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Abstract

This year's edition of the World Energy Investment report presents the latest data and analysis of how energy investment flows are recovering from the shock of the Covid-19 pandemic, including full-year estimates of the outlook for 2021. It examines how investors are assessing risks and opportunities across all areas of fuel and electricity supply, efficiency and research and development, against a backdrop of a recovery in global energy demand as well as strengthened pledges from governments and the private sector to address climate change.

The report focuses on two key questions:

- Whether the growing momentum among governments and investors to accelerate clean energy transitions is translating into an actual uptick in capital expenditures on clean energy projects.
- Whether the energy investment response to the economic crisis caused by the Covid-19 pandemic will be broad-based or if some sectors, geographies and vulnerable parts of the world's population will be left behind.

Acknowledgements, contributors and credits

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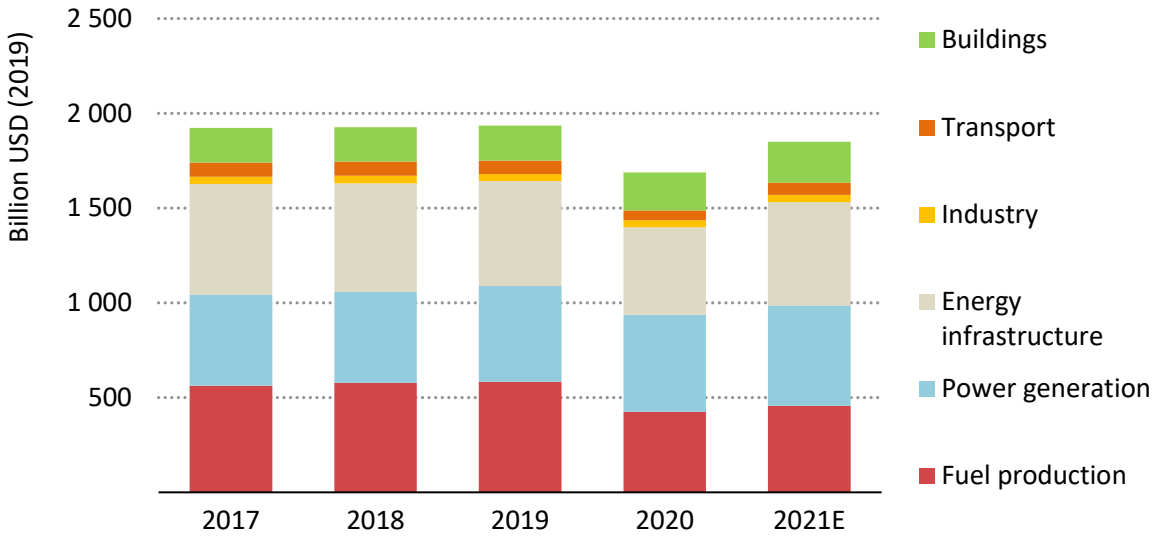
Executive summary

Global energy investment is set to rebound by around 10% in 2021, reversing most of the drop caused by the pandemic

In 2021, annual global energy investment is set to rise to USD 1.9 trillion, rebounding nearly 10% from 2020 and bringing the total volume of investment back towards pre-crisis levels. However, the composition has shifted towards power and end-use sectors – and away from traditional fuel production.

Prospects for investment have improved markedly along with economic growth, although there are significant country-by-country variations. Global energy demand is set to increase by 4.6% in 2021, more than offsetting the 4% contraction in 2020, according to the latest IEA estimates. While many energy companies remain in a fragile financial state, there are signs developers are using the window provided by accommodative monetary policy and government backing to plan infrastructure developments and investments in new projects.

Global energy investment, 2017-2021



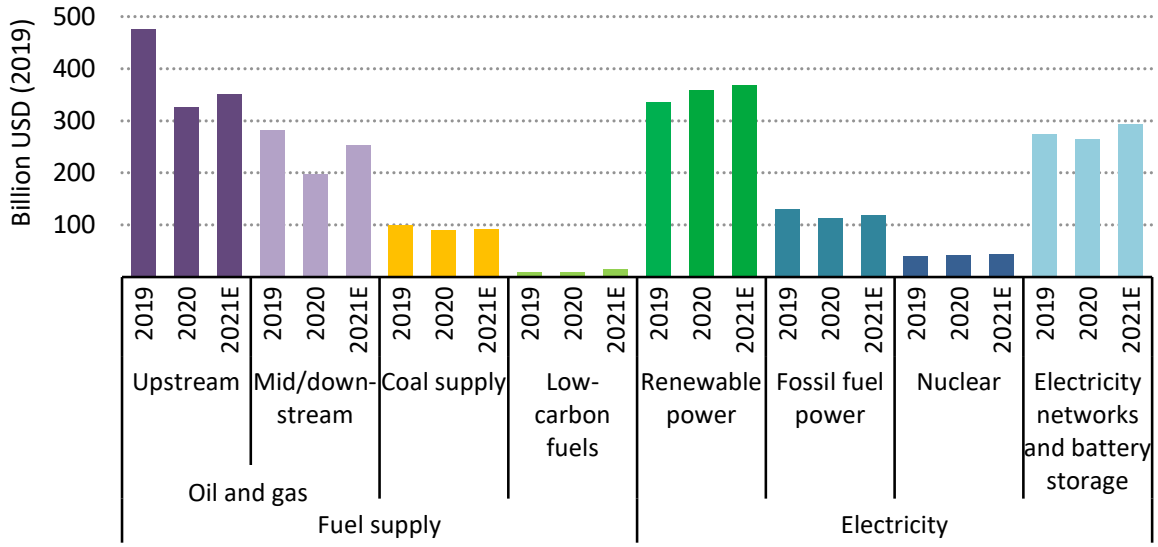
Notes: Energy infrastructure includes midstream and downstream oil and gas infrastructure, electricity networks and batteries.
Investment is measured as the ongoing capital spending in energy supply capacity (fuel production, power generation and energy infrastructure) and energy end-use and efficiency sectors (buildings, transport and industry). The scope and methodology for tracking energy investments is available in the methodology document.

The anticipated upswing in investments in 2021 is a mixture of a cyclical response to recovery and a structural shift in capital flows towards cleaner technologies. But despite an urgent need to shift to a more sustainable energy pathway, global carbon dioxide (CO_2) emissions are again on the rise, following the largest-ever annual decline in 2020.

Electricity, led by buoyant spending on renewable power, continues to take the largest share of overall supply investment

After staying flat in 2020, global power sector investment is set to increase by around 5% in 2021 to more than USD 820 billion. Renewables dominate investment in new power generation and are expected to account for 70% of 2021's total of USD 530 billion spent on all new generation capacity. Investment in grids and storage makes up the remainder. Thanks to rapid technology improvements and costs reductions, a dollar spent on wind and solar photovoltaic (PV) deployment today results in four times more electricity than a dollar spent on the same technologies ten years ago.

Global energy supply investment by sector



Renewable investment has thrived in markets with well-established supply chains where lower costs are accompanied by regulatory frameworks that provide cash flow visibility – and where lenders and financiers that understand these sectors well are seeking sustainable projects to support. Demand from the corporate sector for clean electricity to meet sustainability targets has also played a role.

Much of the spending resilience in 2020 was concentrated in a handful of markets, most notably the People's Republic of China (hereafter, "China"), which saw a remarkable year for wind power investment, as well as the United States and Europe. For the fifth consecutive year, capital spending in the power sector in 2020 was higher than for oil and gas supply.

Electrification was also a major driver of investment spending by final consumers. Electric vehicle sales continue to surge along with a proliferation of new model offerings by automakers, supported by fuel economy targets and zero-emissions-vehicle mandates.

Policies remain a crucial driver for many energy investments, with the impact of recovery plans becoming visible in some countries

In economies where governments have more fiscal space and are able to borrow at low rates, recovery strategies offer a major opportunity to boost investment in infrastructure, efficiency and clean energy technologies. In the case of infrastructure, after declining for the fourth consecutive year in 2020, spending on electricity grids is expected to rise in 2021, led by China and Europe. Proposed infrastructure spending in the United States, if approved, would add to this momentum.

Spending on energy efficiency improvements is set to increase in 2021 by nearly 10% in response to renewed economic growth and initial effects of recovery programmes. However, against a backdrop of relatively low fuel prices, growth is heavily concentrated in markets and sectors with clear government policies, such as the buildings sector in Europe. Policies and stimulus spending are spurring projects in new areas such as low-carbon hydrogen and carbon capture utilisation and storage (CCUS).

Yet despite these encouraging signs, stimulus spending on clean energy technologies is falling well short of what is needed to ensure a sustainable recovery from the Covid-19 crisis. Many developing countries lack the means to pursue expansive recovery strategies, and early signs of inflation in some economies has led to questions about how long the current environment of low interest rates will last.

Momentum from net zero pledges and sustainable finance is yet to translate into large increases in actual spending on clean energy projects

Over the last year, there has been a proliferation of commitments by governments, companies and financial institutions to achieve net zero emissions by 2050 or soon thereafter. The financial community in many advanced economies has rallied around sustainable finance, launching funds and initiatives to channel growing appetite from capital markets and to comply with new disclosure rules. Sustainable debt issuance[1] has risen rapidly, reaching a record USD 600 billion in 2020, and the mainstreaming of green bonds is increasingly accompanied by new types of securities and performance-based instruments to support more complex transitions.

Clean energy companies have performed well on financial markets, with renewable power companies outperforming both listed fossil fuel companies and public equity market indices in recent years, and with lower volatility. Valuations remain high after a particularly strong run-up in prices in the second half of 2020, even though there was some pullback in early 2021.

Even if spending on clean energy is set to rise in 2021 by around 7%, financial flows have grown more rapidly than actual capital expenditures. There is a shortage of high-quality clean energy projects. This is compounded by inadequate channels to guide available funds in the right direction and a lack of intermediaries capable of matching surplus capital with the sustainability needs of companies and consumers.

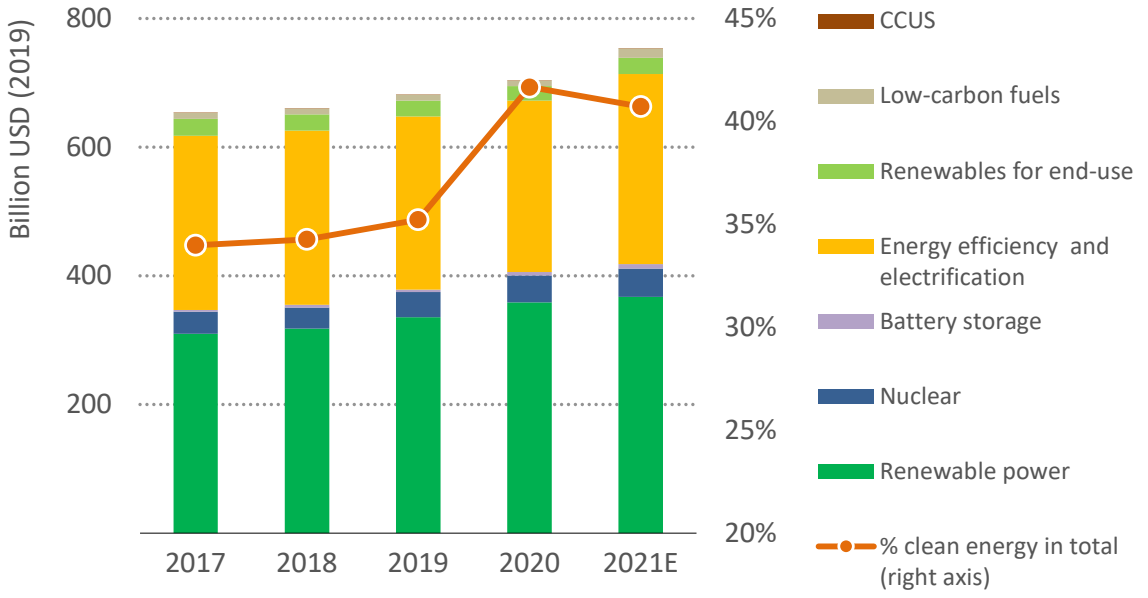
Clean energy investment is on a moderate upswing, but remains far short of what will be required to avoid severe impacts from climate change

The USD 750 billion that is expected to be spent on clean energy technologies and efficiency worldwide in 2021 remains far below what is required in climate-driven scenarios. Clean energy investment would need to double in the 2020s to maintain temperatures well below a 2°C rise and more than triple in order to keep the door open for a 1.5°C stabilisation. Moving to a climate-aligned energy pathway hinges on a broad range of government actions, including attention to the financial architecture that can accelerate direct investments in market-ready solutions and promote innovation in early-stage technologies. As emphasised in

[1] Excluding social bonds.

the new IEA Roadmap to Net Zero by 2050, policies need to drive a historic surge in clean energy investment this decade.

Global investment in clean energy and energy efficiency, 2017-2021



Clear policy signals from government would not only reduce uncertainties associated with clean energy but also avoid potential costs from investing in assets that risk being underutilised or stranded. Mismatches in the speed of adjustment can create risks, for example, if a slow pace of grid investment leads to bottlenecks for wind and solar PV, or if oil and gas suppliers transition away from hydrocarbons faster than do their consumers. As financial regulators work to align capital flows with climate goals, slower progress in the real economy can lead investors to over-value some sectors while penalising others, creating a volatile ride along the way.

The gap between today's investment trends and a sustainable pathway is larger in emerging market and developing economies

In contrast to advanced economies and China, investment in emerging market and developing economies (EMDEs) is set to remain below pre-crisis levels in 2021, in large part because their twin public health and economic crises are more prolonged. EMDEs outside China account for nearly two-thirds of the global population but only one-third of global energy investment and just one-fifth of clean energy investment.

These EMDEs need to achieve a large increase in investment from a starting point of less fiscal space and more constrained access to sources of finance than advanced economies. Financial pressures on utilities and other major investment players in EMDEs have been exacerbated by the pandemic, which has also resulted in setbacks in the drive to expand access to modern energy. This is a major fault line in global energy transitions, which we will examine in detail in a major new IEA special report, entitled *Financing Clean Energy Transitions in Emerging Market and Developing Economies.*[2]

The balance of investment in fossil fuels is shifting towards state-owned companies

Upstream oil and gas investment is expected to rise by about 10% in 2021 as companies recover financially from the shock of 2020, but spending remains well below pre-crisis levels. Firmer demand and higher oil and gas prices have led to diverging investment strategies. Cost control remains a common theme, but some major national oil companies are looking to invest counter-cyclically to gain market share. Qatar's decision to move ahead with the world's largest liquefied natural gas (LNG) expansion, and to include carbon capture in its development plans, is a strong statement of intent to maintain a leadership position in LNG.

There are strong pressures on private companies to keep oil and gas portfolios in check. Despite higher prices, the major oil companies are holding aggregate oil and gas spending flat in 2021, and their share of overall upstream spending is now at 25%, compared with nearly 40% in the mid-2010s. The shale sector is, for the moment, sticking to its newfound commitment to capital discipline, using higher revenues in 2021 to pay down debt and return money to shareholders rather than to increase output.

The predominance of state-owned companies is also visible in coal supply, with investment dynamics largely determined by what happens in China and India. In China, the policy priority is to modernise the sector by shutting down small, inefficient mines and investing instead in large, fully mechanised mines. In India, the main driver behind domestic investment is to reduce coal imports.

Overall, the overwhelming bulk of fuel supply investment in 2020 went into fossil fuels – 84% to oil and gas and 14.5% to coal (which is a much less capital-intensive sector). Around 1.3% was spent on low-carbon fuels. Today's

[2] This report is being produced by the IEA in collaboration with the World Bank and the World Economic Forum, for launch on 9 June 2021.

investment spending on fuels appears caught between two worlds: neither strong enough to satisfy current fossil fuel consumption trends nor diversified enough to meet tomorrow's clean energy goals.

An uptick in investment decisions for new coal-fired power plants underscores that coal is down, but not out

The rising share of renewables in new power generation investment has been accompanied by a sharp drop in approvals for new coal-fired power plants, which are some 80% below where they were five years ago. However, there was a slight increase in go-aheads for new coal-fired projects in 2020. This was largely due to China, where the government lowered restrictions on building new plants, giving a green light for construction in more provinces. Cambodia, Indonesia and Pakistan were other countries where coal-fired final investment decisions (FIDs) picked up in 2020. Those three countries together approved almost 5 gigawatts (GW) of new coal capacity in total. In India, the amount approved dropped below 1 GW, its lowest level in a decade.

China's coal-fired FIDs in 2020 were about 25% their 2010 level, India's less than 5%. FIDs for gas-fired power plants edged down globally in 2020 but were still more than double those of coal (50 GW versus 20 GW). A large reduction in FIDs for new gas-fired capacity in the United States more than offset growth in parts of Asia (outside China and India).

From a low base, investments by the oil and gas industry in clean energy technologies are starting to pick up.

Oil and gas companies are coming under increasing pressure to adapt their investment strategies to the needs of clean energy transitions. This takes different forms, including commitments to reduce emissions resulting from oil and gas supply or to invest into new areas such as clean electricity or sustainable fuels.

In 2020, clean energy investments by the oil and gas industry accounted for only around 1% of total capital expenditure. However, our tracking suggests that commitments to diversify investment, led by large European companies, are already starting to have an impact. If performance so far in 2021 is maintained for the full year, the share of capital investment by the oil and gas industry going to clean energy investments could rise to more than 4% in 2021. Project financing for offshore wind – closely aligned with industry strengths – was considerably higher in the first quarter of 2021 than in the whole of 2020.

Support for innovation is a key pillar of net zero plans, but 2020 saw diverging trends between government and corporate spending on energy research & development

Public spending on energy research & development (R&D) continued to rise in 2020, with the share of low-carbon technologies in the total rising to 80%. However, energy R&D spending by the private sector dropped by around 2% as the pandemic caused cuts to corporate budgets. Governments have a key role to play in ensuring that the world's capacity to bring new technologies to market is not disrupted by the pandemic.

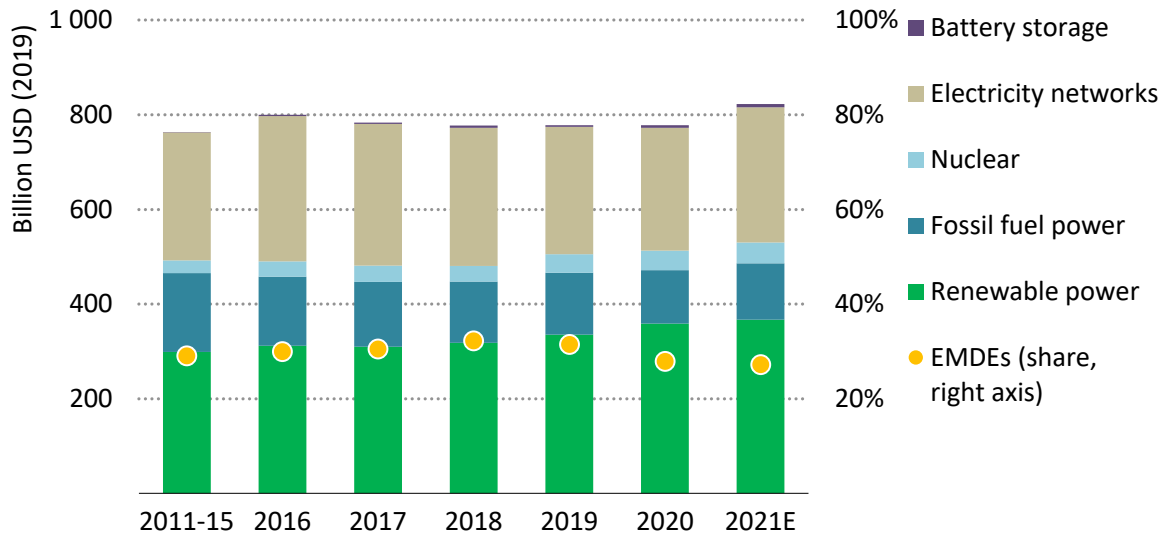
The signals for investment in low-carbon energy innovation in early 2021 are broadly positive. Major economies have highlighted innovation and increased funding as part of their drive to net-zero emissions. In total, we estimate that through 2030, over USD 50 billion of public funds could be available for major demonstration projects for large-scale low-carbon energy technologies, including CCUS and other ways to mitigate industrial emissions. Another source of optimism is the observed resilience in 2020 of early-stage venture capital funding for low-carbon energy technologies.

Electricity

Overview

Investment in the global electricity sector is expected to increase by around 5% in 2021. The pandemic flattened investment in this sector in 2020, as the resilience of spending on renewables compensated for drops in electricity grids and larger reductions in fossil fuel generation. The resumption of growth in electricity spending is a reflection of the central role of electricity in development strategies and energy transitions, alongside expectations of improvements in the economy and in the overall public health situation.

Global investment in the power sector by technology, 2011-2021E



Note: EMDEs = Emerging Market and Developing Economies, excluding China.

China and the United States continue to attract about half of global power sector investment, both showing positive investment growth in 2020 despite the pandemic. This was driven by a large increase in spending on renewables projects – especially wind – in advance of a withdrawal of the previous subsidy regime in China, and a deadline for eligibility for tax credits in the United States. After a record year, investments in renewables could fall in China in 2021 (though they are likely to stay at levels well above 2019), despite the country's announced 2060 carbon-neutrality target. New support for clean energy investment in the United States includes both financial aspects as well as permitting and regulatory

changes, which are likely to spur increased investment in 2021 and beyond. Investment in Europe's power system was also relatively resilient through the pandemic, and is likely to grow in 2021, led by higher spending on renewables, especially as disbursements of the European Union (EU) Green Recovery package kick in during the second half of 2021 and beyond.

However, the overall state of play in EMDEs (excluding China) is less upbeat. Power sector investment in EMDEs was more affected by the pandemic and the economic downturn in 2020, down by 10% compared with the previous year. The anticipated recovery is not enough to bring spending back to pre pandemic levels, in large part because the twin public health and economic crises are more prolonged. EMDEs account for nearly two-thirds of the global population but for less than one-third of power sector spending. Market uncertainty, lockdowns and reduced revenues fed into lower spending outlays on new projects, especially in India, the Middle East and North Africa, and Southeast Asia. Despite the 2021 increase, trends in EMDEs remain well out of step with the massive scale-up in investment required in these countries to meet sustainable development goals.

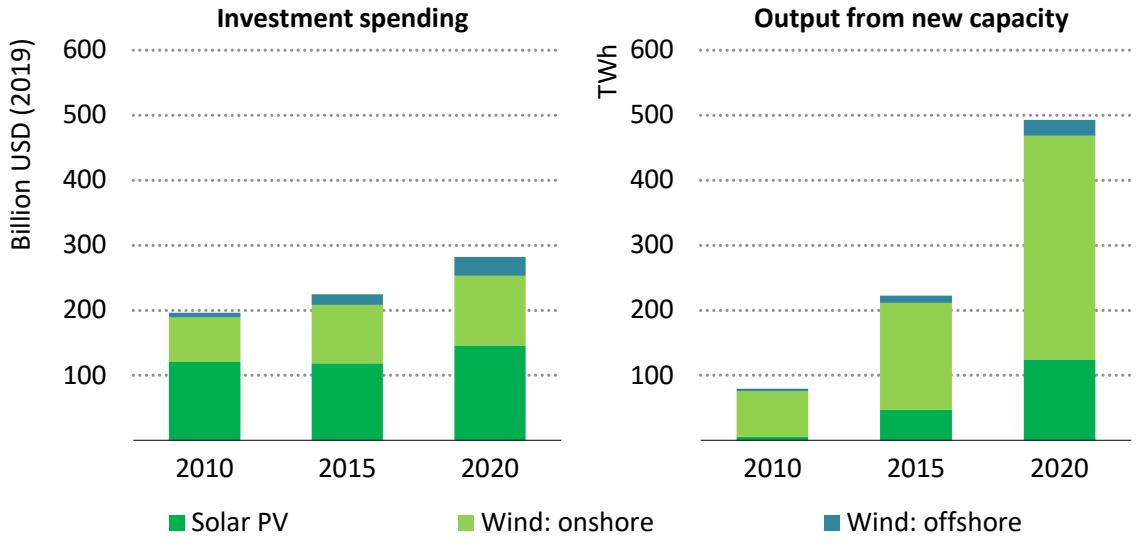
Electricity generation

Investment in renewables was remarkably robust in 2020 and continues to dominate spending on new generation

Renewables are dominating inflows of capital to new power generation capacity, and these investments remained robust in 2020 given the disruption caused by Covid-19. The share of renewables in total power sector spending (including network infrastructure) was above 45% in 2020. A further increase in renewable investment is expected in 2021 as economies recover.

Capital expenditures for renewables increased by around 7% in 2020 compared with 2019, despite capital costs continuing on a downward trend. For example, utility-scale solar PV installation costs decreased by 10% in 2020 while onshore wind decreased by 5%, on a global average basis. Overall, a dollar spent on wind and solar PV deployment in 2020 is associated with four times more output than a dollar spent on the same technologies ten years earlier, because of technology improvements and reduced costs.

Investment in solar PV and wind power and its expected generation output, 2010-2020



Source: IEA calculations with capital cost data from IRENA (2021) and capacity factors from IRENA (2019).

The 45% increase in renewable deployment in 2020 was largely due to a record year for wind power installations. Wind capacity almost doubled compared to 2019, to 114 GW, while solar PV also expanded by almost a quarter, reaching almost 135 GW. An astonishing 70 GW of new wind power capacity was brought online in China, while the United States followed in second place, connecting more than 15 GW of onshore wind.

There was a negative shock to renewable investments in many EMDEs in 2020 but there were also some exceptions. Viet Nam, for example, managed the crisis remarkably well while continuing to attract capital to renewables: the phase out of feed-in tariffs (FITs) for solar PV projects resulted in a drop in utility-scale investment, but distributed PV drove a continued boom in 2020, with over 9 GW of rooftop solar installed.

Investments in renewables are set to continue growing in 2021, consolidating the record growth of 2020 albeit at a slightly slower rate. Renewables are central to achieving enhanced emissions targets, including net-zero pledges, announced by countries and companies around the world. Costs and capacity factors for key technologies continue to improve, especially for solar PV that reached new record lows in various tenders and auctions across the world during 2020 and the beginning of 2021. This included around USD 13 per megawatt-hour (MWh) in a 700 megawatt (MW) auction in Portugal in August 2020 (PV Magazine, 2020), followed by a record low of just over USD 10/MWh announced in Saudi Arabia in early 2021 for a 600 MW project (Taiyang, 2021). In addition, the stocks of

renewable players have also done well, helped by expansive monetary policy and a generally positive market sentiment towards low-carbon assets.

Solar PV – rather than wind – is set to lead the growth in renewables spending in 2021, given its competitiveness and the existing pipeline of projects committed in tenders, auctions and corporate power purchase agreements (PPAs). Investments in solar PV are anticipated to grow by more than 10% in China, India, the United States and Europe. This growth stems not only from the commissioning of utility-scale solar PV projects, but also from an uptick in investments in distributed solar PV facilitated by improving economic and public health conditions.

While net-zero strategies and low financing costs set a very positive context for renewable generation in advanced economies, permits and licences could hinder some of this momentum, especially for onshore wind. These factors are starting to represent a bottleneck in Europe, where permits take long to obtain and decisions are at times challenged in court (Wind Europe, 2021). Under subscription was also a problem in wind auctions in Germany. This is also true in many EMDEs, on top of land- and grid-related issues. In India, wind auctions were at a standstill in the first half of 2020 and 60% of the capacity auctioned in the second half was not allocated.

These constraints are less visible in relation to investment in offshore wind, which is expected to continue to show strong growth, given rising policy support in Europe and around the world. There are strong expectations of low prices for new offshore wind tenders in Germany, Japan, the United Kingdom and the United States. In May 2021, the US authorities gave the green light for the construction and operation of the 800 MW Vineyard Wind project off Massachusetts, the country's first large-scale offshore wind project.

Nuclear power, which represents around 5% of total global investment, was also quite resilient in 2020 and is set to increase in countries with well-defined nuclear expansion plans such as China, India and the Russian Federation (hereafter, "Russia"). China, for example, commissioned 2 GW in 2020, but started construction of 3 GW, about three times more than in 2019, and has plans to build more nuclear plants in the coming years to align with its 2060 target for carbon neutrality.

Investment in fossil-based generation decreased considerably in 2020, by more than 10%, given lower demand and electricity prices, although there were notable differences between countries and regions. Around a third of the 2020 drop came from India, driven by lower spending in coal-fired plants, disruptions caused by

lockdowns and lower electricity demand. In the United States, investment increased, stemming from an uptick in investment in gas-fired plants, as firm capacity becomes scarcer given the continued penetration of variable renewables and the continuation of coal retirements (around 10 GW in 2020). Spending on US fossil-fired plants is anticipated to rise in 2021. In China, investment in fossil fuel generation declined in 2020 and is expected to do so again in 2021, although the reduction in 2021 is at a much lower rate than in previous years, consistent with our findings on project approvals.

Final investment decisions for dispatchable power

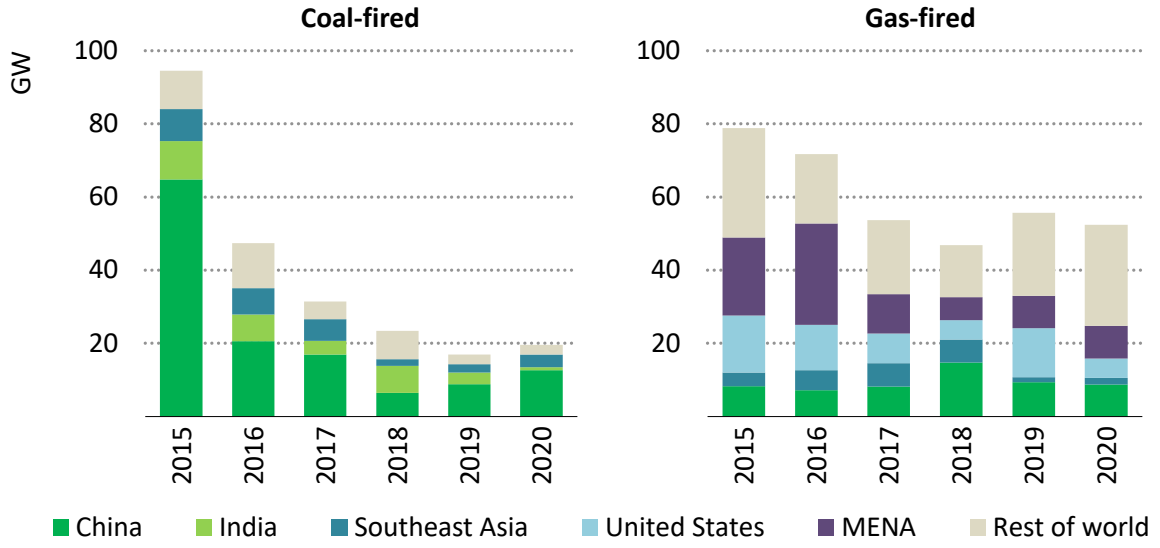
An uptick in investment decisions of coal-fired power in 2020 shows that, while coal is well down, it is not out

In addition to our estimates of today's investment flows to different parts of the energy sector, i.e. current annual capital spending, our tracking of projects that reach financial close or begin construction provides an additional forward-looking indicator of future activity. These FIDs for large-scale dispatchable power increased in 2020 to almost 95 GW.

This includes an uptick in FIDs for coal-fired power, which reached 20 GW in 2020, the first increase since 2015. Even though these FIDs are now 80% below where they were five years ago, this is nonetheless a reminder that energy transitions do not follow a simple storyline. The increase came largely from China, with a 45% increase compared with 2019, reaching almost 13 GW Nearly three times more capacity obtained approvals for construction.This came after the government lowered restrictions on building new plants, giving a green light for construction in more provinces. Cambodia, Indonesia and Pakistan were other countries where coal-fired FIDs picked up in 2020, approving almost 5 GW in total, while they dropped in India to less than 1 GW, the lowest level of the decade. China's coal-fired FIDs in 2020 were a quarter of where they were in 2010, India's less than 5%.

A considerable amount of coal is still included in power expansion plans across several Asian countries, even in countries that are also pushing strongly for renewables. Viet Nam is a good example, in that it is targeting almost 130 GW of renewable capacity by 2045 while also more than doubling its anticipated coal-fired capacity over the same period, according to the latest national power development plan draft .

FIDs for coal and gas, 2015-2020 (GW)



Note: MENA = Middle East and North Africa.
Source: IEA calculations based on McCoy (2021).

Investment decisions for gas-fired plants edged down in 2020, largely due to a considerable reduction in FIDs in the United States, which more than offset growth in Asia (outside China and India). FIDs for the largest sources of low-carbon dispatchable generation – hydropower and nuclear – were more than 20 GW, 40% higher than the previous year, driven by FIDs of hydro power in India, to provide balancing for increased shares of variable renewable generation.

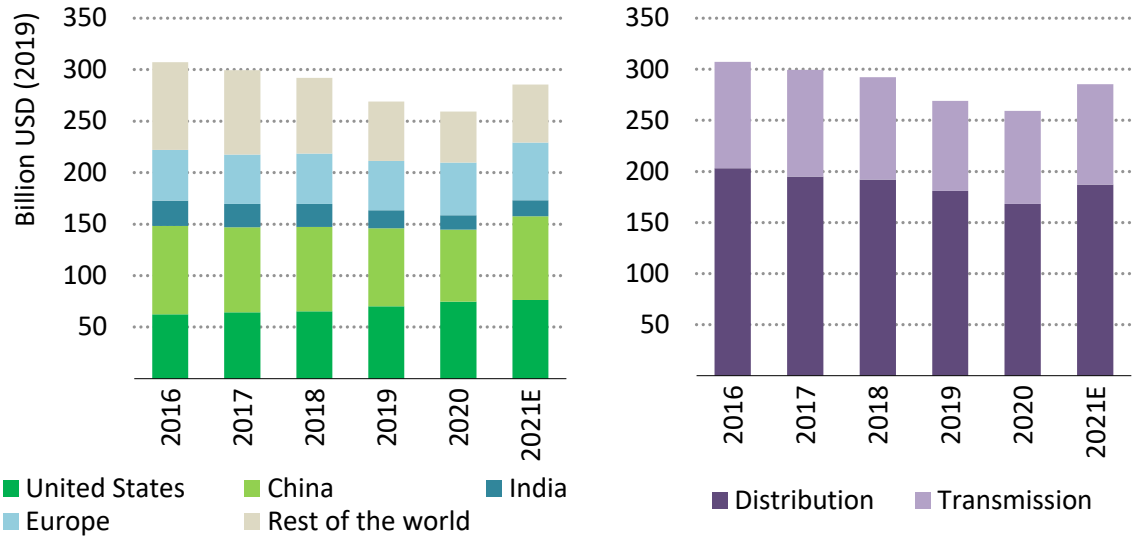
Grids and storage

The decline in grid investment is likely to be reversed in 2021 with rising infrastructure spending in Europe and China – and major plans announced in the United States

After declining for the fourth consecutive year in 2020, spending on electricity grids is expected to go up substantially in 2021. Most of the 2020 decline stemmed from a reduction in China and several EMDEs, which more than outweighed increases in the United States and Europe. In China, the majority of the drop came in the distribution sector, as targets for rural power grid expansion had been met and focus shifted to transmission, which represents a smaller share of grid investments. However, there are large expansion plans expected for 2021 – especially in China and Europe – which are set likely change this trend. In Europe,

for example, the 2021-30 grid expansion plans provide the foundation for increased investment, supported by the recovery plans.

Investment in grids by geography and segment, 2016-2021E



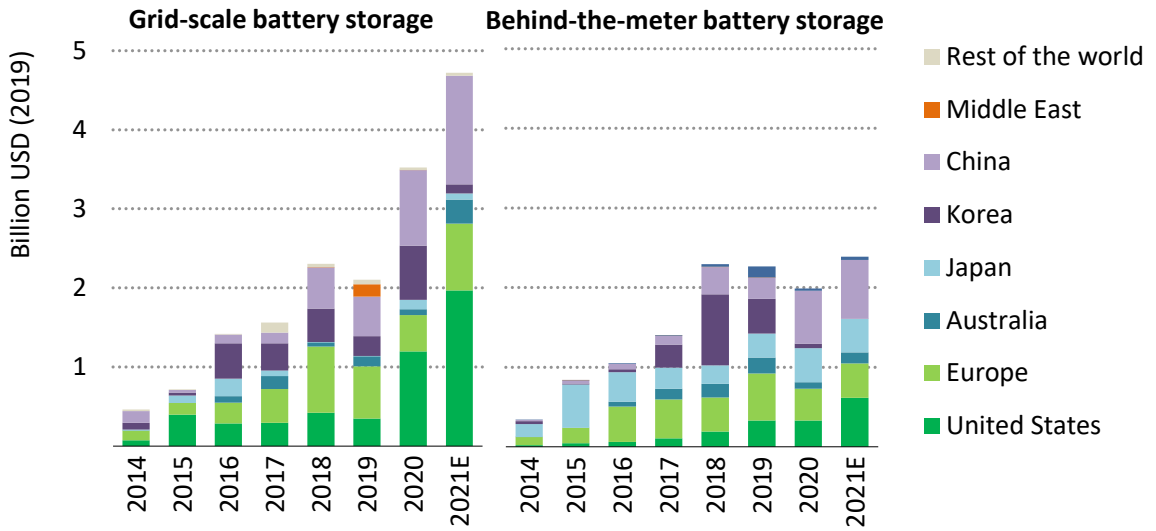
Note: Investment in electricity networks is calculated as capital spending for installed lines, associated equipment and refurbishments.

In the United States, the proposed American Jobs Plan includes measures to build a more resilient electricity transmission system as part of the drive for carbon-free electricity by 2035. This includes the creation of a targeted investment tax credit and efforts to better leverage existing rights-of-way along roads and railways for high-voltage lines. These kinds of measures underline the broader importance of policies and regulation in faciltating network investments, by incentivising connections to the grid, especially for new wind and solar projects; simplifying procedures to make public land available for electricity infrastructure; speeding up response times; or rethinking authorisation procedures for minor categories of projects.

Despite the pandemic, investment in battery storage increased by almost 40% in 2020, to USD 5.5 billion. Given the strong momentum of the sector and the big pipeline of projects, this trend is set to continue over 2021. Spending on grid-scale batteries rose by more than 60%, driven by the push for renewables investment and growing presence of hybrid auctions with storage. Average costs continued to reduce substantially, by an average 20%. This also helped drive the impressive resilience of grid-scale batteries, especially in the United States and China – which installed over 1 GW – followed by Korea and Europe.

On the other hand, investments in behind-the-meter storage decreased by 12%, as these assets are generally financed by households and small and medium companies that were generally more affected by the Covid-19 pandemic. Nonetheless, behind-the-meter storage is expected to pick up again in 2021 as the global economy improves.

Battery storage investment, 2014-2021E



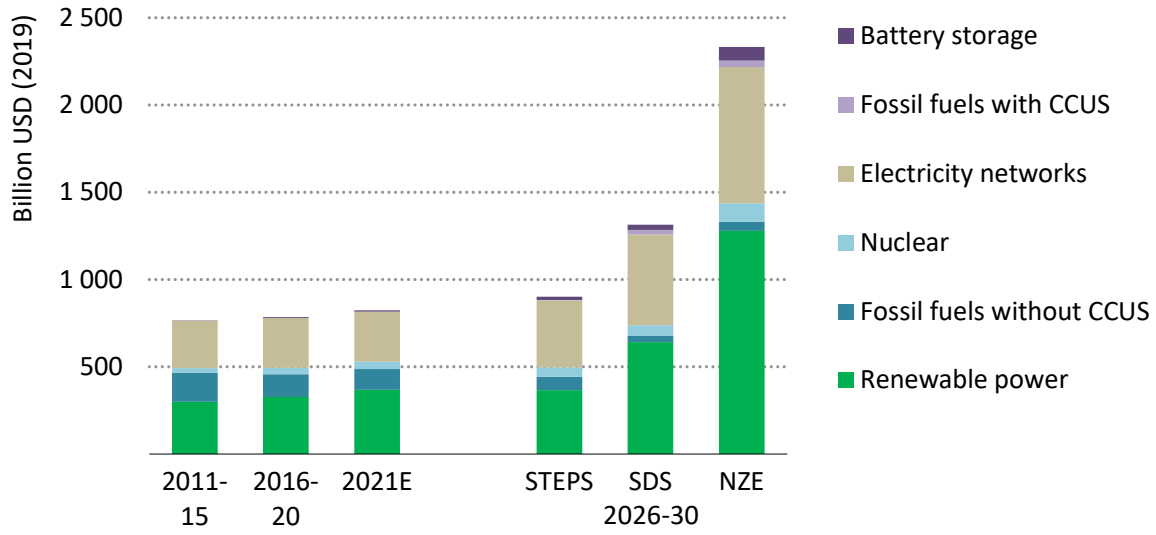
Source: IEA calculations based on Clean Horizon (2021), BNEF (2021), China Energy Storage Alliance (2021).

Implications

Electricity investment is still a long way short of what is needed for a cleaner and more electrified energy future

The headline numbers for investment in electricity show some positive signs, notably the resilience in 2020 and the prospective increase in 2021. However, analysis of some of the details – and a comparison with what would be required in climate-driven scenarios – present a much more sobering picture. The world is a long way short of the path that needs to be followed to avoid severe impacts from climate change. The slight increase in FIDs of new coal-fired plants in 2020 shows that not all indicators are pointing in the right direction.

Global investment in the electricity sector compared with annual average investment needs, 2025-2030, by scenario



Note: STEPS = Stated Policies Scenario, SDS = Sustainable Development Scenario, NZE = Net Zero Emissions by 2050.

In advanced economies and in China, the availability of money for power sector investments does not appear to be a binding constraint – there is strong competition for high-quality investment opportunities against a backdrop of low lending rates and pressure to increase exposure to clean energy. However, the flow of projects is often intermittent, due to time-limited subsidy programmes or other administrative and permitting constraints. Improving the certitude and clarity of investment frameworks will be key to unlocking private capital at scale for mature technologies such as wind and solar PV.

At the same time, policy makers need to ensure that the pace of change on the generation side is matched by investment in robust energy grids, storage and all forms of flexibility: the priority attached to infrastructure in recovery strategies is a positive signal in that regard.

By contrast, the signals from many EMDEs are a source of much greater concern. With few exceptions, the downside risks to investment from the pandemic are more substantial, the risks facing new clean electricity and infrastructure investments are higher, and sources of finance more constrained. This topic is examined in much more detail in forthcoming IEA analysis, entitled *Financing Clean Energy Transitions in Emerging Market and Developing Economies*.

Fuel supply

Overview

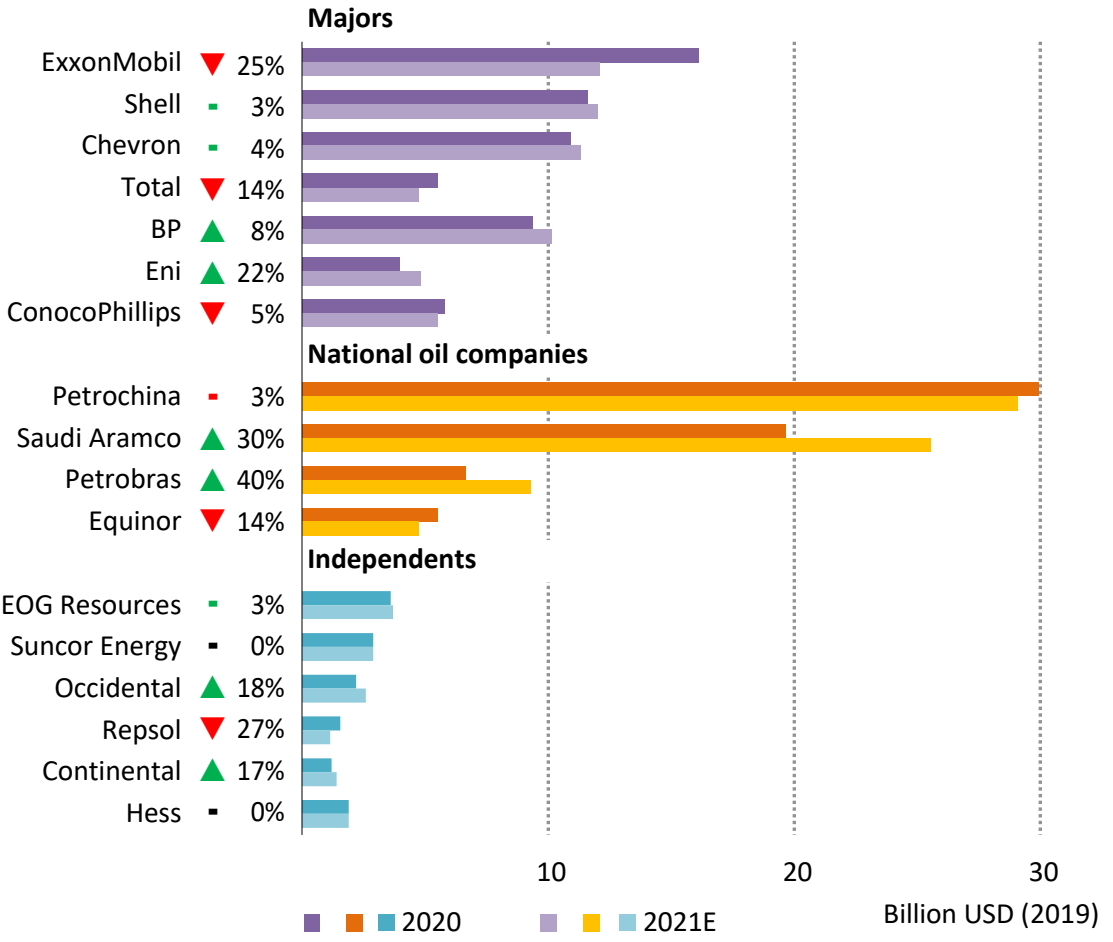
After a precipitous fall in 2020 of more than 25%, total fuel supply investment is expected to rebound by about 14% from just over USD 620 billion to nearly USD 710 billion in 2021. The vast majority of fuel supply investment in 2020 went into fossil fuels – around 84% to oil and gas and just over 14.5% to coal (which is a much less capital-intensive sector). Only around 1.3% was spent on low-carbon fuels. However, as we explore later in this section, companies – including in the oil and gas industry – are starting to allocate more capital spending to projects in low-carbon fuels and CCUS; this is set to have a tangible influence on future investment trends.

Oil and gas upstream

Upstream spending set to rise in 2021, but the oil and gas industry remains under strong pressure from the pandemic and from energy transitions

The oil and gas industry has never seen a year like 2020, and the reverberations are still being felt in the finances and strategies of companies across the sector. After a sharp decline in 2020, our bottom-up analysis of publicly announced oil and gas company spending plans shows an 8% increase in upstream spending in 2021, taking the total spending to over USD 350 billion, but this remains well below 2019 levels.

Upstream spending by selected company, 2020-2021E



Source: IEA calculations based on company reporting.

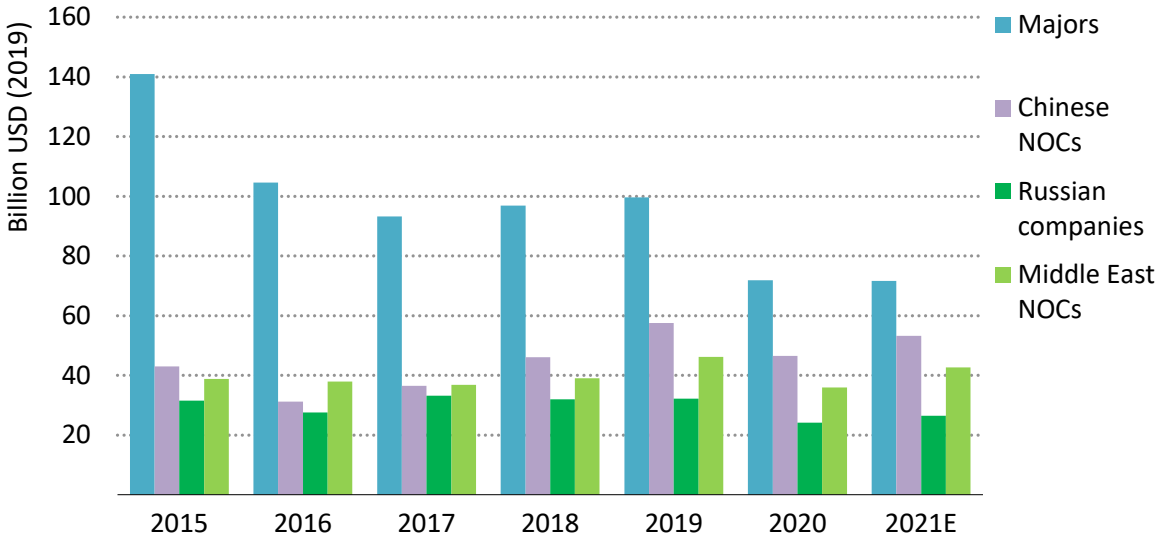
Prices and revenues have been higher in the first quarter of 2021, but it is far from certain that this will trigger additional upstream spending. Companies face multiple dilemmas as they put together their spending plans. Demand uncertainties related to the pandemic and the speed of energy transitions are accompanied on the supply side by the large spare capacity held by countries in the OPEC+[3] grouping, and questions over the pace at which OPEC+ supply cuts will be unwound.

There are variations among companies but, in aggregate, the Majors are holding a conservative line on upstream capital spending plans: these are essentially flat compared with 2020 (-2%). Continued investor pressure to diversify into low-carbon energy underpins more modest spending programmes, which are also aimed at reducing debt and supporting dividend payments (see discussion below

[3] OPEC+ comprises the members of the Organization of the Petroleum Exporting Countries as well as Azerbaijan, Bahrain, Brunei, Kazakhstan, Malaysia, Mexico, Oman, the Russian Federation, South Sudan and Sudan.

on the industry in transition). Upstream spending by the Majors as a group has traditionally been well above the levels from their peers in the Middle East, Russia and China; this is no longer the case.

Upstream spending by selected company types



Source: IEA calculations based on company reporting.

The shale sector is another crucial bellwether for investment trends and market balances. After another round of belt-tightening in 2020, shale players face the unfamiliar prospect of generating significant free cash flow in 2021. For the moment, the industry is using the influx of cash to pay down debt and return money to shareholders, rather than increase output. Investors have welcomed this commitment to capital discipline. However, if or when a leaner and more profitable sector starts to regain the confidence of capital markets, priorities could swing again back towards growth.

Caution remains the watchword also for the exploration sector, which slumped already in the 2010s as companies turned to shale (which does not require exploration in the usual sense). Exploration activity is sharply down in most parts of the world, with the main pocket of activity outside of the Middle East being in offshore Brazil, Guyana and Suriname.

The overall expectation is that upstream investment by National Oil Companies (NOCs) increases by around 10% in 2021, but this average figure masks a range of spending plans, strategies and financial pressures. While many NOCs still face severe revenue and spending constraints, some are stepping up countercyclical investments. China's NOCs – PetroChina, China National Offshore Oil

Corporation (CNOOC) and Sinopec – have announced large capital budgets for 2021, with PetroChina having the largest upstream programme of any company. Some large players in the Middle East are also in expansion mode, with Saudi Aramco and Abu Dhabi National Oil Company (ADNOC) both charged with increasing production capacity by around 1 mb/d in the coming years. ADNOC announced a USD 120 billion spending programme for 2021-25 with this in mind. Saudi Aramco plans total capital expenditures of USD 35 billion in 2021 (versus USD 27 billion in 2020); although the need to keep revenue flowing to the state during the crisis has pushed up the company's borrowing, taking on an extra USD 90 billion in debt in 2020.

Refining

Pressure to consolidate and retool for a new age is growing in the refining sector

The refining industry had an extremely challenging year in 2020 with the collapse in oil demand. Estimated refining investment (greenfield and upgrades) fell by more than a quarter to just under USD 38 billion, a sharp reversal from the record-high investment in 2019. As the most lucrative products such as gasoline, diesel and jet fuel registered large declines, refinery runs fell to 74.4 mb/d, a level last seen in 2010, and margins plunged to their lowest in at least two decades. This triggered a wave of announcements of closures for 2020-26, mostly in advanced economies, amounting to 3.6 mb/d in total.

However, refining expansion plans are continuing in parallel in regions with access to cheap feedstock and growing markets, most notably in developing economies in Asia and the Middle East. These regions, which accounted for 80% of the investment in 2020, are expected to underpin a rebound in investment in 2021. Some 8.5 mb/d of new refining capacity is still expected to come online over the period to 2026, resulting in 4.9 mb/d of net capacity additions. The projected scale of net capacity additions is much larger than that of refined product demand growth, which is likely to force further capacity closures or repurposing.

A number of refiners have started to retool for a new age characterised by structural demand shifts from transport fuels to non-combustion uses (such as petrochemical feedstock) and accelerating momentum for energy transitions. Some are betting on the most resilient part of demand – petrochemicals – by making investments in petrochemical integration. Others are expanding into low-carbon businesses such as advanced biofuels, chemical recycling and low-carbon hydrogen in order to secure new sources of revenue. For example, some

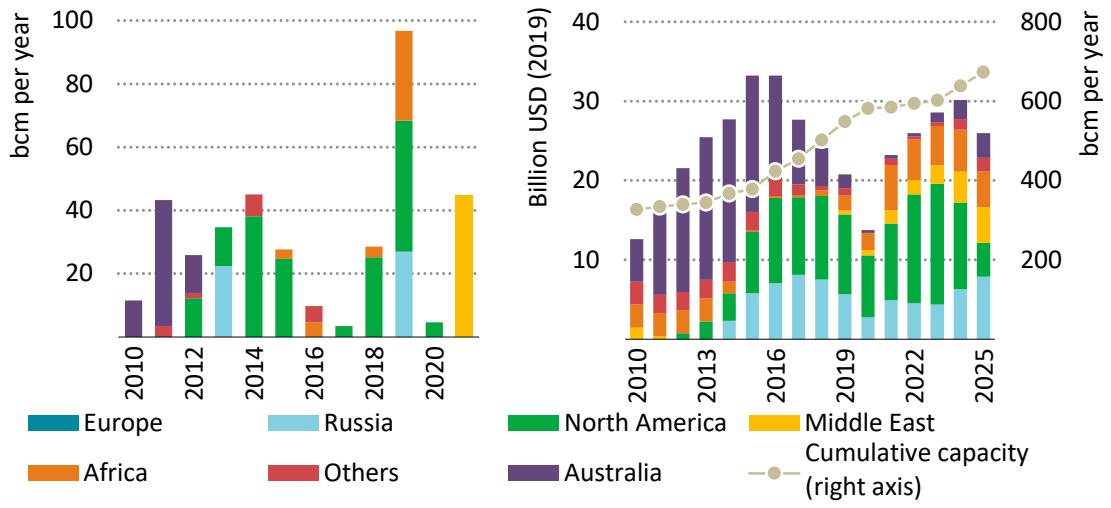
345 thousand barrels per day (kb/d) of refining capacity has already been converted to biorefineries and there are plans for 840 kb/d more. These strategic shifts are set to grow against a backdrop of increasing electro-mobility.

Liquefied natural gas and pipelines

Qatar makes a strong statement of intent with its move to expand LNG capacity

LNG liquefaction investment dropped by more than a third in 2020 but is expected to grow by more than two-thirds in 2021 to over USD 23 billion. Qatar, Russia and the United States are set to pick up construction project activity, although the outlook remains very uncertain in Mozambique due to security concerns. LNG demand grew by 1% in 2020 (net of reloads), setting it apart from natural gas consumption as a whole, which recorded a 1.9% decline. However, the record year for financial close on new LNG projects in 2019 was followed by a year in which only one project reached FID – the 3.25 million tonne per annum (Mtpa) Costa Azul project in Mexico – from a queue of over 200 Mtpa worth of potential projects worldwide. This investment standstill was due to a combination of excess supply and low global gas price benchmarks, widespread capex cuts by the major national and international oil companies, uncertainty about future LNG demand related to the economic impacts of the pandemic, and a lack of buyer appetite for long-term LNG contracts.

Sanctioned LNG export capacity (LH) and annual investment spending on sanctioned projects (RH)



Note: bcm = billion cubic metres.

Market signals for LNG picked up in late 2020, with a sharp rebound in prices due to colder weather across Asia, a drop in nuclear and coal in Japan and Korea, and unplanned outages of LNG terminals: in early 2021, some spot LNG cargoes were bought for up to USD 40 per million British thermal units. US LNG exports ramped up to record highs in late 2020 and entered 2021 with strong growth, spurred in part by falling charter rates.

The announcement in February 2021 of an FID for Qatar Petroleum's 33 Mtpa North Field East expansion, the largest single LNG project by capacity ever sanctioned, ensures continued capacity growth from the mid-2020s. The company also launched a trading arm in 2020 to participate in the growing spot market for LNG through physical and derivatives trading. As the lowest-cost supplier with ample gas reserves, Qatar and its expansion, inclusive of carbon capture, casts a long shadow over other aspiring LNG projects, particularly those in the United States where there is a long queue of potential projects seeking to move to FID. Qatar's bid to offer low-emissions LNG is also a statement of intent to burnish the environmental credentials of LNG. It comes at a time where a growing contingent of buyers have made net-zero commitments and appear interested in measuring, and in some cases offsetting, the emissions associated with their contracted cargoes.

On the import side, there are nearly 200 bcm of regasification capacity under construction worldwide. Despite construction delays due to Covid-19 and project-specific issues, a pipeline of new projects, particularly in Asia, is aiming to ensure that infrastructure is in place to satisfy anticipated growth in demand.

Natural gas pipelines saw a mixture of traditional project advances and delays in 2020 while natural gas grid operators in mature markets began to eye opportunities to build and operate cross-border hydrogen networks. In the United States, additional Permian associated gas volumes secured routing to export options in Mexico and the US Gulf Coast with the completion of KinderMorgan's Permian Highway pipeline and Whitewater/MPLX's Aqua Blanca Delaware gathering system, which will connect to Whistler in 2021. In Europe, gas infrastructure and hydrogen network planning are becoming increasingly integrated: the industry-led European Hydrogen Backbone initiative foresees some 40 000 km of hydrogen pipeline infrastructure in Europe by 2040, with two-thirds of this being repurposed pipelines.

Biofuels (liquids and gases)

Policies are cushioning some of the effects of the slump on biofuels

Near-term investment prospects for liquid and gaseous biofuels are heavily reliant on government policies to counteract the uncertainties created by the pandemic, in particular the lower operating margins arising from lower fuel prices. Investment in these projects dipped in 2019 and fell further in 2020 to just over USD 8 billion. In the case of liquid fuels, the focus for new production capacity is changing from ethanol to hydro-treated vegetable oil (HVO), also known as renewable diesel, for which global production capacity is set to triple by 2025. For example, in the United States, policy-driven demand of HVO from the federal Renewable Fuel Standard (RFS2), California's Low Carbon Fuel Standard (LCFS) and the reintroduced Blender's Tax Credit has not only counterbalanced the effects of the pandemic but also caused a flurry of investments in production capacity, including the conversion of several traditional refineries. Investment in biodiesel capacity remained strong also in Asia and Brazil.

Ethanol capacity investments are driven by Brazil and China, which together represent around half of global investments, followed by Southeast Asia, but Covid-19 has affected investment plans in several markets. Capacity in China has doubled since 2017, and several large new plants are under development. In 2020, due to ethanol shortages associated with the Covid-19 pandemic, the Thai government pushed back the policy making E20 the principal blend for passenger vehicles. Brazil scaled back the 2020 target for its RenovaBio policy by 50% and the 2021 target by 40%, due to Covid-19 demand decreases.

Biomethane is emerging as a promising low-carbon alternative to natural gas. The current market is about 8 bcm – a tiny fraction of total natural gas supply – but investment activity has picked up in recent years as several countries, particularly in Europe and North America as well as Brazil, China and India, have encouraged its use, primarily in the transport sector. There are now more than 1 000 biomethane plants around the world, incentivised by a variety of policy instruments such as quotas, direct subsidies, tax exemptions and guaranteed offtake agreements. Several oil majors, notably Total, BP, Shell and Chevron, have recently announced forays into biomethane, following earlier initiatives by many European utilities and gas grid operators.

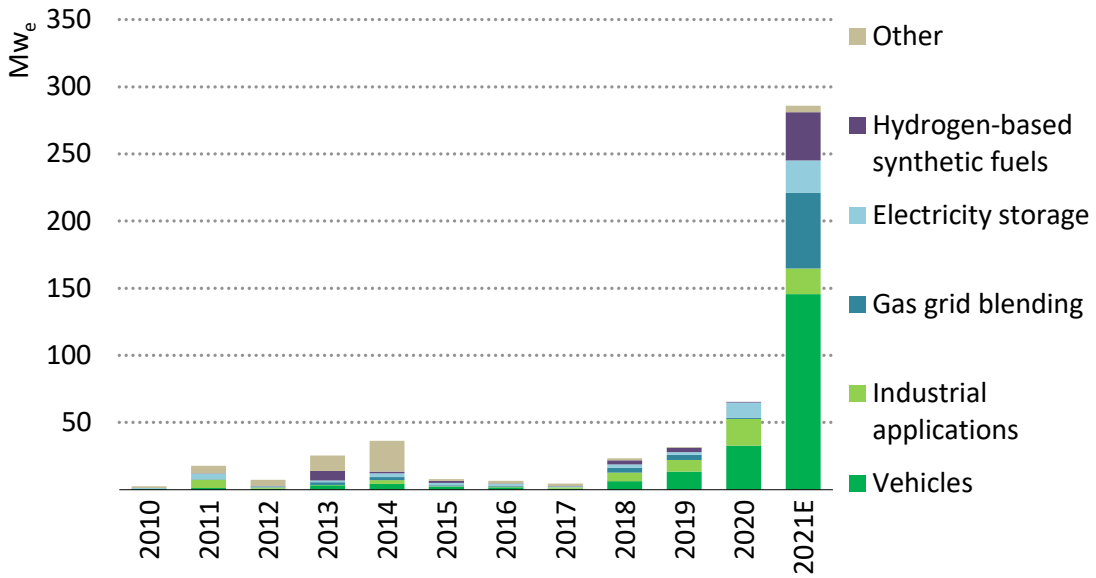
Hydrogen

Stimulus spending is giving low-carbon hydrogen a major boost

Despite setbacks to some projects and near-term uncertainty about its market growth, hydrogen is perhaps unique among fuels in that its prospects are stronger in mid-2021 than before the pandemic. This outcome rests in part on the reliance of hydrogen projects on government grant funding, for which plans have been markedly expanded in economic recovery plans around the world. Nine countries plus the European Union published hydrogen strategies or roadmaps in 2020 and one so far in 2021, with nearly twice this total currently under development.

Although current production and consumption are modest, expectations for the near-term expansion of low-carbon hydrogen[4] are higher than ever. Spending in the four areas of project planning, project completion, equipment manufacturing and equity purchases were all at record levels in 2020. Capital investment for low-carbon hydrogen is gaining momentum, with the electrolysers coming online in 2020 alone representing nearly USD 70 million.

Capacity of electrolysers for hydrogen production by commissioning year, by intended use of hydrogen



Notes: 2021E values represent estimates based on successful completion of all projects publicly stating a 2021 commissioning data as of the start of 2021. MWe = megawatts of electricity input; in some cases this is calculated from hydrogen output volumes if otherwise not stated. Includes electrolysers for the supply of hydrogen for energy purposes or as an alternative to fossil fuels in industry, such as chemical production and oil refining.

[4] For low-carbon hydrogen, either the emissions associated with fossil-based hydrogen production are prevented, for example by capturing and storing the CO_2, or the electricity input to hydrogen produced from water is renewable or nuclear sources.

Project completions in the area of water electrolyser installations for energy purposes reached an estimated 65 MW_e globally in 2020. While this was far below the 140 MW_e that project developers at the start of 2020 were aiming to commission, it was nonetheless more than double 2019 levels. Vehicle fuelling and industrial applications led the intended uses of hydrogen from these electrolyser projects. Much of the focus in Europe has turned to industrial applications, including the steel and refining sectors, as early markets for captive low-carbon hydrogen production. In Japan, the power sector is receiving renewed attention for hydrogen as a means of electricity storage and replacing coal and natural gas with ammonia and hydrogen. However, at 50%, the share of electrolysers installed for transport applications was at its highest point since 2010 due to the expansion of this type of project in China.

Several hundred MW_e of electrolysers are currently under construction or seek financial close for an announced commissioning before the end of 2021. Although delays can be expected for some projects, orders have recently been placed for delivery of some large electrolysers in 2021 and 2022, notably a 20 MW_e plant for fertiliser production in Spain, a 24 MW_e plant for chemicals manufacture in Germany and a 20 MW_e plant for a refinery in Denmark. As in 2020, developments in China will play a major role in determining the overall level of investment. Not all of these electrolysers are expected to produce exclusively low-carbon hydrogen, however, with the majority anticipated to run on grid electricity, at least initially.

In addition to electrolyser installations, investment activity in electrolyser manufacturing and equity investments in electrolyser technology companies reached new highs. For alkaline electrolysers, European manufacturers have published plans to expand existing plants to achieve a capacity of around 8 GW_e per year, compared with roughly 2 GW_e globally in 2020. In Europe, there are plans to more than double proton exchange membrane production capacity to over 1 GW_e per year by 2023, and there have been recent announcements that, if realised, could expand anion exchange membrane and solid oxide electrolyser production to over 1 GW_e per year in total. In a sign of the high interest of investors – including corporate investors – in early-stage hydrogen technology companies, H2Pro, Hystar, Syzygy Plasmonics and Utility Global all had successful fundraising rounds in recent months.

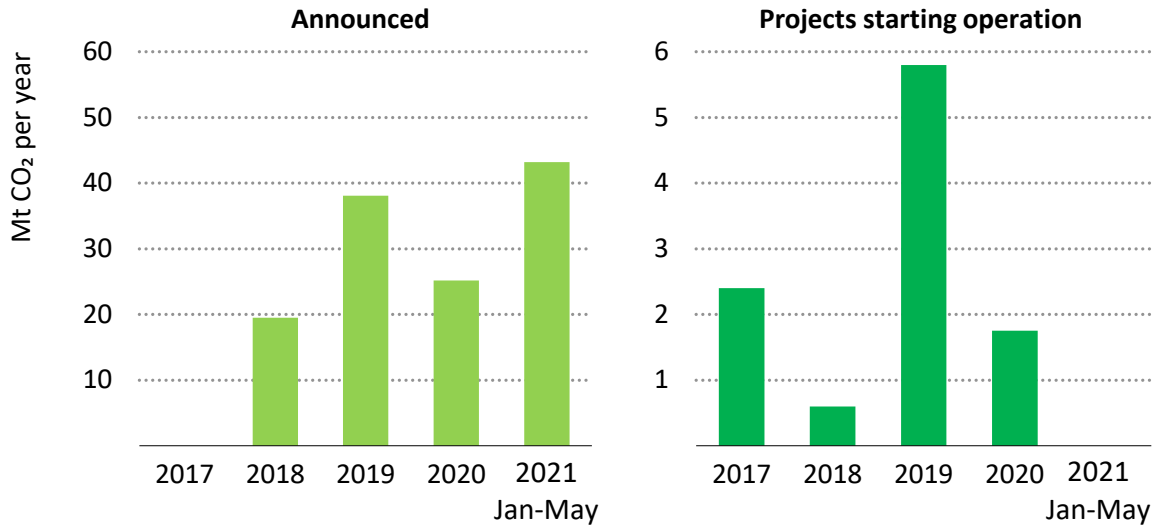
No FIDs were taken in 2020 for projects to produce low-carbon hydrogen from fossil fuels with CCUS but interest has risen sharply, including in fossil fuel producer countries that are exploring hydrogen or ammonia exports.

Carbon capture technologies

After a long wait, signs that CCUS may be preparing for take-off

From the start of 2020 to early May 2021, governments and industry pledged more than USD 12 billion to CCUS projects and programmes. Investments in CCUS technologies are starting to increase, prompted by increased policy support in some key markets, rising scrutiny of the emissions intensity of fuel supply, and improved co-ordination and alignment along the complex chain of interests involved. Nonetheless, the conversion rate of announcements into CCUS projects that actually start operation remains fairly low.

Announced CCUS projects versus projects starting operation



Notes: "Announced" includes the CO_2 capture capacity of projects by year of public announcement. "Projects starting operation" includes the maximum CO_2 capture capacity of new facilities by the year the facility was commissioned.
Sources: Based on GCCSI (2021) and IEA tracking and analysis.

Projects to watch out for include Longship in Norway, which will initially capture and store CO_2 from local industry with plans to expand to include additional industrial facilities across Europe. The central component of Longship is the Northern Lights CO_2 storage project, backed by Equinor, Total and Shell, which secured government funding in 2020 and launched as a joint venture in March 2021. Integrated CCUS projects for large industrial clusters are also an increasing focus: the Port of Rotterdam (which accounts for some 15% of total Dutch emissions) has reportedly secured backing from the government and is looking to take FID in early 2022. UK-based CCUS projects, including Northern Endurance

Partnership, Net-Zero Teeside and Zero Carbon Humber, received over USD 230 million in funding from the UK Industrial Strategy Future Challenge Fund to complete front-end engineering needed to take projects to FID.

A push to lower the emissions intensity of delivered LNG is behind Qatar Petroleum's plan to include a CCS component to its North Field East expansion. In the United States, NextDecade has announced its intention to take FID in 2021 on a 5 Mt CCUS project to offset emissions at two of its proposed Rio Grande liquefaction trains, together with Occidental. Valero, BlackRock and Navigator Energy Services have announced a partnership to gather, transport and store 5 Mt of CO_2, initially focusing on CO_2 from ethanol plants in the US Midwest but open to other industrial facilities. Proposed amendments and enhancements to the 45Q tax credit as well as new support for CO_2 transport and storage infrastructure could further boost CCUS investment prospects in the United States. Meanwhile, Elon Musk recently pledged USD 100 million for a carbon capture technology competition, and the Microsoft Climate Fund is backing various efforts to capture carbon including direct-air capture.

The oil and gas industry in transition?

From a low base, spending in clean energy by oil and gas companies is starting to pick up

Oil and gas companies have been proficient at delivering the fuels that form the bedrock of today's energy system, but against a backdrop of persistently high global emissions they are coming under increasing pressure to deliver solutions to climate change. These may sound like binary choices, but most companies will try to do both: in practice the two are closely interlinked, as most of the financial resources for diversified spending, at least initially, will come from traditional investments in supply.[5]

Traditional business areas cannot continue as usual: all operations have to be low-cost in today's market environment; they also have to be low-emissions. In many jurisdictions, investment and market opportunities are closely linked to a company's ability to deliver on environmental performance. For example, the recent North Sea Transition Deal agreed in the United Kingdom made any future

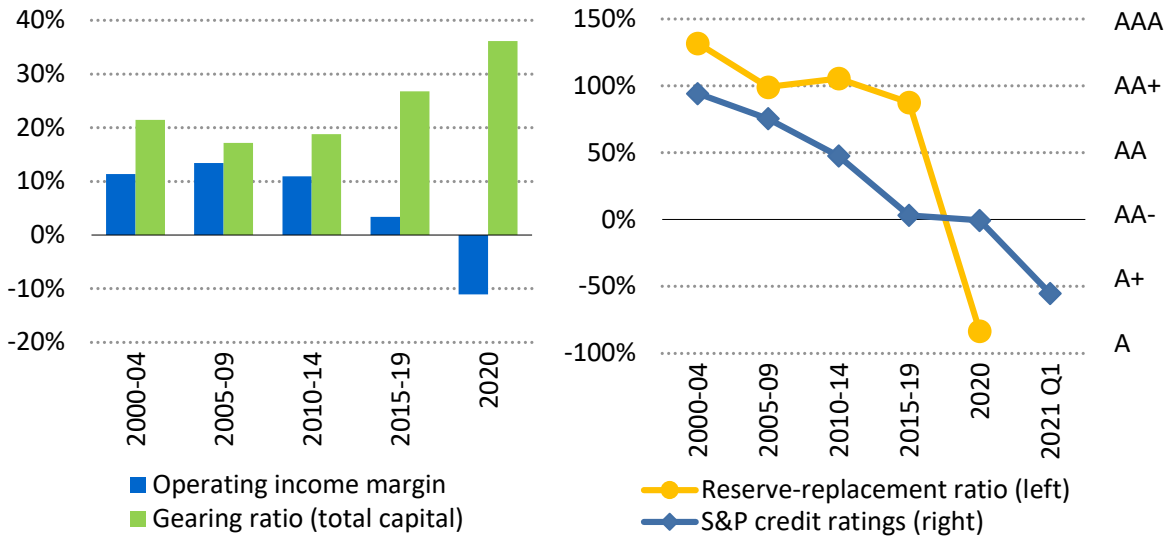
[5] There are a handful of cases where this is clear-cut, when a company simply exits the fuel supply business, e.g. in the way that some diversified mining companies, e.g. Rio Tinto, have simply exited the coal business, or when Ørsted sold its oil and gas upstream assets. It is worth noting, however, that these exits do not necessarily reduce supply, as the assets are bought and operated by others.

licensing rounds contingent on the industry hitting targets for emissions reductions, while also tying the industry's capabilities to new technologies such as offshore wind, hydrogen and CCUS.

A crucial distinction among different types of oil and gas companies concerns access to resources. While NOCs have, in most cases, a large domestic resource base to which they have exclusive or preferential rights, the same is not true for all. As international players retreat from exploration, so their funnel of new projects gradually narrows and they move towards a model where they rely on their best-performing existing assets to fund any new supply investments and to make their strategic moves into new areas and technologies. Company approaches to energy transitions vary greatly, but all have seen a drop in reserve-replacement ratios to an average of 80% over the last decade (BP recently ceased using reserve-replacement ratio as a strategic performance indicator).

As majors downsize portfolios, and midsize international independents struggle to access capital, smaller resource-holding countries – especially those in developing economies – are left with a smaller potential pool of investors and operators. Some host governments, for example in Angola or parts of West Africa, are reviewing upstream terms in order to retain investor interest; this may open up additional opportunities for internationally minded NOCs, including those in China and Russia.

Key financial performance metrics for the Majors



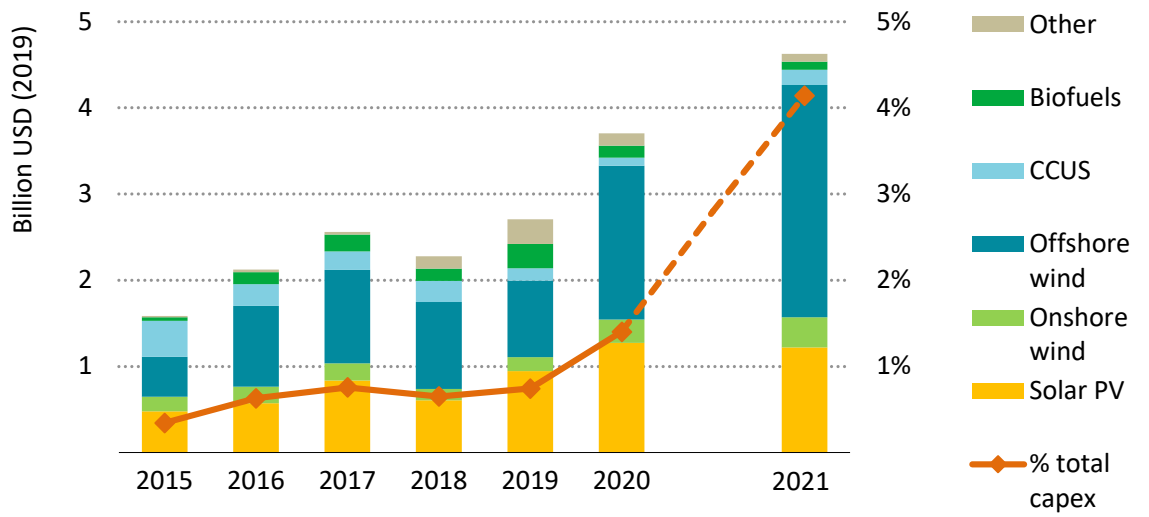
Note: In this classification, the "Majors" grouping includes seven companies: BP, Chevron, ExxonMobil, Shell, Total, ConocoPhillips and Eni. Credit ratings are averaged by company market capital at the time ratings were given.
Source: Bloomberg Terminal (2021).

Capital expenditure on clean energy has been a minor share of overall investment, but this is changing as companies – most notably the large European players – seek to ramp up clean energy investment. BP says it will increase its annual clean energy investment from USD 500 million in 2019 to USD 5 billion per year by 2030, with an interim goal of USD 3-4 billion per year by 2025. Total has announced that some USD 2.5 billion of its planned total investment of USD 12-13 billion in 2021 will go into renewables and electricity (including gas-fired power). Shell is targeting a 25% share of investment on clean energy capital expenditure by 2025. Eni's strategic plan for 2021-24 targets 20% of average yearly capex of EUR 7 billion to clean energy projects.

NOCs have displayed a range of strategies in line with individual company strengths, but on the whole they are staying closer to their core oil and gas supply businesses. Direct investments in renewables are typically motivated by a drive to reduce emissions intensities rather than to diversify into electricity supply. CNOOC, Petrochina and Sinopec have targeted peak carbon emissions from operations by 2025 largely via renewable investments in solar and offshore wind. A number of companies, including Saudi Aramco and ADNOC, are exploring possibilities to develop low-carbon hydrogen production, as well as investments in CCUS.

Emerging oil and gas company transition strategies have spanned project finance, mergers and acquisitions, venture capital, and R&D spending, and cast a wide net across clean energy businesses. Our project tracking for 2021 suggests that these commitments are already starting to have an impact. If maintained for the full year, this performance would mean that the share of capital investment going to clean energy investments could rise to more than 4%, from 1% in 2020. Project financing for offshore wind - closely aligned to industry strengths – was already considerably higher in the first quarter of 2021 than in the whole of 2020.

Clean energy investments made by selected oil and gas companies, including data through May for 2021



Notes: Companies included in this tracking are the Majors and selected others: ADNOC, CNPC (China National Petroleum Corporation), CNOOC, Equinor, Gazprom, Kuwait Petroleum Corporation, Lukoil, Petrobras, Repsol, Rosneft, Saudi Aramco, Sinopec and Sonatrach. The estimated share of total capex in 2021 is based on projects announced through 9 May 2021 and assumes that this pace of investment is maintained through the year.

Sources: IEA calculations based on Bloomberg (2021); BNEF (2021), Clean Energy Pipeline (2021); company reports.

Coal

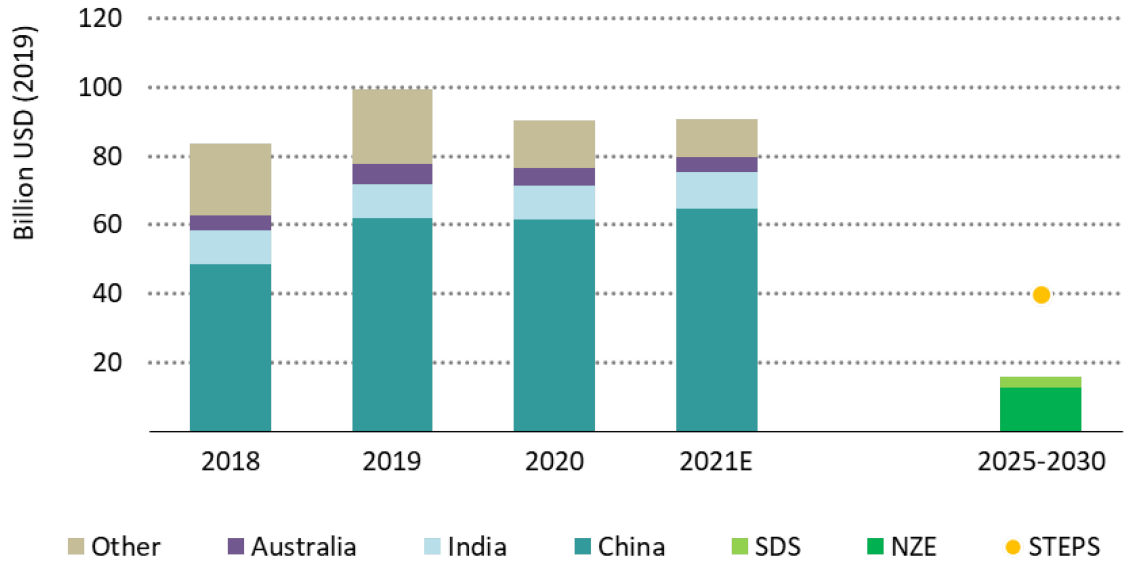
Coal supply investments are determined by what happens in Asia, led by China and India

Investment in coal supply is expected to rise slightly in 2021, after a larger reduction of nearly 9% in 2020. Global investment dynamics are largely determined by what happens in Asia, notably in China and India. Only 17% of global consumption involves international trade; the vast majority of the world's coal is produced within Asia, for consumption in the country in which it is produced. As a result, investment trends in coal supply are largely determined by domestic-oriented companies, often state-owned, in these countries. Coal investment in China and India in 2020 stayed at similar levels to 2019, whereas in the rest of the world they fell substantially, by around one-quarter. International coal players, competing for that 17% share of global consumption, face challenges familiar to many commodity producers related to boom-and-bust cycles. In addition, they are the focus for climate-related pressure by investors and other stakeholders, in particular regarding investments in thermal coal and lignite.

In China, coal supply investment is targeted at modernisation of the sector. This involves continued efforts to shut down small inefficient mines and invest in fully

mechanised, modern mines. At the corporate level, the reorganisation of companies through mergers and acquisitions, promoted by the government, is creating a smaller number of players with stronger financial capabilities. In India, a key objective is to reduce imports – with state-owned companies, mainly Coal India Ltd (CIL), but also Singareni, investing to ramp up production, while developers of captive blocks are investing to reduce dependency on CIL and/or imports. The government is also seeking to encourage commercial mining via a series of auctions. In 2020, the response to the first round was lukewarm, limited to Indian companies, and the government has launched a second tranche in 2021.

Investment in coal supply



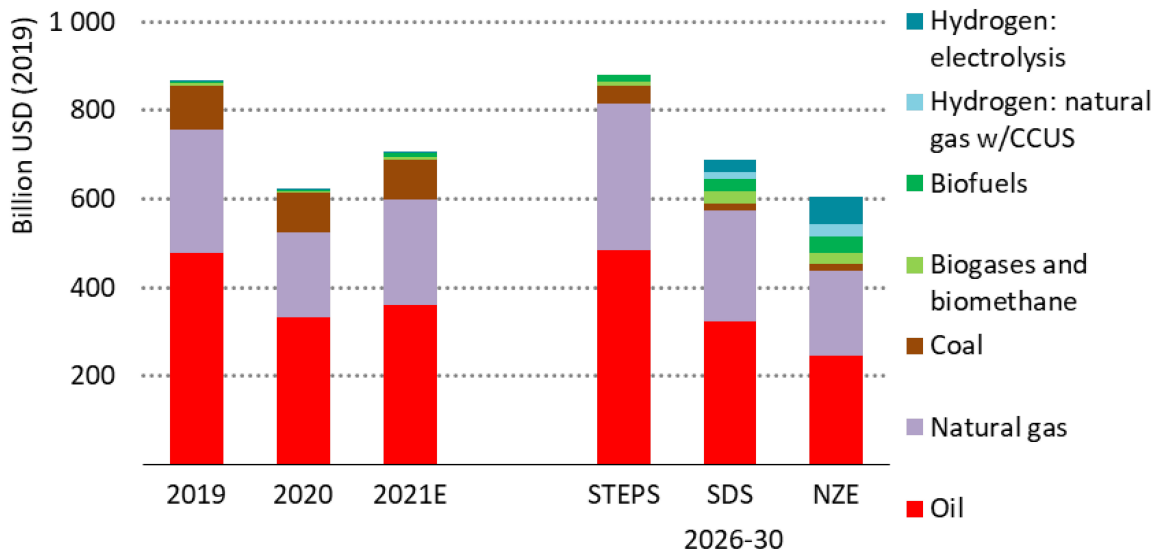
The demand trajectory is the main uncertainty facing investors, especially for any new mining projects, given China's announced target of carbon neutrality by 2060 and the burgeoning pace of renewables investment in India, alongside increasingly ambitious climate pledges in many advanced economies. Financing and underwriting coal projects are becoming ever more challenging, with more difficulties for thermal coal than for coking coal. In the case of international diversified miners, the weak prospective for demand is reinforced by the pressure from shareholders, environmental, social and governance (ESG) requirements and also regulations such as the EU taxonomy, which are increasing scrutiny on the carbon footprint of every stakeholder.

Implications

Fuel supply investment decisions are caught between competing visions of the future, but fuels of different sorts will be vital whichever pathway the world follows

Today's investment spending on fuels appears caught between two worlds, neither strong enough to satisfy current fossil fuel consumption trends nor diversified enough to meet tomorrow's clean energy goals. Investments in low-carbon fuels, such as hydrogen, biofuels and CCUS, are picking up but still lack mature opportunities to scale up spending as required in climate-driven scenarios. There is a differentiation to be made between oil and natural gas, with investments in the latter being generally more resilient. But what emerges clearly from our analysis is that, whichever way the world evolves, the production, handling and distribution of fuels continues to be a pivotal element of a well-functioning energy system. Whichever way the world evolves, the production, handling and distribution of fuels – of different types – continues to be an important element of a well-functioning energy system.

Global investment in fuel supply compared with annual average investment needs, 2025-2030, by scenario

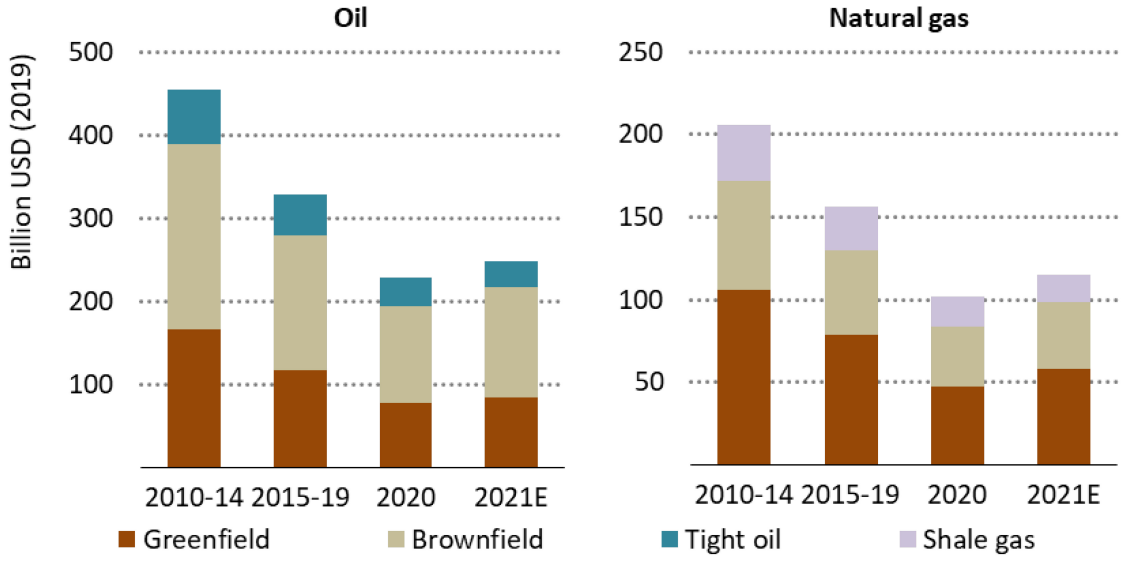


In the case of oil and gas, upstream investment is now half of what it was in 2014, while oil and gas demand – even with the effects of the pandemic – has not changed to anything like the same extent. The industry is undoubtedly able to do

"more with less" today: upstream operations are much leaner and more efficient, and costs have contracted as companies rationalised project designs and plans. There has also been a strategic shift in favour of smaller, more modular investments with shorter lead times, as a way to limit upfront capital spending, accelerate paybacks and reduce exposure to long-term risks. Nonetheless, the volume of oil and gas resources subject to FIDs in 2020 was at its lowest level in decades; discovered volumes were also down close to historical lows. Spending in 2014 appears excessively high; the "new normal" in 2020-21 is now geared towards a future in which consumption of oil and gas is much more constrained.

While trends in the power sector are moving towards a higher reliance on capital-intensive technologies that have lower operating expenditures, upstream oil and gas is moving may be moving in the opposite direction – becoming an 'opex' rather than a 'capex' business. Many companies are seeking to harvest as much as they can from existing "brownfield" operations rather than expand aggressively into new areas. In a Net Zero by 2050 Scenario, brownfield investments, alongside some projects under development and those approved as of 2021, would be the only upstream investments required.

Breakdown of oil and natural gas upstream spending



Source: IEA calculations based on Rystad (2021).

For some, the retreat in upstream spending is a clear signal that the world is entering a new price cycle, in particular for oil, as the supply side transitions away from hydrocarbons faster than do the world's consumers. This is indeed a possibility, if oil and gas investment levels stay where they are and policies

affecting their use do not strengthen considerably. The influence of decline rates is too often ignored but they exert a powerful force on future production: in the absence of continued investment, production from existing fields falls at a rate of roughly 8% per year; so, if upstream spending slows for a given country or company, then their “supply transition” can become very rapid.

In practice, the prospects for a near-term tightening in markets are limited by the spare capacity held by the world’s major resource holders, notably in the Middle East, who stand to pick up most of any recovery in demand. This would mark a shift in markets and market influence compared with the 2010s, when US shale met the majority of global demand growth. A similar dynamic is visible in the global gas outlook, as a result of Qatar’s determination to maintain its leadership in LNG.

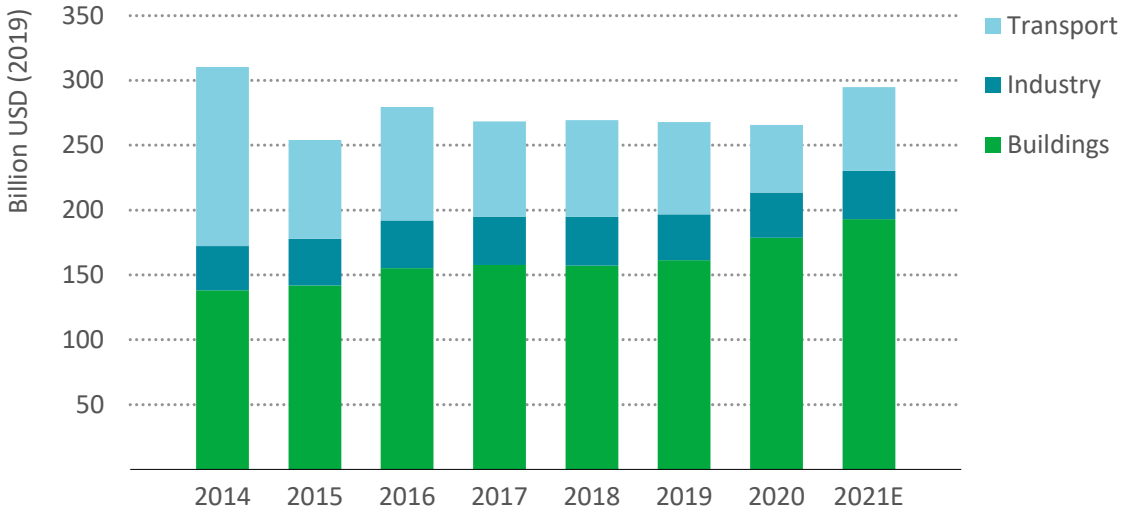
Energy end-use and efficiency

Overview

Energy efficiency investment has faced a difficult environment due to the pandemic. Strains on corporate and household budgets, uncertainty about the pace of recovery, and lower fuel prices create the risk of delay in spending on more efficient buildings, appliances, industrial equipment and vehicles. With weaker economic incentives, government policies and the design of stimulus packages play critical roles in determining the pace of investment.

Trends in efficiency investment in 2020 bear witness to the importance of these policy drivers, as energy efficiency investment in buildings received a boost from existing emissions reduction policies and some stimulus-related government programmes, mostly in Europe. In other regions, however, spending on efficiency has fallen, or grown more slowly, due to a downturn of construction activity. Transport-related efficiency investment fell in 2020, while estimated spending in the industry sector remained stable.

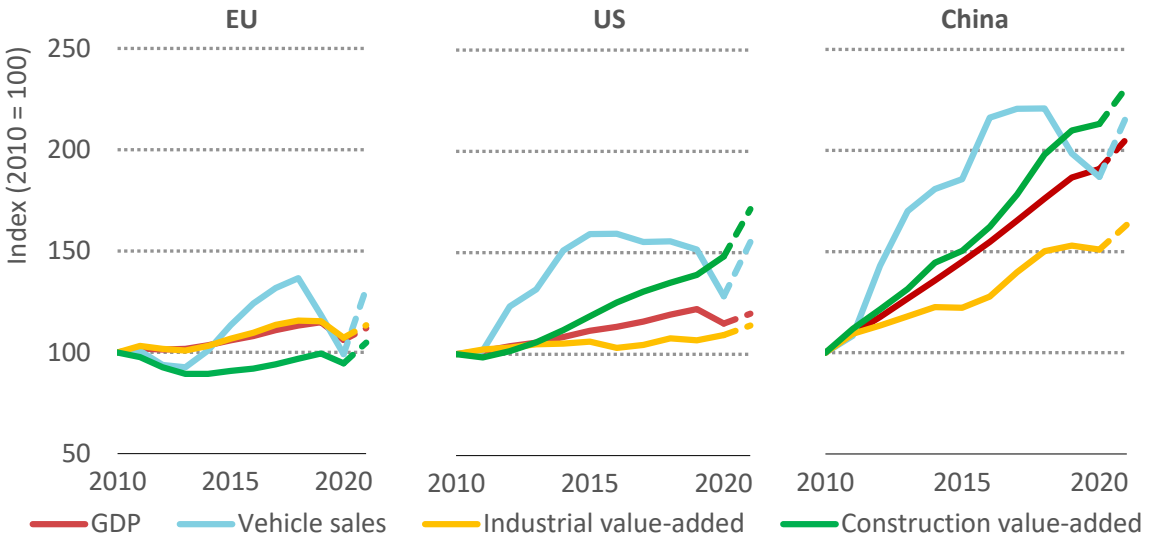
Global investment in energy efficiency by sector



Notes: 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. For more information, see methodology document.

Trends for efficiency spending in 2021 remain highly uncertain and will depend on the pace of economic recovery – which will shape consumer and corporate demand – as well as on government support and the inclusion of efficiency measures in recovery packages. Based on current expectations, a number of key indicators that shape efficiency spending in China, the United States and Europe are set to rise: vehicle sales in particular, as well as indicators of construction and industrial activity.

Selected indicators influencing efficiency investment in three major economies, 2010-2021E



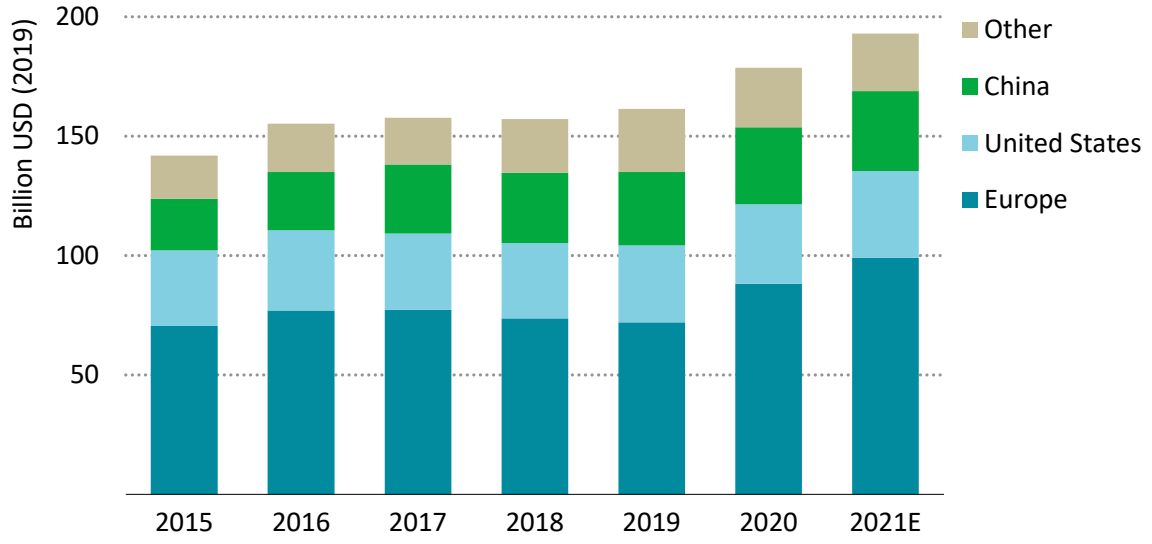
Notes: GDP = gross domestic product. GDP and value-added are in constant currency units.
Sources: IEA calculations based on BEA (2021); Eurostat (2021); NBS (2021).

Buildings

Policies and stimulus spending have put a floor under investment in more efficient buildings

Energy efficiency investment in buildings has caught some policy momentum, allowing the headline global figure to remain robust through the pandemic. Our estimate rose by an unprecedented 11% to almost USD 180 billion in 2020 from over USD 160 billion in 2019. Despite the negative impact of the pandemic on the global building construction sector, which is estimated to have fallen by around 2% to USD 6 trillion in 2020, a ramp-up of investments in Europe was strong enough to accelerate global investments in this area.

Efficiency and electrification investments in the buildings sector



Efficiency investment in buildings is determined by two main factors. First, by construction industry activity and its delivery of a proportion of low-energy or sustainable rated buildings with efficiency above building codes; most efficiency investments in EMDEs such as China, India and Southeast Asia are related to new construction. Second, by the renovation and refurbishment of existing buildings with more efficient systems, which occur either through building owner direct investments, or through government policies; these account for the larger shares of efficiency investments in Europe and North America.

The strong growth in 2020 was mainly driven by a doubling of KfW's efficient construction and renovation programmes to EUR 30 billion in Germany, based on decisions made before the Covid-19 crisis. However, existing buildings' policies in Europe are also set to be reinforced by recovery strategies and stimulus spending. Italy, for example, implemented a Superbonus programme that offers a tax incentive worth 110% of the investment for energy-efficient renovations. The French government announced nearly EUR 7 billion for energy efficiency improvements in private homes, office buildings and public buildings such as schools and town halls, with support available from 2021 onwards. Over USD 20 billion worth of investment is 2020 can be attributed to electrification and the increase in usage of heat pumps.

Thus far, the United States has not yet directed additional funding towards energy efficiency investment, beyond existing programmes. However, proposed infrastructure-related policies in the United States could quickly change the

investment landscape for energy efficiency, if adopted. Asian markets presented a mixed picture with India and the Association of Southeast Asian Nations (ASEAN) region showing declines in energy efficiency investment in buildings, while China saw a 5% increase along with modest growth in Japan and Korea.

Transport

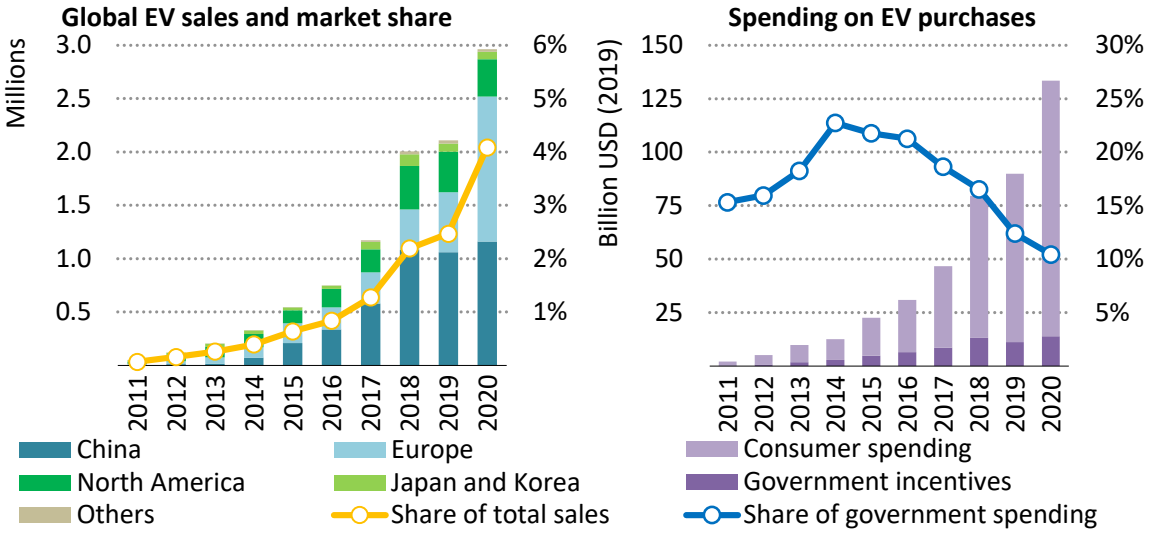
Electrification is the main source of efficiency gains in the transport sector

Investment in transport efficiency has been subject to conflicting forces. Turnover in the overall transport stock has slowed due to the fall in overall global car sales, and hesitancy in some markets to commit to more efficient purchases. However, this trend was offset to a degree by buoyant sales of electric vehicles (EVs), which are a highly efficient technology. Overall, we estimate that transport efficiency investments were over USD 50 billion in 2020, a 26% drop on 2019. Our provisional expectation for 2021 is around USD 65 billion.

The standout trend in efficiency investment in 2020 relates to EVs, which account for the majority of efficiency-related spending gains in transport. A surge in sales in Europe and China has been underpinned by stimulus spending (e.g. Next Generation EU Recovery fund and EV purchase subsidy in France, Germany and the United Kingdom) and strong policy support (e.g. mandatory emissions reduction targets for new cars in Europe and mandatory new EV quotas in China), as well as by improved performance and a wider choice of models. For the first time since 2015, EV sales in Europe outpaced those in China.

However, the growth in global passenger EV sales has been offset by a slowdown in sales of electric buses and light commercial vehicles, where companies and municipalities have struggled to justify higher upfront cost for electric models despite lower lifetime fuel costs. In other major markets where policy support was less strong, outside Europe and China, EV sales dropped by 8% on average, alongside a steep decline of 15% in total passenger car sales. Although the share of government support in overall spending on EV purchases has been on a downward trend, less mature EV markets (including many other EMDEs) will still require strong policy and financial support to kick-start growth.

Trends in global EV sales and purchase spending

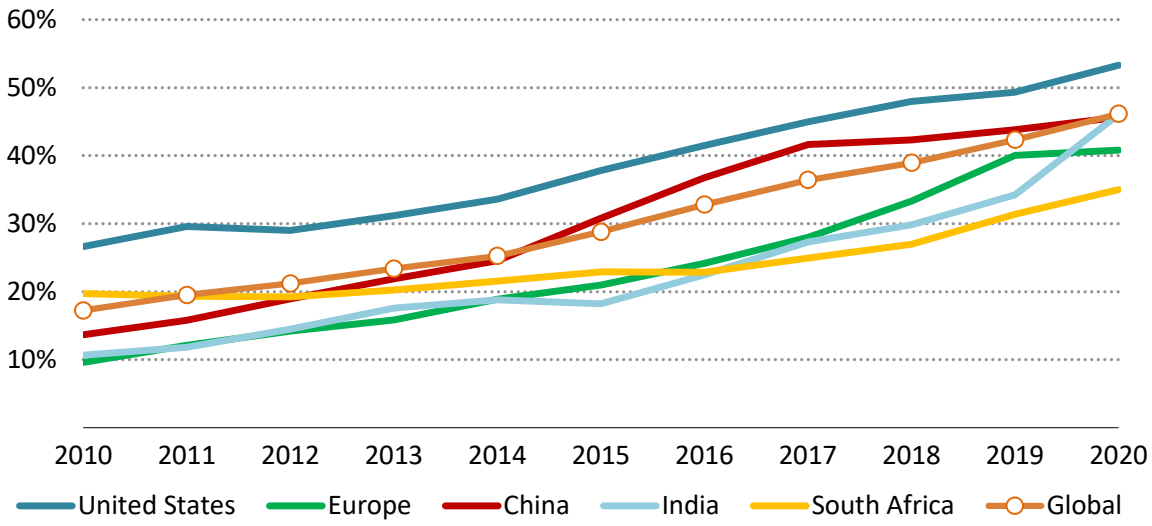


Notes: EVs include plug-in hybrids, battery electric and fuel cell vehicles for passenger cars. Government spending includes direct and tax expenditures on battery-electric vehicles and plug-in hybrid EVs. Spending is inclusive of sales taxes. Government incentives are assigned per model in each year based on national policy documents and include tax incentives and transfers to consumers or manufactures to reduce purchase prices. Non-purchase incentives, such as lower road taxes or parking fees, are not included.

Sources: IEA (2021a); MarkLines (2021).

One noticeable trend in transport efficiency is the continued popularity of SUVs, offsetting some of the benefits in increased share of EV sales in 2020. Despite the increased availability of electric SUV models and improvement in fuel efficiency in new SUV models, an average SUV still consumes around 20% more energy than medium-sized vehicles (IEA, 2021b). Global sales of SUVs declined by 7% while their share of new car sales rose to 46% in 2020, a new record in 2020. More than half of new cars sold in the United States and 46% of cars sold in China are SUVs (these two markets account for over 50% of global SUV sales). The share of SUVs in European sales levelled off at just around 40% in 2020. Although the total number of SUVs sold in India fell in 2020, the share of SUVs climbed to 46% due to a drop in total passenger car sales.

Share of SUVs in total passenger car sales in key markets



Note: Crossover utility vehicles and pickup trucks reported as commercial vehicles are not included.
Sources: IEA calculations based on MarkLines (2021) and OICA (2021).

Industry

The economic downturn has slowed investment in more energy-efficient industrial equipment

Investment in energy efficiency contracted by an estimated 1% in 2020, with the reductions coming mainly from heavy industrial sectors including steel, chemical, cement, paper and aluminium companies. Curtailed operations due to the pandemic and the economic slump brought down industrial output in energy-intensive industries by around 4%, and limited the upgrade of less energy-efficient industrial equipment in industry sectors as well as expenditure on new energy-efficient capital purchases.

China was one of the few economies with growth in real industrial value-added in 2020, a rise of some 3%. As such, it maintained its position as a leader in industry efficiency investment with a total share of over 40%, followed by India (9%) and Southeast Asia (8%). However, the investment growth in China was offset by the reduction in other major economies including the United States and Europe, where both the gross industrial value and the investment spending by ESCOs declined in 2020.

Industry efficiency investment is heavily affected by the enabling efficiency policies such as energy performance standards and incentive mechanisms for energy

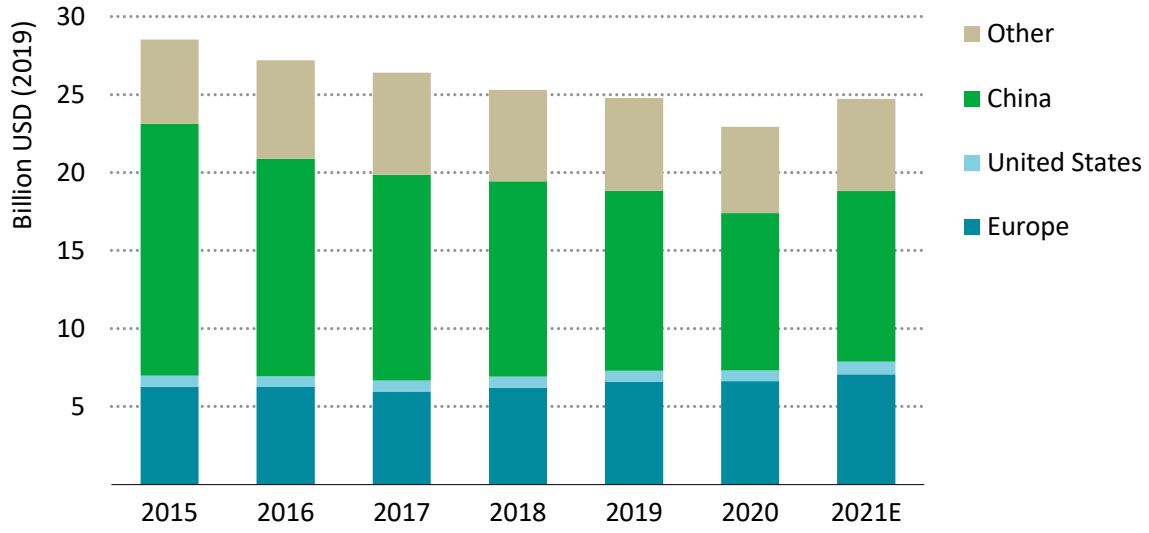
savings and emissions reductions.Only 35% of the global industrial energy demand is covered by energy efficiency policies, a deficit that needs to be narrowed to deliver the scale-up of investment that would be required in climate-driven scenarios. In the early 2010s, China and India set mandatory targets to save energy in industry sectors (e.g. the 11th Five-Year Plan in China and the Perform Achieve and Trade Scheme in India) but other emerging economies have yet to implement similar schemes for their industrial sectors.

Renewables for end-use

Outside the power sector, a much less dynamic picture for investment in renewable applications

Investment in renewables for end-use, including solar thermal applications (for district, space and water heating), bioenergy and geothermal, reached USD 23 billion in 2020, a 10% decline compared with 2019. Investment has been on a declining trend in recent years, but is set to rise in 2021. China and Europe, which represent three-quarters of total investment, drive the prospective increase, but this depends on economic growth and the extent of policy support. The cost of solar heat for industrial processes has fallen by over 40% in Europe and larger plants drove the levelised cost of heat down by half between 2014 and 2020 (IRENA, 2021). Global heat pump sales continued to grow in 2020, driven by installations in France, Germany and Italy, but remain tied to new building construction. The cost of heating with heat pumps is decreasing as new installations and economies of scale are realised in Europe and the technology becomes more affordable.

Investment in renewables for end-use



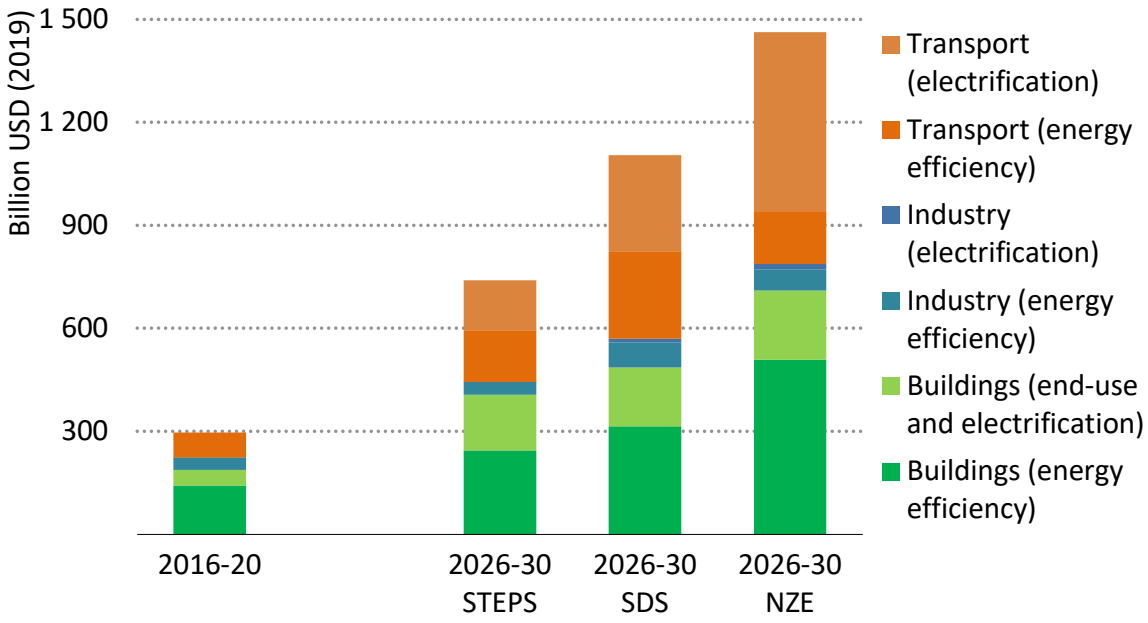
Implications

Efficiency and end-use investment lags far behind what is required to hit net zero goals

Global energy efficiency, as measured by the energy intensity of the global economy, has to improve at a rate of at least 3% per year in order to be consistent with the SDS, and by 4% per year by the end of the decade in a scenario consistent with reaching net-zero emissions by 2050. Prior to the crisis, the rate of progress was well short of the pace required, and the pandemic pushed this indicator down to only 0.8% in 2020.

Accelerating the pace of efficiency improvements will require a dramatic increase in related investments, incentivised by stronger policies. The levels of investment seen in recent years are set to rise in the 2020s in the STEPS, a reflection of greater attention to efficiency in post-Covid and net-zero strategies as well as a pick-up in the turnover of the capital stock as economies recover. But this projection is dwarfed by the requirements of climate-driven scenarios, which see a rapid surge in sales of electrified and more efficient vehicles, wide-ranging industrial efficiency gains, and a continued ramp-up of spending on efficient new buildings and retrofits. All of these changes need to be enabled by strong policy supports and improved financing conditions.

Global investment in end-use and energy efficiency compared with annual average investment needs, 2025-2030, by scenario



R&D and technology innovation

Overview

The world's capacity to bring new technologies to market has been weakened as a result of the disruptions caused by the pandemic. Governments can ensure that this weakness is short-lived through stimulus funding and measures that boost private incentives to innovate. For many energy technologies, increased public funding is needed to assume most of the risks of basic research and first-of-a-kind demonstration projects, as well as leveraging private investment in R&D and steering it towards priority needs for future net-zero emissions energy systems.

In 2020, trends in energy innovation spending diverged between governments and corporations. Our tracking showed a clear albeit gradual trend towards higher government spending on low-carbon energy R&D, while private-sector energy R&D spending dropped as the pandemic caused corporate budgets to be cut or led to underspending on projects. Market uncertainties and lower sales revenues have reduced the funds available to entrepreneurs seeking to scale up new technologies.

At the start of 2021, the signals for investment in low-carbon energy innovation are positive and they come from both public and private sources. As core elements of their plans to transition their energy systems to net-zero emissions, major economies including China, Japan and the United States have highlighted innovation and proposed increased levels of funding. In China, documents in support of the 14th Five-Year Plan 2021-25 give a central role to energy innovation: China's National Science and Technology Major Projects budget could rise above the current level of around USD 3 billion per year and include more energy-related projects.

Japan's proposed Green Innovation Fund would allocate around USD 19 billion to low-carbon energy technology demonstration between 2021 and 2031, complemented by USD 15 billion in tax credits for private involvement in such projects. In the United States, the American Jobs Plan proposes USD 35 billion for energy technology development over eight years, including a new initiative (ARPA-C) to develop innovative approaches to reducing atmospheric greenhouse gas levels and USD 15 billion for demonstration projects for climate R&D priorities.

In total, we estimate that over USD 50 billion of public funds could be available for major demonstration projects of large-scale low-carbon energy technologies up to 2030, including CCUS and other technologies for addressing emissions in industrial sectors. In additional to announcements from China, Japan and the United States, this includes the USD 10 billion EU Innovation Fund, which has already issued calls for large projects, plus funding announcements for CCUS projects in Norway and the United Kingdom.

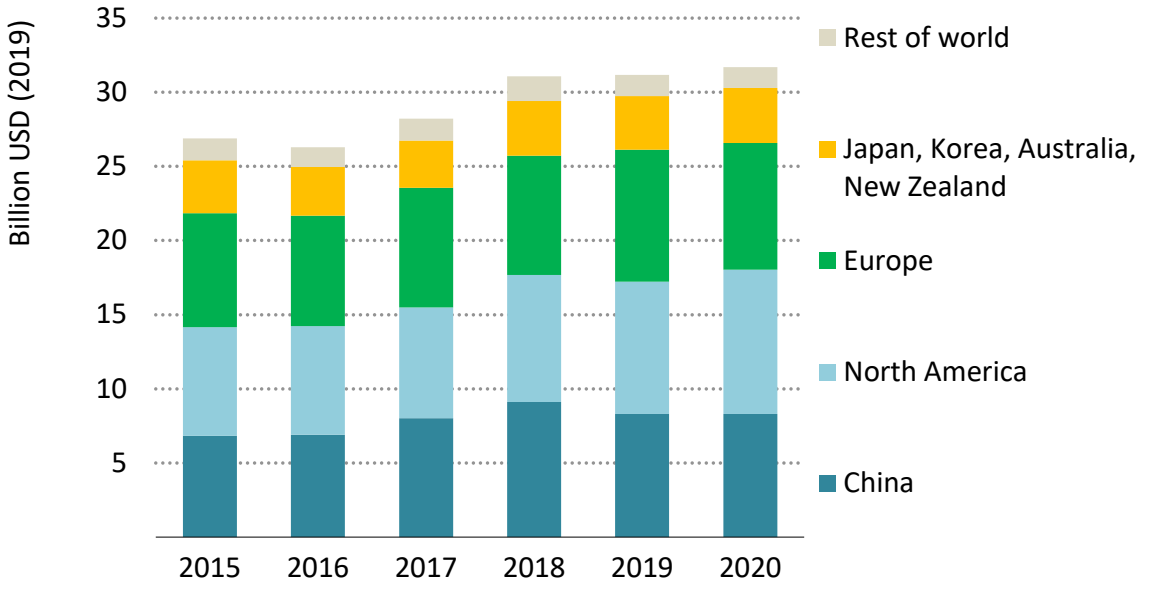
Another source of optimism for the innovation needed to power clean energy transitions is the observed resilience in 2020 of early-stage venture capital (VC) funding for low-carbon energy technologies. Contrary to concerns at the start of pandemic, start-ups seeking to launch their first products onto the market continued to attract finance almost at the same rate as in 2019, and this has continued in early 2021. Investors appear to remain confident that new energy technologies will continue to play a disruptive and profitable role in the energy sector over the next decade. Although the USD 3.5 billion that was invested in early-stage energy VC globally in 2020 is considerably less than investments in clean energy assets – and even corporate R&D spending – it has matured to become a mainstream option for allocating capital to sustainable energy.

Government spending on energy R&D

A clear trend towards higher spending by governments on low-carbon energy R&D

Preliminary information indicates that global public energy R&D spending, including on demonstration projects, rose slightly, by around 2% to USD 32 billion in 2020, confirming that previously committed public budgets were resilient during the crisis. This slow growth continues the slowdown noted for 2019 and stands in contrast with growth rates of 7-10% in 2017 and 2018. However, while the growth rate for R&D spending on all energy technologies remains stubbornly sluggish, the portion of spending dedicated to low-carbon energy R&D has grown somewhat faster and its share has risen consistently, from around 77% in 2015 to 83% in 2020. As the share of fossil fuel energy research has declined in many advanced economies in recent years, China has come to represent more than half of the global total for fossil energy public R&D.

Spending on energy R&D by national governments



Note: R&D includes spending on demonstration projects (i.e. RD&D) wherever reported by governments as defined in IEA (2011). 2020 is a preliminary estimate based on data available by mid-May 2021. The IEA Secretariat has estimated US data from public sources. State-owned enterprise funds comprises a significant share of the Chinese total, for which a preliminary 2020 estimate based on reported company spending and early analyst signals will be revised once official data are available. Other countries not part of the IEA RD&D statistical sharing exercise in 2019 and 2020 have been estimated from public sources and exchanges with government officials. The 2018 value is higher than that shown in World Energy Investment 2020, following a data revision, including the addition of spending by the Japanese Ministry of Environment.
Source: IEA (2021).

Several years of growth in most major regions shows that key governments are actively increasing energy research investments, following their 2015 pledges to double selected areas of clean energy R&D funding as members of Mission Innovation. Membership of Mission Innovation has motivated Brazil to join the IEA research, development and demonstration (RD&D) statistical sharing exercise in 2021 as the first non-IEA country member, improving the quality of this year's data.

The US energy R&D budget rose by 7% for the second consecutive year, setting an annual average growth rate of 6% between 2015 and 2020. Energy efficiency R&D funding, up 90%, and nuclear energy R&D funding, up 45%, have grown the fastest over this period, while the budgets for hydrogen and fuel cells, which shrank up to 2017, are firmly on the rise again. Recent announcements signal growth in all energy areas in the coming years, though patent data indicate a relative technological advantage for the United States in fossil fuel, CCUS and combustion efficiency (EPO and IEA, 2021). Canada, Denmark and Sweden all reported double-digit growth for public energy R&D spending in 2020, while Germany grew more slowly, at 2%, and the government energy research spending of China. Japan and the European Commission declined slightly. In the case of the latter, this reflects the volume of calls issued in 2020 under its multiannual

budget. In May 2021, China confirmed that clean energy will be among the first focus topics of a new competitive process for R&D funding under the 14th Five Year Plan.

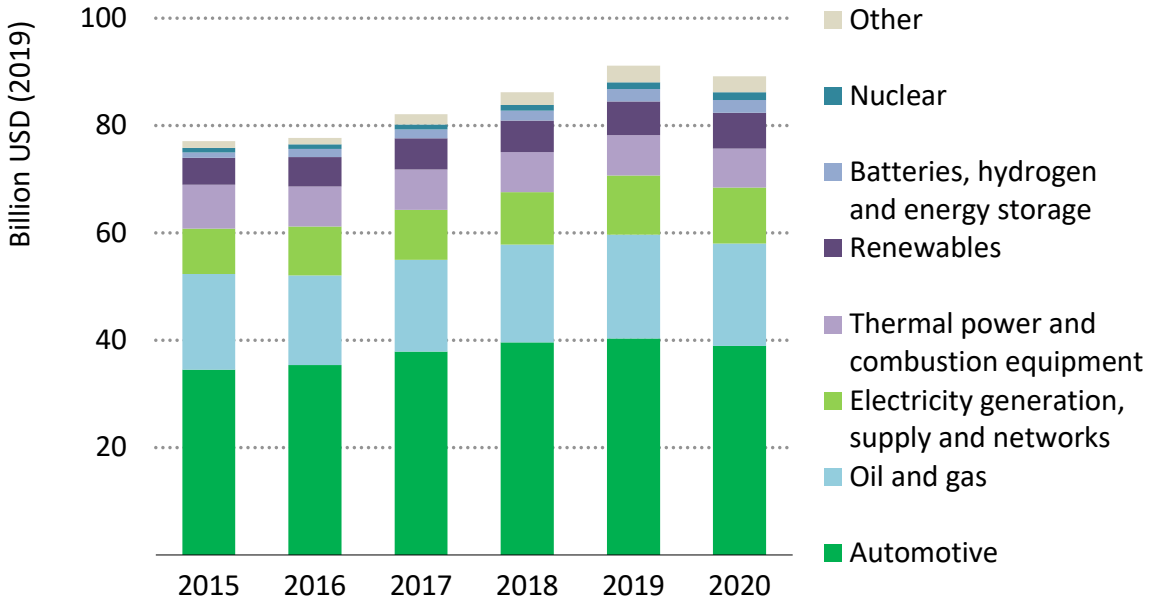
There remains some uncertainty over how public energy R&D spending will fare as government budgets recover from the pandemic. However, it is expected that the impact of stimulus spending on large-scale demonstration projects in China, Japan, the United States and Europe will boost the aggregate global value in coming years. At the same time that demonstration projects receive more prominence among research funders, there is also an increasing appetite among governments for diversified policy support, including the use of public procurement, incubation and prizes for entrepreneurs to induce and nurture inventions in companies and research institutes. Such policy experimentation, coupled with evaluation and good-practice sharing, can enhance the impact of government spending, as can other forms of international co-operation. It is of critical importance that governments take the lead in stimulating innovation at all stages from lab to market in sectors where emissions reductions will be hardest (IEA, 2020a).

Corporate energy R&D spending

Private-sector energy R&D spending dropped in 2020 due to lower corporate budgets and underspending on projects, and now needs to pick up

Company research spending in energy-related fields fell by around 2% in 2020, with around USD 89 billion tracked by our analysis of listed companies in the energy sector and related sectors. While the impact of Covid-19 on other components of energy innovation spending remains unclear, a reduction in corporate R&D was widely expected as companies faced reduced revenues. However, R&D budgets tend to suffer less than capital investment budgets when revenues drop, and in 2020 the R&D ratio (R&D spending divided by revenue) remained broadly constant across the major energy sectors. This is consistent with a strategic incentive to retain R&D staff and capabilities and complete ongoing projects, so as not to weaken a source of long-term competitiveness. Consequently, the level of corporate energy R&D did not fall far below 2018 levels and, so far, it appears to be a dip in a steady growth trend rather than a break in the trend. Nonetheless, this dip has opened up a large gap relative to the pre-pandemic trend line that would have risen above USD 100 billion in 2021.

Spending on energy R&D by globally listed companies, by sector of activity



Notes: "Other" comprises coal mining, coal distribution and certain energy efficiency technologies that can be isolated from end-use sectors, such as insulation. Fuel cells are included with hydrogen. Corporate energy R&D spending includes reported R&D expenditure by companies in sectors that are dependent on energy technologies, including energy efficiency technologies where possible. Automotive includes technologies for fuel economy, alternative fuels and alternative drivetrains. To allocate R&D spending for companies active in multiple sectors, shares of revenue per sector are used in the absence of other information. 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 underrepresented. Depending on the jurisdiction and company, publicly reported corporate R&D spending can include capitalised and non-capitalised costs, from basic research to product development. The total reported here for 2019 is higher than that estimated at the time of publication of World Energy Investment 2020, before all company filings for 2019 were available and before the latest adjustment of sectoral classifications. Spending by oil and gas companies represents the most significant upward revision, USD 1 billion.

Source IEA calculations based on Bloomberg (2021).

Corporate R&D spending was lower in 2020 than in 2019 in some of the largest energy technology areas, with the reductions occurring in electricity generation and networks (-6%), automotive (-3%), thermal power and combustion equipment (-3%) and oil and gas (-2%), In the oil and gas sector, higher spending in China offset declines at European and US companies. However, for the largest firms in each of these areas, R&D spending did not generally decline as fast as revenues. Automotive companies drove much of the increase in energy R&D up to 2018 – in particular through expanded EV development, but they have had little growth in 2019 and have fallen back below 2018 levels. Given that firms are likely to remain cautious with budgets in 2021, this trend may be misaligned with companies' electrification plans as well as the need for fuel economy improvements to accompany the shift to larger vehicles (see "Energy end-use and efficiency" section). Spending by companies focused on renewables and nuclear equipment was more resilient and continued to increase.

On a country and regional basis, US-based companies reduced their energy R&D spending most in 2020, with a cut of nearly 10% from the aggregate amount, followed by European companies at -7%. Japanese companies, many of which have a long-standing tradition of investing in research projects, often in support of government objectives, increased R&D spending increasing by 1% in 2020, while Chinese company energy R&D spending rose even faster, by 3%. Since 2019, listed companies from China have outspent those in our sample from other countries.

Looking beyond spending on energy technologies to consider total R&D funding of companies in some other critical sectors for the energy transition, the impact of the pandemic is less apparent. Aggregated spending on R&D by companies in the cement and steel sectors rose slightly in 2020, and it was broadly stable among companies in aviation and shipping. As with the automotive sector in general, however, the R&D combined budgets of companies producing trucks and commercial vehicles and their components fell by 5% in 2020 compared to 2019.

Venture capital funding of early-stage energy technology companies

The pandemic has not curbed investor appetite for clean energy start-ups

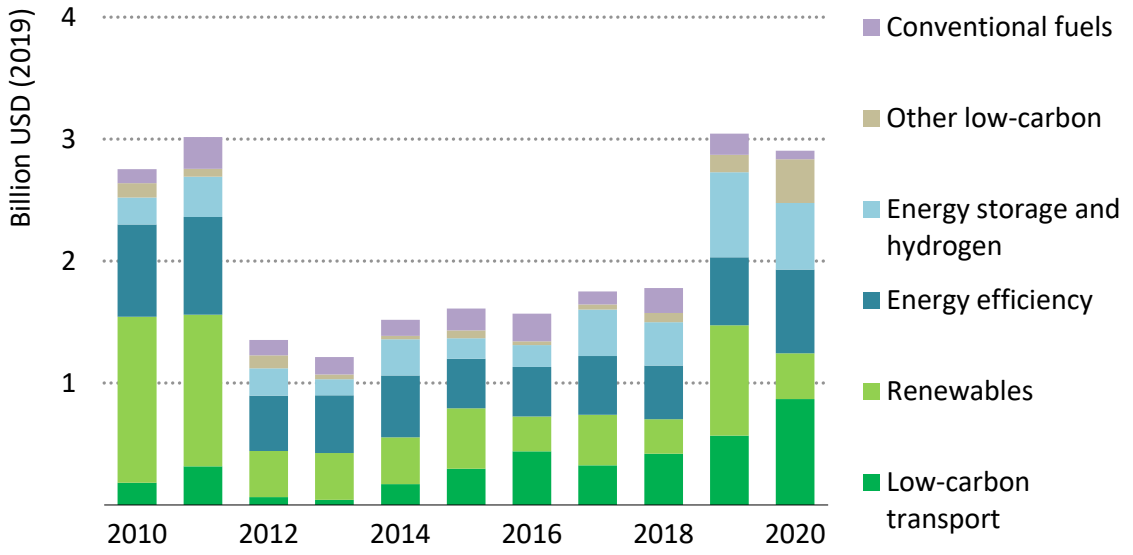
Although clean energy start-ups continued to attract high levels of investment through the Covid-19 crisis, the market lost momentum in the first half of 2020. Early-stage VC investments decreased in 2020 relative to 2019, falling to USD 3.5 billion. These sums are far lower than those spent on energy R&D by governments and companies, but this private-risk capital plays an important role. It enables market creation and scale-up of technology propositions that have a clear near-term value proposition, especially those that do not require high levels of upfront development and capital. The value of large, outlier deals in 2020 was much lower than in recent years, with a complete absence of the billion-dollar early-stage deals in electro-mobility that increased the totals in 2016-19. When excluding large deals of above USD 150 million in a single deal the total was around USD 3.1 billion worldwide, well above the levels of 2012-18. Furthermore, the total number of deals, including those for which no financial data is available, jumped by 17% in 2020. Europe continued to increase its share

of global investment in early-stage energy start-ups, with its total deal value almost doubling in 2020, offsetting declines in the two other major markets of China and the United States.

The recovery of investment in the second half of 2020 has continued into the first quarter of 2021, for which preliminary data indicate a record quarter for early stage energy VC deals. This has been led by energy storage and hydrogen start-ups in the United States and Europe, as well as several large funding rounds in China for battery developer Svolt and electric vehicle company Leap Motor.

This recovery demonstrates not only that start-ups and investors adjusted successfully to new ways of working in the second half of 2020, but it also demonstrates two larger trends. First, tech stocks are viewed as a haven for capital due to the turmoil in more traditional sectors, with Tesla continuing to blaze a trail for others. Second, investors are increasingly convinced that energy transitions are happening and will be underpinned in the near term by proactive government policies and robust corporate demand. Rather than dealing a significant blow to the promising pipeline of low-carbon energy technology entrepreneurs, 2020 is more likely to be remembered as a year of stronger momentum for venture investment in low-carbon energy, with the proliferation of companies going public through special-purpose acquisition companies demonstrating appetite for start-ups. In addition, more risk-averse investors, including institutional investors, are now including clean energy VC exposure in their portfolios. This shift towards more investor appetite for providing risk capital to early-stage energy technology companies is a significant development. However, its impact depends on the pace at which the supply of high-potential, scalable ideas from research can rise, especially from publicly funded labs and projects.

Global early-stage venture capital investments in clean energy technology start-ups



Notes: Includes seed, series A and series B financing deals. Outlier deals of more than USD 150 million that distort the year-on-year trend are excluded from the deal value; they totalled USD 4100 million in 2010, USD 2.2 billion in 2016, USD 850 million in 2017, USD 4.7 billion in 2018, USD 990 million in 2019 and USD 340 million in 2020. Low-carbon transport includes alternative powertrains and their infrastructure, among other technologies, but not shared mobility, logistics or autonomous vehicle technology unless specifically designed for the electric mobility market. Within Renewables, bioenergy includes transport biofuels but not biochemicals. Other low-carbon pertains to CCUS and smart grids. Conventional fuels covers fossil fuel extraction and-use, fossil fuel-based power generation, and conventional transport fuel economy.

Source: IEA calculations based on Cleantech Group (2021).

Nevertheless, the late-2020 rebound does not compensate for the slower start to the first half of the year. When excluding large, outlier deals, the average disclosed deal value for early-stage start-ups was around USD 7 million, which is 17% less than in 2019. Although the number of deals increased by 10%, investors allocated less capital to each one. In some cases, investors may have been less willing to put capital at risk, while in others, they may have taken the opportunity to invest at lower valuations. For energy storage and hydrogen start-ups, the average value of disclosed deals dropped by 5%, as newer technology areas suffered more than incremental improvements to existing ones such as EV chargers. In 2021, governments have the chance to shift from defensive and non-selective measures to counter the worst of the pandemic's impacts, to actively supporting innovation in target technology areas (IEA, 2020b).

Corporate VC investment provides another sign of the relative health of clean energy technology innovation in contrast to spending cuts elsewhere in the energy system. Similarly to corporate energy R&D, which dipped in 2020, corporate investments in energy technology start-ups, including corporate VC, decreased by 10% in 2020, to USD 5.2 billion, but remained significantly above 2012-18 levels. Large corporations see a strategic case for direct investment in innovative, nimble technology players that they can learn from in the short-term and possibly acquire

in the future. However, traditional energy actors (i.e. fossil fuel companies, utilities, independent power producers, energy equipment and services) have consistently accounted for a decreasing share of these corporate investments in recent years, dropping to just below 15% in 2020. Investments from oil and gas companies fell most in 2020, by 65%.

In contrast, investments by companies in the transport sector more than doubled, and the combined investments of companies in the information and communication technology and transport sectors represented 80% of the total. In fact, were it not for a few large growth-stage deals from these sectors – such as General Motors' investment of USD 1.9 billion in Nikola Motors and investments by Alibaba, Amazon, Baidu and Tencent in Evergrande, Rivian, WM Motor and XPeng – corporate VC in energy would have declined in 2020.

Implications

Accelerating innovation cycles to meet net-zero goals will require more stimulus funding, broad collaboration and a push to catalyse private investment at scale

New and better technologies will be crucial to tackle climate change and other environmental problems associated with energy use, alongside the adoption of existing advanced technologies. Technological innovation has the potential to reshape or entrench the competitive positions of different fuels and energy sources. In this way, it will play a key role in determining the stringency and costs of the policy options for accelerating energy transitions. As indicated by our review of corporate VC trends, this innovation will come from both within the energy sector and from other sectors, as well as fundamental scientific advances. Success will depend on nurturing these linkages, boosting funding for entrepreneurs and R&D projects and investing in enabling infrastructure and fixed assets.

The higher levels of attention that clean energy innovation is currently attracting are essential given the urgency of the challenge. Acceleration of innovation cycles to meet net-zero goals will require close cooperation among universities, research institutions, companies, governments and the finance sector, as well as more well-targeted public and private spending on R&D and support for early-stage scale-up.

Taking the example of much-needed commercial-scale demonstration projects in key sectors, the IEA estimates that USD 90 billion in public funding needs to be

mobilised as soon as possible to complete a portfolio of demonstration projects before 2030 (IEA, 2021c). This compares with the roughly USD 25 billion already budgeted by governments to 2030, which (as discussed above) could expand to some USD 50billion based on recent announcements.

The technologies concerned – mostly related to electrification of end-uses, CCUS, hydrogen and sustainable bioenergy, e.g. for long-distance transport and heavy industrial applications – need to be quickly demonstrated at scale in multiple configurations and regional contexts, in most cases requiring projects to run in parallel. This is in stark contrast with typical practice in technology development, where learning is transferred across consecutive demonstration projects in different contexts to build confidence before widespread deployment commences. Public funding would assume the risks of such first-of-a-kind projects and leverage private investment. However, increased public funding on this scale would represent a departure from recent trends: government spending on energy R&D worldwide, including demonstration projects, has been falling as a share of GDP, from a peak of almost 0.1% in 1980 to just 0.03% in 2019.

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