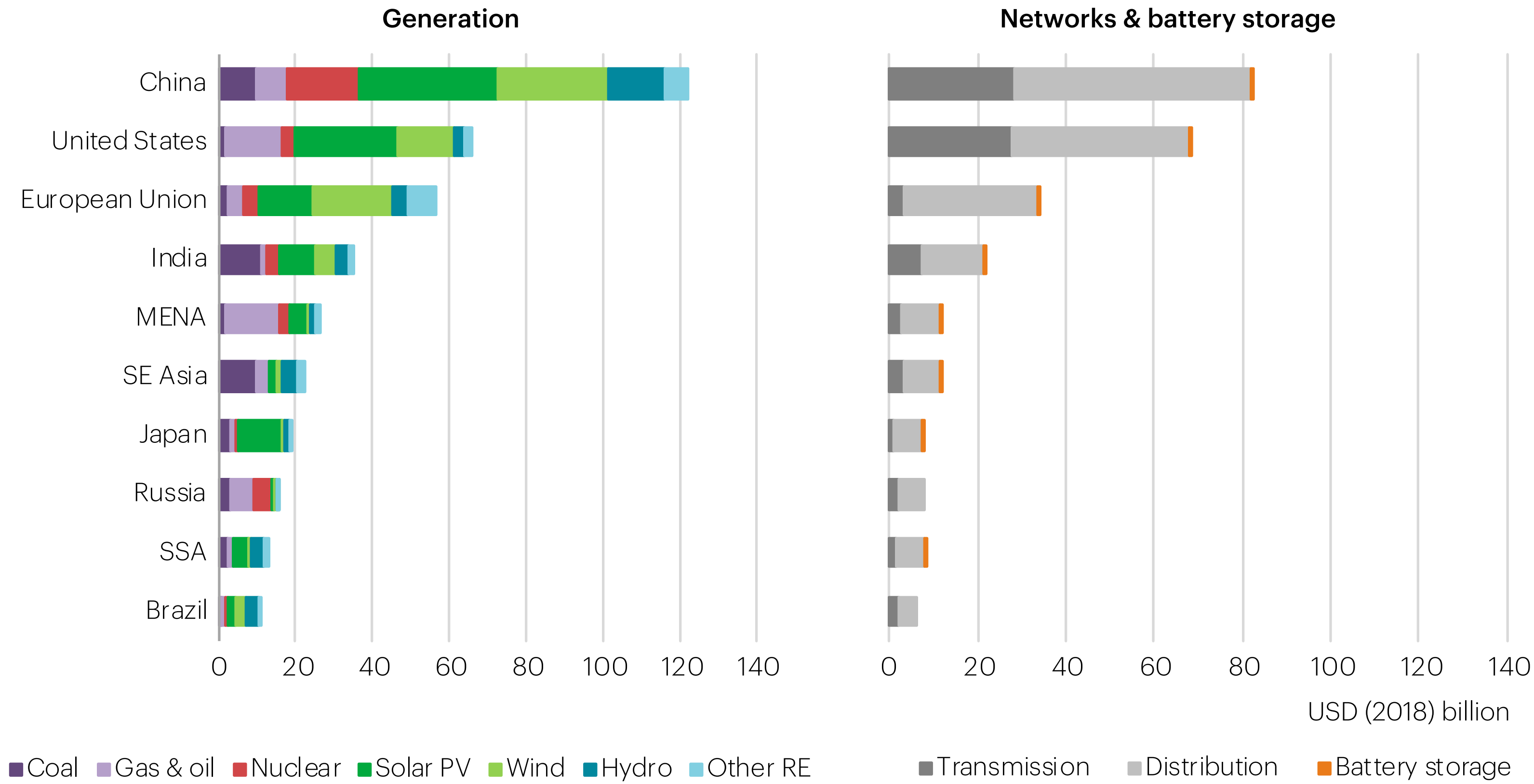
Change in power sector investment in major countries and regions, 2015-18



Note: MENA = Middle East and North Africa; SSA = sub-Saharan Africa; other renewables = bioenergy, geothermal, solar thermal electricity, and marine.

In 2018, China remained by far the largest market for power investment

Power sector investment by major countries and regions, 2018



Note: MENA = Middle East and North Africa; SSA = sub-Saharan Africa; other RE = other renewables (bioenergy, geothermal, solar thermal electricity, and marine).

In most regions, low-carbon sources were the largest part of generation spending...

In 2018, upper-middle-income countries – with over 40% of the world population (including China and much of Southeast Asia and Latin America) – comprised nearly 45% of power investment, a share that has been stable over the past five years. Lower-income markets – also 40% of the population – saw their share rise to over 17%, largely due to India. Power investment has fallen slightly in high-income countries since 2016.

Asia has accounted for nearly three-quarters of the growth in power sector investment over the last decade, with China alone accounting for nearly half. Over 2015-18, however, the United States registered the largest growth in power sector investment, mainly due to higher spending on the grid.

Although China continues to account for more than a quarter of the total, its power investment declined by 7% in 2018, the first fall this century, largely due to a continued reduction in spending on coal power, but also from lower solar PV and grid investment. The fastest growing power investment markets in the world, on a percentage basis, were Australia, Mexico, India, and the United States.

In the United States, power investment rose by 7% in 2018. Gas-power investment fell from near five-year highs while renewables (two-thirds of generation spending) jumped 16%, with deployment driven by falling costs in solar PV and wind, the availability of federal tax credits, state portfolio standards, and corporate procurement. Grid investment increased by 8% in support of reliability and resilience goals.

Power investment in the European Union declined by 4% in 2018, and Europe is investing almost half than it did in 2010. Its share of global power investment has halved to around 15%, though this partly stems from spending on relatively higher-cost renewables in the early part of the decade.

…while fossil fuel power investment played a bigger role in the MENA region, and Southeast Asia

Renewables in Europe accounted for three-quarters of generation investment in 2018, even as spending fell to its lowest level since 2007. Investment in wind power projects in Europe declined but remained the largest source, and offshore wind projects accounted for around half of wind investment. In Europe, there is increased interest from industry in financial risk management strategies for renewables, amid changing policies and increasing roles for sources of remuneration outside of government schemes (see section on Financing and funding trends).

In India, total renewable power investment topped fossil fuel-based power for the third year in a row, supported by tendering and uncertain financial prospects for new coal power. Grid investment rose by 4%, with one-fifth increase in transmission, but spending in distribution remained flat.

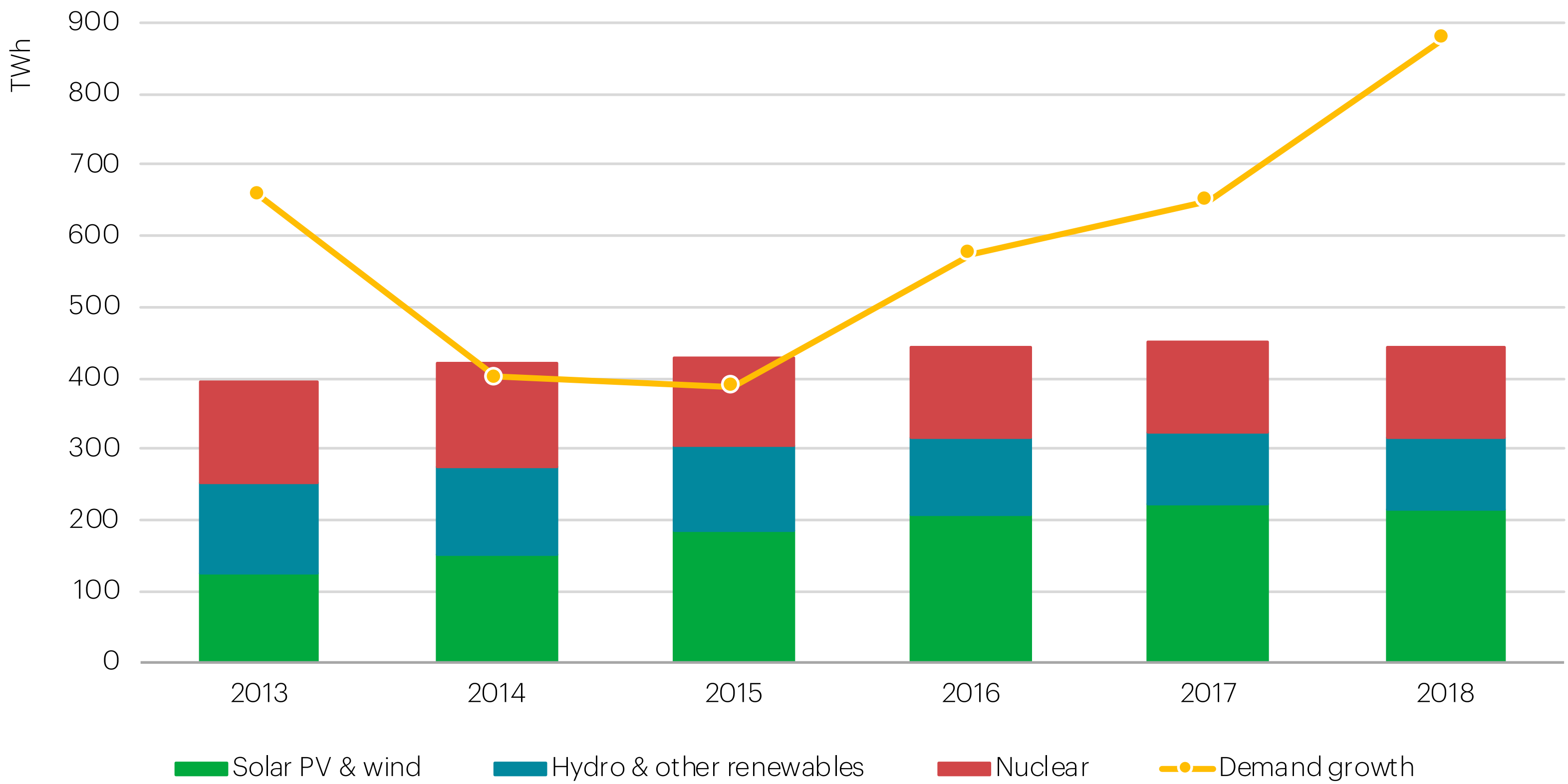
The MENA region and Southeast Asia were the two main areas where investment in fossil fuel power was higher than renewables. But the growth rates differ starkly – in the past five years, MENA power sector investment has risen by nearly 40%, while in Southeast Asia it has remained around the same level, in part due to risks related to grid development, financial performance of incumbent utilities and the poor bankability of renewables projects in markets such as Indonesia and Vietnam.

In sub-Saharan Africa, power investment grew 8% in 2018, though has grown over 80% since 2010. This growth has all come from generation, over 65% of which was in renewables. Spending on grids – critical for electrifying a large part of the population without access and connecting new generation – has stagnated. In many countries, investment is hampered by weak regulatory frameworks, lengthy project timelines, persistent financial strains on utilities and limited public finance.

Implications of power investment

Despite recent progress, the expected output from low-carbon power investments is not keeping pace with demand growth

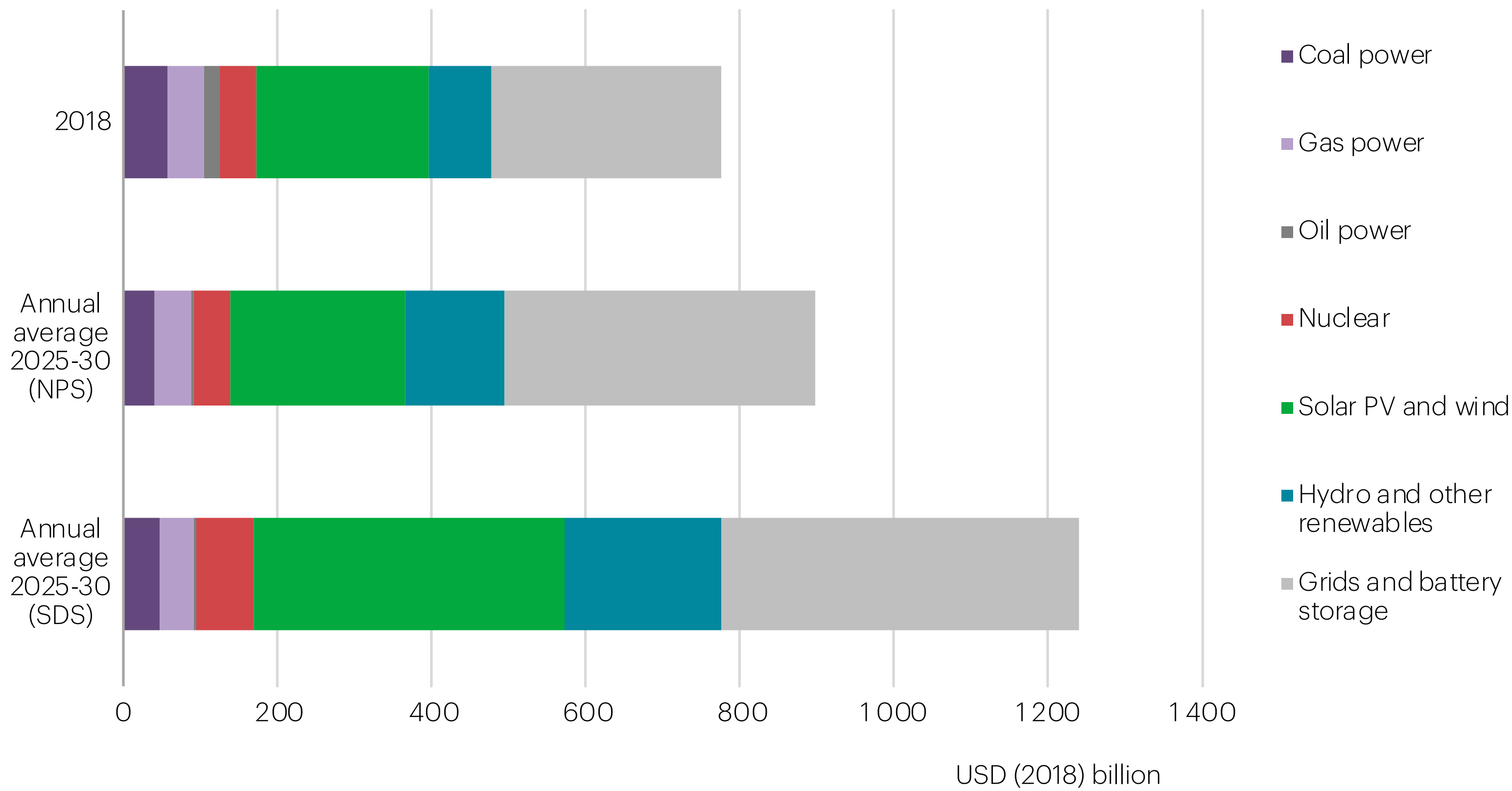
Expected generation from low-carbon power investments compared to electricity demand growth



Note: Expected generation is based on the expected annualised output of the capacity associated with investment in a given year. TWh = terawatt hour. NPS = New Policies Scenario; SDS = Sustainable Development Scenario.

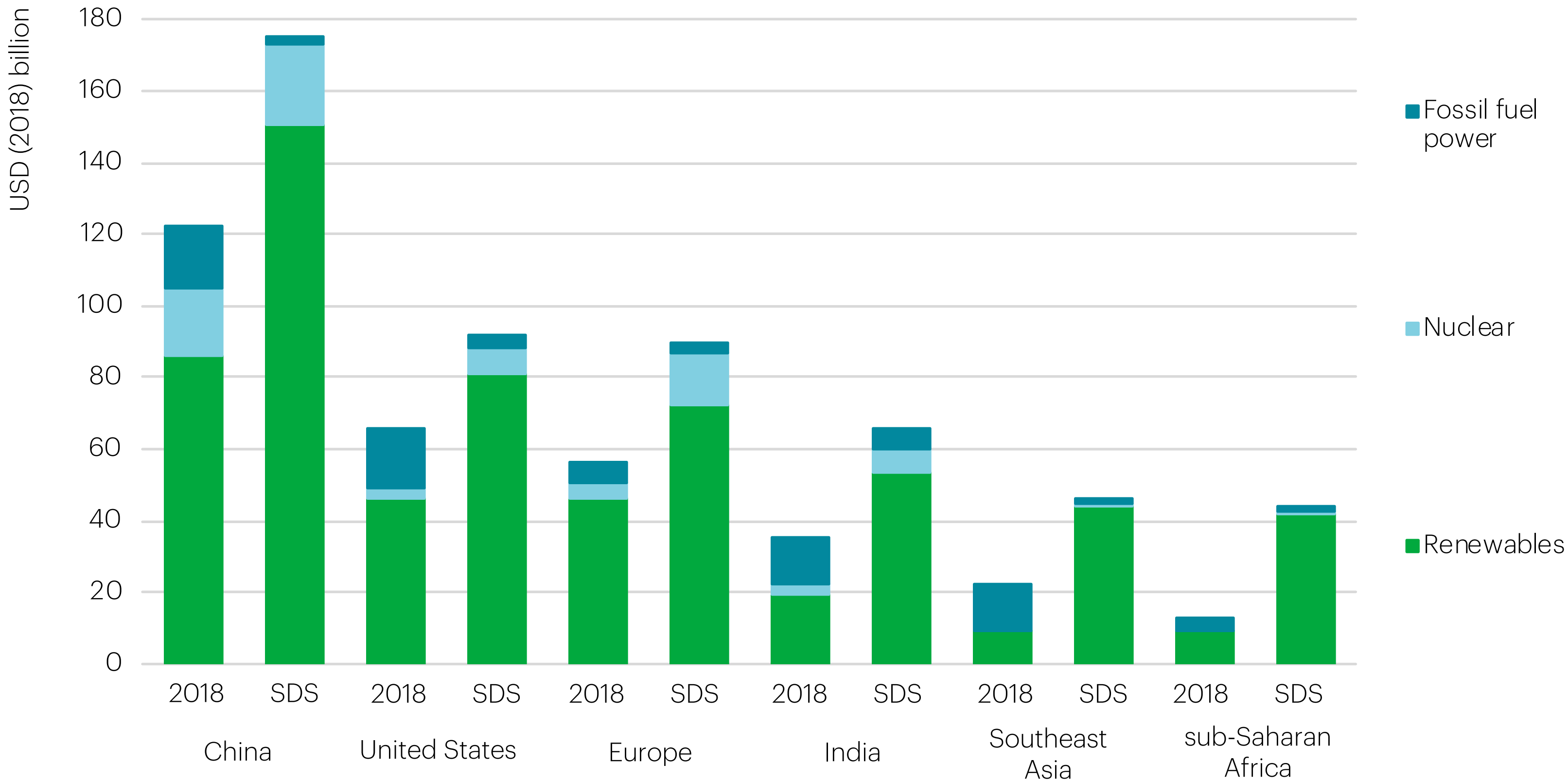
Power investment in 2018 was lower than projected annual spending in the IEA scenarios

Global investment in the power sector by technology compared with investment needs in IEA scenarios



Across all regions, a boost in generation spending would be needed to support energy transitions, particularly in low-carbon sources

Power generation investment by region compared with annual investment needed in the SDS (2025-30)



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

Overall, current investment in power is poorly aligned with future needs and challenges

Power investment was almost 15% below the average annual needs for 2025-30 as projected in the NPS but over 35% less than the annual needs in the SDS. The 2018 data suggest a continued need for capital reallocation to meet energy security and sustainability goals, not only to bring in more low-carbon power but also to ensure that renewables-rich systems can operate with sufficient flexibility.

In 2018, coal power investment, at under USD 60 billion, decreased 3% compared to previous year. This was still higher than the levels projected in IEA scenarios, with the largest differences found in Asia, particularly in China, India, and Southeast Asia.

Spending on gas-fired generation in 2018 was also higher than projected in the scenarios, but by less than coal, a reflection of the flexibility value of gas in the power system. The largest difference was in the United States. In Europe, where investment in thermal capacity of all types has slumped, gas power investment would need to rise (NPS) or be sustained (SDS).

Investment in nuclear power was only 3% less than the needs under the NPS but nearly 40% less than spending required in the SDS, with the largest gaps in Europe, the United States, and China.

Renewables spending in 2018 was lower than projections under both scenarios – nearly 15% compared to the NPS but 50% compared with the SDS. While the largest gap is seen in wind, more renewable spending would be needed across all technologies and geographies in the SDS, despite falling costs.

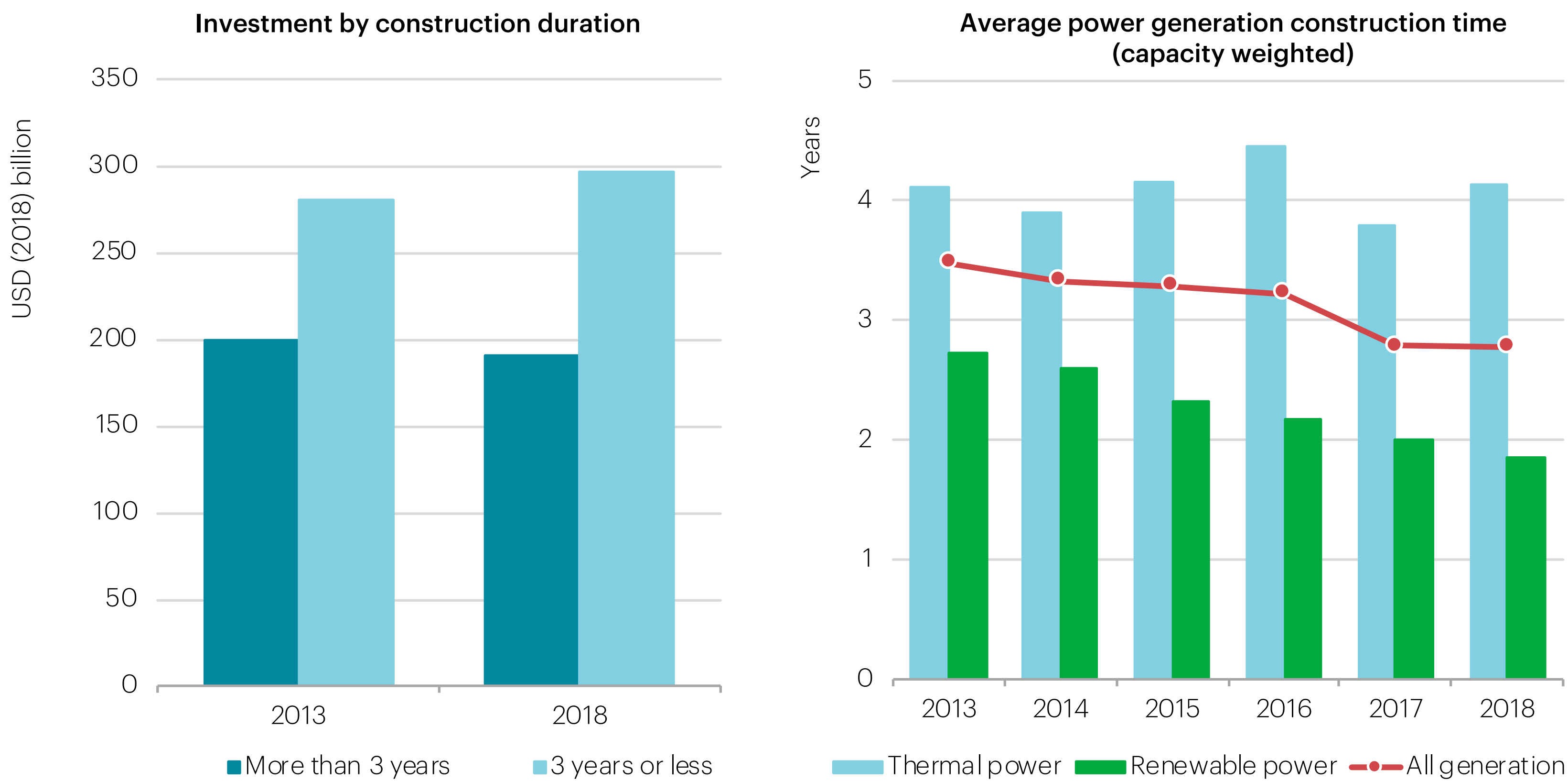
Investment in grids and battery storage was also lower than in both scenarios, by around 30%. Gaps were most acute in areas with large electrification needs (e.g. India and sub-Saharan Africa), where utilities challenge to recover their fixed costs and set the adequate cost reflective tariffs.

Costs and project development

Trends in construction duration and capital costs for power generation (67-70)

Generation spending and additions have tended towards shorter-cycle projects

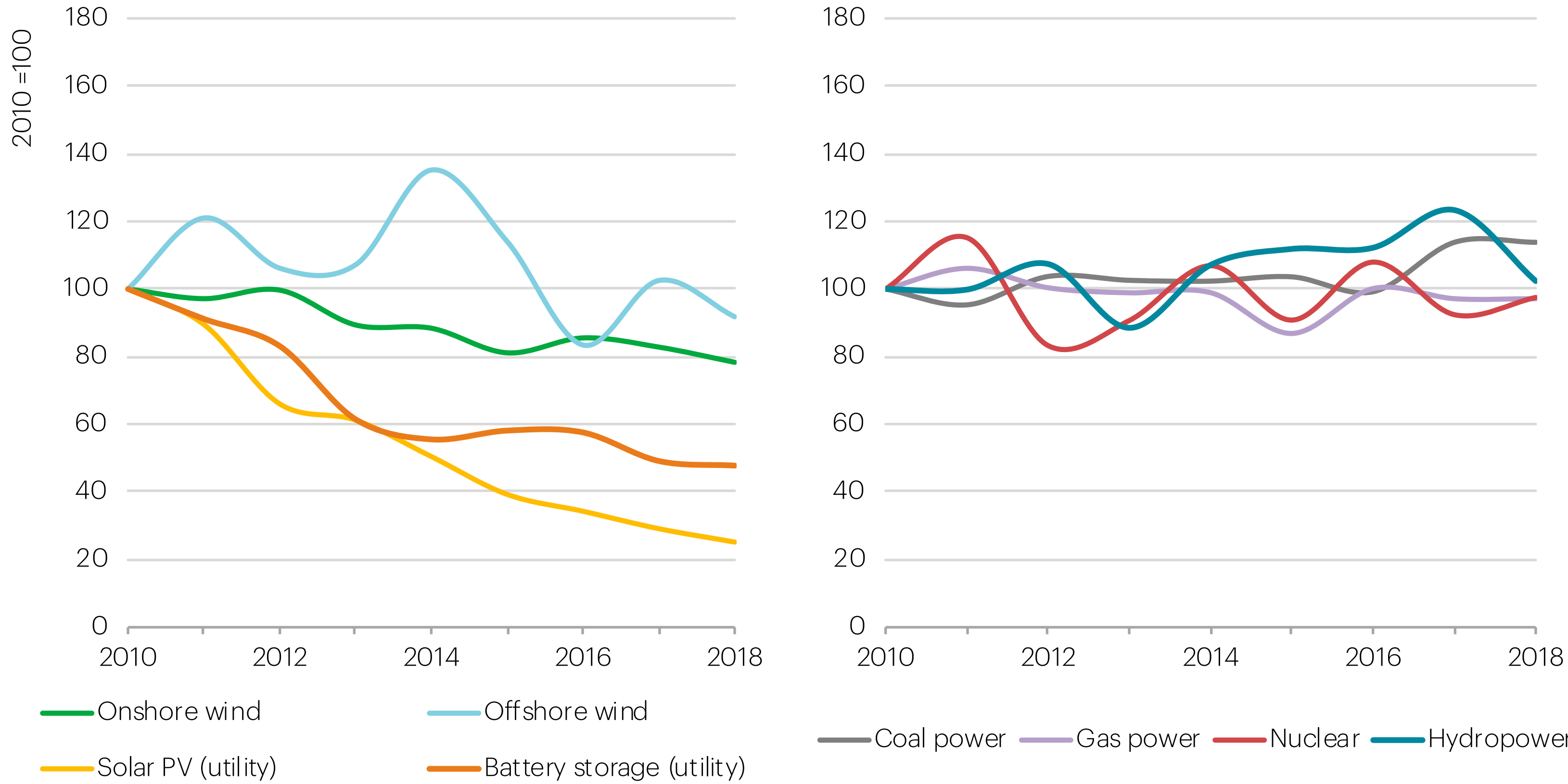
Total generation investment by construction duration and capacity-weighted construction times by sector



Note: Construction times are measured as the duration from final investment decision to commissioning.

Meanwhile, cost declines continued for variable renewables

Change in global weighted average capital costs for newly commissioned power capacity, 2010-18



Note: Utility = utility-scale

Source: IEA analysis with costs for solar PV, wind, and hydropower based on IRENA (2019).

Industry has improved development times for some technologies...

A growing share of power generation investment has been in projects built in three years or less and average construction times for new capacity have fallen. This trend is helped by policy support for renewables and (in some countries) for flexibility, improvements in project development and economics for some technologies, as well as industry competition and a greater focus on risk management.

This shift is consistent with recent progress in capital cost reductions, which have mostly occurred in variable renewables (and batteries), benefitting from technology progress.

It is important to remember that cost curves for all technologies depend strongly on the location of deployment and annual pricing dynamics in equipment markets.

Capital costs for solar PV continued to decline in 2018 and are down three-quarters since 2010. Capital costs for onshore wind are down 20% since 2010. In offshore wind, dramatic capital cost declines have not yet appeared in operating projects, but expectations of lower costs ahead, combined with better financing terms (IEA, 2018a) and increased capacity factors - with the use of more advanced turbines and sites moving further out to sea - have driven auction prices lower (IEA, 2018b).

Developers have generally improved construction times for solar PV and wind. This partly reflects deployment in areas with faster timelines but also technology and project design improvements and the increased role of competitive bidding in policies. Still, barriers before and after construction – e.g. permitting, land acquisition, and the timely signing of Power Purchase Agreements (PPAs) and grid connections – persist in some markets.

…but progress has been slower for larger, more complex projects

The average costs for thermal power have changed little since 2010, but some new trends are emerging.

Gas power (CCGTs) is one area that has benefitted from recent improvements in project development and equipment pricing. These improvements have stemmed from intense competition among suppliers and engineering, procurement, and construction (EPC) companies in the face of a slowing global market combined with the increased modularity and standardisation of project designs.

Costs and construction times have generally increased for coal power, reflecting in part larger plant sizes and more complex project designs. A growing share of coal power investment is in high-efficiency plants with advanced pollution control systems, responding to local concerns over air quality but locking in potentially large future emissions of CO_2.

However, with the slowing of China's domestic coal power additions, industry sources have reported that increased competition from Chinese EPC companies seeking business abroad is putting some downward pressure on pricing for new coal power plant costs in places like Southeast Asia.

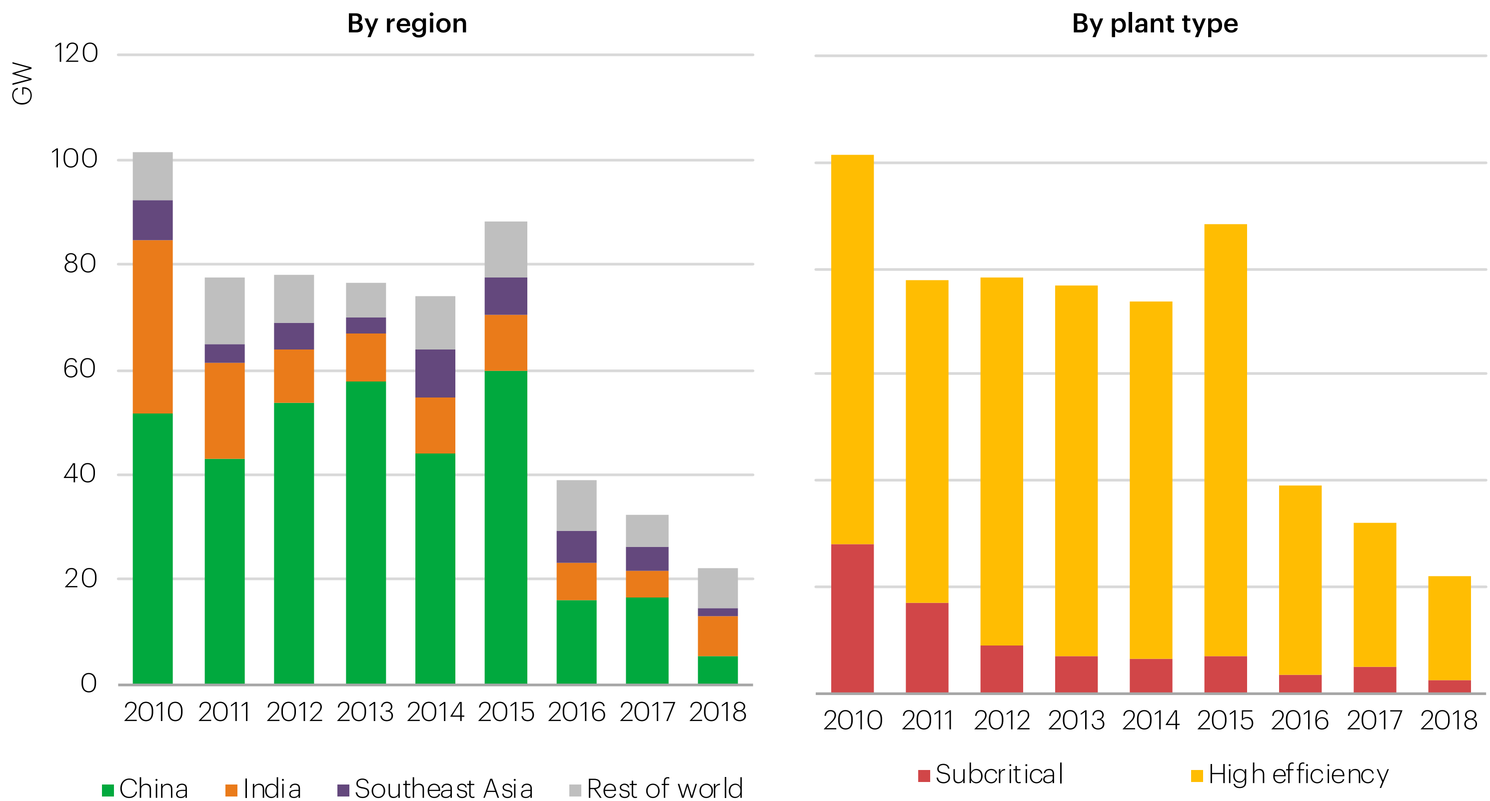
For hydropower, where costs are location specific, the share of deployment in China has decreased over the past decade, raising the global weighted average. Within different regions, costs have changed little. Construction times for new capacity have risen, reflecting generally larger plant sizes but also land and water management requirements that can increase project complexity.

FID trends for power generation

Final investment decisions for dispatchable power generation (72-74)

Final investment decisions for new coal power plants declined again

Coal-fired power generation capacity subject to an FID

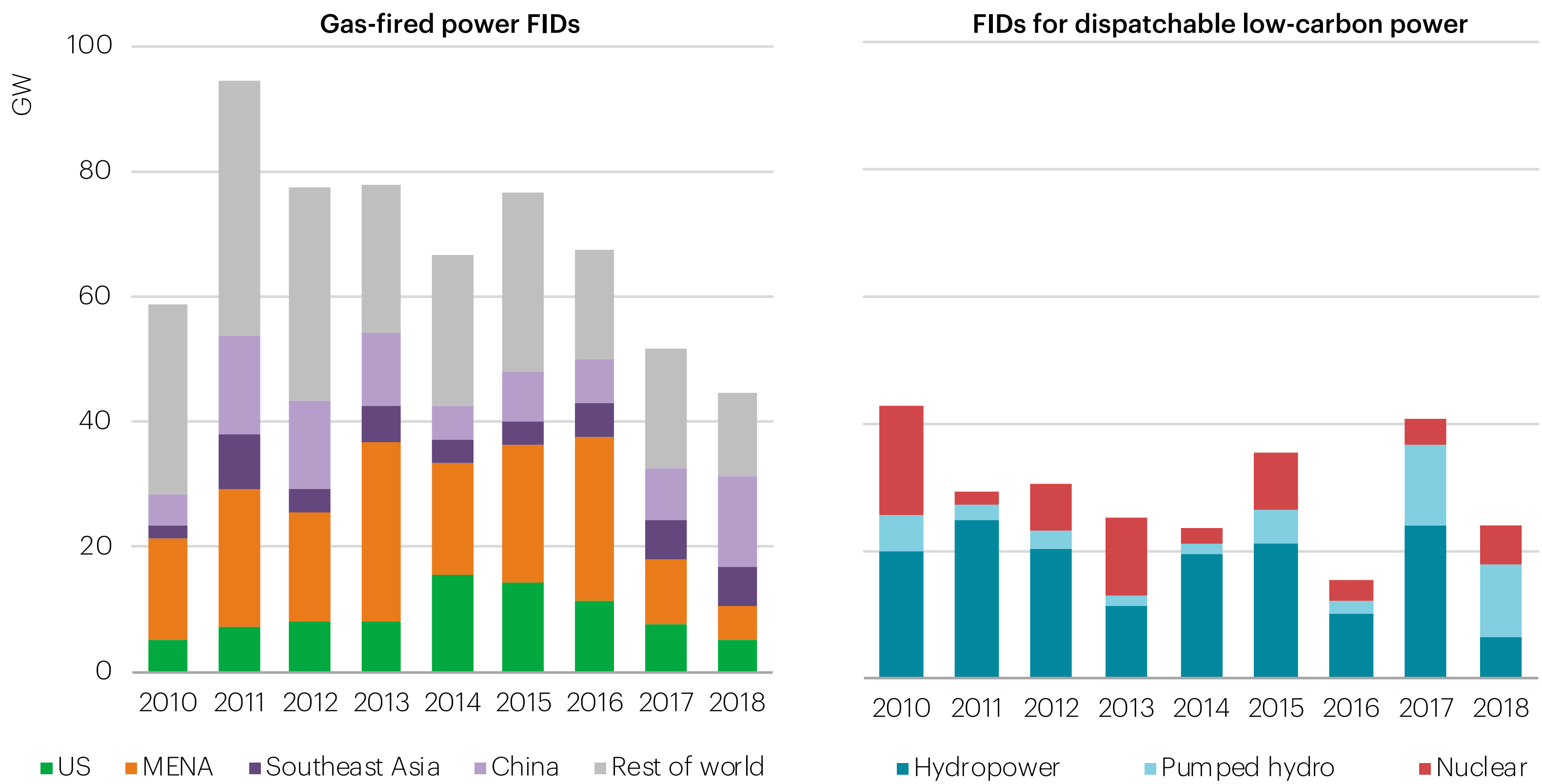


Note: GW = gigawatt.

Source: IEA analysis with calculations based on McCoy Power Reports (2019)

FIDs for gas power dropped too and approvals remained at low levels for nuclear and hydropower

Gas-fired power generation capacity and low-carbon dispatchable generation subject to an FID



Source: IEA analysis with calculations based on McCoy Power Reports (2019) and IAEA (2019)

Overall, FIDs for large-scale dispatchable power have fallen 55% since 2010

FIDs (i.e. decisions to start construction for the first time) for the main sources of large-scale dispatchable power – coal, gas, nuclear, and hydropower – fell by a quarter in 2018 to 90 GW, 55% lower than in 2010.

In 2018, coal-fired power FIDs declined by 30% to 22 GW, their lowest level this century. Most FIDs are now for high-efficiency plants, with inefficient subcritical plants comprising only 10%. The largest fall in FIDs was in China, but levels in Southeast Asia were their lowest level in 14 years. India was the largest market, now largely oriented towards supercritical technology, but levels were 80% lower than in 2010.

In China, the central government has made efforts in recent years to restrict permitting and plant construction, amid signs of overcapacity and local air pollution concerns. There is some uncertainty over the capacity under construction in China, which could affect investment levels ahead – reports suggest some plant sites, where activity was previously suspended, may be resuming construction.

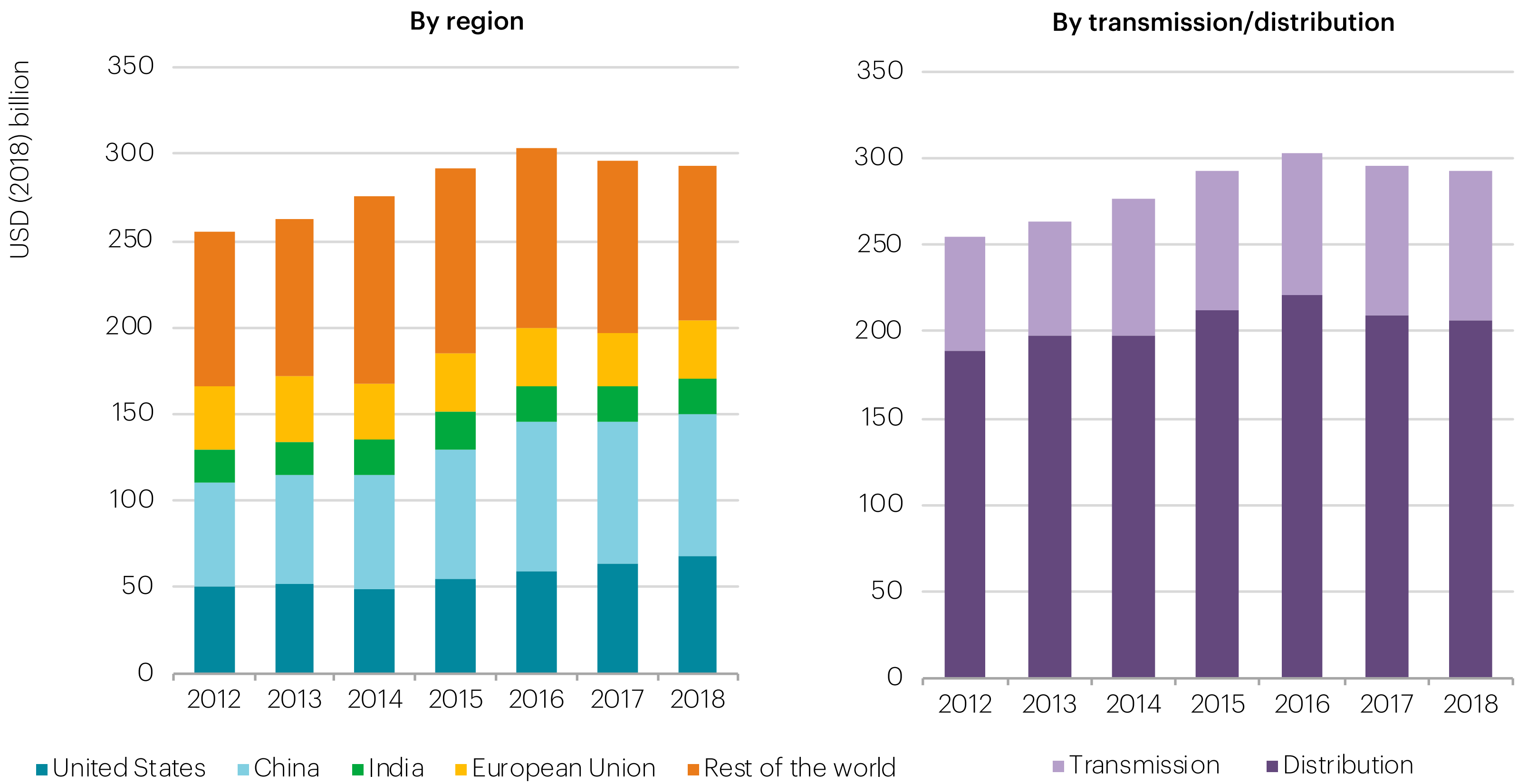
FIDs for gas-fired power also dropped for the third consecutive year, by nearly 15%, though remained twice as high as those for coal. The largest declines in gas FIDs were in the MENA region (-50%), where there is excess capacity in the power system, and the United States (-30%). In contrast, they grew in China by 70%, and for the first time more gas-fired power capacity was sanctioned than that of coal.

FIDs for the largest sources of low-carbon dispatchable generation – hydropower and nuclear– were 40% lower than in 2017. Construction starts for new nuclear power plants rose by 50% in 2018, none of which were in China, but were lower than grid connections. Pumped hydro accounted for the majority of hydro projects taking FID in 2018 for the first time.

Networks and battery storage

Global investment in electricity networks has stalled the past two years…

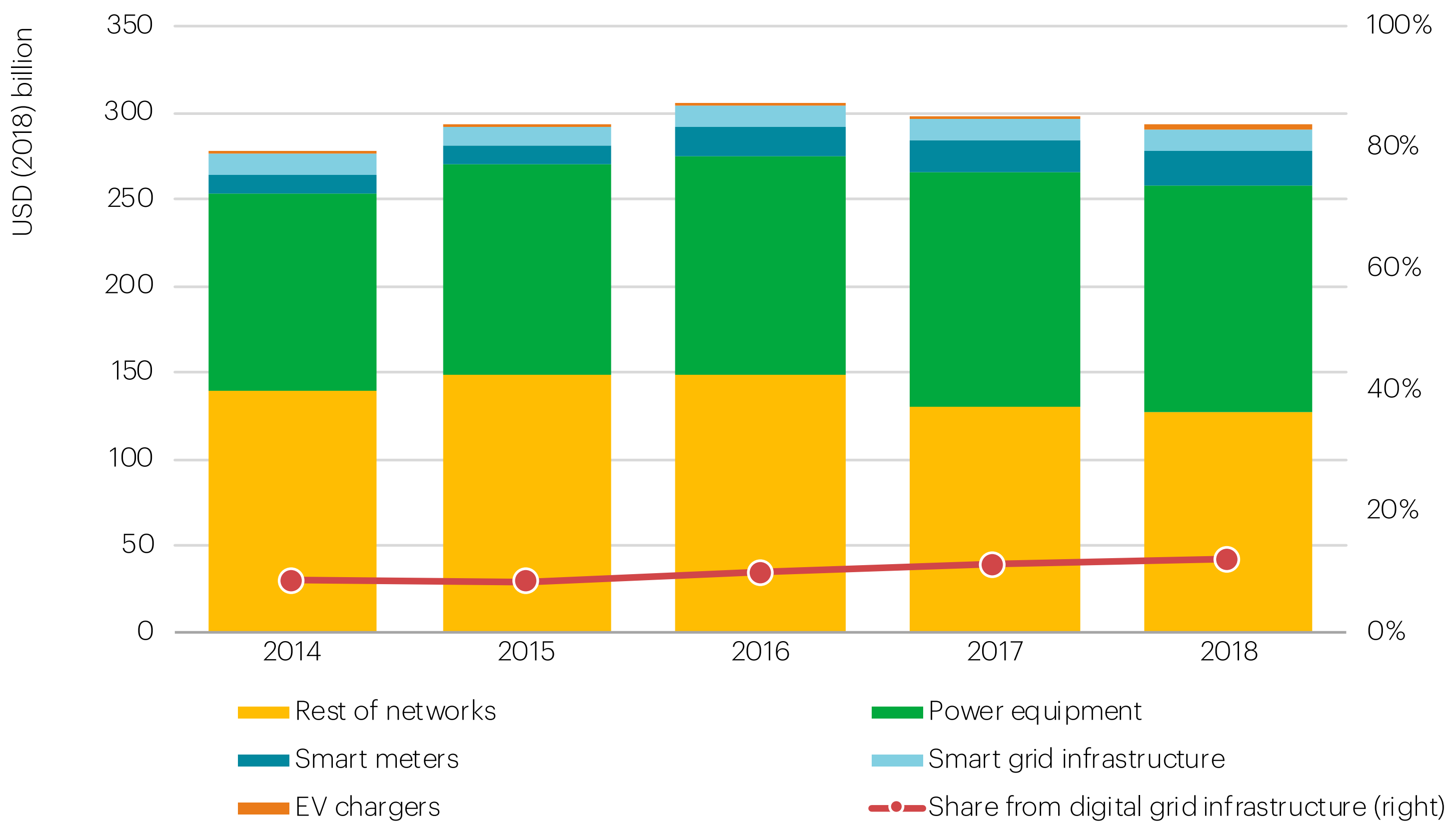
Investment in electricity networks



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

...but spending on digital grid technologies has continued to rise

Investment in electricity networks by equipment type



Note: Two- and three- wheeler EV charging stations are excluded from the analysis. Smart grid infrastructure comprises utility automation equipment at substation level.

Increases in grid spending were registered in the United States, Europe & India

Investment in electricity grids dipped by 1% in 2018; China and the United States were nearly half of spending.

Global spending on transmission grids, around 30% of network investment, has risen steadily during the last five years, supported by the connection of more generation, the system integration of variable renewables, and large-scale interconnection projects, though in some areas, constraints associated with permitting planning and project development remain investment challenges.

Grid investment in the United States increased by 8%, with around 60% of spending in the distribution grid. Regulators continue to emphasise grid resilience and reliability. The potential downsides of underspending were in the spotlight in California with wildfires related to a lack of maintenance and replacement of distribution assets at the end of their lifetime.

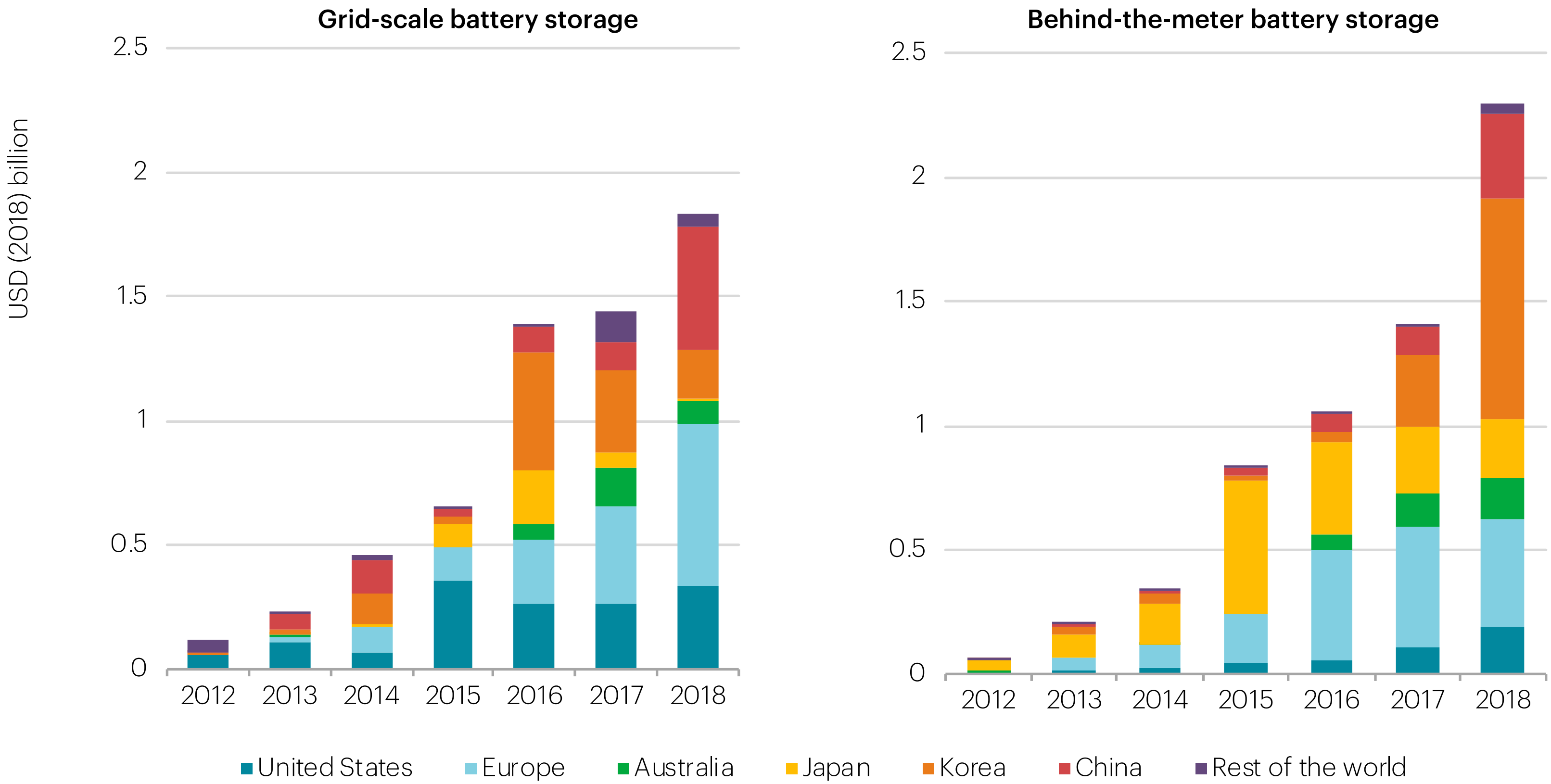
Spending in the Europe Union rose by 8%, largely due to investment in transmission. In their long-term planning, the European Network of Transmission System Operators identified USD 10 billion of annual transmission spending needs through 2030, implying a notable boost from current spending levels.

India's grid spending grew to over USD 20 billion, led by transmission, while distribution moderated. The Central Electricity Authority recently identified needs for USD 40 billion of transmission spending in the next three years, 60% higher than current levels.

Investment in digital grid technologies rose by almost 10% to USD 35 billion. Most of this was in smart meters and grid automation equipment, but spending on EV charging stations rose by 60% to over USD 3 billion, with reports of utilities, automotive companies and oil companies moving to invest more in the space. Spending on traditional equipment remained the largest part of investment at nearly 45%.

Investment in stationary battery storage surged to over USD 4 billion…

Investment in stationary battery storage



Source: IEA analysis with calculations based on Clean Horizon (2019), China Energy Storage Alliance (2019) and BNEF (2019).

...and capacity additions continued to far outpace cost declines

Investment in battery storage rose by 45% to a record of over USD 4 billion in 2018. This was driven by strong increases in both grid-scale and behind-the-meter batteries, which were the majority of installations.

Capital spending on grid-scale battery storage increased by 30% compared with 2017, totalling more than 1.2 GW installed in 2018 . Deployment in Europe (particularly the United Kingdom) and the United States comprised half of 2018 investment, supported by capacity mechanisms and contracts. China was the region with the largest growth, as it registered a fourfold increase compared to 2017.

Behind-the-meter investment jumped by 60% in 2018, almost reaching 1.9 GW of capacity added last year. Korea led 2018 capacity additions, supported by tariff designs that aimed to shift peak demand in the industrial and commercial sectors – charging during low-load hours and discharging during peak hours benefitted from price discounts and premiums compared with the prevailing retail prices.

Average costs for commissioned grid-scale battery projects declined in 2018 to under USD 400 per kilowatt hour (kWh), with an average duration of 4 hours. Behind-the-meter projects saw more significant declines to near USD 800/kWh. For both types, 35-40% of the cost was associated with the battery pack, suggesting a significant role for other factors (e.g. mounting equipment, cabling, and labour) in overall costs.

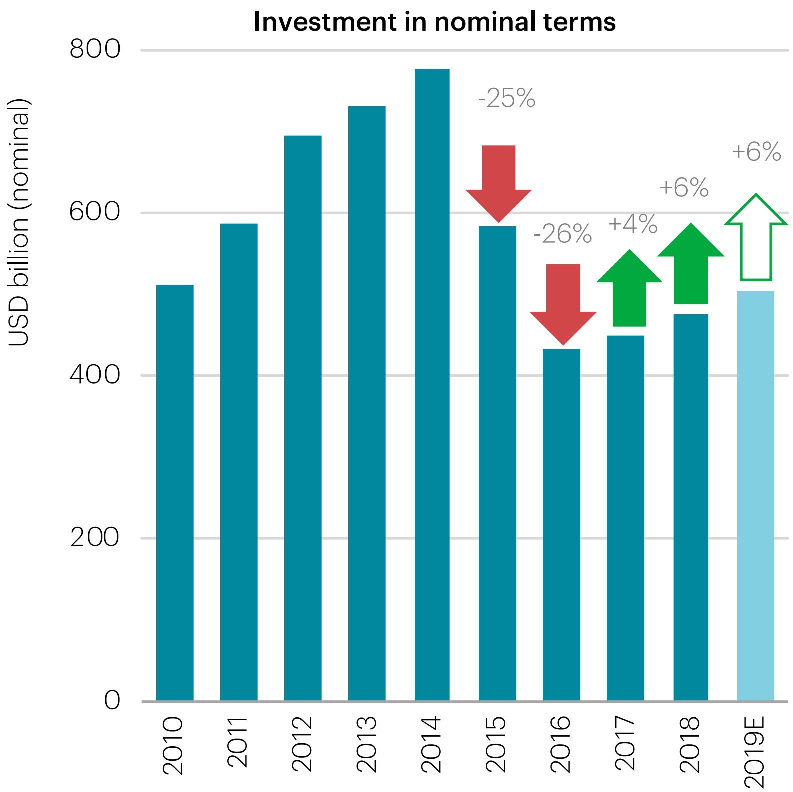
While pumped-hydro projects remained the largest part of new electricity storage, lithium batteries continued to be by far the largest part of battery deployment. In parallel, grid and ancillary services remained the main application of these deployments, but there has been rising investment in batteries directly integrated with variable renewables plants (see Financing and funding trends).

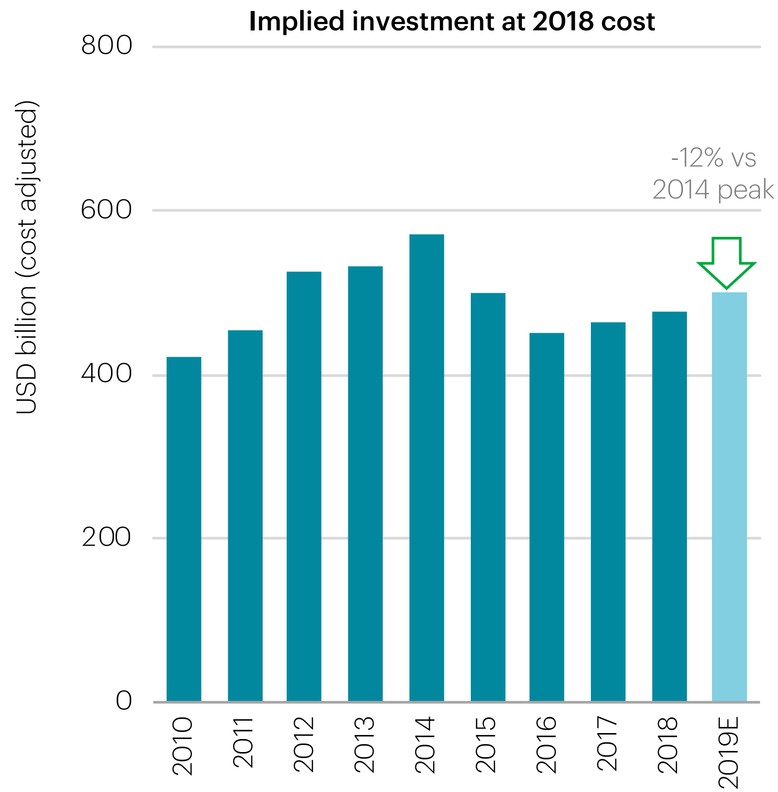
Fuel supply

Investment in upstream oil and gas

Upstream oil and gas investment is set for another modest rise in 2019

Global upstream oil and gas investment





Shale remains dynamic, but the investment focus is shifting to conventional assets

In 2018, companies spent in aggregate slightly more than the guidance they provided to the market, encouraged by rising oil prices throughout the year (until the last quarter). We have revised upwards our 2018 estimates for the rise in global upstream spending in 2018, from 5% to 6%.

Our estimate for global upstream investment in 2019 is USD 505 billion, a 6% increase in nominal terms (a 4% increase in real terms) on the previous year. Three years of modestly higher spending still leave this figure nearly USD 300 billion lower than the peak reached in 2014.

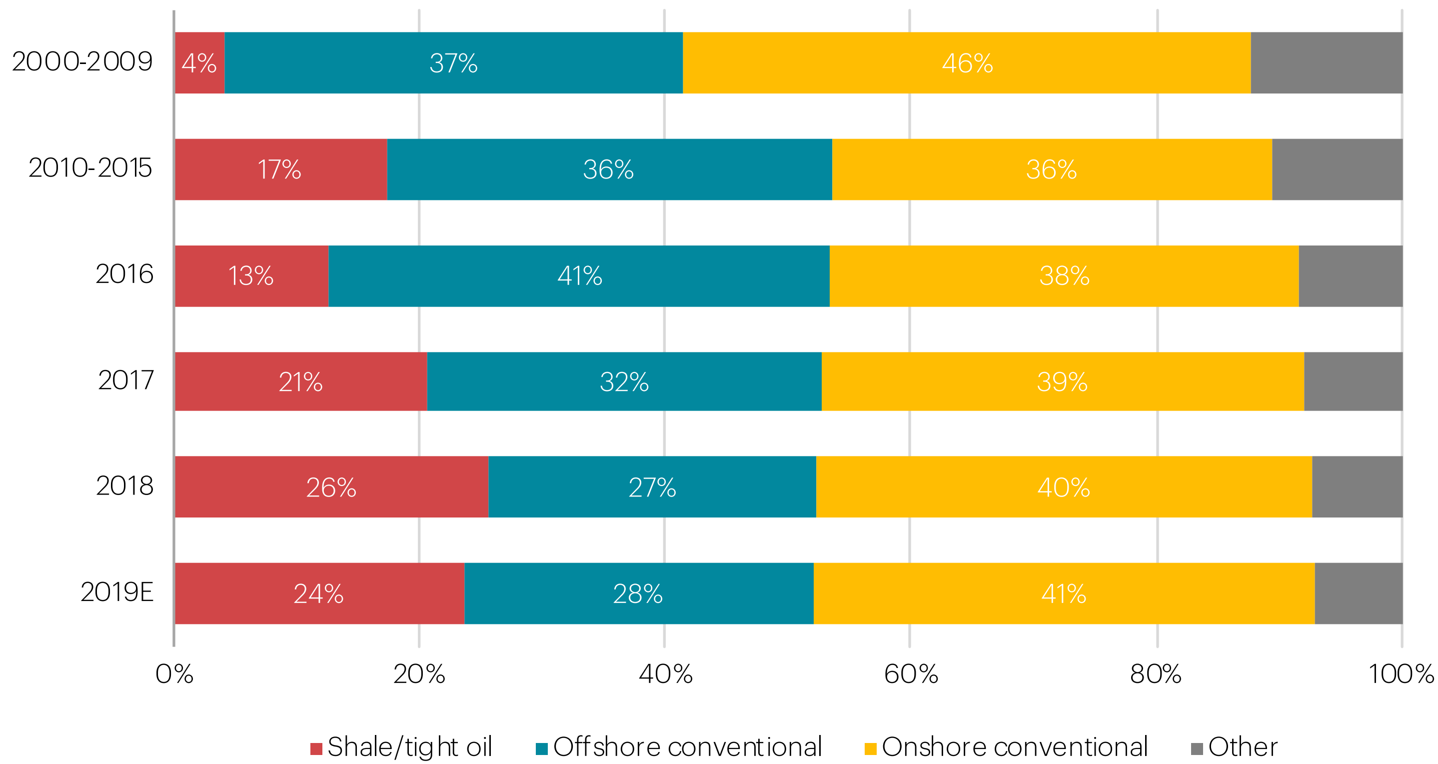
Adjusted for declining upstream costs, the reduction in spending is less stark. The 35% reduction in nominal spending from 2014 to 2018 turns into a much smaller 12% fall in activity.

The main upstream story of the last few years has been a shift in spending towards shale (tight oil and shale gas) in the United States. The investment landscape for shale remains dynamic with the arrival at scale of the majors, but this is being offset by a more subdued outlook for most of the pure shale players, for whom the priority is now to live within their means.

The signs in 2019 are that the balance of spending is starting to shift again. In our assessment, the fastest growth in upstream investment this year is set to be in conventional projects, rather than in shale. This also means that some upstream markets that have been in the shadow of the United States in recent years are starting to move back into the limelight.

Shale has levelled off at around a quarter of total upstream spending

Share of global upstream oil and gas investment by asset type



Note: Offshore and onshore indicated in the chart include investment in conventional offshore and onshore assets.

Source: IEA analysis with calculations from Rystad Energy (2019) and company reports.

Conventional spending is turning the corner

The reaction of the large, conventional operators to lower prices since 2014 has had four main components:

- Maximise revenue from existing operations; the share of brownfield spending has risen, up to 67% of the total in 2018 from less than 60% in 2016.
- Cut costs wherever possible.
- A greater focus on smaller assets that can be brought to market more quickly, notably shale.
- Defer spending on more complex new projects until they are redesigned and simplified to be competitive at lower prices.

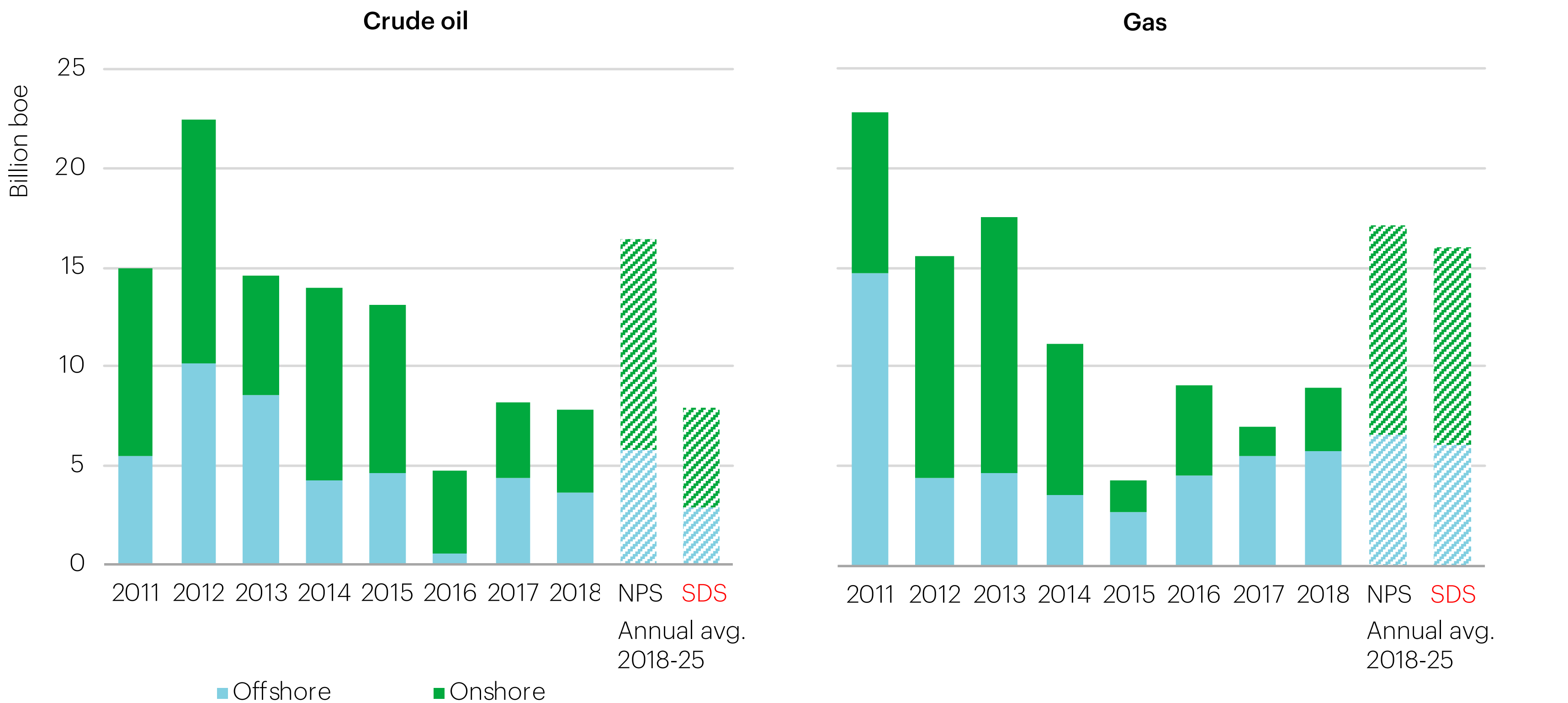
These changes were reflected in the composition of upstream spending. Conventional oil and gas projects remain the predominant channel for investment, but their two-thirds share of the total in 2018 was a historical low. Within this segment, spending on offshore projects has been squeezed hard; the offshore share in upstream spending fell by over 10 percentage points between 2016 and 2018.

There are signs in the 2019 guidance that conventional spending in general, and offshore investment in particular, may be turning a corner. This is being led by the Middle East and Latin America.

Shale assets have rapidly increased their weight in global upstream investment this decade, reaching 26% of the total in 2018. For 2019, we expect a marginal decline in this share, to 24%, as the reduction of investment anticipated by shale pure operators is only partially compensated by rising spending in shale basins announced by some of the majors.

Time for a rebound in conventional project approvals? (1/2)

Crude oil and gas conventional resources sanctioned by asset type

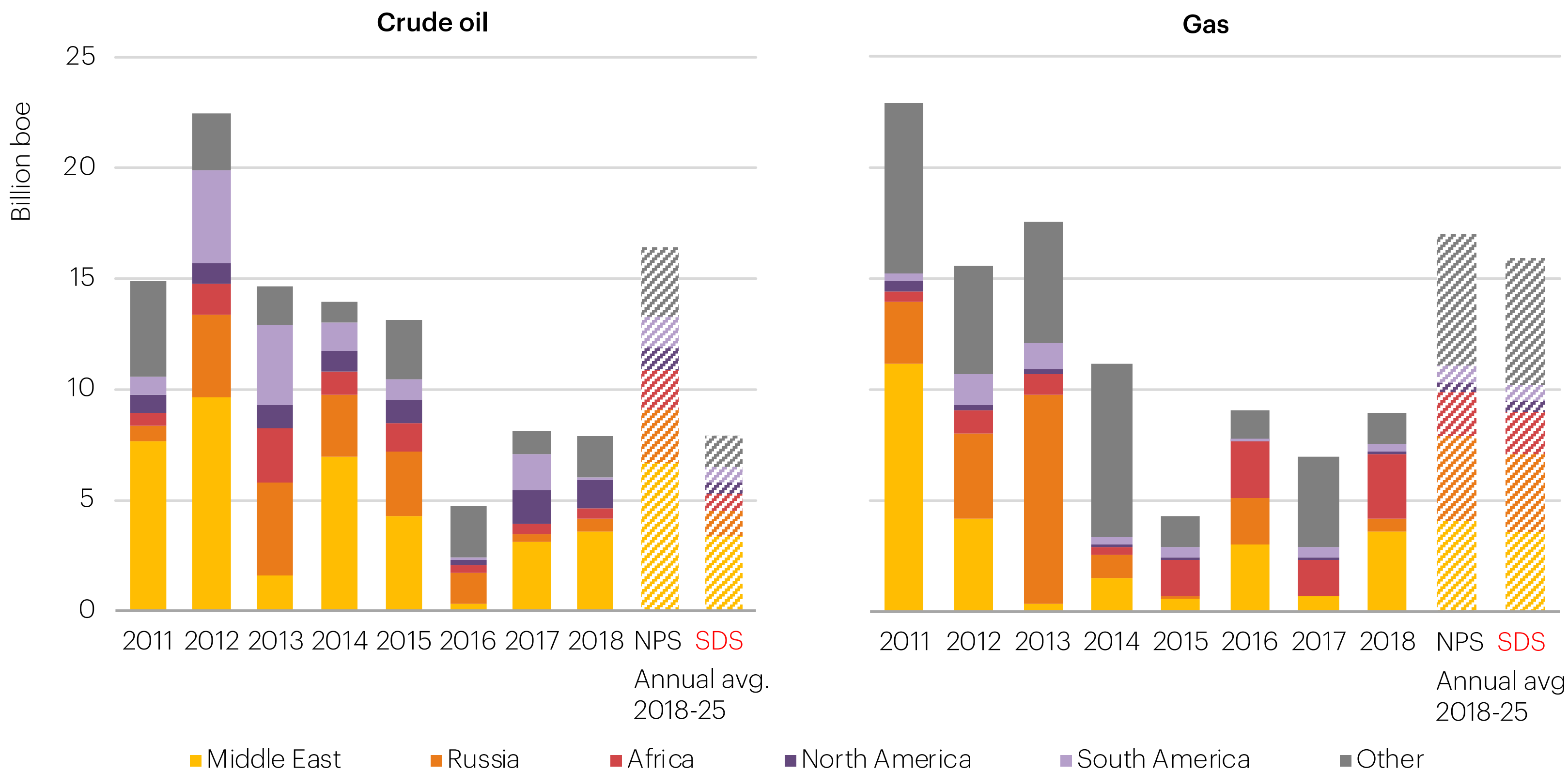


Note: The NPS and SDS show the annual average of sanctioned resources between 2018 and 2025 under the IEA New Policy Scenario (NPS) and Sustainable Development Scenario (SDS) respectively.

Source: IEA analysis with historical sanctioned resources based on Rystad Energy (2019).

Time for a rebound in conventional project approvals? (2/2)

Crude oil and gas conventional resources sanctioned by key region (excluding shale/tight oil)



Note: NPS and SDS show the annual average of sanctioned resources between 2018 and 2025 under the IEA New Policy Scenario (NPS) and Sustainable Development Scenario (SDS), respectively.

Source: IEA analysis with historical sanctioned resources based on Rystad Energy (2019).

The offshore sector is showing clear signs of life

The last three years (2016-18) saw very low levels of conventional oil and gas resources being sanctioned for development. Approved conventional oil resources averaged 7 billion barrels of oil equivalent (boe), 60% lower than the previous five years, while conventional gas resources, at 8.3 billion boe, were 40% lower.

If oil and gas demand continues to grow as in the NPS, then there would need to be a substantial increase in resources sanctioned for development to keep the market in balance. Guidance from companies suggests that such an acceleration in new project approvals is indeed possible in 2019.

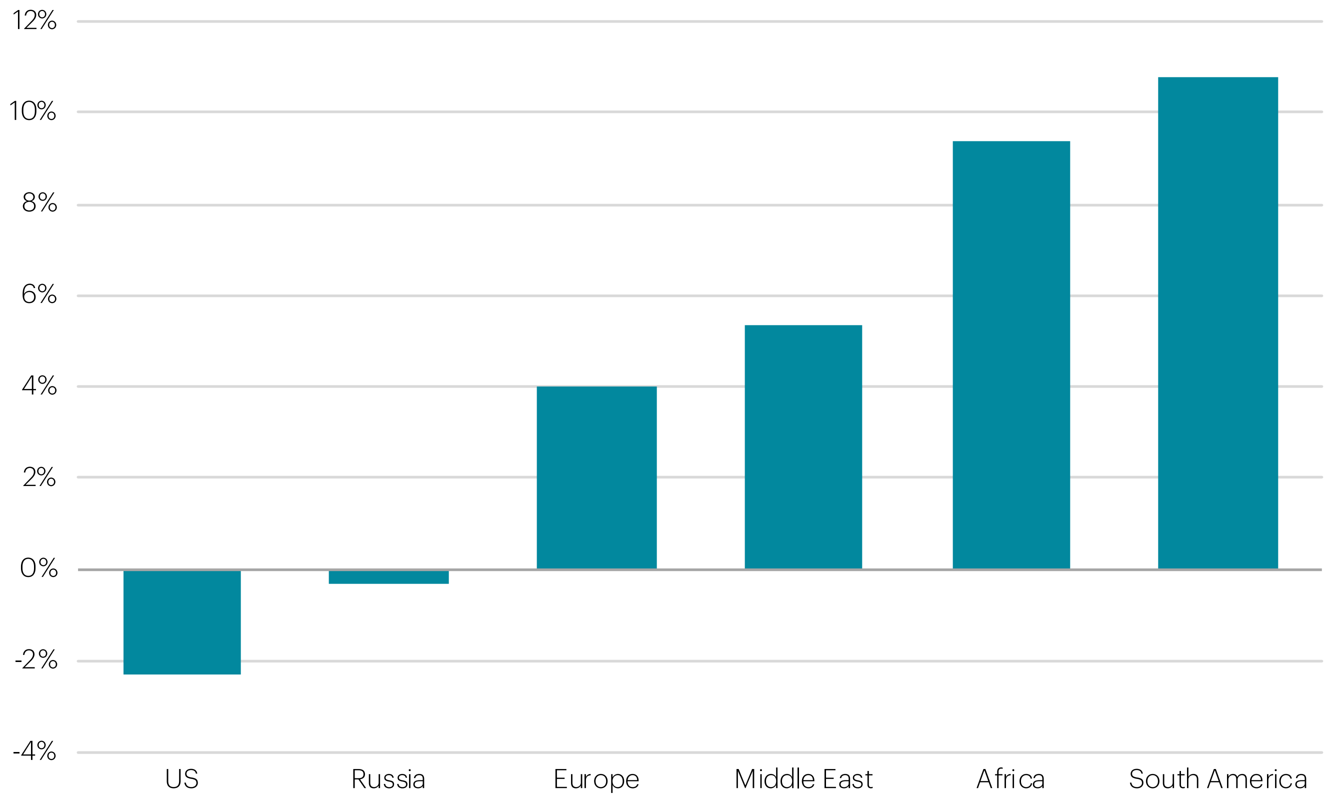
Companies are only moving ahead with their highest-value projects, but several are expected to go ahead. Many of these are offshore: in the Gulf of Mexico, Guyana, the North Sea, and Brazil as well as large integrated liquefied natural gas (LNG) projects, such as the expansion of the Qatar terminals and the sanctioning of gas fields in the Rovuma basin off Mozambique.

The renewed attraction of offshore projects is linked to the precipitous decline in break-evens over the last few years due to lower costs for offshore supplies and services, shortened timing to bring first oil and gas into production as well as simplified and standardised project designs.

ExxonMobil expects its Guyana and Brazil's Carcara deepwater projects to give an internal rate of return (IRR) in excess of 30%. Total anticipates its Angola offshore projects to achieve an IRR in excess of 20% at an oil price of USD 50/barrel.

After strong growth in 2017 and 2018, the rise in US upstream investment is expected to take a pause in 2019....

Change in upstream investment by selected region, 2018-2019



…and the Middle East and Latin America are seen leading the spending growth

Our estimates point towards rising spending in 2019 in almost all key producing regions. In the Middle East, some of largest national oil companies (NOCs), including Saudi Aramco, Abu Dhabi National Oil Company, Qatar Petroleum, and Kuwait Petroleum Corporation, have signalled their intention to step up their upstream activity in order to sustain oil production levels and meet rising domestic gas needs.

Upstream spending in Latin America is expected to increase in 2019 by just above 10%, driven mainly by Brazil, Guyana, Argentina and Colombia. In its five-year strategy, Petrobras unveiled higher spending, and several international companies are increasing their activities in Brazil's offshore.

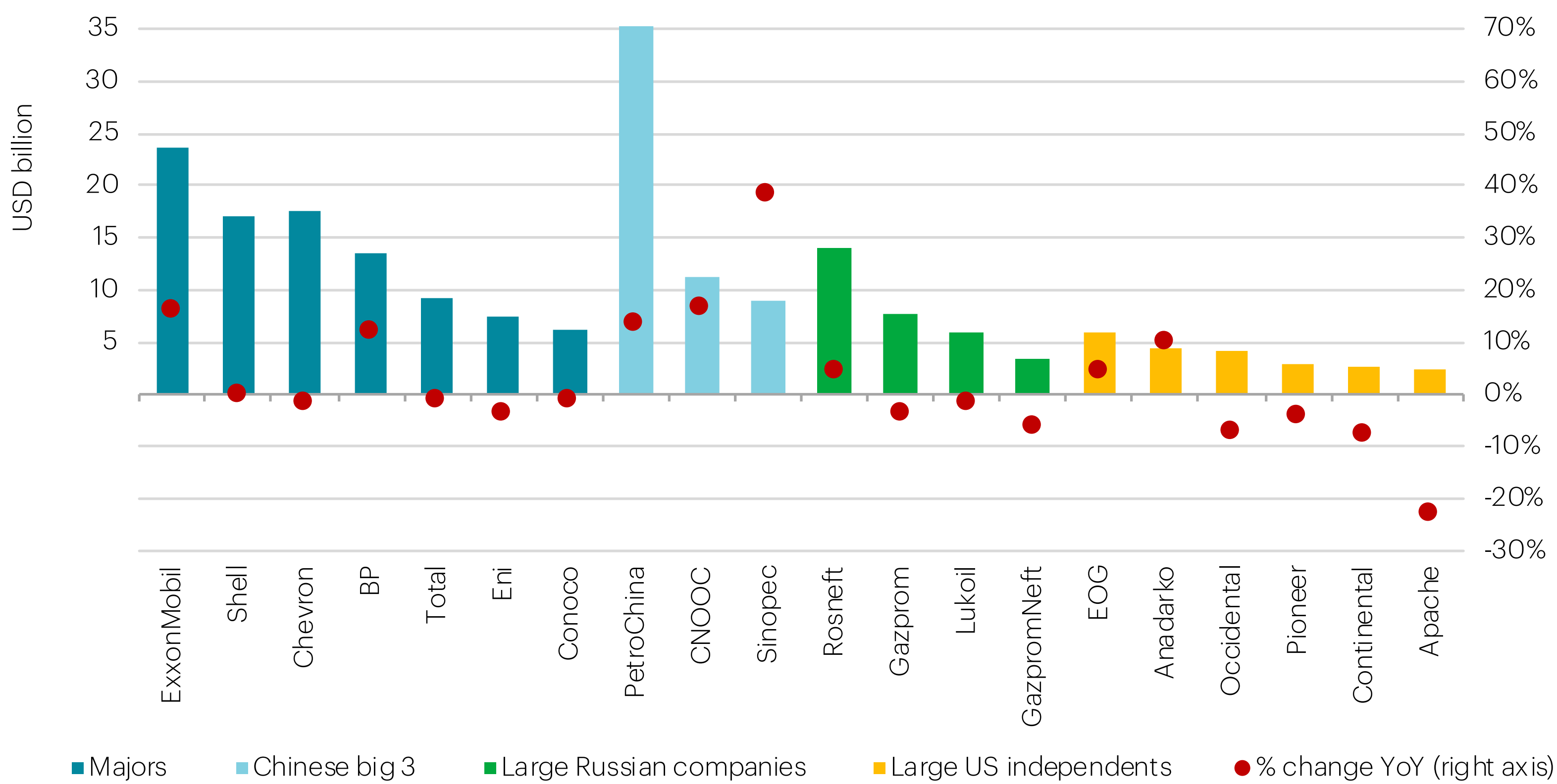
Investment is expected to be on the rise again also in Europe, driven by higher spending in the North Sea, including the first phase of the massive Johan Sverdrup field. African upstream spending is also set to trend higher after a very subdued period in recent years.

With the exception of Rosneft, large Russian companies are set to keep upstream spending around or slightly below the levels in 2018 (in dollar terms). Investment activity will be shaped in practice by the OPEC+ agreement, as well as by anticipated changes to Russia's upstream tax regime.

Overall investment by NOCs remained quite resilient during the downturn and their spending is expected to rise in 2019. Chinese NOCs have announced large increases in their capital budgets, and this will help keep the overall share of NOCs in total upstream investment at around 43% in 2019, close to historical highs.

Upstream investment in 2019 varies by company

Expected upstream oil and gas investment in 2019 by company type (and 2019 vs 2018 change)

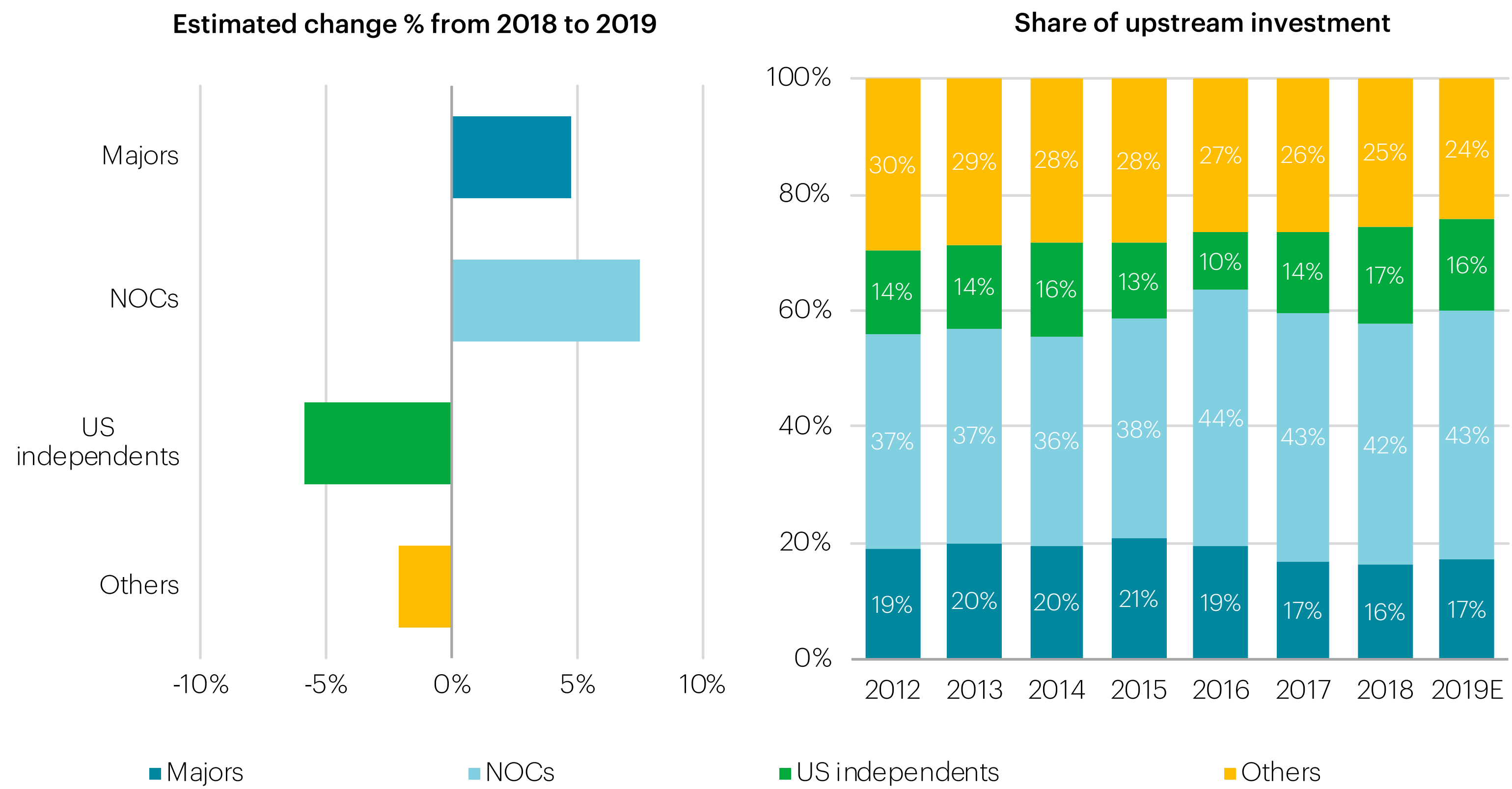


Note: CNOOC = China National Offshore Oil Corporation

Source: IEA analysis with calculations based on company reports and guidance

The share of NOCs in total investment remains close to record highs

Global upstream oil and gas investment by company type



Note: Data for 2019 are IEA estimates based on company guidance, consultations with industry experts, and other sources.

Source: IEA analysis with data based on company reports and Rystad Energy (2019).

Diverging company trends in investment activity in the United States

The share of the United States in global upstream spending has risen from 17% to 24% over the last ten years, but this upward trend is likely to be checked in 2019.

There are divergent investment trends between the US independents and the majors. Increased demands for capital discipline and investor returns are putting a cap on spending by the independents, especially for those companies operating exclusively in shale plays. However, the impact on production is likely to be mitigated by a decrease in the inventory of drilled but uncompleted wells (DUCs) and further operational efficiency.

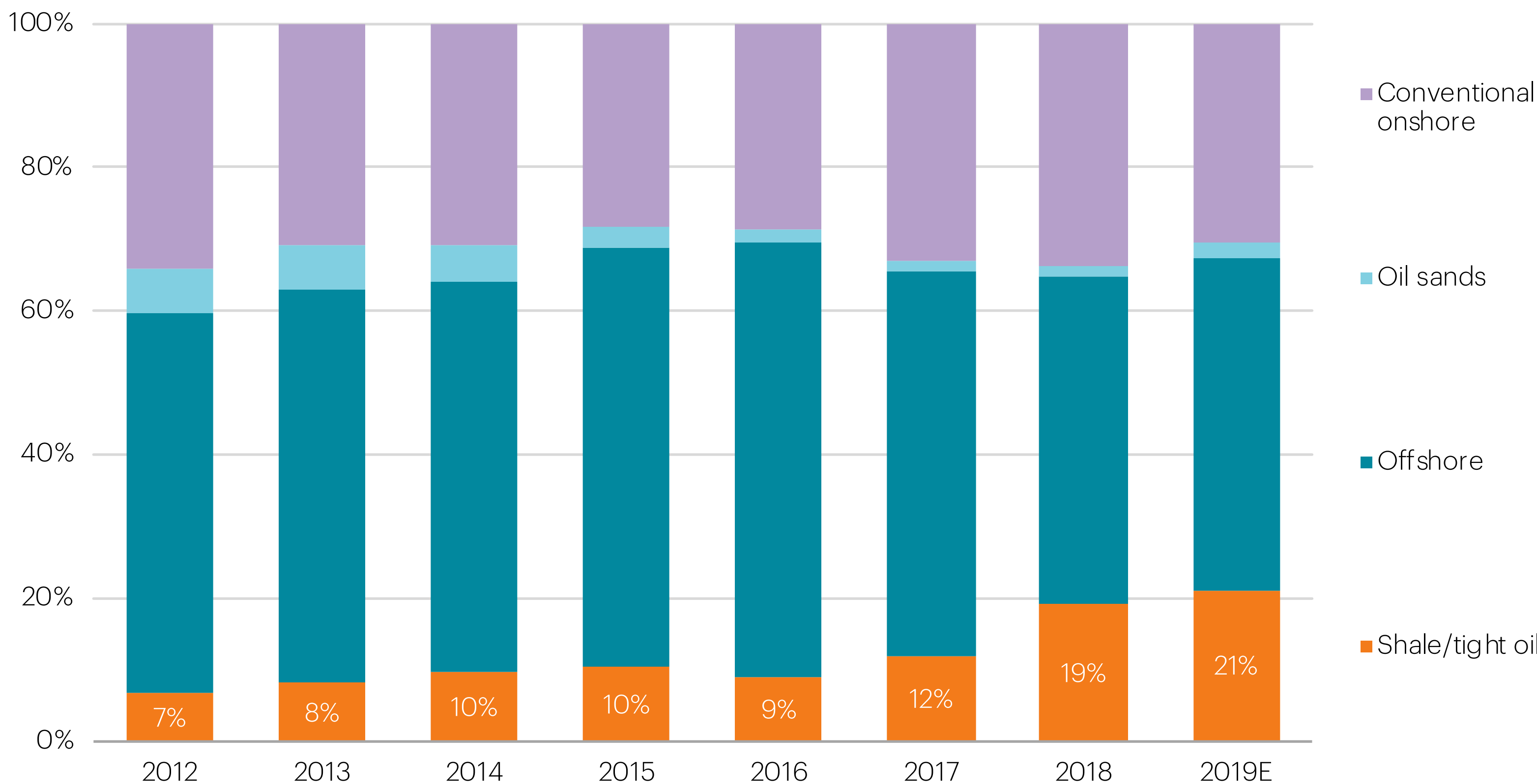
Pioneer, Continental, WPX Energy, Parsley Energy, Centennial Resource Developments, Apache, and Noble all announced spending cuts for 2019 (while maintaining robust production growth projections). Our assessment, based on guidance provided by pure-shale operators and US independents, suggests that upstream investment from this group in 2019 could be lower by some 6% than in 2018. For the moment, the commitment to capital discipline appears to be holding despite higher prices.

In contrast, international oil companies have maintained or increased their upstream US plans. Exxon and Chevron have made the Permian Basin a centrepiece of their strategies, while Shell and BP are increasing their positions. This will give the majors a much greater role in US supply and could encourage further consolidation in the sector.

As a result, 2019 is on track to be the first year where investment growth in shale assets passes from independents to big oil companies. This is a remarkable change for a sector which has until now been dominated by smaller operators. The growing footprint of large players means that investments might become less volatile.

The majors are making their mark on shale

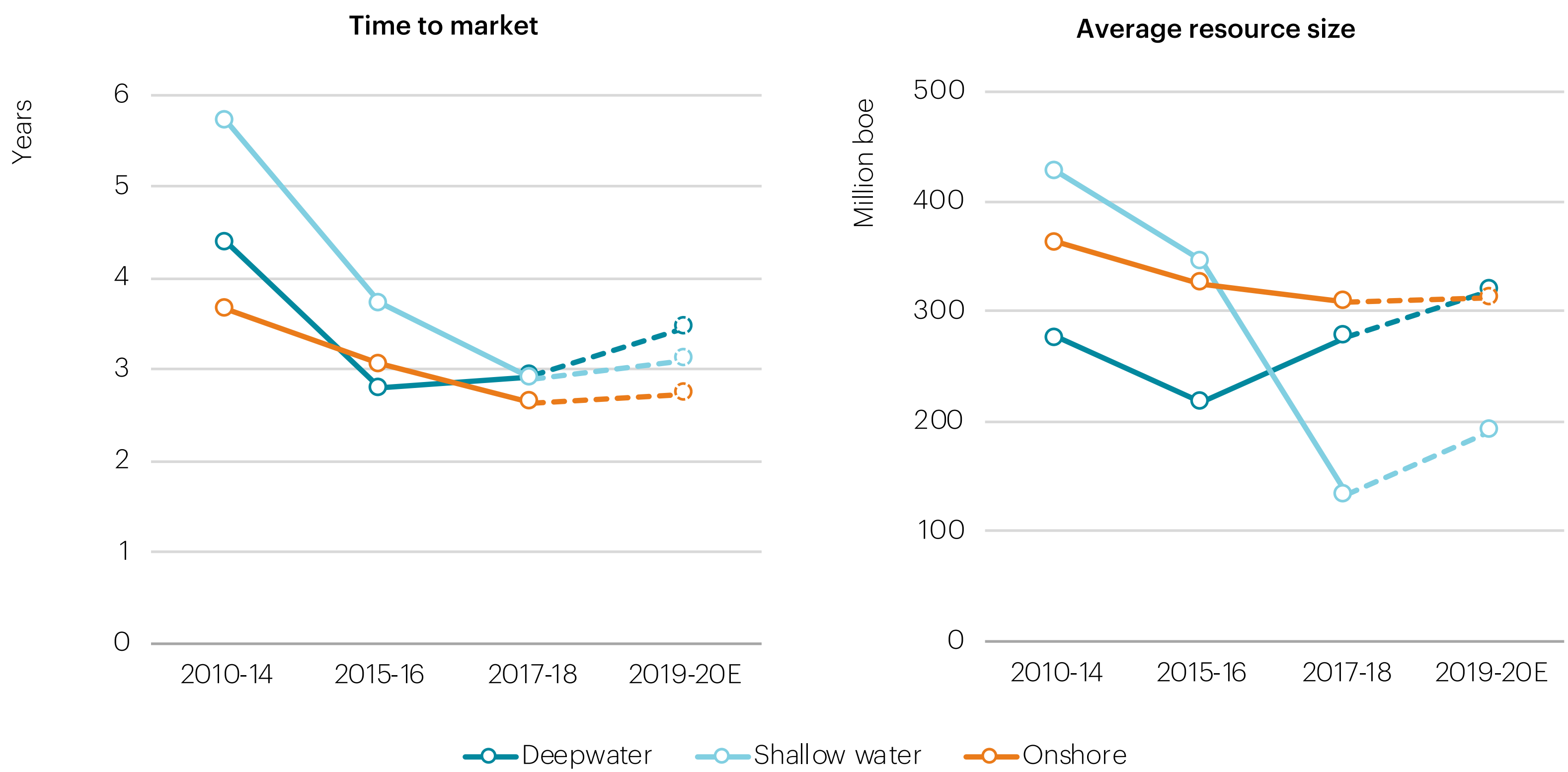
Upstream investment by majors, adjusted for cost inflation



Source: IEA analysis with calculations based on IEA upstream investment cost indices, company reports and Rystad Energy (2019).

The shift to shorter-cycle conventional projects continues...

Time to market and average resource size of projects by FID year



Note: Time to market indicates the time from final investment decision (FID) to production start-up. We examine conventional oil and gas projects (i.e. excluding unconventional resources such as shale/tight oil) whose sanctioned resource volumes are 50 million boe or more.

Source: IEA analysis with calculations based on disclosures by company announcements and Rystad Energy (2019).

…reflecting industry preferences to limit upfront capital outlays and reduce exposure to longer-term risks

The emphasis on shorter cycle projects highlighted in previous editions of the World Energy Investment Report (see IEA, 2018a) continues in 2019. There remains a preference among many operators to limit upfront capital spending, accelerate paybacks, and reduce exposure to long-term risks. Greater exposure to shale is one aspect of this, but companies are also rethinking the way they approach conventional projects.

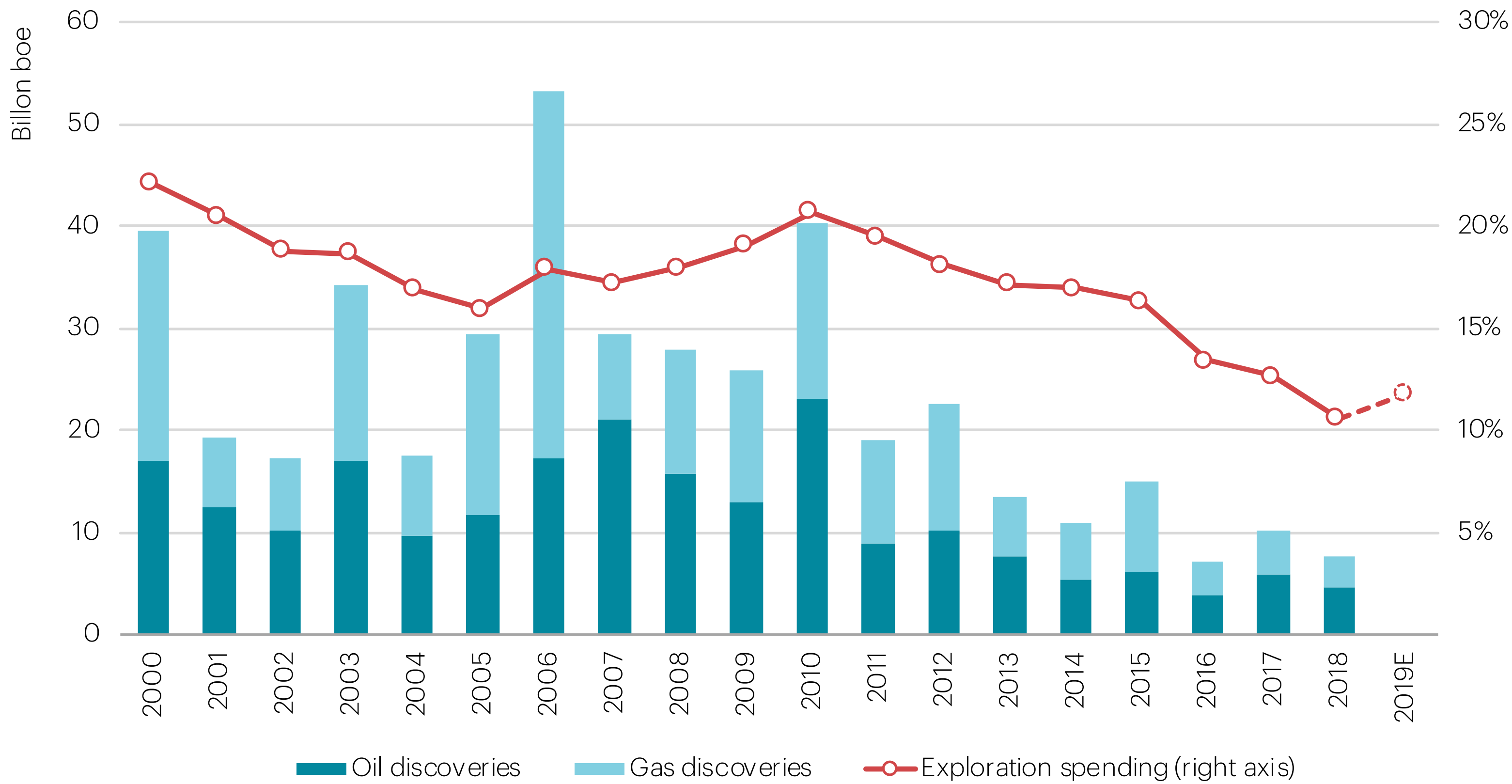
Since the 2014 downturn, the oil and gas industry has moved away from its traditional focus on larger-scale, capital-intensive projects with long lead times. The trend has instead been to fast-track the execution of smaller projects or to divide large projects into multiple phases. Lead times for new projects have fallen sharply.

In the offshore sector in particular, projects are moving from the final investment decision to first production much more quickly than they used to, and at lower costs. This experience is now encouraging operators to sanction new and larger projects. Based on guidance announced by companies, we expect that in 2019 and 2020 the average size of offshore projects will increase by over 20% but without a corresponding increase in time-to-market.

The overall result is a shift away from large, bespoke projects (often characterised by delays and cost overruns) towards smaller, standardised ones, with a strong accompanying focus on efficiency and capital discipline. This also means that the oil and gas industry is increasingly relying on assets that generate cash flow more quickly but also that deplete at a more rapid pace. This could increase the possibility of market volatility.

Discoveries are at record lows, but exploration may be turning a corner…

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



Source: IEA analysis with calculations based on Rystad Energy (2019).

...and investment in exploration could see a slight uptick in 2019

After many years of decline, investment in exploration is set to rise to USD 60 billion in 2019, an increase of 18%. Nonetheless, the share of exploration in total upstream investment remains almost half the level in 2010.

Companies started to reduce exploration investment even before the 2014 oil price collapse, but the downturn accelerated the trend, and spending in the sector almost halved between 2014 and 2018. While companies are expected to keep spending on exploration under close control also in 2019, the anticipated increase would be the first one since 2010.

Similar to other parts of the upstream industry, the exploration sector has undergone significant structural changes in recent years. Budget cuts and financial constraints have driven the deployment of more efficient rigs and a decline in the cost of seismic surveys, ultimately leading to an overall reduction in the average project break-even.

The contraction of exploration activities translated into a massive reduction in discovered resources. Between 2014 and 2018, the discoveries of conventional crude oil amounted on average to 5.2 billion boe per year, two-thirds lower than the average of the previous decade (and over one-fifth of the oil discoveries since 2015 were in one country, Guyana). The trend was similar also for gas discoveries, at 5.0 billion boe per year in the 2014-18 period versus 15.1 billion boe in the previous decade.

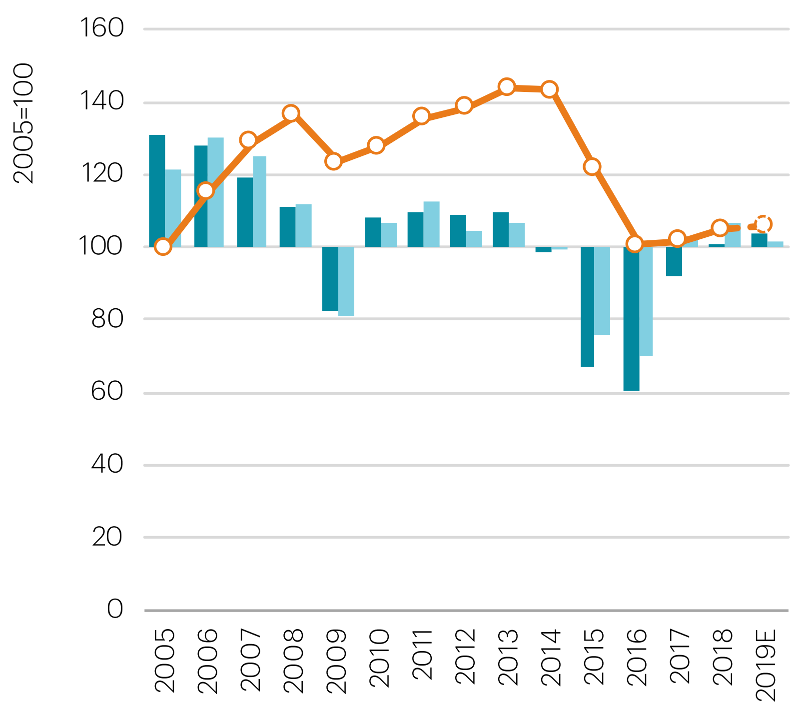
However, some signs of recovery have already been evident in Q1 2019, with important offshore discoveries in Cyprus[1], Guyana (again), South Africa, and Angola.

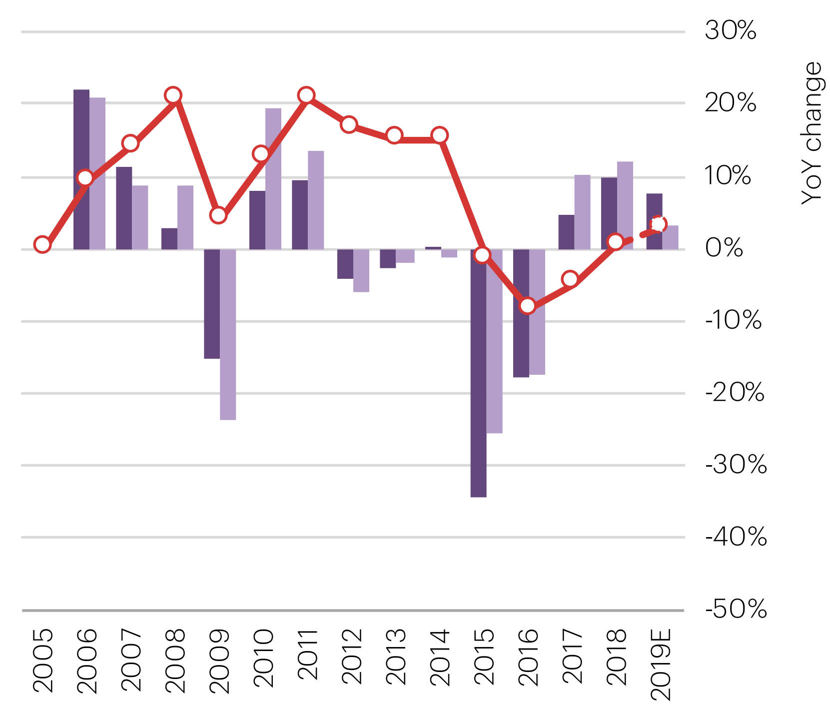
1) Note by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

Note by all the European Union Member States of the OECD and the European Union
The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Upstream costs have edged higher, but with few signs of overheating…

Upstream oil and gas cost indices



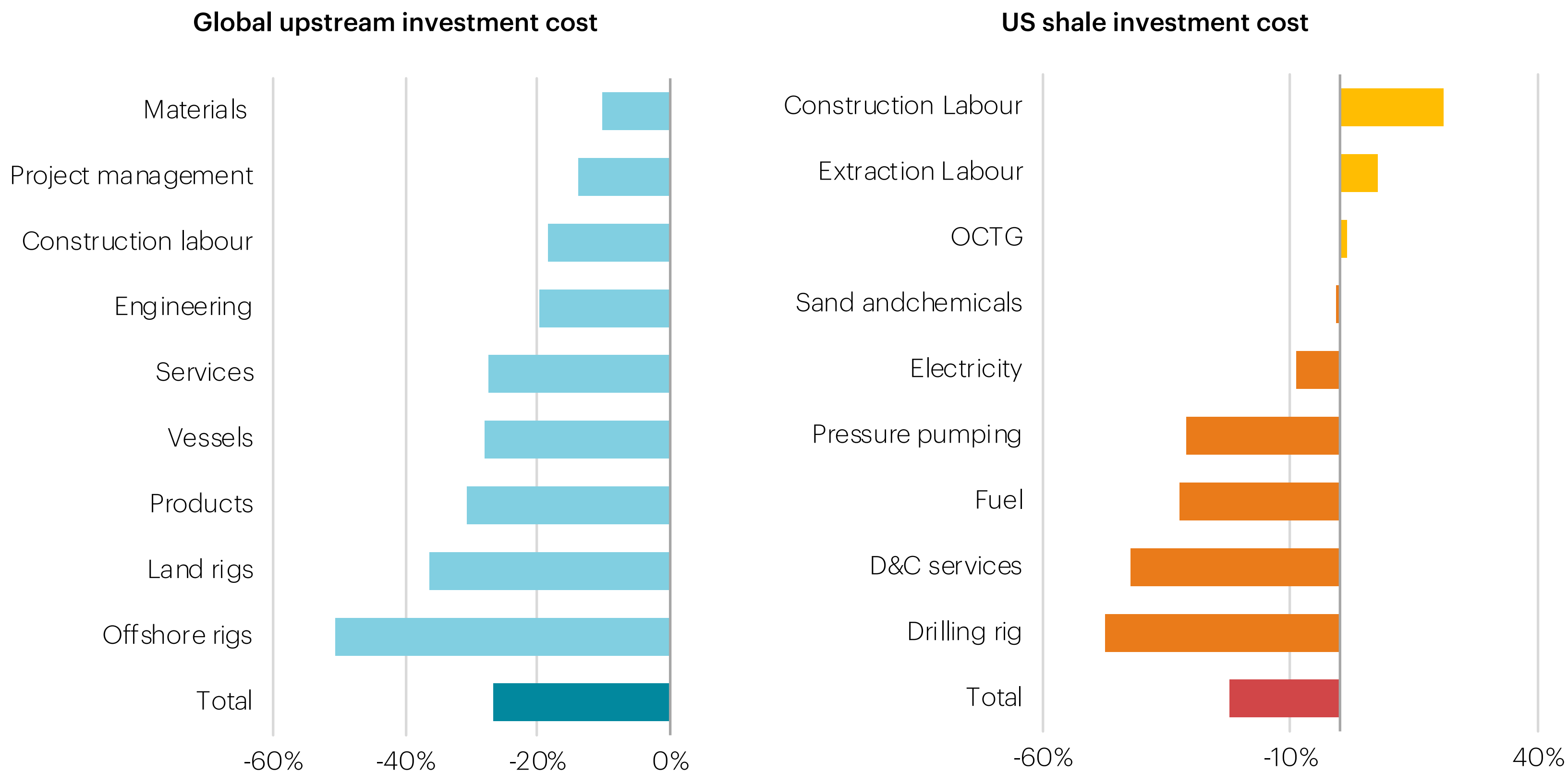


Production cost (right axis) Exploration cost (right axis) UICI (left axis)

Drilling cost (right axis) Completion cost (right axis) US Shale cost index (left axis)

...with overall costs still more than 20% below the peaks reached in 2014

Change in selected cost components, % change from 2014 to 2018



Notes: OCTG = oil country tubular goods; D&C = drilling and completion.

Doing more with less – oil and gas industry keeps costs in check

Following a 3% rise in 2018, global upstream costs are expected to rise by around 1% in 2019. This overall trend is the product of two diverging factors: on the one hand, increased upstream activities and the consolidation of the service industry are supporting higher costs; on the other hand, companies continue to target cost savings with limited pricing concessions to service companies, helped by the continued overhang in the market for some services and equipment.

The picture varies across regions and sectors. The steep fall in prices in the offshore industry has finally halted, although they remain at very depressed levels. For most equipment and services, cost inflation is still limited, while materials including cement and steel are declining on the back of weaker economic fundamentals.

Costs for the conventional upstream sector are still significantly below the levels seen in 2014. Rig rates, both onshore and offshore, are over 30% lower, but all key cost components are showing a significant discount compared with the pre-downturn levels.

Costs in the shale industry are affected by a different set of factors. We expect cost inflation in 2019 of around 5% – lower than the 12% seen in 2018.

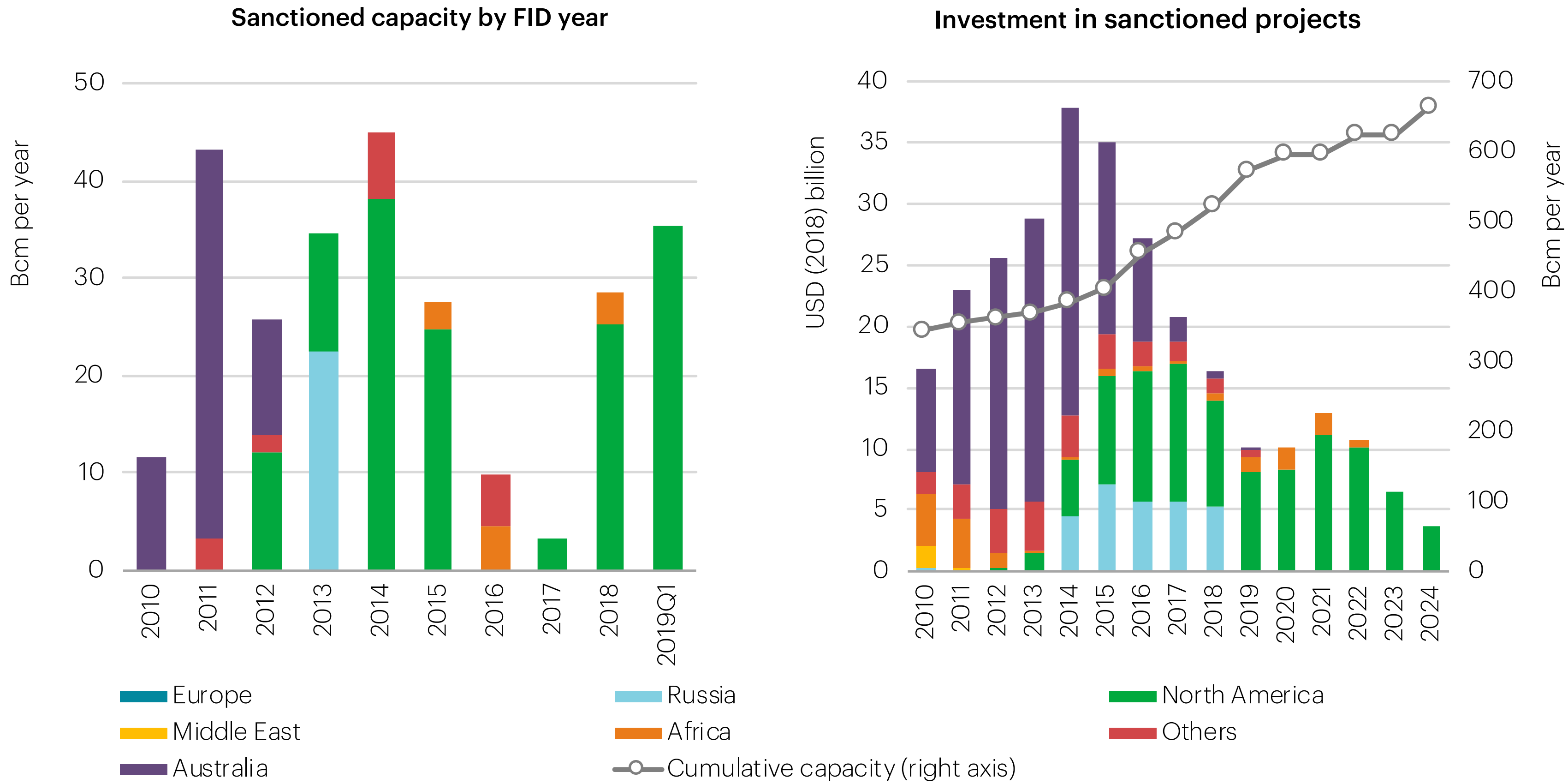
The key inflationary components for shale activities in 2019 are shortages of personnel, which push costs higher in the drilling and completion (D&C) services component, and drilling rigs, where the market for high-spec rigs remains tight even though the level of activity is also slowing somewhat.

The costs of pressure pumping and proppants are expected to taper off as a large increase in sand supply from new local production sites is helping to keep pricing and transportation costs down in the Permian Basin.

Investment in oil and gas midstream and downstream

The logjam of new LNG project approvals has been broken…

World LNG liquefaction capacity and investment by country/region



Note: The investment estimates correspond to the actual spending in a given year and are calculated considering 53 projects sanctioned since 2000 up to April 2019.

Source: IEA analysis with calculations based on company reports and websites.

...and 2019 could be a big year for new gas infrastructure

After a two-year lull, four new LNG projects have been sanctioned since mid-2018 (three in North America and an FLNG in offshore West Africa). These projects will add almost 60 billion cubic metres (bcm) of nominal liquefaction capacity by 2025, with overall investment of over USD 40 billion.

A bullish outlook for gas demand is encouraging companies to consider the sanctioning of additional LNG plants. The ones considered most likely to reach FID in 2019 include the 45 bcm capacity expansion announced by Qatar, the Arctic LNG 2 project in Russia, and the ExxonMobil-led consortium in Mozambique Area 4, among others. If all those projects reach FID this year, 2019 will represent a historical record for decisions on LNG capacity expansion.

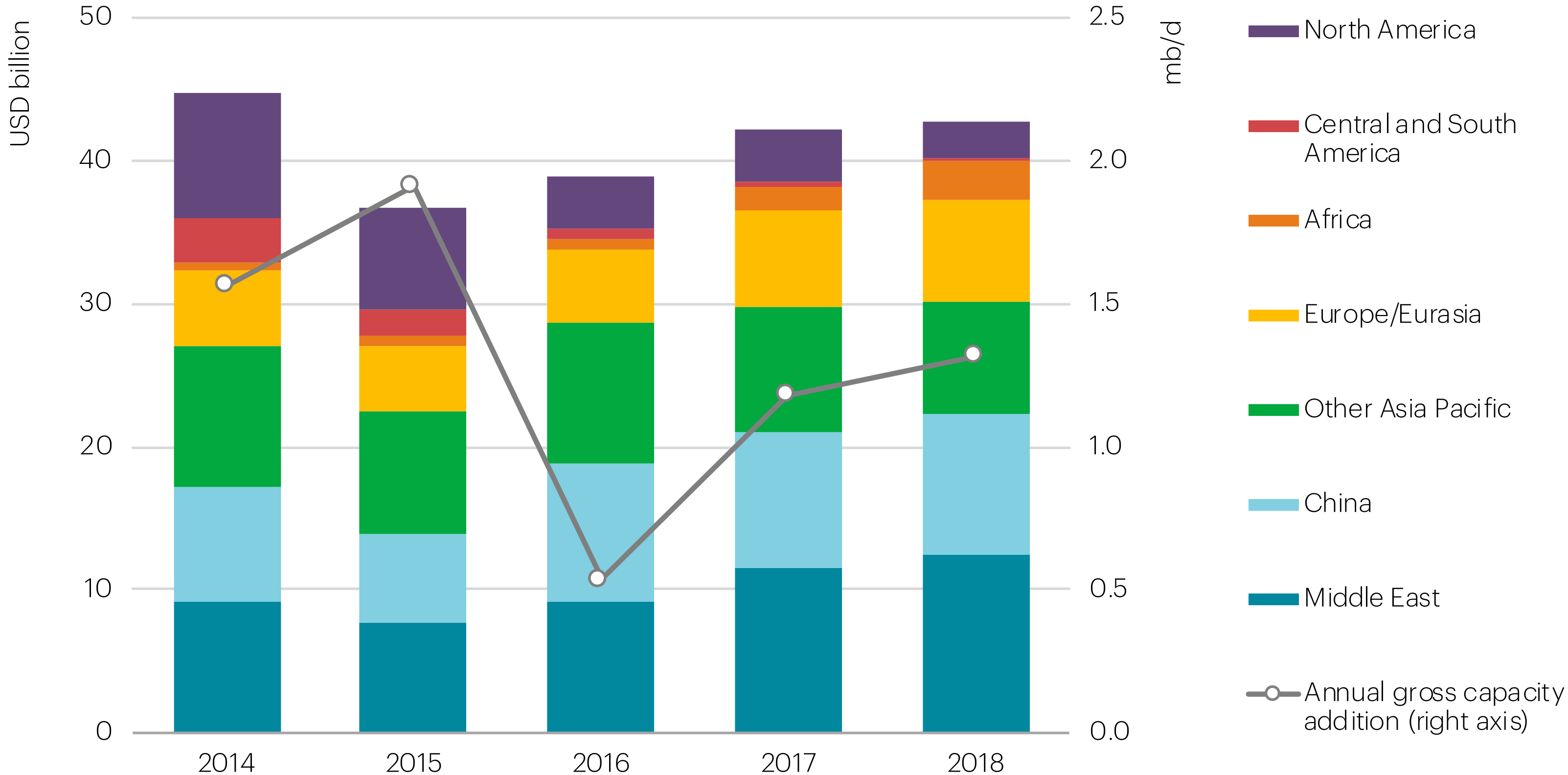
Recent years have seen also a wave of new major pipeline projects. Gazprom led developments, with three major pipelines announced to be completed and operational by end of 2019: the 55 bcm/yr Nord Stream II to Germany through the Baltic Sea; the 38 bcm/yr Power of Siberia to China, and the Turkstream connecting Russia and Turkey through the Black Sea with two 15.75 bcm/yr lines.

In the United States, the shale revolution has triggered the development of several new pipelines. Texas and the prolific Permian Basin is the epicentre of the development of new pipelines, mainly aimed at connecting rising oil and gas production from the basin to the Gulf Coast.

The construction of new oil pipelines has been prioritised so far in the Permian, but the lack of evacuation capacity for associated gas production has raised concerns as a possible constraint for further oil supply growth. The debottlenecking of gas supply in the Permian is expected by end-2019 with the entering into operation of the 20-bcm/yr Gulf Coast Express pipeline.

Refining investment continues to rise, led by Asia and the Middle East...

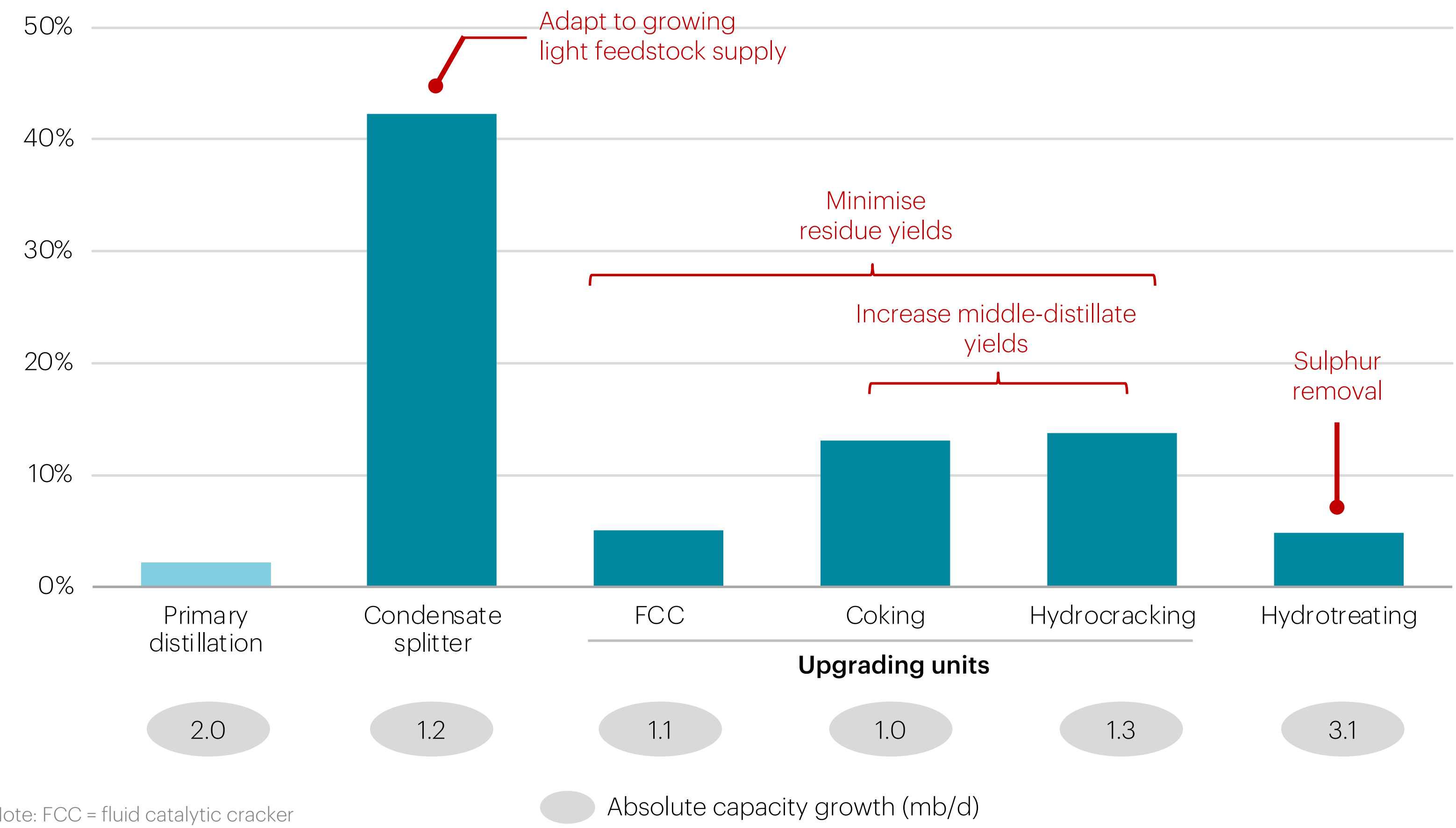
Investment in oil refineries (greenfield and upgrades) by region



Note: The figures reflect estimates of ongoing capital expenditures over time and do not include maintenance capex.

...in part to adapt to changing characteristics of demand and supply

Net growth in refining capacity by unit type, 2014-18



Note: FCC = fluid catalytic cracker

Refiners are responding to the IMO 2020 regulation in diverse ways

Non-exhaustive examples of IMO-related refining investments

Type	Description	Examples
Residue desulphurisation	Removes sulphur from vacuum residue and produces more LSFO	• SK Innovation: building a vacuum residue desulphurisation facility to be operational from 2020
Upgrading	Adds residue cracking units to reduce HSFO production and increase lighter products production	• ExxonMobil: investing in refinery upgrades in the United Kingdom (Fawley) and Singapore (Jurong) • S-OIL: commissioned a residue upgrading complex in 2018
Solvent de-asphalting (SDA)	Processes heavy fuels to clean middle distillates and provides increased crude flexibility	• Shell: commissioned a new SDA unit at its Pernis refinery in 2018 • Neste: started up an SDA at its Porvoo plant • Hyundai Oilbank: operating an SDA unit at its Daesan plant
Yield adjustments	Adjusts configuration in favour of gasoil relative to gasoline by redirecting some of the atmospheric gasoil and residue streams away from FCCs	• Mostly in the United States

Note: HSFO = high-sulphur fuel oil, LSFO = low-sulphur fuel oil, FCC = fluid catalytic cracker. The IMO regulation limits the sulphur content in marine fuels to no more than 0.5% from 2020.
Source: Press research.

Refiners are gearing up for changing market environments

After rising from a dip in 2015, refining investments have remained high, reflecting a wave of investment decisions in recent years. Capital spending on refining units (new units and upgrades) and maintenance amounted to USD 43 billion and USD 24 billion, respectively. This is expected to result in large amounts of new capacity coming online in 2019 and beyond, suggesting potentially greater competition in the refining sector in the years ahead.

Around 70% of the investment in refining units in 2018 was made in Asia (where regional product demand is growing) and the Middle East (where companies are pursuing vertical integration). Several companies in the Middle East, such as Saudi Aramco, are also pursuing investment opportunities in growing Asian markets, such as China, India, Korea, and Malaysia.

In addition to primary distillation capacity, refiners are increasingly investing in various upgrading and desulphurisation units to adapt to changing demand, supply, and regulatory environments:

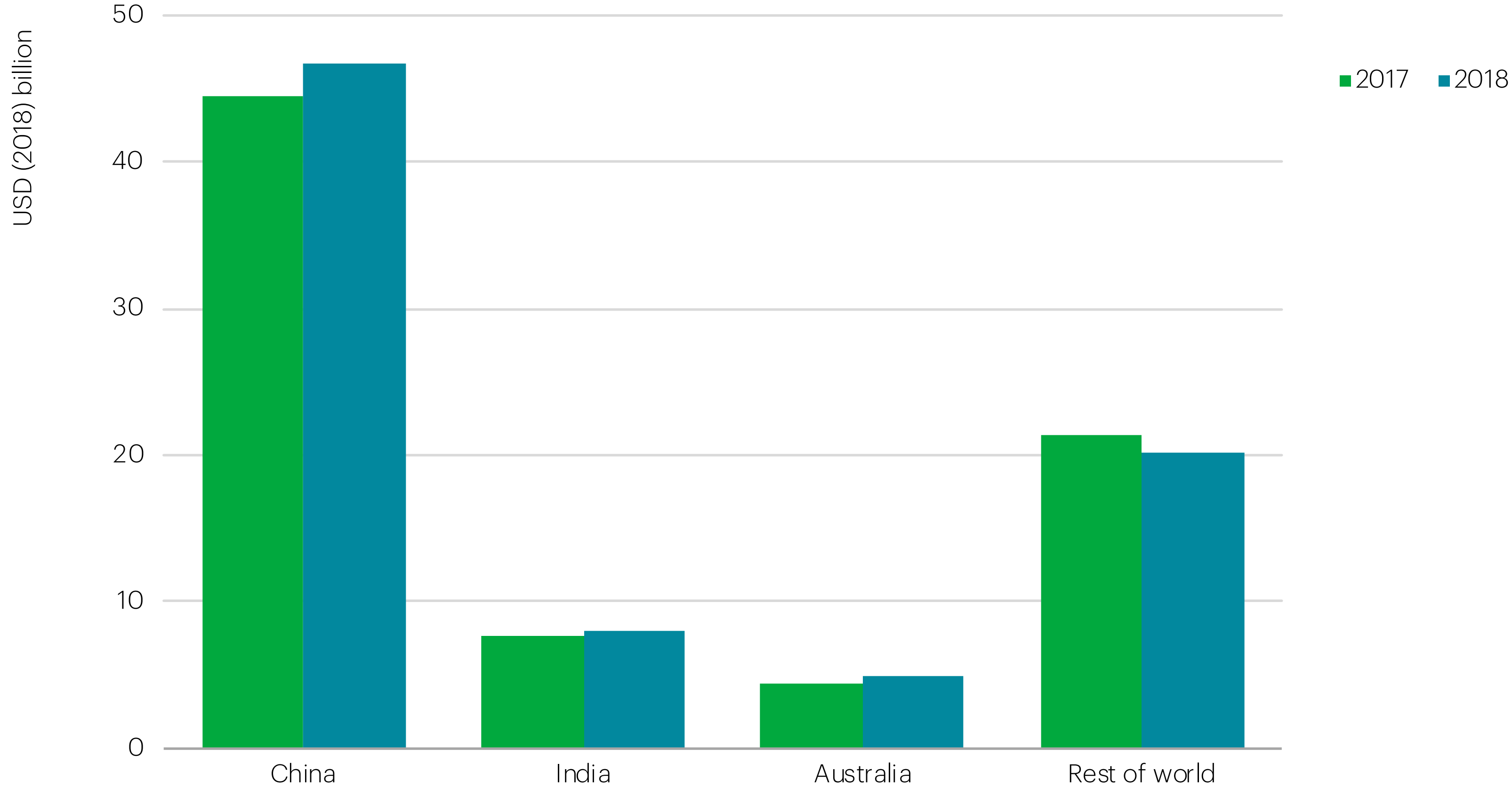
- Upgrading capacities grew by 9% between 2014 and 2018 to minimise the production of heavy residue. Investments in coking and hydrocracking units were higher, reflecting refiners' efforts to target more middle distillates production (such as diesel).
- Tightening product quality standards, such as the Euro emissions standards and the International Maritime Organization's sulphur cap, underpinned growing investments in desulphurisation units, which are set to grow rapidly in the coming years.
- Condensate splitter capacities registered a strong 42% growth, primarily in the United States, Iran, and Korea in light of a growing light feedstock supply.

Coal supply investment

Investment in coal supply and change 2018 vs 2017 (111-112)

Coal supply investment increased for the first time since 2012...

Investment in coal supply by selected country and region



…but the divestment movement is gathering momentum

In 2018, global investment in coal supply increased by 2% to USD 80 billion as investment ramped up in almost all the major producing regions (China, India, and Australia). This was the first increase since 2012, although investment remains far below the peaks reached in the early 2010s. The investment was almost all for sustaining production levels rather than opening new mines.

China, accounting for 45% of global coal production, remains the key driver of total investment in the sector. China's investment in coal supply increased to over USD 45 billion in 2018 after five consecutive years of decline. Most investments were aimed at sustaining production and increasing productivity and safety by closing unsafe, inefficient mines and replacing them with more efficient ones.

Coal supply investment in India grew by 5% in 2018, underpinned by policy favouring domestic production while reducing imports as much as possible, amid a substantial growth of coal consumption driven by economic growth and higher power demand.

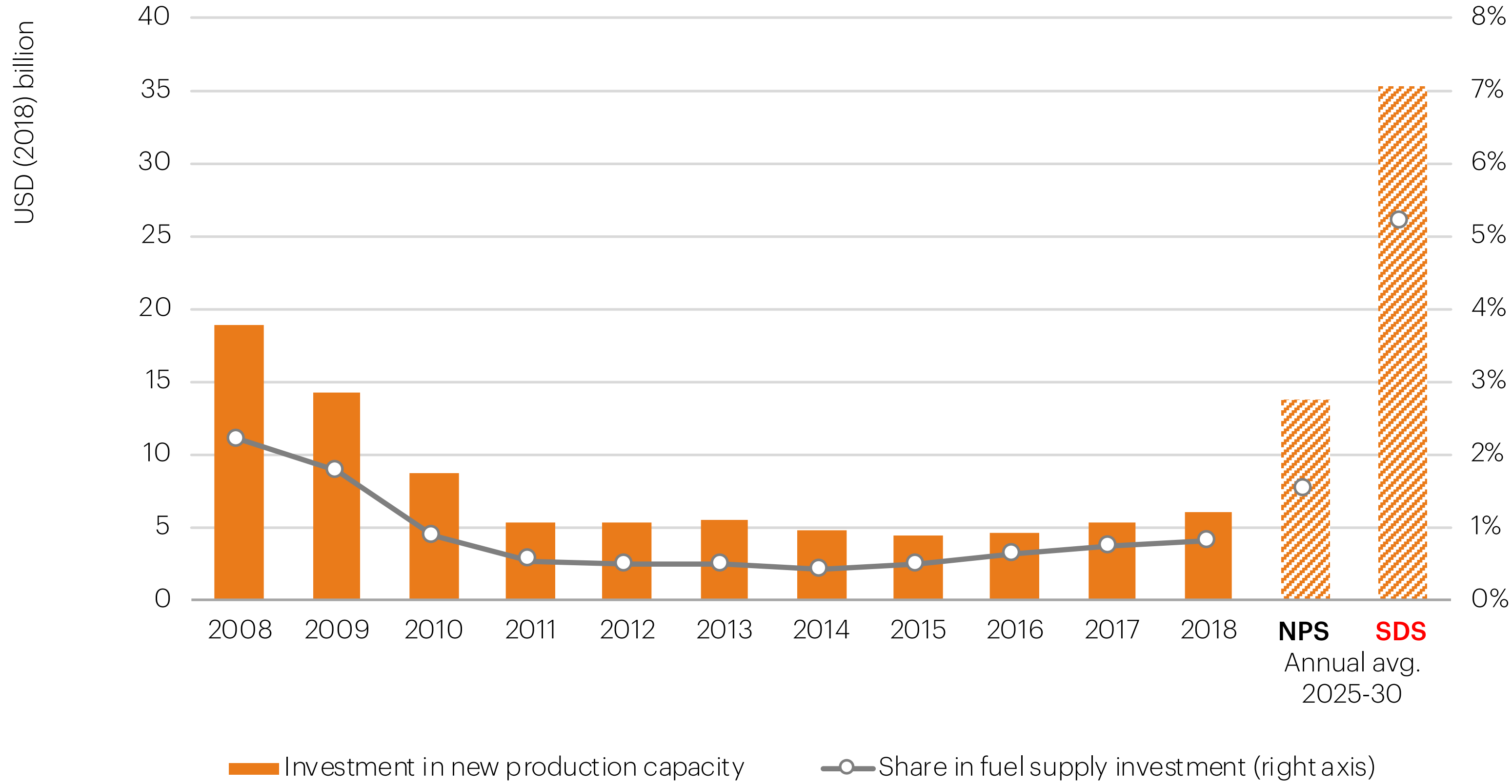
Rising coal prices and soaring seaborne coal trade over the last couple of years are providing signals to coal-exporting companies to increase capital spending, but there are few signs of a strong pick-up in spending. The stronger capital discipline put in place during the 2013-15 price downturn has relaxed, but expansionary capital expenditures are scarce, in particular for greenfield projects.

The divestment movement – where investors allocate capital away from the coal sector – is gaining steam. China's State Development & Investment Corporation, some Japanese trading companies, and QBE, the largest Australian insurer, announced the end of exposure to the sector. Glencore, the world's largest coal exporter, declared a coal production cap, in response to investor pressure.

Biofuels investment

Biofuels investment has risen somewhat from recent low levels…

Investment in biofuel production capacity



Note: Biofuels include crop based ethanol, cellulosic ethanol, fatty acid methyl ester (FAME) biodiesel, hydrotreated vegetable oil (HVO), among others.
Source: IEA analysis with estimates based on data from IEA (2018c) Renewables 2018 and F.O. Licht (2019).

…but the sector needs further policy support to achieve the SDS trajectory.

In 2018, investments in transport biofuels production capacity increased by 12%, led by China where 10% ethanol blending is to be rolled out nationwide, and the United States where most investment went towards adding production capacity at existing plants. Brazil saw stable capacity additions, with record ethanol demand in 2018 and the RenovaBio biofuel policy due to commence in 2020.

The increase was partly offset by a decline in investment in Europe, largely due to a weakening long-term outlook for policy support for conventional biofuels in the updated Renewable Energy Directive, and in Southeast Asia where countries such as Indonesia and Malaysia have production overcapacity.

Investment in ethanol production capacity accounted for 80% of the biofuels investment over the last five years, one-tenth of which went to advanced ethanol (cellulosic ethanol). The remaining 20% was in biodiesel and the growing trend of investment in hydrotreated vegetable oil production.

Biofuels investment represented less than 1% of the total investment in fuel supply. In absolute terms, the investment in 2018 was 70% below its level from a decade ago when investment was boosted by policy support and rapid market expansion in Europe and the United States.

A stagnation in investment over the past several years was led by the "blend wall" effect in the United States, which refers to structural challenges relating to vehicle suitability and fuel distribution infrastructure for higher ethanol blends, challenging economic conditions in the Brazilian market and policy uncertainty in Europe, combined with lower oil prices from late 2014.

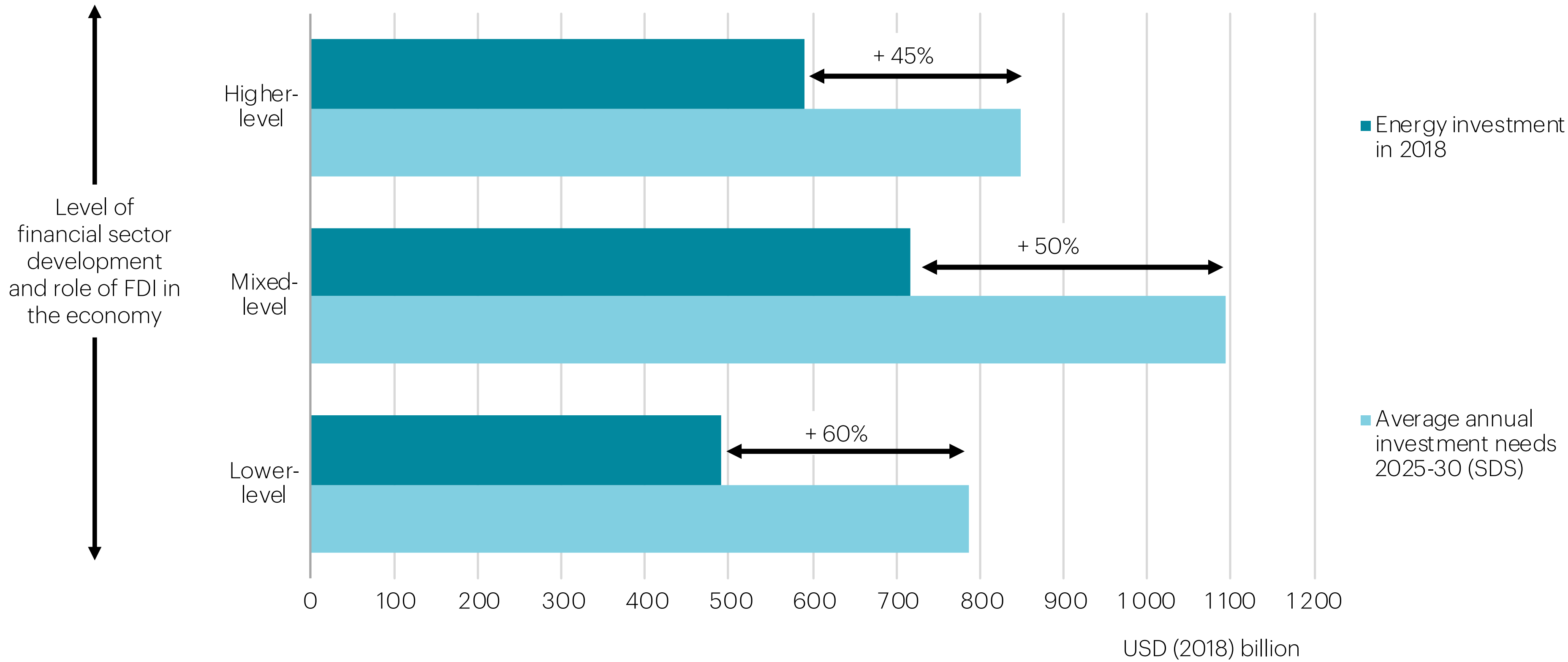
Investment in the sector would need to increase six fold in the next decade to achieve the trajectory in the SDS, indicating the importance of increased policy support to scale up sustainable biofuel deployment and facilitate innovation for advanced biofuels.

Financing and funding trends

Cross-sector financing trends

Access to capital is critical to supporting energy investment...

Energy investment, classified by financial sector development and the role of foreign direct investment (FDI) in the economy



Note: Financial sector development in a given country or region is assessed as the share of private credit to gross domestic product (GDP) and the share of stock market capitalisation to GDP. FDI = foreign direct investment; the role of FDI is assessed by the share of net FDI inflows to GDP. SDS = Sustainable Development Scenario.

Source: IEA analysis with calculations for financial system development and FDI are based on World Bank (2019).

...and gaps are largest in the least financially developed markets

Energy investment has a strong link with country-level financial conditions. Deep availability of capital from private institutions, liquid capital markets, and access to domestic and foreign sources, complemented by limited public finance, are hallmarks of a supportive enabling environment.

In 2018, one-third of energy investment was concentrated in areas with both well-developed financial systems and good access to foreign capital (higher-level). This category includes markets such as the United States, a number of European countries. and Australia, where private credit, equity markets . and foreign sources of capital all play a relatively strong role in the economy.

Around 40% of investment was in economies with mixed conditions. Some large markets, such as China, have relatively well-developed domestic financial systems but lower levels of FDI in the economy. Others, such as Brazil and Mexico, have benefitted from rising shares of FDI in recent years but have relatively constrained domestic finance. Countries in Southeast Asia are highly mixed.

A quarter of spending was in areas with lower levels of development, where state-backed capital plays a stronger role. This category covers a wide spectrum. In India, the availability of private credit has increased substantially in recent years. In contrast, Indonesia and much of sub-Saharan Africa, outside of South Africa, are more constrained for capital, particularly for early stage project preparation.

Looking ahead, investment gaps are largest in areas currently with mixed or lower-level financial conditions, i.e. those areas with relatively high capital constraints in their economies. In the SDS, 70% of energy investment is projected in such regions, meaning that the need to boost investment in sustainable energy is highest in the regions with the least-developed financial sectors.

Key theme: Risks, returns, and investment across energy sectors

Energy investment decisions are made with an eye towards profitability but also by perceptions of risk and business factors. Recently announced intentions by some actors to shift their capital allocations to a different mix of fuels and technologies merit a look at some of the financial and non-financial drivers.

The two main reasons given for capital reallocation are: 1) to invest more in sectors seen as supporting energy transitions or, 2) to invest less in areas now perceived as riskier. For example, a few European oil and gas majors now plan to invest more in power, while many utilities, whose portfolios were previously oriented towards thermal power, have boosted activity in renewables, grids, and end-use services. A number of financial investors have signalled restrictions on financing coal assets.

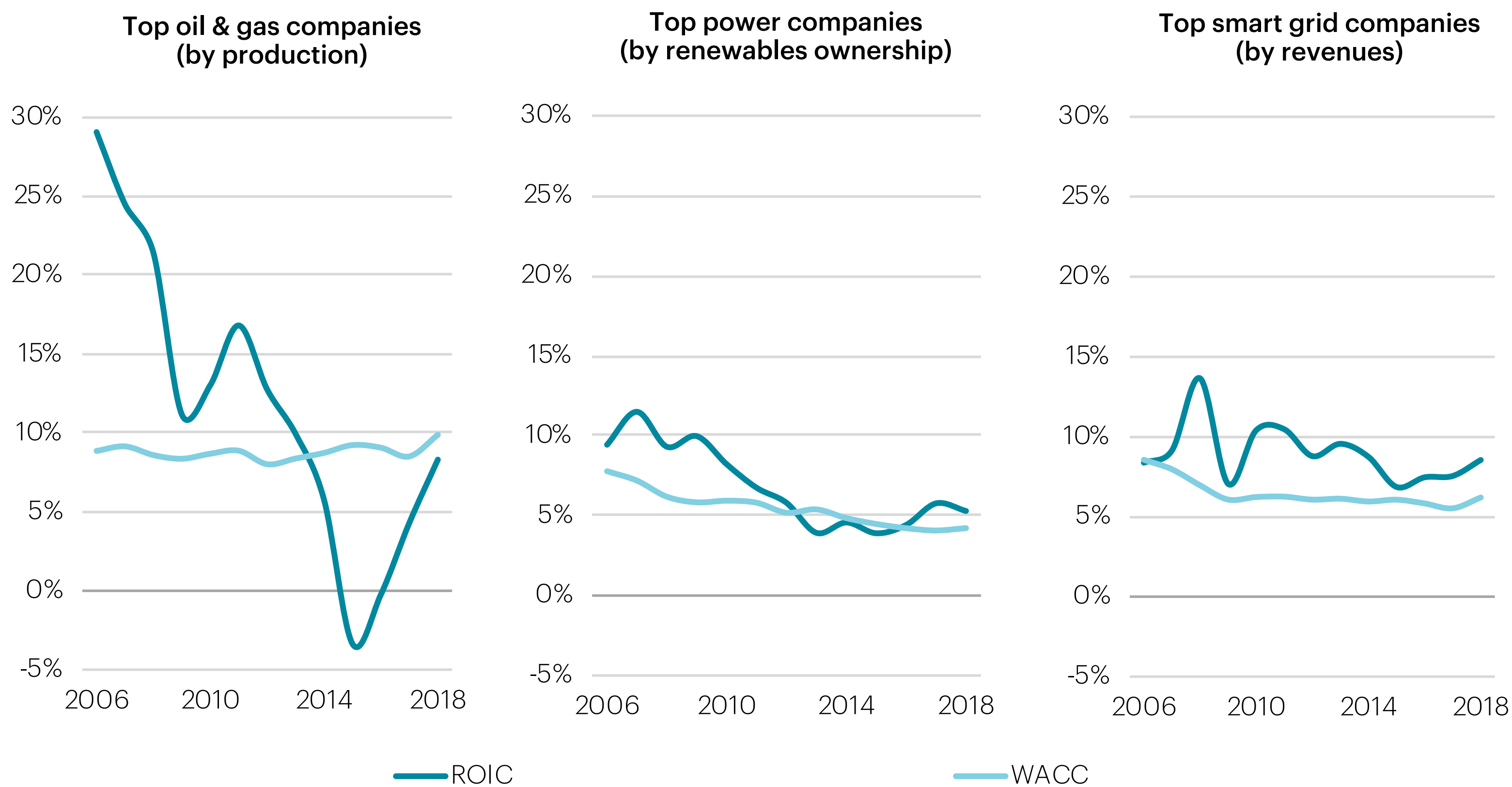
The SDS includes a modest overall increase in investment but a major capital reallocation towards low-carbon power and grids. However, today's energy market trends are not at all consistent with the SDS, with rising emissions and insufficient deployment of many clean energy technologies (IEA, 2019c).

While increased investment activity by power companies in renewables and grids is reflected in this report's data, capital reallocation is less evident in the data for the oil and gas industry. So far, oil and gas activity in power has come more from company acquisitions (e.g. in solar PV, EV charging, and batteries), while capital spending on renewables has remained less than 1% of that for fuels.

Slides 121-122 illustrate how returns and risks for investments by listed companies in different energy sectors are evolving by comparing two measures: the profitability of investments (ROIC) and the cost of financing them (WACC). The difference in the metrics provides an indicator of an industry's ability to create shareholder value, a driver for any decision to access and allocate capital.

Over time, the oil and gas industry has shown higher, but volatile, return on investment; in power-related sectors, returns have been steadier, but lower

Return on invested capital (ROIC) and after-tax weighted average cost of capital (WACC) for listed energy companies

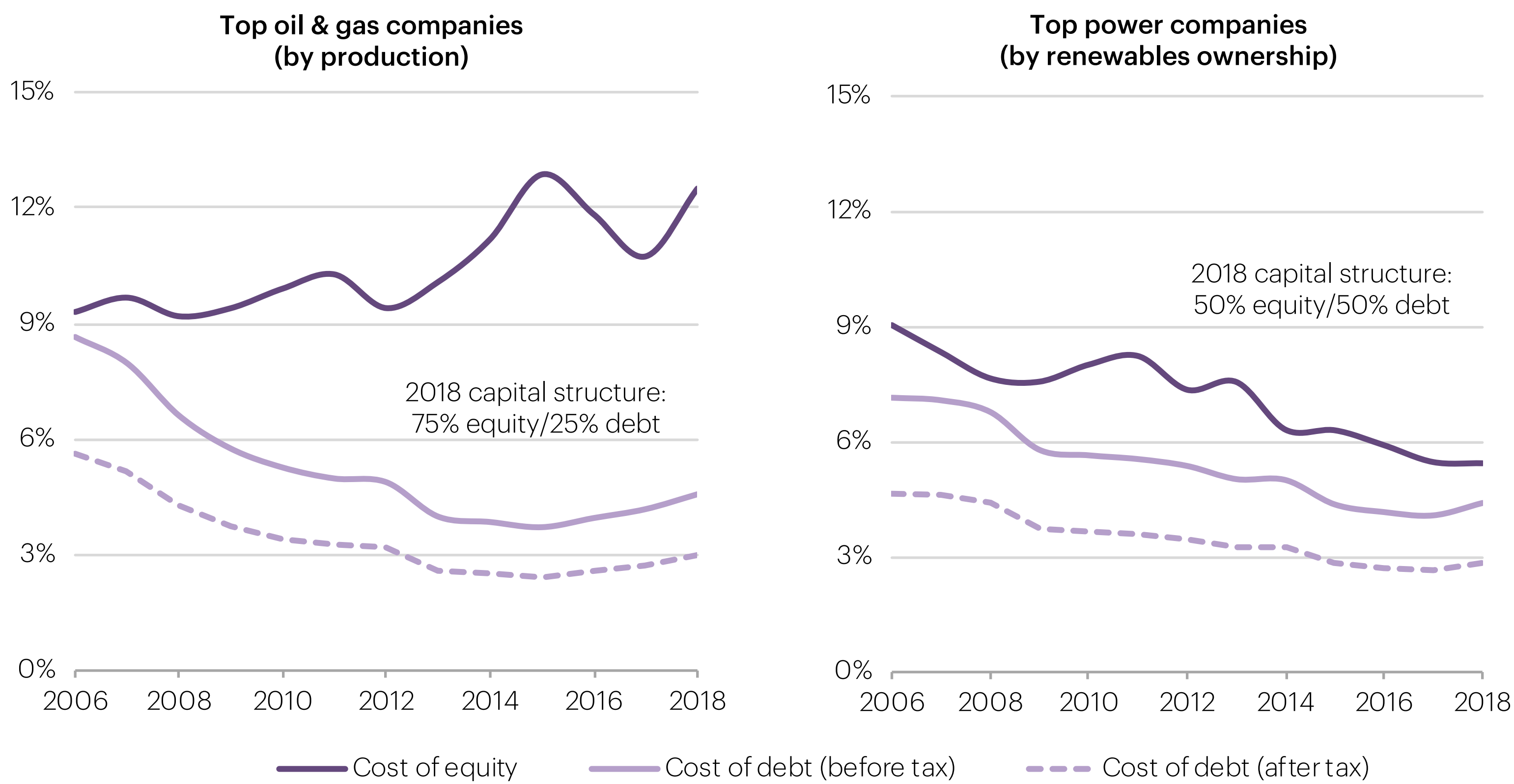


Note: The samples contain the top 25 listed energy companies (in 2018) by oil and gas production, power companies by ownership of solar and wind capacity and companies involved in investing and supplying smart grid assets, by total revenues. Companies based in China and Russia are excluded from the analysis. Industrial conglomerates, with large business lines outside of energy are also excluded. Return on invested capital measures the ability of a company's core business investments to generate profits, expressed as operating income adjusted for taxes divided by invested capital. The weighted average cost of capital is expressed in nominal terms and measures the company's required return on equity and the after-tax cost of debt issuance, weighted according to its capital structure. The tax rate is assumed at 35% for all companies.

Source: IEA analysis with calculations based on company data from Thomson Reuters Eikon (2019) and Bloomberg (2019).

The cost of capital has trended downwards for the power companies, but has recently risen for the oil and gas companies

Drivers of weighted average cost of capital (WACC) for listed energy companies



Note: The samples contain the top 25 listed energy companies (in 2018) by oil and gas production and power companies by ownership of solar and wind capacity. Companies based in China and Russia are excluded from the analysis

Source: IEA analysis with calculations based on company data from Thomson Reuters Eikon (2019) and Bloomberg (2019).

Recent financial metrics appear more favourable for power companies investing in energy transition…

The financial measures show that the oil and gas and power sectors are very different in terms of profitability and financing. Historically, oil and gas has been characterised by higher returns, higher cost of capital, and greater volatility. More capital-intensive power has shown lower profitability but with lower cost of finance and a degree of market volatility that is more balanced with regulated assets.

Over time, returns on investment for top oil and gas companies (majors and E&P by current production) dropped from high levels as market fundamentals and oil prices weakened. This was followed by a recovery in the past three years, thanks to higher prices, cost reductions and careful project selection.

Industry funding costs, which reflect a strong share of equity, were stable until 2014 when market data showed a rising return on equity required by investors. This stemmed, in part, from an increase in volatility, or systematic risk, associated with company stock prices, as expressed by a higher beta.

Returns on investment for top power companies, ranked by current ownership of solar PV and wind, declined over the past decade, with weaker profitability for thermal generation exposed to lower wholesale prices. Returns improved somewhat in the past three years, benefitting from investments in assets with more contracted revenues (e.g. renewables) as well as higher power prices.

Declining funding costs partly cushioned lower returns in power, where debt plays a bigger role. Debt became less costly with lower interest rates but also from the improved maturity and risk profile of renewables. With increases in US rates in 2018, debt financing costs rose. But required equity returns fell over time from reduced volatility, indicated by a declining industry beta.

...but signals do not appear adequate for the major reallocation of capital needed in SDS

Smart grid companies (illustrating another part of the power supply chain) have seen more consistent, positive performance, buoyed by sustained demand for new equipment and regulatory support for networks. Funding costs reflect a high influence of equity given a focus on technology development.

Putting the pieces together, the recent movement in financial metrics suggest better performance, on average in terms of average shareholder value creation, by power industries focused on energy transitions than by oil and gas companies. This may help to explain the interest by some oil companies in cross-sector investment, with potential benefits from diversification and new business development.

However, investment decisions in the energy sector are shaped by complex factors that are difficult to quantify, including demand expectations, human capital and supply chain issues, business synergies, as well as the financial and reputational risks from potentially stronger climate policies.

So far, many oil and gas companies (e.g. in the United States) are seeing operational improvements and a focus on higher-return core assets as a better recipe for long-term profitability than investing elsewhere in energy.

Supportive policy frameworks have been instrumental in encouraging investment in renewables, but there are questions over how these policies will evolve and what this might mean for risk allocation between public and private actors (see Key theme on Financial risk-management for renewables).

In sum, current market signals are not incentivising the major reallocation of capital needed to reach the goals of the SDS. This also suggests a need for better understanding of the evolution of the risks, returns, financing sources, and other factors that would accelerate energy transitions.

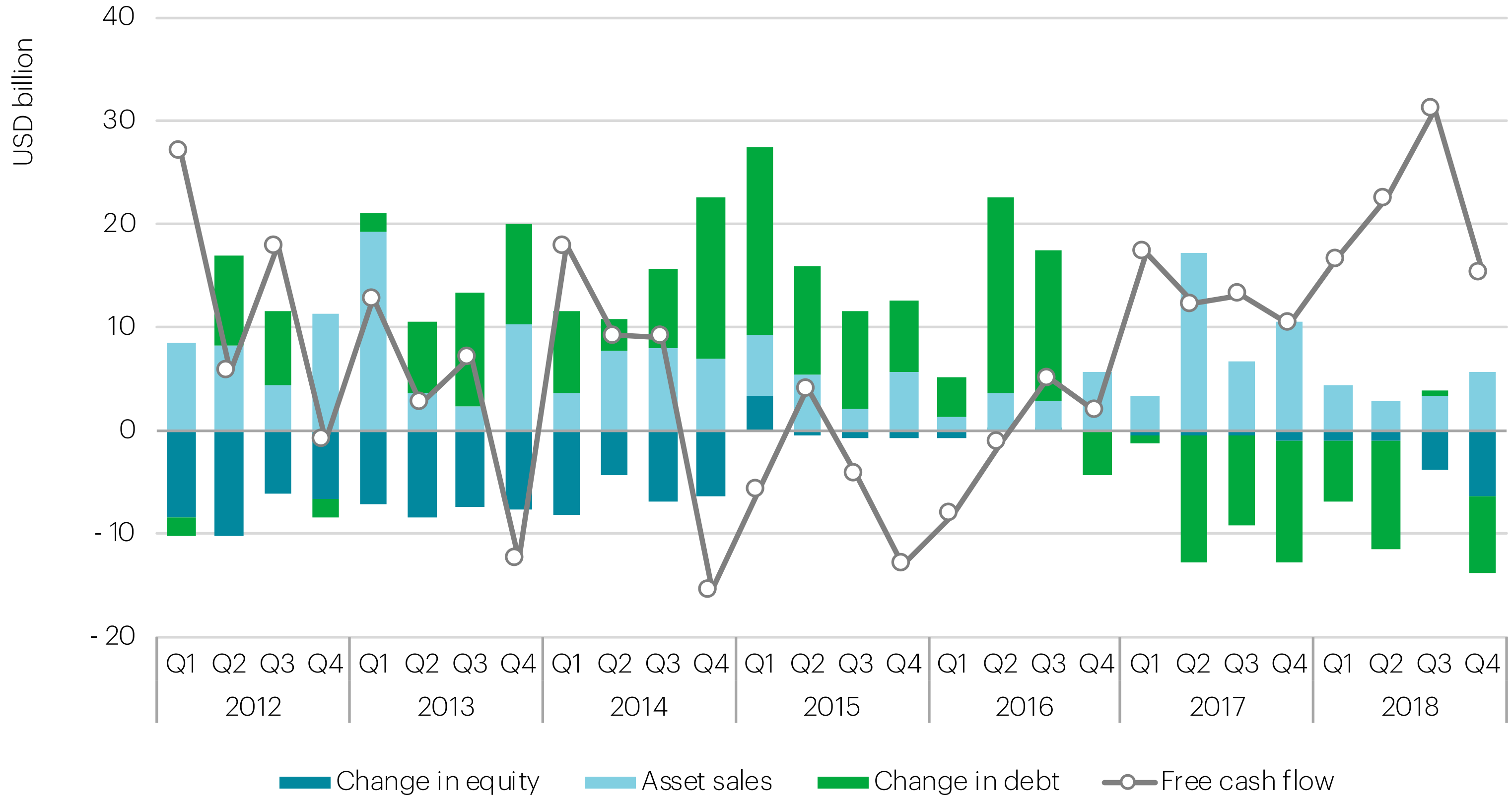
Trends in oil and gas financing

Financial performance of oil & gas majors and US independents (126-129)

Key theme: Profitability and productivity of the US shale industry (130-131)

The financial conditions of oil and gas majors improved in 2018

Majors indicative source of finance and free cash flow

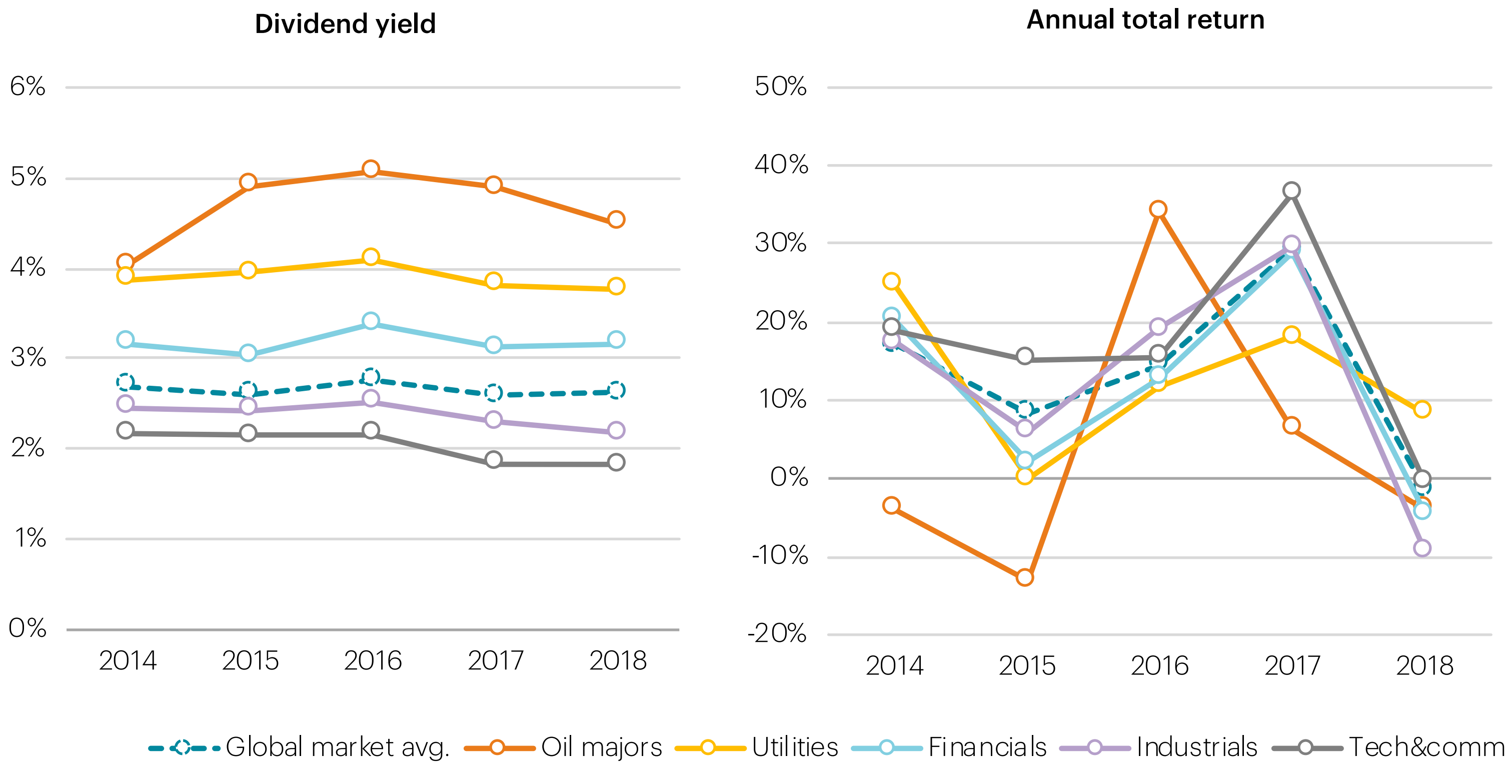


Note: Free cash flow is cash from operating activities less capital expenditure. It excludes change in working capital.

Source: IEA analysis with calculations based on company filings and Bloomberg (2019), Bloomberg Terminal.

High dividend yield has been a factor in attracting long-term equity investment in majors, but recent total return has trended below the market

Equity performance of majors and global listed companies by selected sector

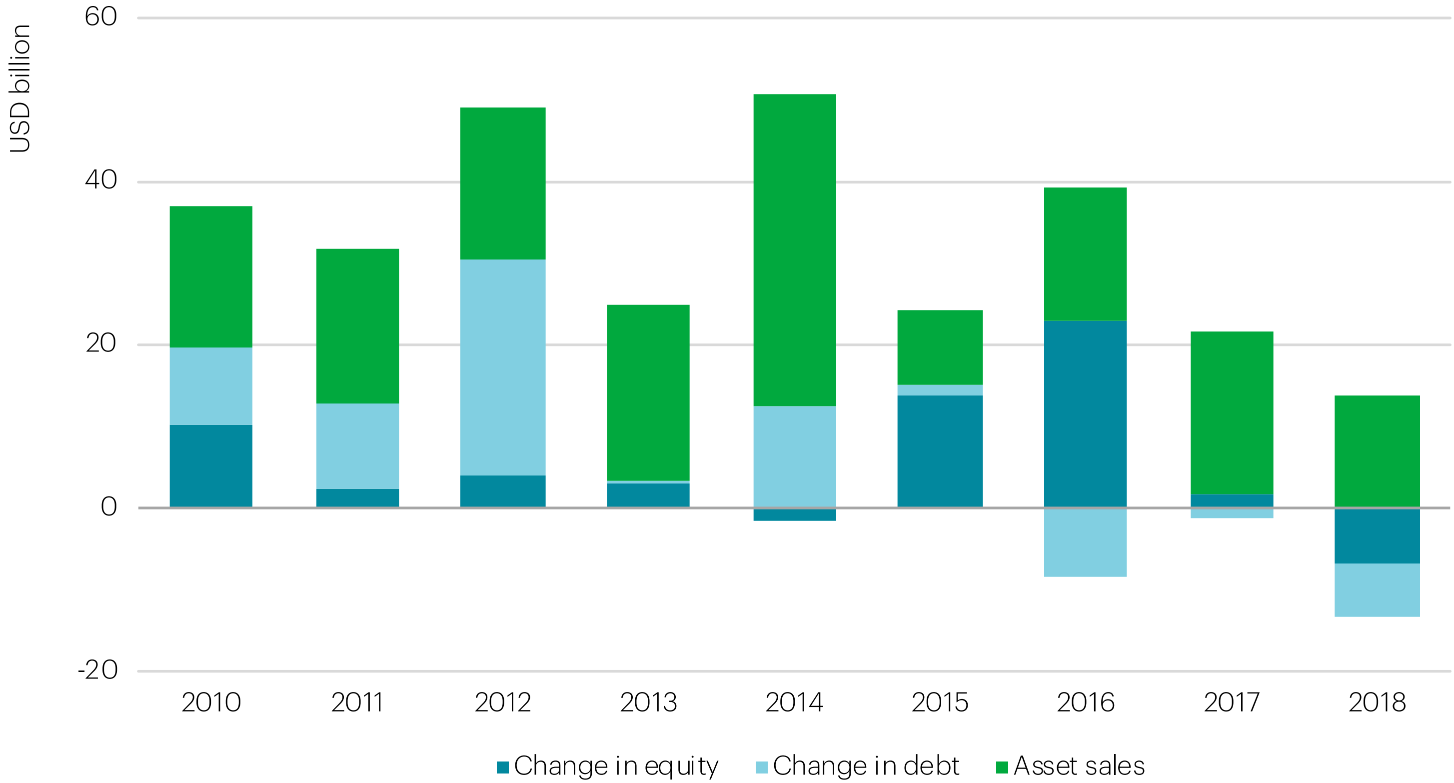


Note: Tech&com=technology and communications. The charts Include all listed companies in the world with over USD10bn (United States dollars) of market capitalisation as of 15 April. The dividend yield and annual total return by sector are the averages weighted with market capitalisation in each year. The total return refers to the sum of the share price change and dividend during a given year divided by the share price at the beginning of the year.

Source: IEA analysis with calculations based on company filings and Bloomberg (2019), Bloomberg Terminal.

US independents have reduced dependence on external fundraising

US E&P independents indicative source of finance



Note: Includes data on 48 US E&P independent companies.

Sources: IEA analysis with calculations based on company filings and Bloomberg (2019), Bloomberg Terminal.

Oil and gas companies have focused on reducing leverage and improving shareholder value creation

Since mid-2016, the majors have enhanced their financial conditions due to a combination of higher oil prices, improvements in operational efficiency, and cost reductions. In 2018, free cash flow reached almost USD 90 billion, a level not seen since 2008.

The improvement in financial conditions has also allowed the majors to reduce the high leverage levels reached during the downturn period while returning value to shareholders. After having increased their debt by more than USD 115 billion during 2014-16, in the last two years, companies have decreased their debt exposure by around half of this amount.

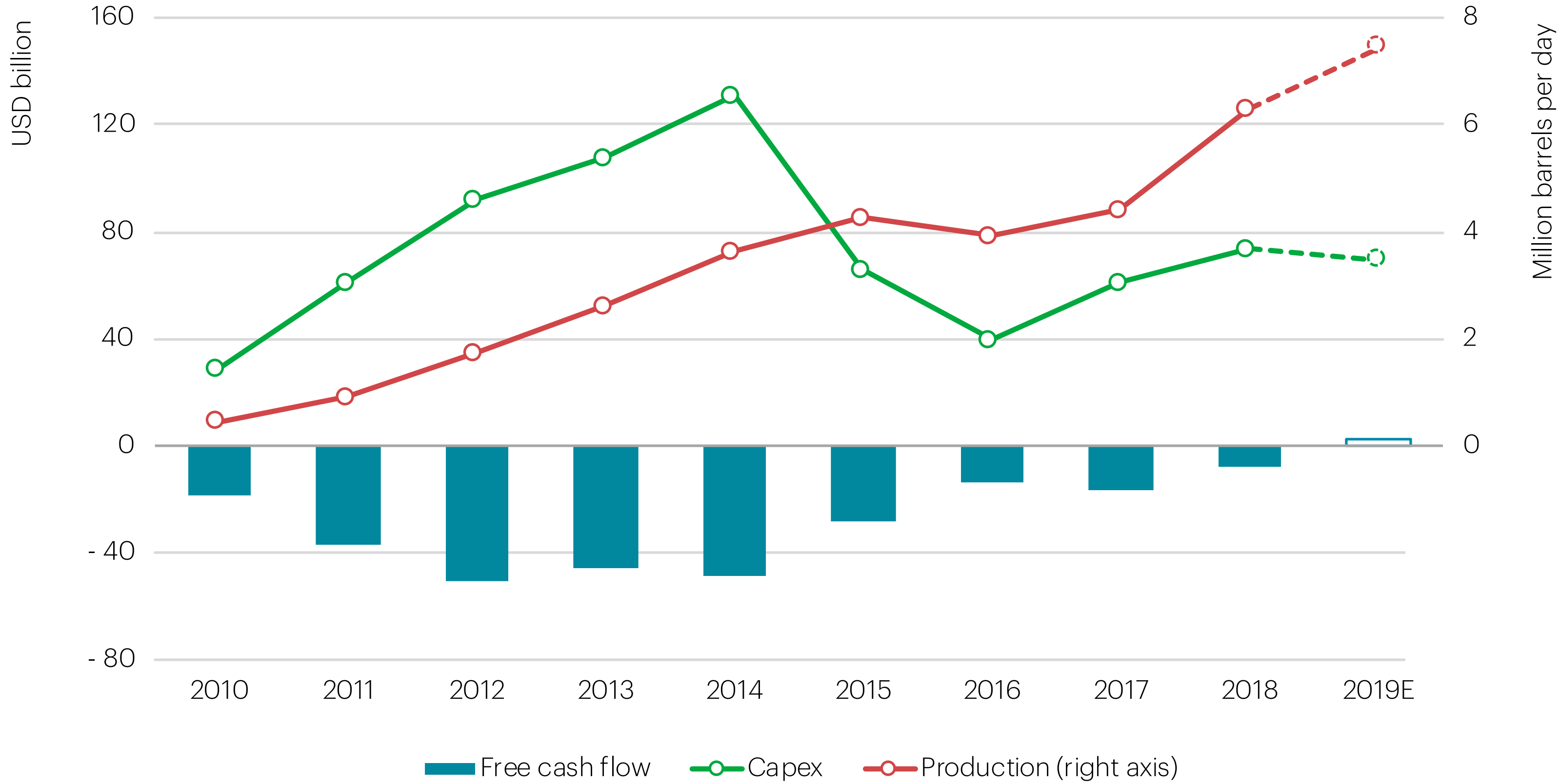
During the 2014-18 period the majors maintained high dividend levels, compared to other industries, distributing nearly USD 50 billion per year on average to shareholders. They also re-introduced share buybacks; in the 2018, these reached the highest level since 2014. Nevertheless, on a total return basis, the oil majors underperformed the market benchmark during this period, with relatively high dividends partly offset by bouts of weaker share prices.

Independent US shale companies have typically relied on new debt, selling assets or issuing new equity for financing their operations. But their call on external financing has been reduced since 2016, thanks to efficiency in their activities, cost reductions, and a more disciplined approach to balancing the investment and cash flow generated by their own activities.

While shale companies in aggregate overspent also in 2018, the ratio between capex and cash flow has constantly declined from almost 2 in 2015 to just over 1 in 2018. Furthermore, shale companies have paid back debt and began to return cash to their shareholders via share repurchases.

Key theme: Profitability and productivity of the US shale industry

US light tight oil production, investment and free cash flow



Source: Calculations based on IEA (2019a), company filings, Rystad Energy (2019), and Bloomberg (2019), Bloomberg Terminal.

Will the shale industry finally be profitable in 2019?

In mid-2018, we anticipated that the shale industry was on the verge of finally achieving a positive free cash flow for the entire year. The US shale sector indeed showed significant improvements in the financial sustainability of its operation, with its cash flow rising by about 50% while investment increased by only 20%. Ultimately, the shale industry as a whole did not turn a profit in 2018. Two main factors during the second half of 2018 led to this result:

- Shale companies accelerated spending throughout the year as a response to oil prices steadily increasing throughout the first nine months of 2018.
- Bottlenecks in the evacuation pipeline capacity from the Permian meant large price discounts from the West Texas Intermediate (WTI) price, lowering financial income for shale operators.

Assuming no significant decline in the current level of oil price (WTI price of USD 60/barrel), we estimate the shale industry be on track to finally achieving profitability in 2019 for three main reasons:

- The pressure coming from investors makes independents very likely to stick to anticipated guidance, indicating cash flow neutrality on average at WTI USD 50-55/barrel prices. Although WTI prices have increased by more than 30% in Q1 2019, companies reiterated their commitment to previous plans.
- Takeaway capacity in the Permian is less of a constraint as new pipelines are entering operation.
- The large accumulation of drilled but uncompleted wells (DUCs) can represent an additional source of oil growth with a limited injection of capital. Preliminary data show that the number of DUCs completed in the Permian has been accelerating since February 2019.

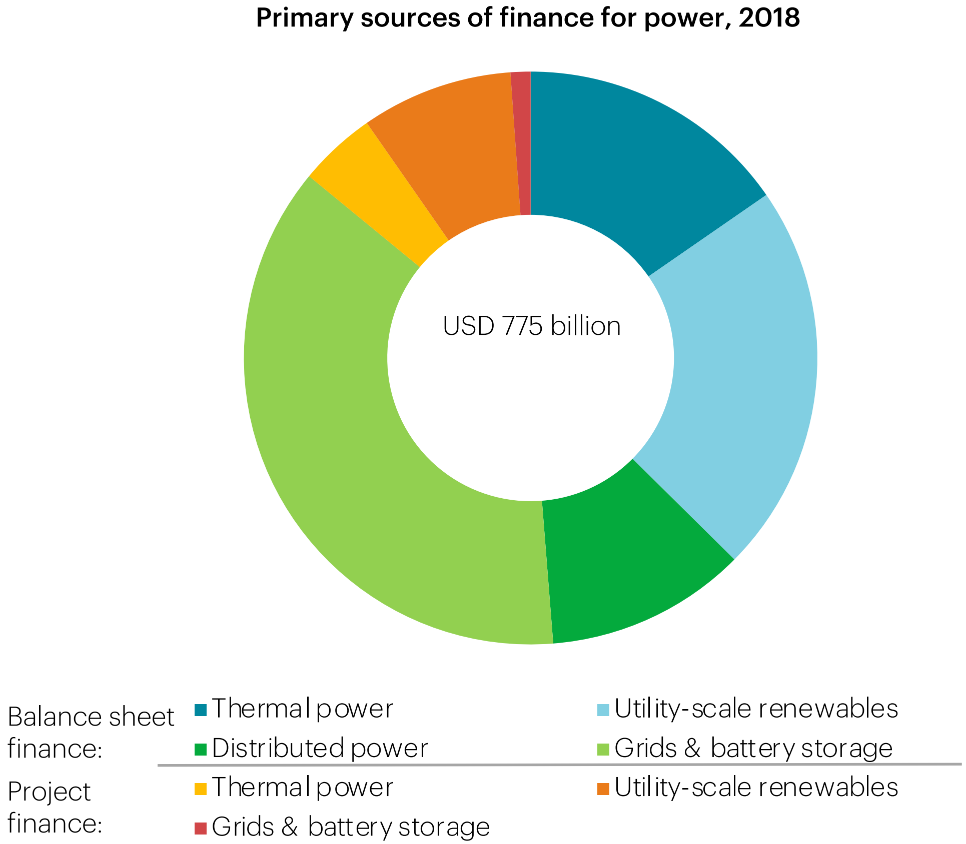
Trends in power sector financing

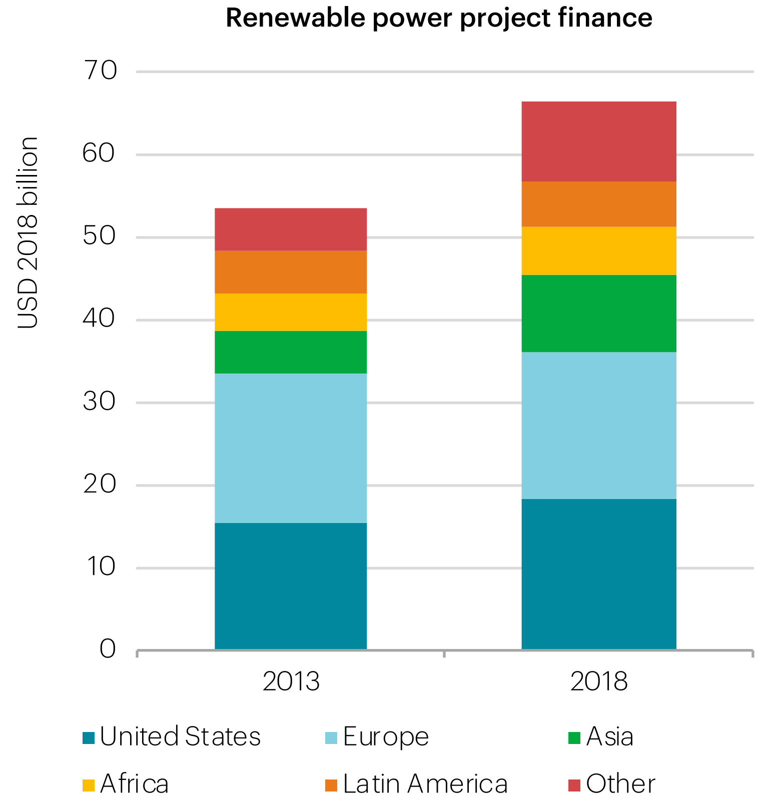
Sources of finance and funding trends for power investments (133-136)

Key theme: How does financial risk management change for renewables as they move beyond subsidies? (137-147)

Most power sector investments are made on company balance sheets but project finance has grown in importance for renewables investments

Global power sector investment by primary source of finance and project finance for renewable power



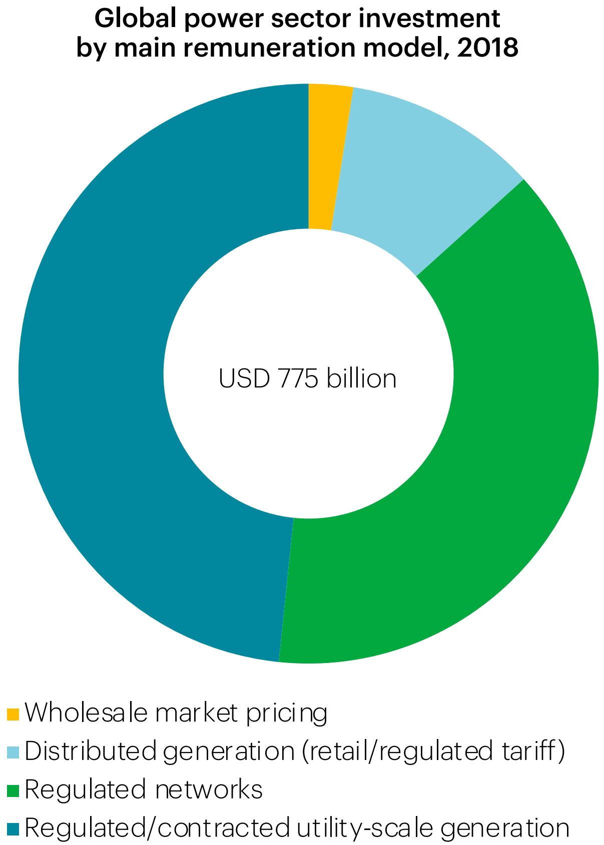


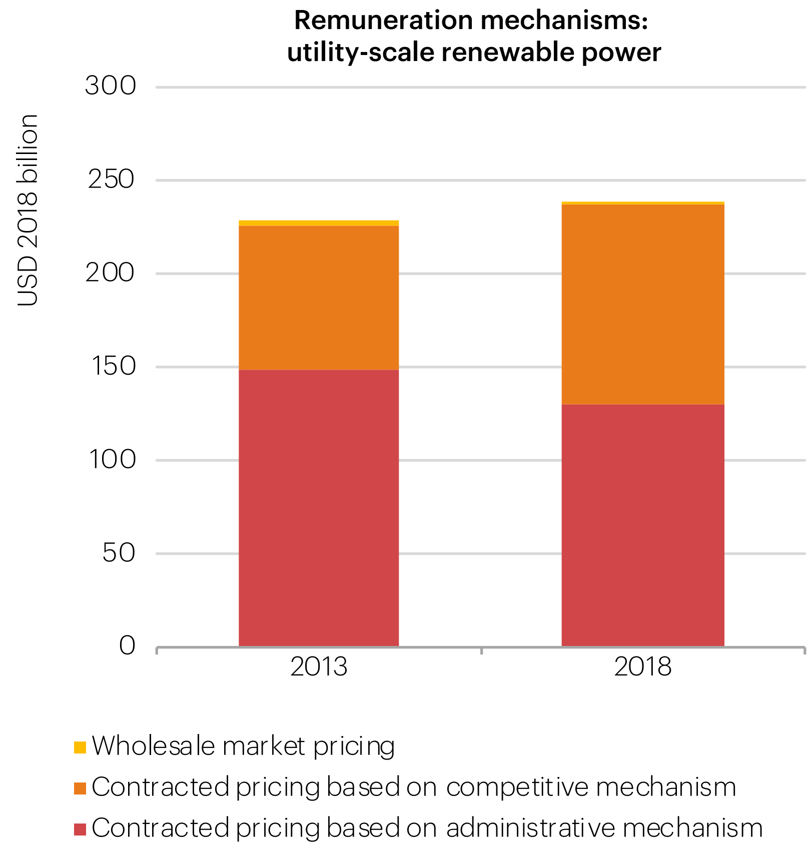
Note: Project finance data are based on disclosed deals and transaction values are adjusted to an actual spending basis.

Source: IEA analysis with calculations for project finance based on data from IJGlobal (2019), WindEurope (2019).

Power investments rely on policies and contracts to manage market risks; for renewables these are increasingly set by competitive mechanism

Global power sector investment by main remuneration model and remuneration mechanisms of renewable power

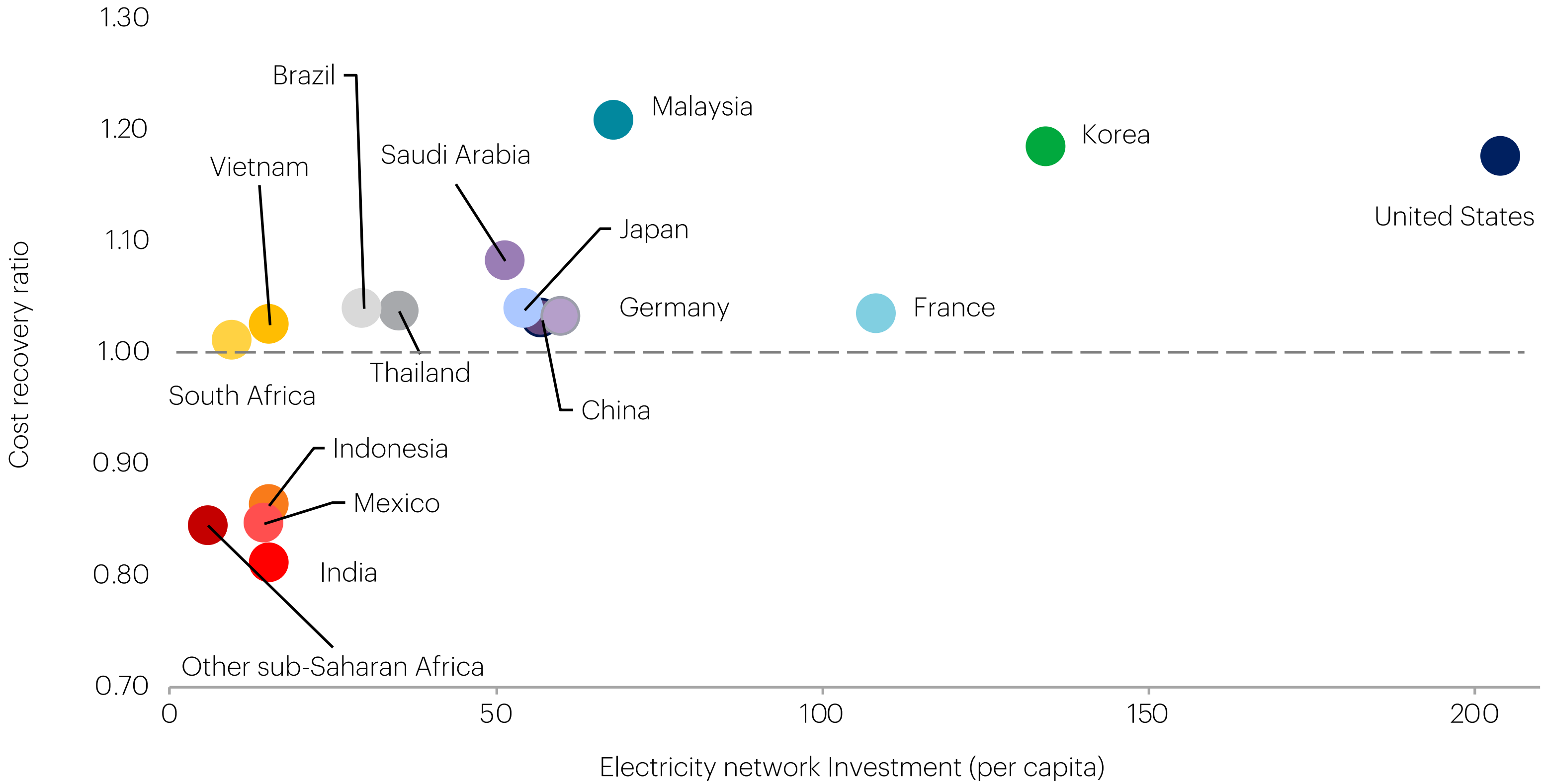




Note: Investments classified under wholesale market pricing may include capacity remuneration mechanisms, which were not separated in the analysis. Remuneration for distributed generation is largely determined by the design of retail electricity tariffs.

Investment in electricity networks strongly depends on regulatory frameworks that enable utilities to recovery their fixed investment costs

Electricity grid investment per capita versus cost recovery ratio for major utilities in selected markets



Note: Data reflect the latest available year for the cost recovery ratio. The size of the bubbles corresponds to the total level of network investment (transmission and distribution). Cost recovery is measured as the ratio of total operating revenues to total operating costs (including depreciation) plus net financing costs for reference utilities and excluding explicit subsidy payments. China = the People's Republic of China .

Source: IEA analysis with calculations for cost recovery based on financial statements of reference utilities in each market. Cost recovery ratios for the United States are based on EEI (2017) and sub-Saharan Africa excluding South Africa are based on Kojima and Trimble (2016).

Overall, there is a strong link between policies and financing for power

About 85% of power investments in 2018 were financed on the balance sheets of utilities, independent power producers, and consumers (for distributed generation). The use of project finance for financing new projects has grown in recent years, with its largest contribution now in the utility-scale renewable power sector. The average debt-to-equity ratio in project finance has generally been around 80:20.

Project finance plays a significant role in the United States where recent tax code changes have not undermined the availability of tax equity for solar PV and wind. In Europe, while project financing for onshore wind has been stable, that for offshore wind has grown as the maturity of the technology has increased and the risks have fallen, thanks to competitive bidding for long-term contracts and, in some markets, system operators assuming grid connection risks. Renewable project finance has also spread into Australia, Japan and Latin America, boosted by policies to help manage the risks.

Over 95% of power sector investment was made by companies operating under fully regulated revenues or long-term contractual mechanisms to manage the revenue risk associated with variable wholesale market pricing. In many countries with competitive wholesale markets, short-term price signals alone remain too low to trigger investments in the most capital-intensive assets (IEA, 2018c).

In 2018, around 45% of utility-scale renewables spending was in projects whose contractual remuneration is determined by competitive mechanisms. These are mostly government schemes - such as auctions, which play an increased role in Europe, India and have started in China, among others – but include other arrangements, such as corporate procurement, which is growing rapidly (see below).

Grids investment depends on planning and regulation; on a per capita basis, it is highest in those markets with cost reflective tariff setting and utilities who can adequately recover their fixed costs.

Key theme: How does financial risk management change for renewables as they move beyond subsidies?

Cash flow certainty is critical for renewable projects to manage risks and facilitate finance. Nearly all utility-scale investments to date benefit from long-term pricing under policy schemes – e.g. auctions for contracts and feed-in tariffs – and physical power purchase agreements with utilities subject to purchase obligations. Looking ahead, most investments benefit from such policies (IEA, 2018b, 2018c).

However, governments face trade-offs in addressing investor risks, affordability concerns and system-friendly development. For example, European market design efforts seek greater integration of variable renewables into markets, and there has been a policy shift from feed-in tariffs to auctions for market premia and contracts-for-differences, which provide revenue certainty, but can increase marketing risks. In the United States, the Production Tax Credit (PTC) is being phased out over time for new wind plants.

Developers can also face risks in the context of existing policy schemes. These may occur when there are mismatches in project capture prices and reference prices used to determine remuneration (which can arise under a contract-for-differences); in project operations extending beyond the horizon of support (some incentives are available for only 10-15 years); as well as unexpected regulatory changes.

In competitive power markets, industry and finance players are increasingly required to have strategies, beyond subsidies, for solar PV and wind projects to manage potential revenue exposure to short-term market pricing over their lifetime. At the same time, there is a growing trend among non-energy corporations to procure renewable power directly, independent of government plans (IEA, 2017).

Slides 138-147 illustrate structures and mechanisms that investors are adopting in response to these trends and assess implications for financing renewables. Successful use of these options depends strongly on the underlying regulatory framework, electricity market design and financial system.

Examples of commercial & financial options to manage market risks for utility-scale renewables

Physical PPA – a bilateral commercial contract where a counterparty (usually utility) purchases at a set price and takes physical delivery of power from a generator. Physical PPAs are common in both competitive and regulated market structures (though the terms and rules can differ greatly) with the duration of contracts for solar PV and wind plants typically ranging from 10-25 years.

Financial PPA – (i.e. corporate/synthetic/virtual PPA and contract-for-differences) – a bilateral financial contract where a counterparty agrees to a fixed purchase price, but does not take physical delivery. Generators sell into wholesale markets and the difference between the reference market price and agreed fixed price is reconciled between parties. Financial PPAs are used in the United States, Europe and other power systems where third-parties transact and are often coupled with the sale of renewable certificates or guarantees of origin.

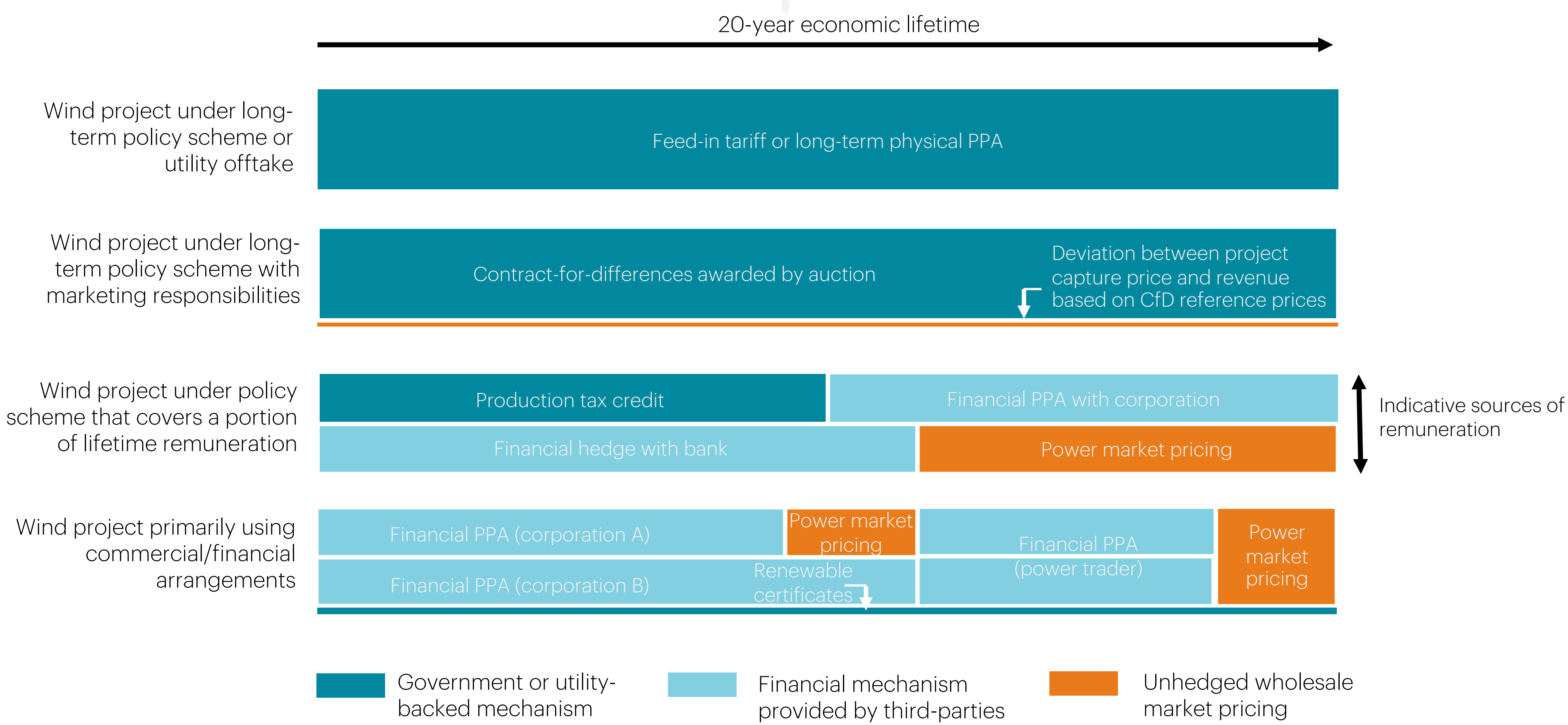
Financial hedge – a bilateral financial contract where a counterparty (often a bank) provides fixed payments in exchange for a variable power price based on a pre-determined settlement point. Bank hedges of up to 12-13 years have been used in the United States.

Proxy revenue swap – a bilateral financial contract where a counterparty (e.g. insurance company) provides a hedge against variable project revenues from uncertain production volume, timing of generation and electricity prices. 5-10 year swaps have been used in the United States and Australia.

Forward contracts – standardized financial contracts for electricity traded on market exchanges for settlement at a future date, involving fewer transaction costs than bilateral options. Where available, electricity forward contracts are traded liquidly usually only 1-2 years ahead, but other commodities (e.g. gas) have liquidity further into the future.

Financial options can help renewables manage market price risk, but such arrangements can also increase project complexity

Illustration of policy and commercial mechanisms to manage market price risks over the lifetime of a wind farm



Investment decisions for "merchant" projects depend on options for risk management as well as supportive policy frameworks and market design

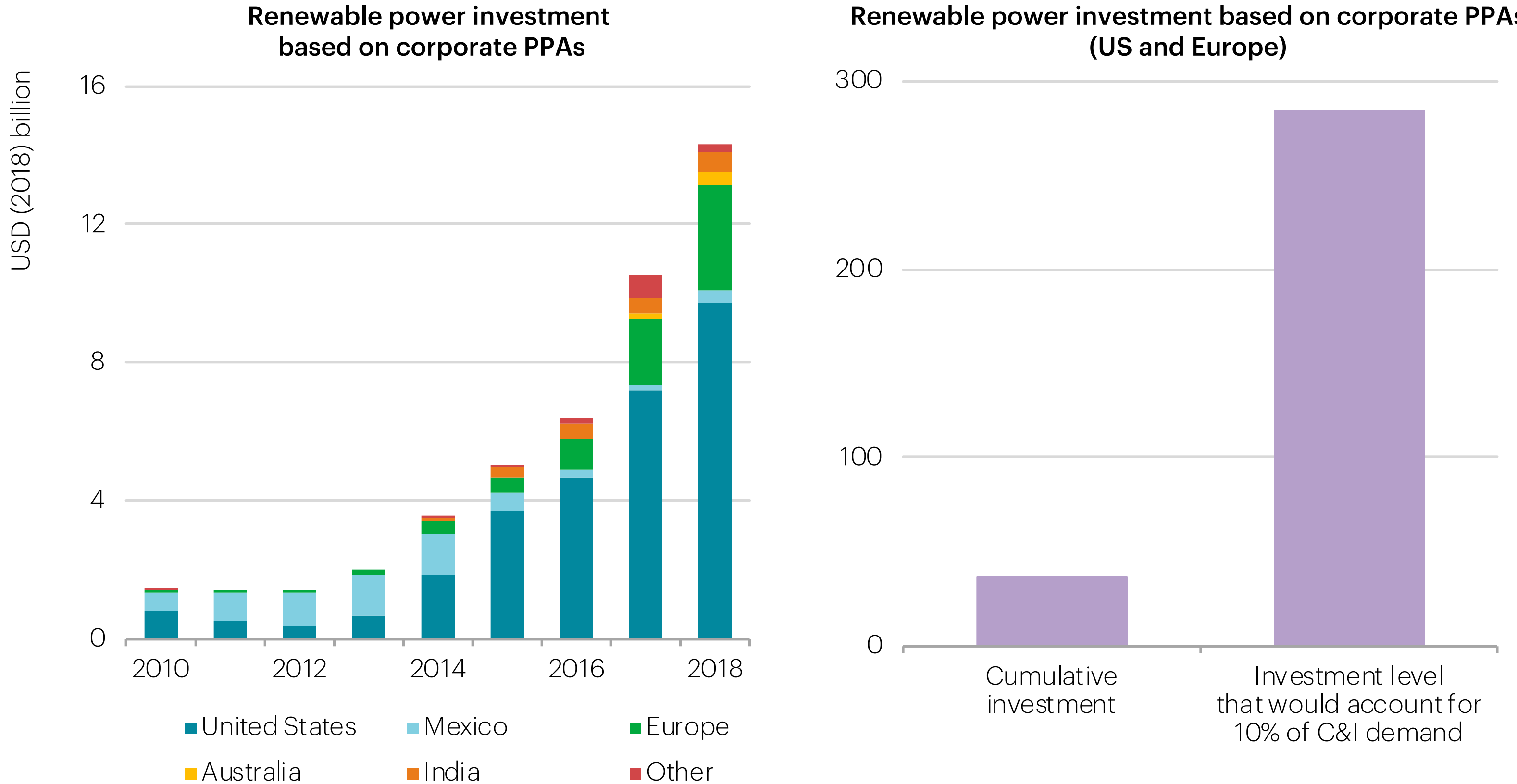
Select renewable power projects with business models reportedly based on "merchant" or "unsubsidized" pricing

Project	Market	Status (reported operation date)	Reported business model and financial risk management features	Policy & regulatory enablers and other revenue streams
Willow Springs Onshore wind (250 MW)	United States (Texas)	Operating	Wholesale market sales with bank financial hedge	Production tax credit & state-led transmission programme (CREZ)
Port of Hirtshals Onshore wind (17 MW)	Denmark	Construction (2019)	Wholesale market sales with financial PPA from trading company	Auction framework for development rights
Hollandse Kust Zuid–1&2 Offshore wind (750 MW)	Netherlands	Construction (2023)	Wholesale market sales; no reported commercial risk management features	Auction framework for development rights; TSO provision of grid connection
Talasol Solar PV (300 MW)	Spain	Announced	Wholesale market sales with 10-year financial PPA with undisclosed counterparty	Partially financed by European Fund for Strategic Investments
York Solar PV (35 MW)	United Kingdom	Construction (2019)	Wholesale market sales; hybridisation with 27 MW battery storage	Ability to sell grid and ancillary services to TSO

Notes: Merchant projects are those whose revenues are derived primarily from short-term wholesale market pricing; TSO = transmission system operator.

Financial PPAs with corporations have boosted renewables spending in some areas, though investment is small compared to total power needs

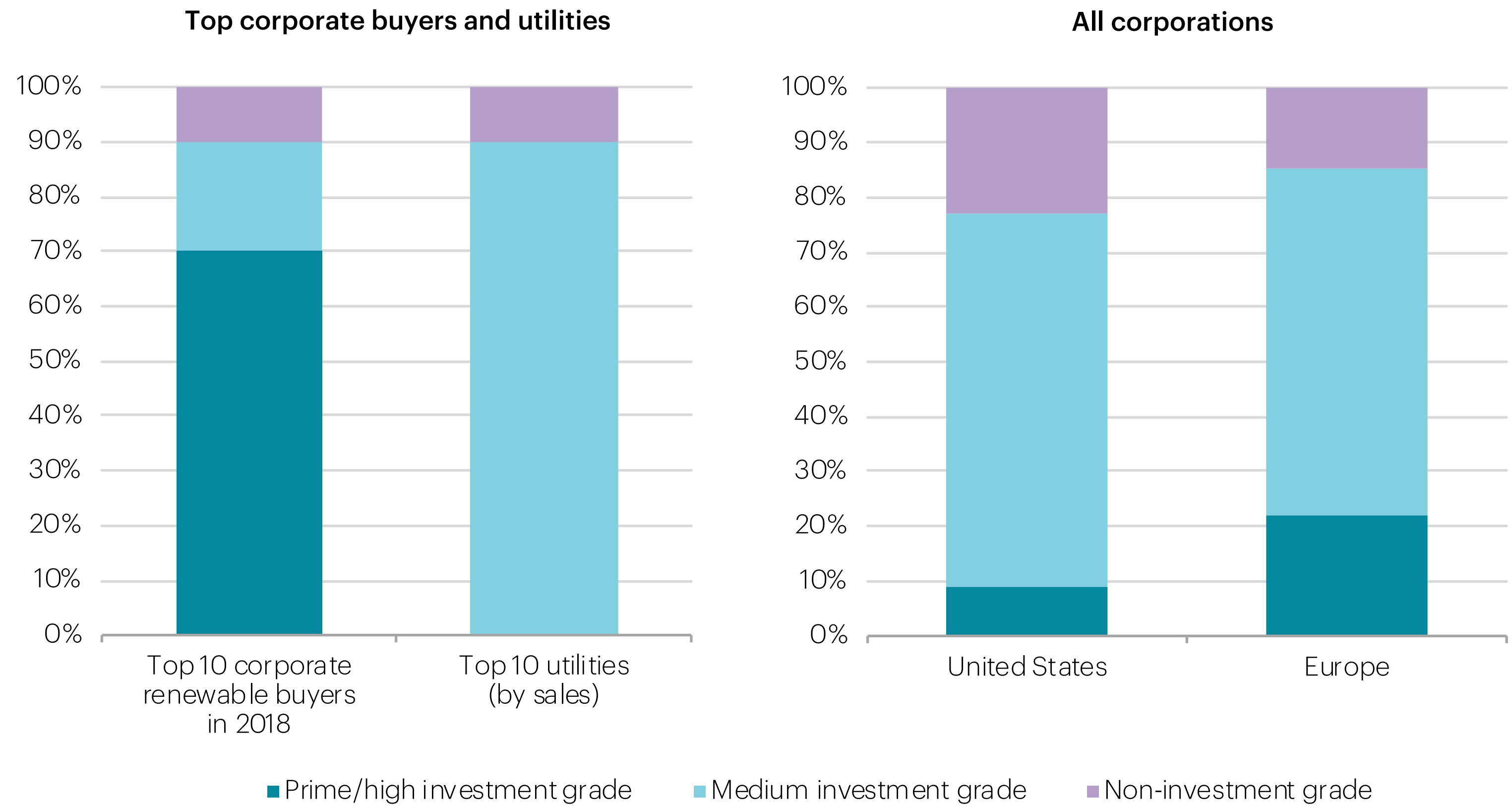
Renewable power investment based on corporate PPAs



Notes: C & I = commercial and industrial electricity demand in the United States and Europe; PPA = Power Purchase Agreement.

Scaling up corporate PPAs would tap into a much larger pool of buyers, but this can raise credit risk and credit evaluation challenges

Credit ratings of the top corporate buyers, utilities and of all corporate debt in the United States and Europe

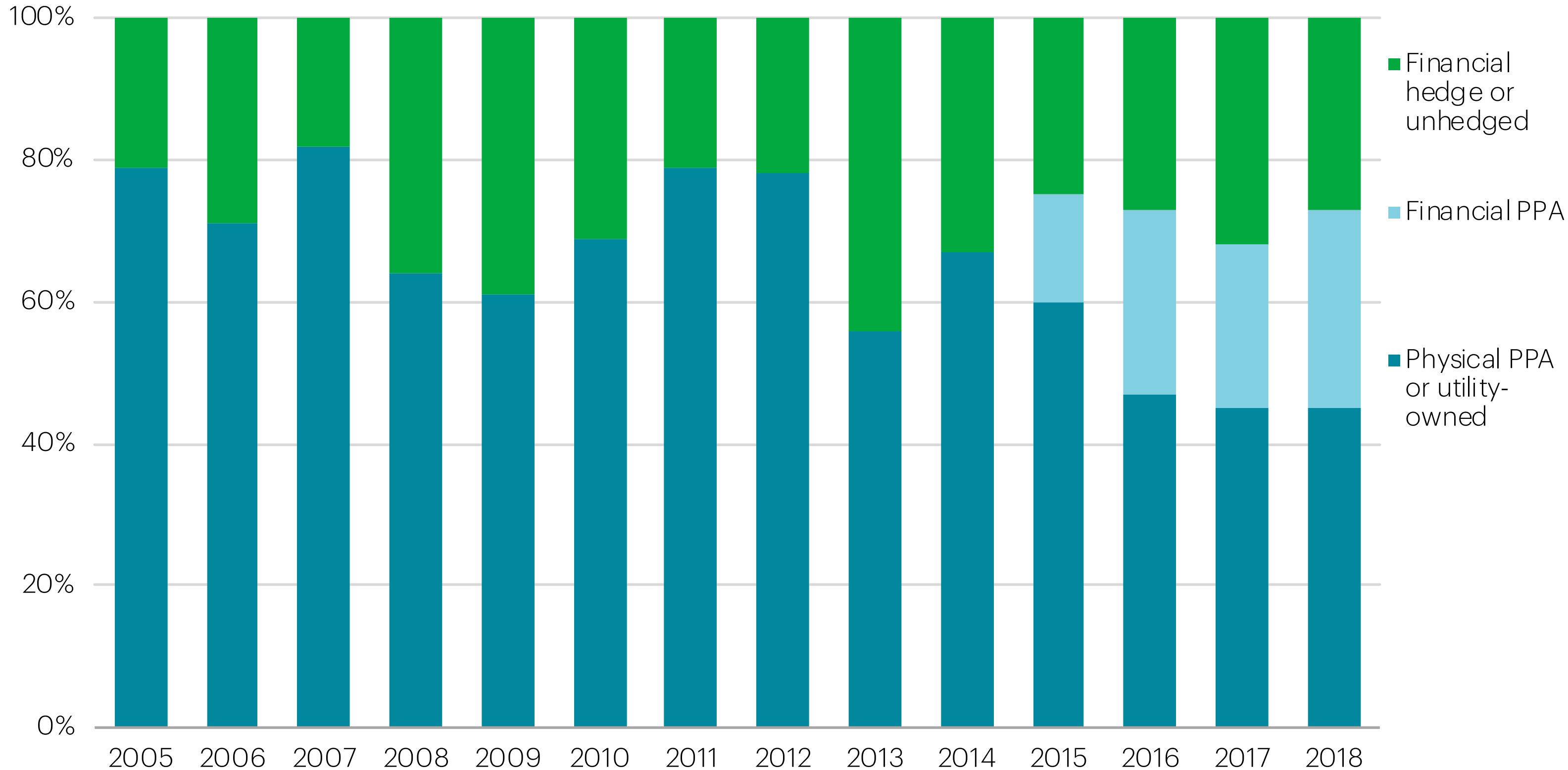


Note: Credit ratings in the graph on the right correspond to the entire outstanding corporate debt market the United States and Europe.

Source: IEA analysis with calculations for credit ratings based on company data from Thomson Reuters Eikon (2019).

Use of financial contracts combined with selling on wholesale markets is prevalent among new US wind farms, complementing tax credits

Share of US wind installations, by commercial structure

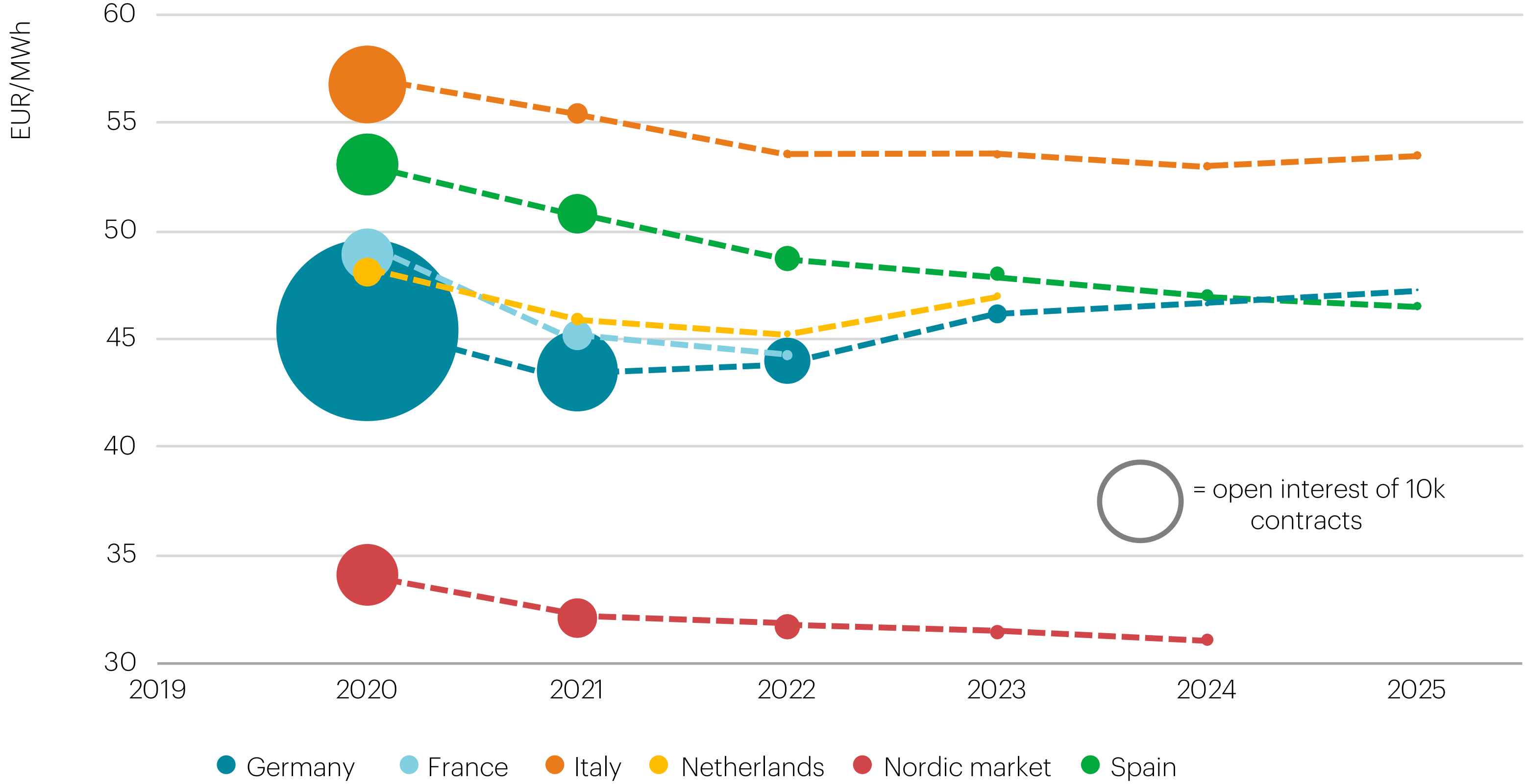


Note: Projects also benefit from the production tax credit, which is available for the first 10 years of project operations.

Source: IEA analysis with calculations based on Bartlett (2019).

In some markets, exchange-traded forward contracts can hedge power prices in the future, but liquidity is limited beyond the first few years ahead

Forward prices for baseload power with open interest, by calendar year, for select European markets

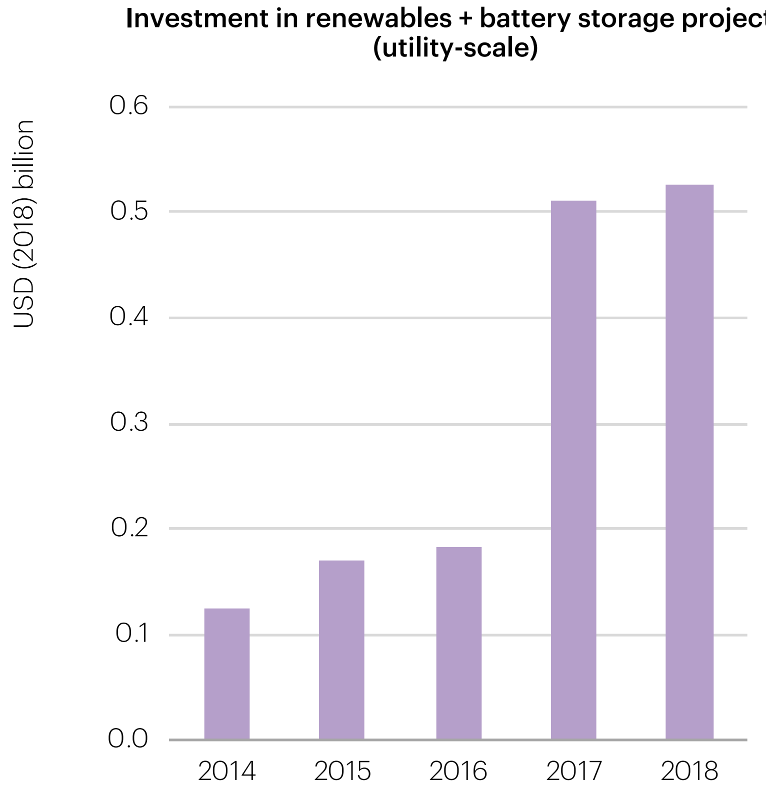


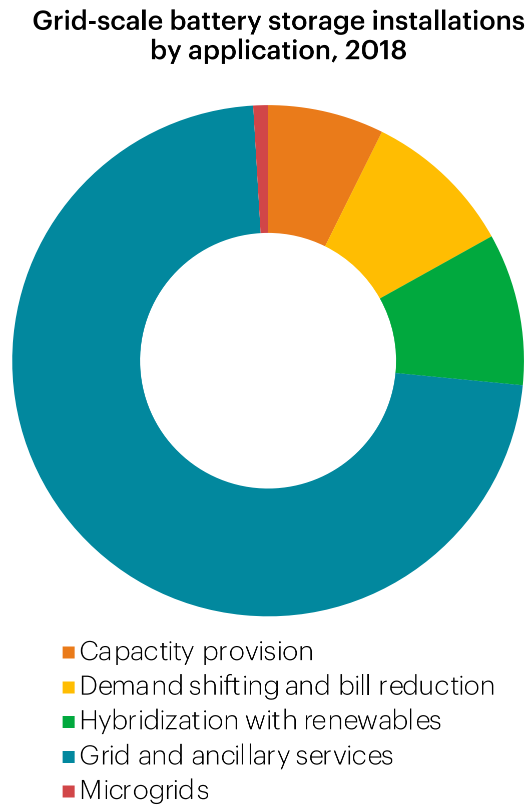
Note: Open interest describes the liquidity and activity level for a given product in the market. It is measured by the number of contracts or commitments outstanding in futures and options trading on an official exchange at any one time.

Source: IEA analysis with calculations based on data from EEX (2019) and Nasdaq (2019).

Pairing utility-scale renewables with batteries provides a technological option for managing market risks; investment remains small but is growing

Global investment in variable renewables plus battery storage and share of grid-scale battery storage installations by application





Source: IEA analysis with calculations based on Clean Horizon and China Energy Storage Alliance (2019).

Summary: financial risk management options can work alongside policies to increase the flow of bankable renewables projects...

Accounting for investments based on risk allocation among private and public actors is challenging. But understanding potential risks and availability of tools to manage them is key to financing.

While few projects have proceeded based on wholesale pricing alone, there is growing interest in finance and technology arrangements to manage risks in competitive markets. These options can act as a complement to policy-based remuneration and provide investment opportunities when availability of physical PPAs may be limited. However, as they can raise project complexity and require private actors to take on more risk, they have potential implications for financing costs, with more reliance on equity and less on debt, which is less able to absorb pricing volatility. More research is needed in this area.

Financial risk management options are no substitute for supportive regulations, appropriate market design and technology development. For example, several offshore wind developments in Europe plan to operate based solely on short-term pricing, but the viability of these projects depends on the long-term outlook for market prices, on the system operator taking on the risks associated with developing and funding the grid connections (up to 15% of the project cost), as well as anticipated enhancements in turbine technology.

Of the arrangements described here, corporate PPAs have emerged as the largest, and their investment grew by one-third in 2018 to nearly USD 15 billion, now accounting for over 5% of global solar PV and wind spending. Their use by large consumers with suitable demand profiles and strong credit ratings has allowed for more debt financing. Still, making a larger energy impact would require a lot more investment – e.g. a sevenfold growth in cumulative spending would be needed to cover 10% of current commercial and industrial demand in the United States and Europe. This suggests involving a greater pool of companies, which could raise challenges in credit risk evaluation and project structuring.

...but an evolution of project complexity and risk allocation with their use also has the potential to impact renewable financing costs

Corporate PPAs have grown in areas (e.g. the United States, Europe) with regulations for contracting and reselling power; utilities who provide billing, balancing, and physical delivery services; and certification that facilitates additionality. In the United States, renewable tax credits have enhanced their use. Still, these contracts (typically 10-15 years) may not fully manage risks over a project's lifetime.

Other bilateral options have garnered interest. Bank hedges were used in a quarter of 2018 US wind installations, enabling projects to manage price risks from selling output in wholesale markets and complementing the production tax credit (available to projects for 10 years). In Australia, a solar PV project reached financial close in 2018 based on a proxy revenue swap with an insurance company.

Use of exchange-traded forward contracts is currently more limited. In European markets, futures only allow for baseload power price hedging (currently at EUR 30-50 [EUR]/megawatt hour for 2023-24), and liquidity is limited more than 2 years out. Still, some energy traders reportedly offer longer contracts on a bilateral basis and, industry interest has grown in the use of gas forward contracts, which have longer-dated liquidity and can be structured to provide a proxy for electricity prices (Aydin, C., F. Graves and B. Villadsen , 2017).

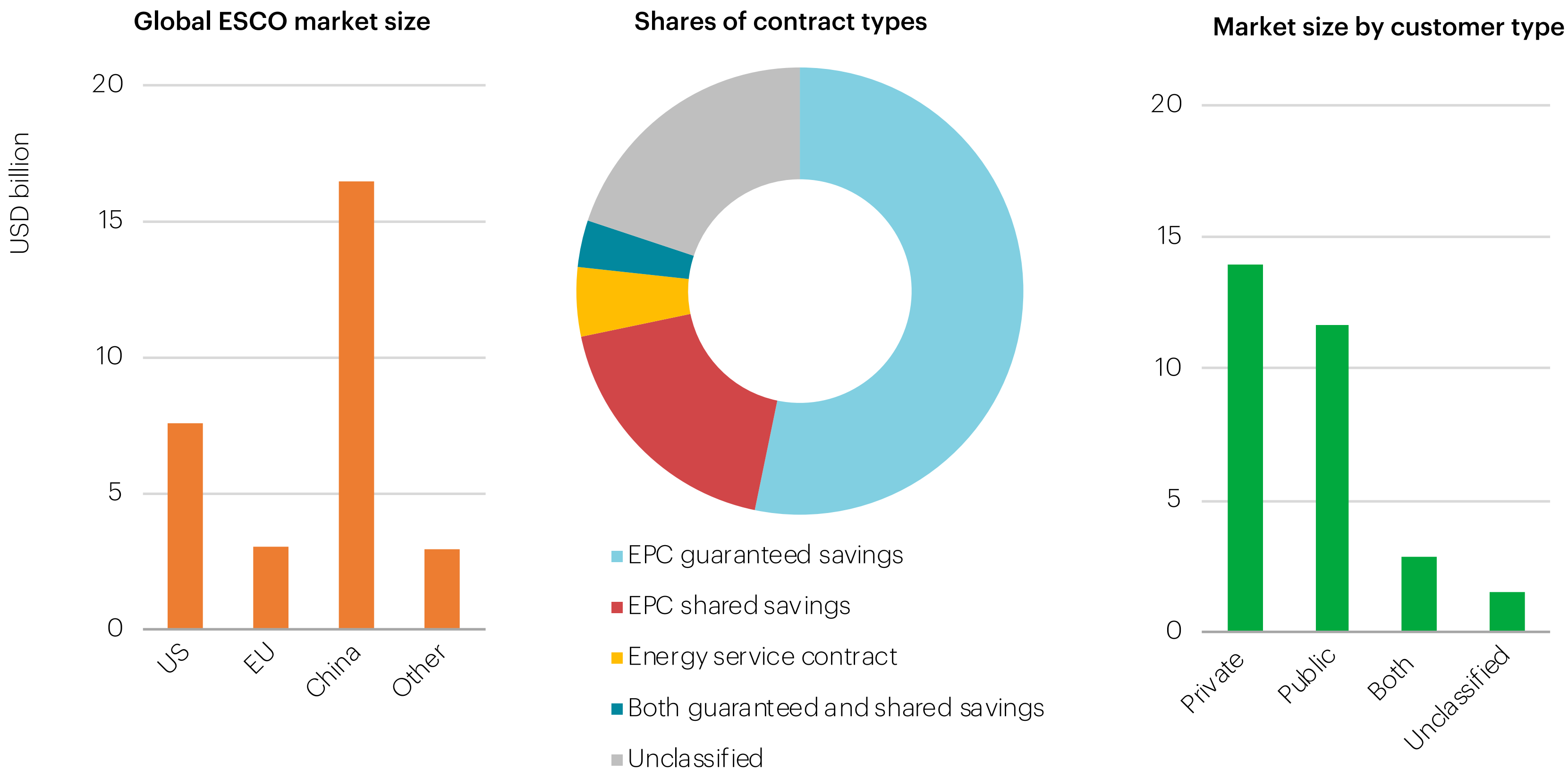
The ability of financial contracts to manage market risks depends on their tenor and how they are structured. Even with a fixed-price contract, projects may still be exposed to basis risk, arising when the price at the settlement point differs from the local price available to the plant, or profile risk, when the timing of revenues received by the plant deviates from that of the contractually determined price.

Finally, some renewables projects have been paired with storage, enabling some dispatchability; this accounts for 10% of grid-scale battery installations. Business models for such plants are complex, relying on a mixture of capacity contracts, grid services provision and wholesale market sales.

Trends in energy efficiency and distributed renewables financing

The market size of energy service companies is around USD 30 billion…

Breakdown of the ESCO market by region, business model, and client



Note: EPC = energy performance contract. Guaranteed Savings guarantee a certain savings on the client's energy bill with the ESCO taking the technical risk and the client securing the funds to pay contractually determined fees to the ESCO. With Shared Savings, the ESCO can provide financing, as well as project development and implementation costs, with the energy savings shared between the ESCO and the client.

Source: IEA (2019, 2018d).

…and China's ESCOs are increasingly engaging the private sector

The market for energy service companies (ESCOs) – who provide energy services and energy efficient equipment to end users – is growing steadily. The global value of the ESCO market (by energy performance contract revenue) was nearly USD 30 billion in 2017, up 8% since 2016. Much of this growth is occurring in China, the largest market by far.

Government policy remains a key driver of ESCO activity. In China, policy incentives have driven ESCO engagement in the private sector, while government procurement rules have been a barrier to further development in the public sector.

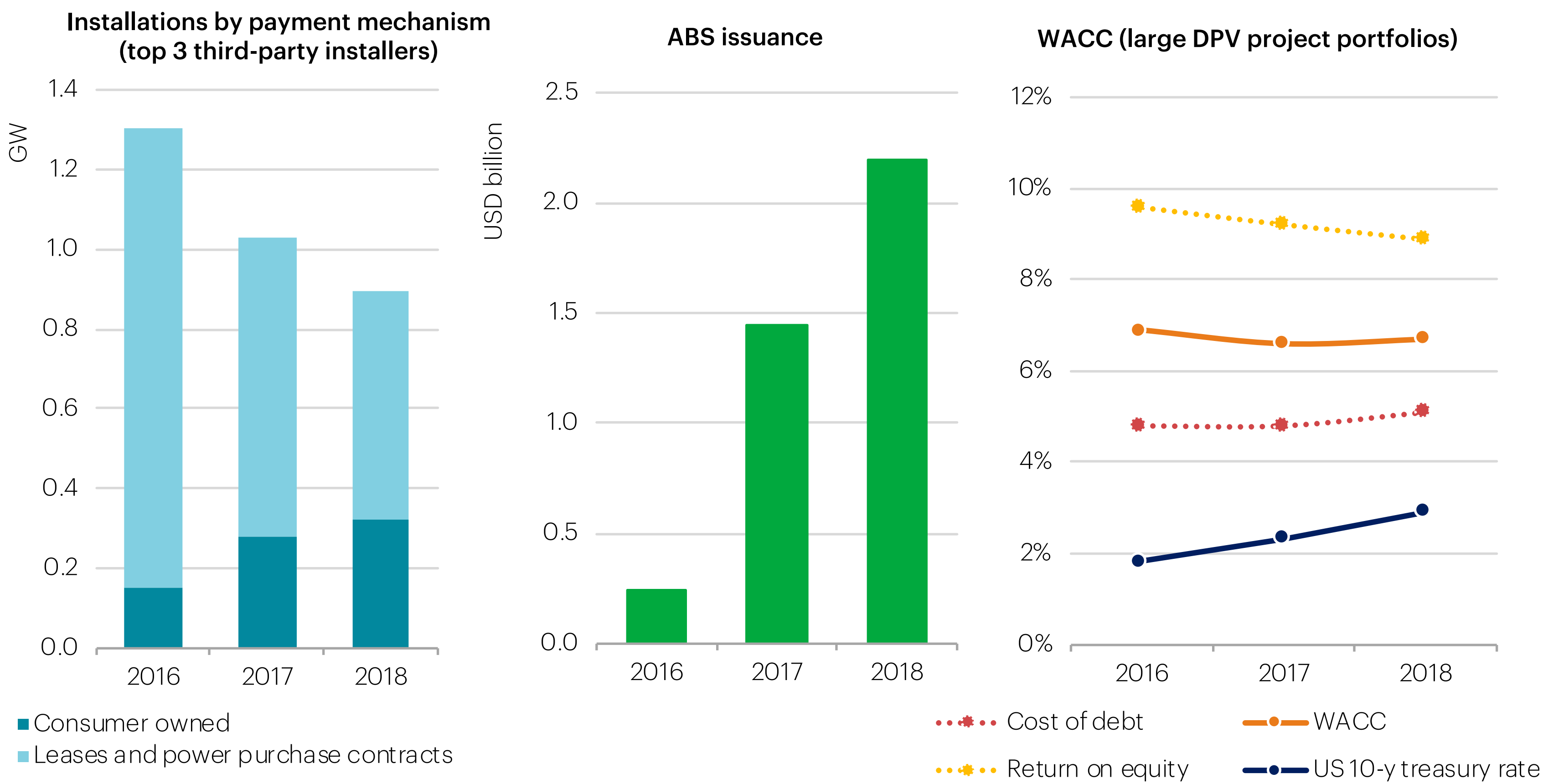
In North America, public sector asset owners are able to obtain debt on favourable terms to finance ESCO contracts. In Europe, where the ESCO market is 10% of the global total, the European Commission recently clarified the terms under which an EPC can be accounted for off-balance sheet. The impact that these changes will have on the European ESCO market is still to be seen.

Globally, nearly half of ESCO investment is for private sector customers. Most agreements between customers and ESCOs are underpinned by energy performance contracts that clarify ongoing payments and commit the ESCOs to installing equipment and guaranteeing savings.

Digital technologies, such as sensors and smart meters, that provide real time information on equipment and system performance, along with analytics and remote monitoring, can improve measurement and verification (M&V) of energy savings in ESCO projects. More accurate information and improved M&V could further facilitate financing of ESCO projects and boost investment in the sector.

Payment and financing options for distributed solar PV have diversified in the United States...

Payment mechanisms, securitisations, and the cost of capital for distributed solar PV in the United States



Notes: ABS = asset back securities; WACC = weighted-average cost of capital; DPV = distributed solar PV; WACC is reported for mid-cost systems and is expressed on an after-tax basis.

Source: IEA analysis with calculations for payment mechanisms based on company reporting; ABS issuance data is based on Climate Bonds Initiative (2019); WACC data is based on Feldman and Schwabe (2018) and Federal Reserve Bank of St. Louis (2019).

...which have helped to keep the cost of financing stable

Investment in distributed solar PV in the United States was around USD 15 billion in 2018, the second largest market after China and the market has remained one of the most dynamic in terms of installations, despite relatively higher capital costs compared with the global average. In addition to policy support at the federal and state level, the availability of finance has continued to improve, with more players and products entering the market.

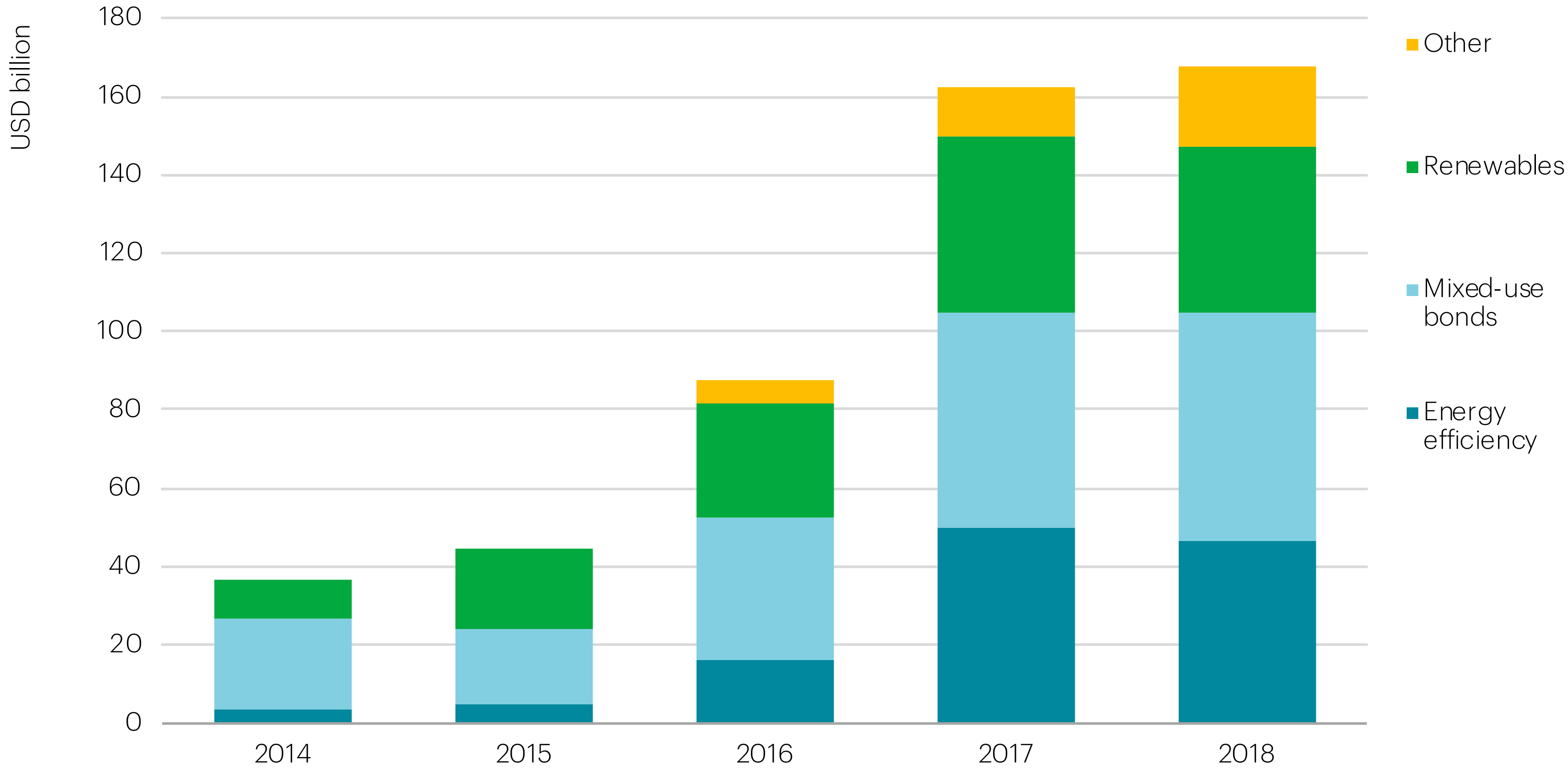
While fewer installations are now made by the top developers, payment mechanisms for distributed solar PV in the United States continue to evolve towards increased consumer ownership, compared with entering into leasing arrangements or PPAs with third parties. This reflects the better availability of financing options for consumers and the desire by developers to ease upfront capital expenditures. A number of financial institutions now offer solar loans, which have helped to facilitate direct ownership.

Developers and financing companies are also using the secondary markets to refinance the leases and contracts on their balance sheets as well as their portfolios of solar loans, which spreads the financing costs and risks among more investors. In 2018, a record amount of asset-backed securities based on US distributed solar PV projects was issued, over USD 2 billion, equal to around 15% of primary financing.

These developments have helped to keep the cost of financing relatively stable. Broadly, the cost of financing for large portfolios of distributed PV projects remained stable in 2018 and was slightly lower compared with two years ago, even as US benchmark interest rates rose, with somewhat more debt used to finance projects and an increased diversity of equity sponsors.

Continued growth in green bonds has supported the financing of energy efficiency and renewables…

Global green bond issuance in the energy sector by intended use of proceeds, 2014-18

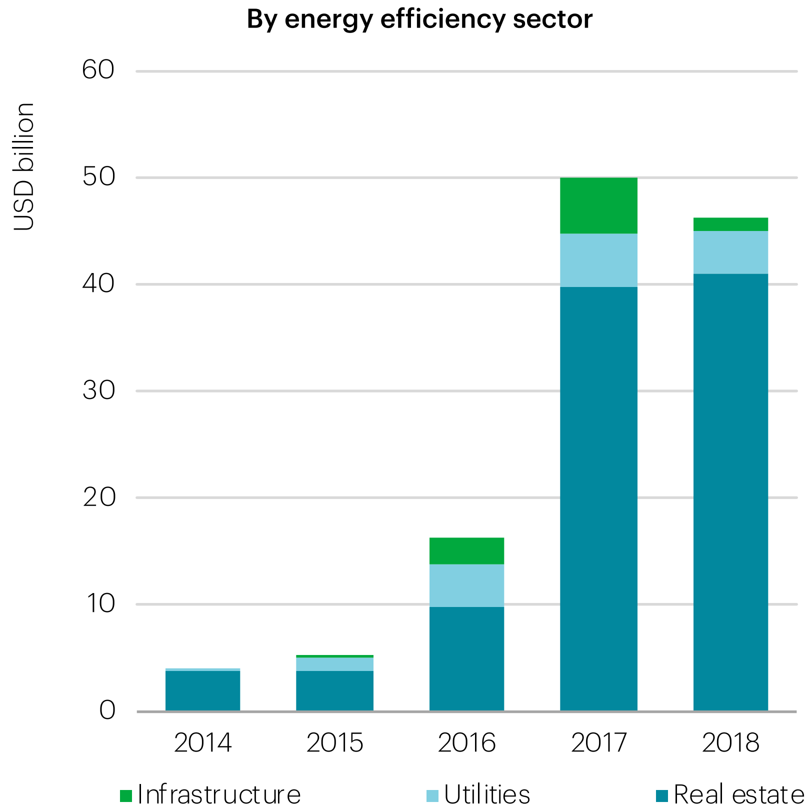


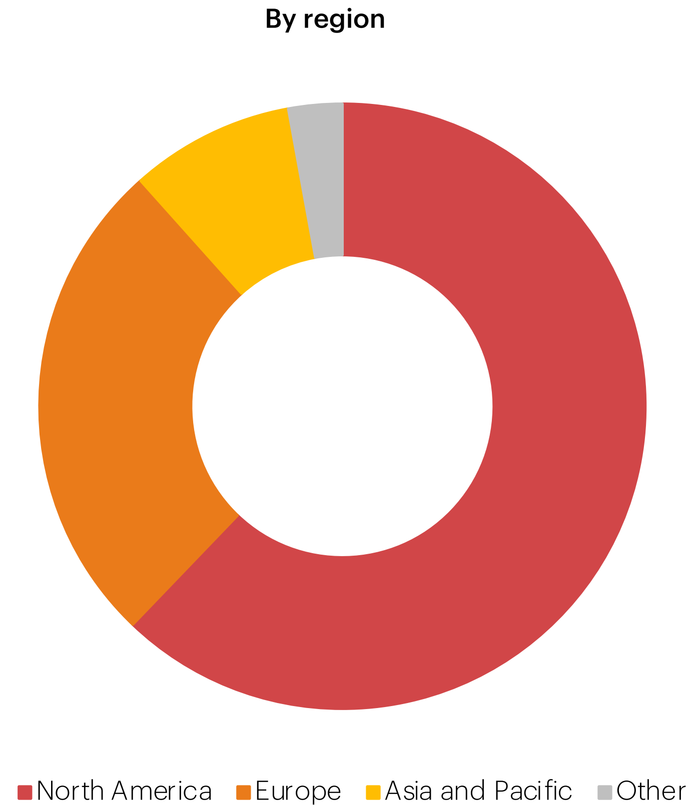
Note: Green bonds included are those labelled under the Climate Bonds Taxonomy and Certification Scheme. Allocation by energy end use follows Climate Bonds Initiative conventions.

Source: IEA analysis with calculations based on data provided by Climate Bonds Initiative (2019).

…but issuance for energy efficiency leveled off in 2018…

Green bonds for energy efficiency, by sector and region, 2014-18





Note: Green bonds included are those labelled under the Climate Bonds Taxonomy and Certification Scheme. Allocation by energy end use follows Climate Bonds Initiative conventions. Infrastructure includes, for example, transport infrastructure developers, such as airports and public transport, and manufacturers of EVs. Real estate and housing includes real estate investment trusts, PACE ABS and mortgage lenders.

Source: IEA analysis with calculations based on data provided by Climate Bonds Initiative (2019).

...and overall issuance of green bonds for energy remained stable

Overall green bond issuance for the energy sector – which acts as an important source of secondary financing in connecting the debt capital markets to companies and projects in energy and other sectors that have environmental benefits – rose to nearly USD 170 billion in 2018.

Growth, at only 3%, slowed significantly compared to the near doubling experienced in 2016 and over 80% growth in 2017, which was boosted by high transaction volumes for mortgage-backed securities arising from the US Federal National Mortgage Association's Green Rewards programme for energy and water efficiency improvements for multi-family housing in the United States.

Green bond issuance for energy efficiency, which was the leading sector in 2017, declined by 8% in 2018 to just over USD 45 billion. Historically, renewables and mixed-use bonds have dominated green bond issuance in the energy sector. In 2018, mixed-use bonds again captured the largest portion of the market.

Green bond issuance for energy efficiency remained strong in the Asia Pacific region and Europe, while the decline stemmed largely from a decrease in the United States.

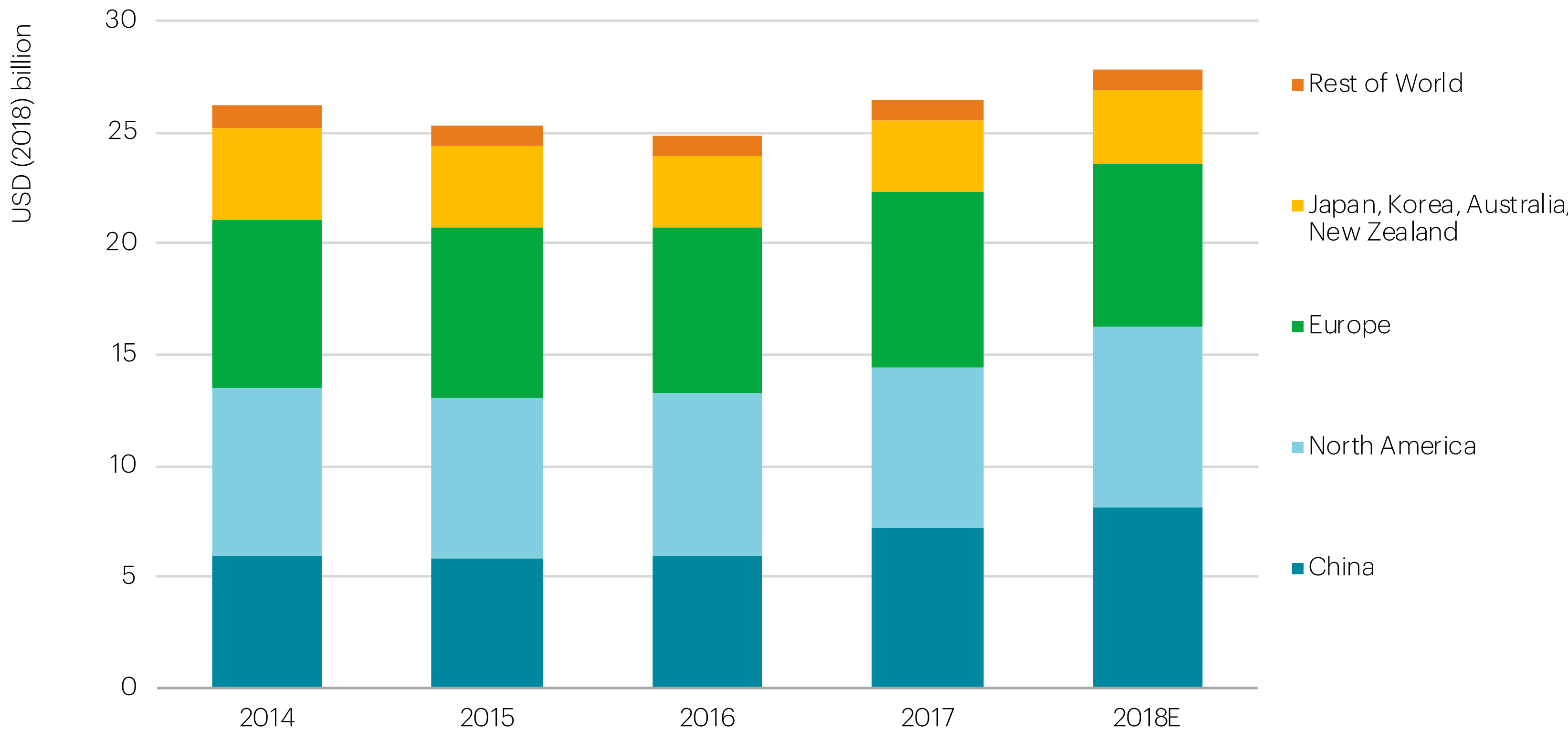
In the United States, there was much less issuance based on loans used in property assessed clean energy (PACE) financing, which facilitates the repayment of loans for energy efficiency improvements through property taxes. There was a large decrease in overall PACE applications in 2018 due to the application of new consumer protection laws and the consequent barriers faced by contractors.

R&D and new technologies

Investment in energy RD&D

Government energy RD&D spending grew 5% in 2018, led by China and the United States

Spending on energy RD&D by national governments, with preliminary 2018 data



Notes: RD&D = research, development and demonstration, as defined by the IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics, 2011. China = the People's Republic of China.

This trend reflects recent pledges and commitments by governments

Preliminary information indicates that governments around the world spent around USD 26 billion (United States dollars) on energy RD&D in 2018, suggesting a 5% increase year-on-year, similar to the previous year's increase.

While indications are preliminary, it appears that spending on the subset of clean energy technologies, which Mission Innovation member countries pledged in 2015 to double over five years, is growing more strongly than total energy RD&D spending.

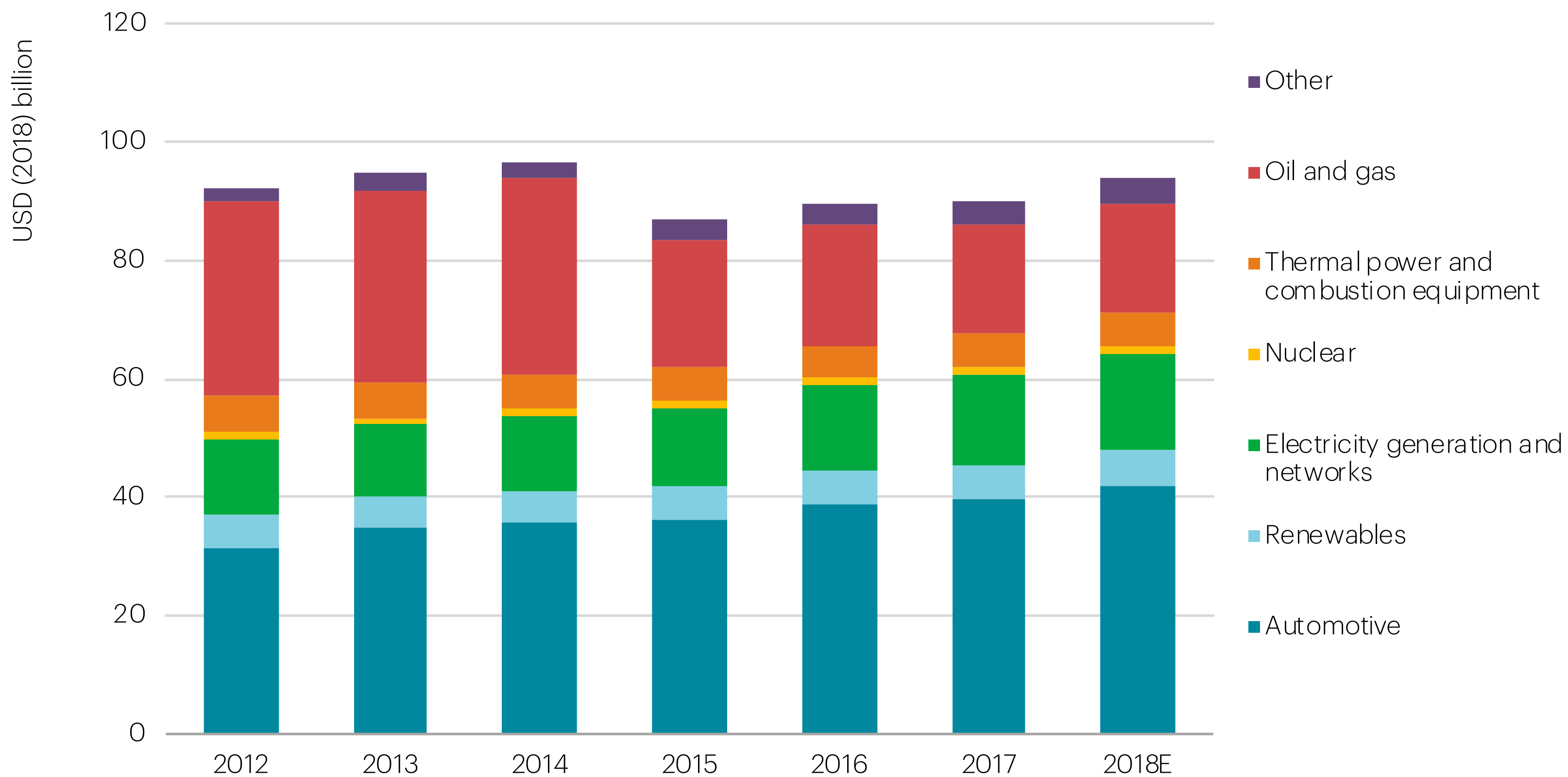
China's energy research and development (R&D) budget grew most in absolute terms in 2018, with spending on renewables and higher-performing fossil fuel technologies increasing the most. The US budget for energy RD&D increased by more than 12% in 2018, with notable rises for solar energy, hydrogen, and alternative vehicle technologies. The budget already passed for 2019 continues the upward trend but with lower growth rates in most areas.

The EU research budget is approved for multi-year cycles and annual variations in spending should be seen in this context. The commitment to energy research remains high, but actual funding for energy research in 2018 fell back by around 15%. While R&D spending for cross-cutting technologies (such as smart grids) rose, it was lower in other areas, notably for energy efficiency and nuclear. Still, as the EU research budget is approved for multi-year cycles, annual variations do not change the overall growth in spending in each funding period.

The five leading countries for public spending on energy R&D were the United States, China, Japan, France and Germany. These five countries accounted for around 70% of all such spending worldwide. RD&D budgets in Denmark and Italy also increased in 2018, while in Germany spending declined 2%.

While energy R&D spending by car companies jumped, oil and gas company R&D has yet to bounce back significantly since 2015

Global reported corporate R&D spending in energy-related sectors



Note: Classifications are based on the Bloomberg Industry Classification System. 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. To allocate R&D spending for companies active in multiple sectors, interviews with company decision-makers and, in the absence of other data sources, the shares of revenue per sector were used. "Other" comprises CCUS, electricity storage, insulation, lighting, other fossil fuels and smart energy systems.. Depending on the jurisdiction and company, publicly reported corporate R&D spending can include a wide range of capitalised and non-capitalised costs, from basic research to product development and, in some cases, resource exploration. It is not unusual for the development of like-for-like substitution products and problem-solving for well-established technologies to dwarf research into new technology areas.

R&D budgets also increased for companies active in energy storage, energy efficiency, nuclear and combustion technologies

The sample of listed companies active in energy technology sectors for which 2018 data is currently available increased their annual energy R&D spending, by around 4% (including automakers). The total energy R&D spending of this sample reached nearly USD 94 billion in 2018. Excluding transport, two-thirds of the total corporate energy R&D was in low-carbon sectors.

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 R&D spending as government policies and competitive pressures drive higher spending on energy efficiency and electric vehicles. Automakers were the biggest contributors to the growth in corporate energy R&D spending technologies in 2018.

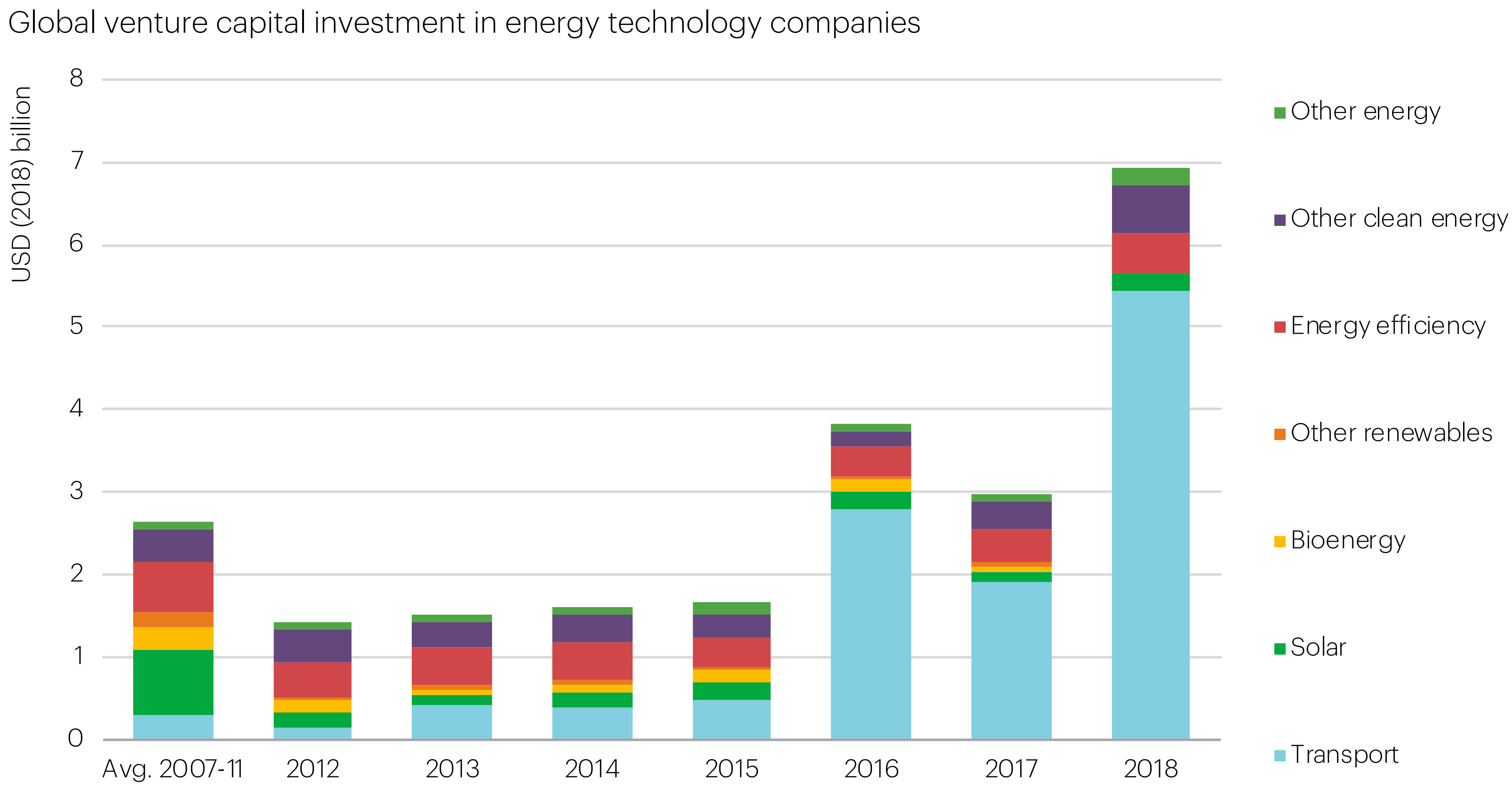
This trend is notable among major European and US car and auto parts companies, whose R&D spending rose by around 7% on average in 2018, compared to 4% for Japanese and Korean firms. However, the increasingly global presence of Chinese automakers is reflected in their R&D spending, which rose more than 20% on average.

Corporate R&D spending by companies in the oil and gas and other fossil fuel extraction sectors showed 1% growth in real terms in 2018, the first increase in R&D spending in this sector since 2014. Spending remains 45% below 2014 levels, however, and is not rising significantly as a share of revenue.

While the rebound of oil and gas company R&D budgets is sluggish, that of electricity generation and supply companies continues to rise. Siemens and General Electric occupied the top spots in the list of the highest global energy R&D spenders, with Petrochina dropping out of the top three for the first time in a decade. Four of the top ten are Chinese companies, and five are in the electricity sector.

Trends in investment for early-stage technologies

A record year for venture capital investment in clean energy



Note: Includes Seed, Series A, and Series B financing deals. Transport includes alternative powertrains and fuel economy but does not include shared mobility, logistics or autonomous vehicle technology. Bioenergy does not include biochemicals. Other energy includes fossil fuel extraction and use.

Source: Cleantech Group (2019), i3 database.

Venture capital action is in clean mobility, while renewables deals shrank

Venture capital (VC) investment in emerging energy companies (seed, series A and B) reached an estimated USD 6.9 billion. While these sums are much lower than those invested in RD&D projects, this is a notable high-point for VC deals in energy, which are mostly focused on clean energy technologies.

While solar energy made up a significant share of transactions before the 2012 cleantech bust, recent growth has been driven almost entirely by clean transportation investment. Most of the transport deals are in EV technology and services.

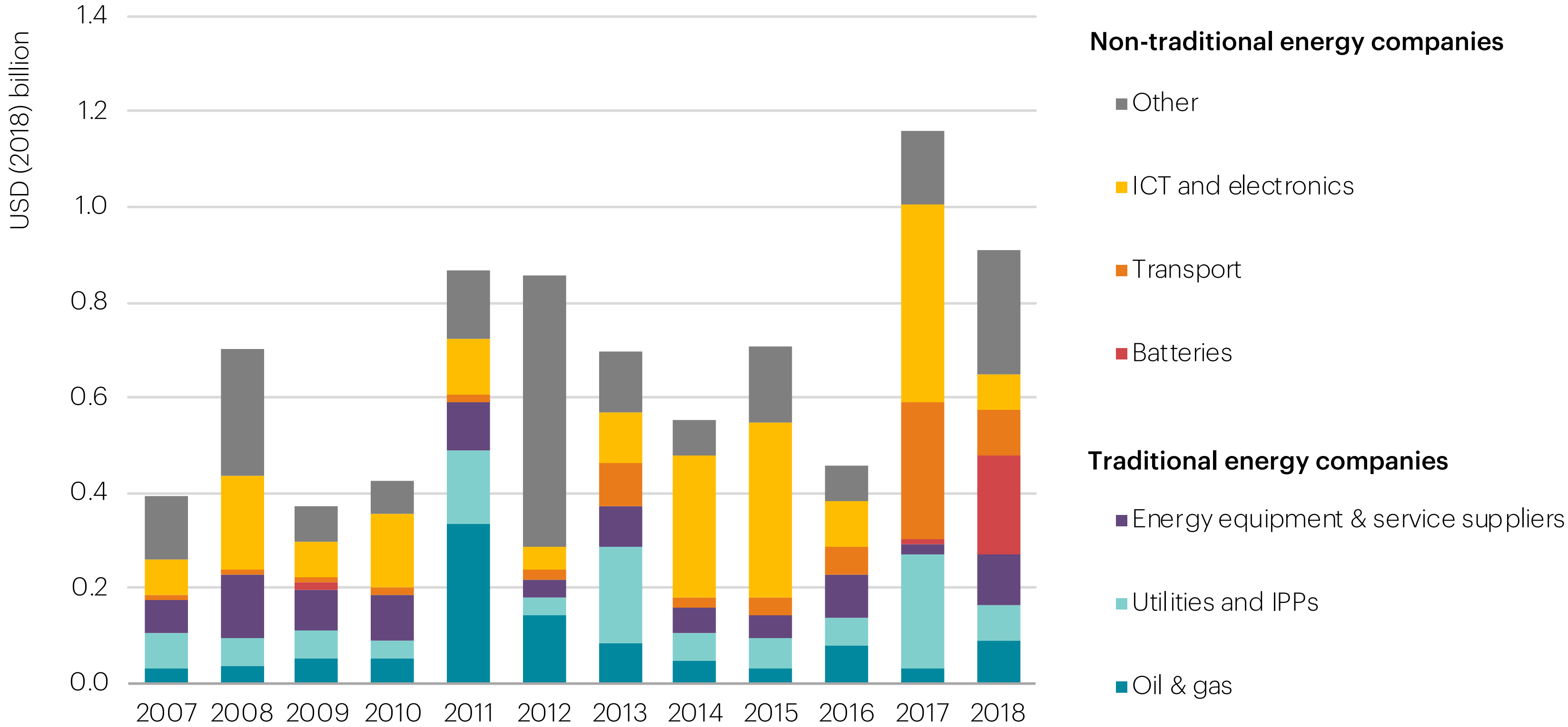
Despite the large increase in deal value, the total number of early-stage VC deals in 2018 was broadly similar to 2017. This indicates a major increase in deal value, driven notably by deals larger than USD 0.5 billion, such as those for electric car firms Evelozcity, Youxia Motors, Xiaopeng Motors, and Byton.

The share of China-based start-ups in total VC value for early-stage energy technologies overtook the traditionally dominant United States, with Chinese companies receiving over half of the deal value. However, excluding large deals (over USD 50 million) raises the US share to over 50%. Only 30 of the 400 deals (7%) were for companies in China, compared to 52% in North America and 30% in Europe.

Outside transport, the biggest increases in VC activity by technology areas were for energy storage, hydrogen, and fuel cells, as well as technologies for fossil fuel extraction and conversion. Investment in Zenobe Energy (a battery storage operator), Malta (a developer of thermal storage), Kayros (an energy data and tracking firm), and Solid Power (a solid-state battery company) were the biggest deals in these sectors 2018.

More companies investing in energy start-ups are from outside the sector

Corporate venture capital and growth equity investments in energy technology companies, by sector of investor



Note: ICT = information and communication technology. Deals types include grant, seed, series A, series B, growth equity, private investment in public equity (PIPE), coin/token offering, buyout, and late-stage private equity. Unless otherwise stated, deal value is shared equally between multiple investors in a single deal. Energy technology companies are defined as per the previous chart.

Source: Cleantech Group (2019), i3 database and IEA analysis.

Investments by battery companies were big deals in 2018

Corporate investments in energy technology start-ups, including corporate venture capital, totalled around USD 0.9 billion in 2018. While 2018 did not see such high deal value as 2017, it remained high by the standards of the "cleantech boom" in the period to 2012. This indicates that large companies see a strategic case for direct investment in innovative, nimble technology players.

Clean transport companies received the most money from corporate investors, with Xiaopeng Motors raising nearly USD 1 billion in total in 2018 and CityScoot raising USD 50 million.

Investments by companies from the traditional energy sectors declined by 7% in 2018. Those by oil and gas companies and equipment manufacturers offset a much larger decline in investments by utilities.

Notable deals were Chevron's investment in ChargePoint (alongside AEP and Siemens); Equinor's in EtaGen gas generators with AEP and Centrica; and E.ON's in tado home energy management.

The role of information and communication technology and automotive companies in energy technology start-ups was less evident in 2018 as their deal value shrank back to near-2016 levels.

However, non-traditional players, notably battery manufacturers, invested more than traditional energy actors. CATL, a Chinese battery company, and FAW, a car company, were involved in an investment in Byton, an electric car company. CATL also invested in Sila battery materials, alongside Siemens.

Overall, companies inside and outside the energy sector are increasingly using corporate venture capital investments as part of a flexible and more open energy innovation strategy.

Signs of interest in CCUS & hydrogen, as battery factories bloom

China's first large-scale carbon capture, use and storage (CCUS) project, for enhanced oil recovery at CNPC's Jilin Oil Field, was commissioned in 2018. There was also a significant jump in announcements of new CCUS projects that could enter operation over the next decade. For the first time since 2010, the number of CCUS facilities that are operating, under construction or in planning around the world rose, reaching 43.

In 2018, the United States expanded and enhanced the "45Q" tax credit for CCUS with up to USD 50 per tonne of CO_2 permanently stored and USD 35 per tonne of CO_2 used in enhanced oil recovery.

Plans for six new CCUS projects were announced in 2018 in Ireland, the Netherlands and the United Kingdom. The focus of new European CCUS projects has shifted towards capturing CO_2 from hydrogen production, with at least four of these six projects planning to inject of low-carbon hydrogen in natural gas networks by 2030.

In 2018, strong recent momentum behind hydrogen projects was maintained, with over 20 MW of electrolysers coming online for energy and climate applications, plus many project announcements for electrolyser projects up to 100 MW in scale, mostly in Europe. Overall, the value of the electrolysers installed in the last two years is around USD 20 to 30 million per year. However, the level of investment is insufficient for a sustainable and self-financing hydrogen sector for the longer term.

Expansions of battery manufacturing capacity for electric vehicles announced in 2018 are expected to translate into major investments ahead. Large producers shared plans for USD 20-30 billion of spending on over 400 GWh of capacity by the mid-2020s. Production in 2018 was around 70 GWh.

Annex

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Graham Weale	Ruhr University Bochum
Paul Welford	Hess

Methodology and scope of energy investment tracking in WEI 2019

Type	Technologies / sectors covered	Description
Fuel supply	Oil and gas supply (upstream; oil refining ;and downstream-transport and LNG facilities), coal supply (mining and infrastructure), biofuels (production capacity)	Investment is tracked based on a bottom-up analysis at company or project level (upstream oil and gas, oil refining, LNG facilities, biofuels), government and industry statistics (coal supply) and product supply/demand analysis (oil and gas transport).
Power generation investment	Fossil fuel (oil, coal, gas), renewable (wind, solar PV, hydro, biomass, geothermal, solar thermal, marine) and nuclear plants	Investment in power generation is accounted for as the annual capital spending that is estimated during a plant's construction time.
Energy efficiency investment	Buildings, industry and transport	Investment in energy efficiency includes incremental spending by companies, governments, and individuals to acquire equipment that consumes less energy than that which they would otherwise have bought
R&D spending	Public and private funding	R&D investment is tracked based on a bottom-up analysis of publicly reported spending data.
Sources of finance	Financing arrangements and instruments used to finance assets for energy sector investment.	Analysis based on reported data on financial transactions.

Note: For a more extensive description of the World Energy Investment methodology, please visit iea.org/media/publications/wei/WEI2019-Methodology-Annex.pdf.

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