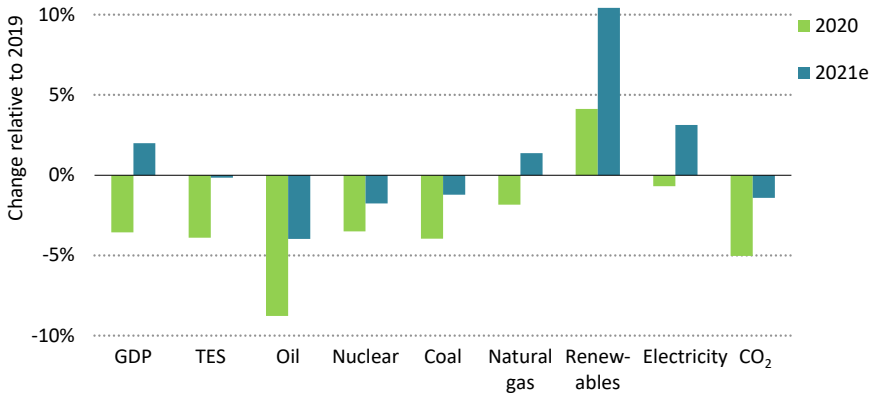
SUMMARY

- Recovery from the Covid-19 pandemic is underway, but it is uneven, prone to reversals and relatively carbon intensive. The economic impacts appear to have bottomed out in most cases in late 2020 or early 2021, with the exception of China which started its recovery earlier. Countries with fiscal means and access to vaccines are seeing a robust rebound. However, many emerging market and developing economies face continued risks due to low vaccination rates and rising indebtedness.

Figure 2.1 ▷ Change in key global indicators for energy demand and emissions, 2020 and 2021



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Renewables have continued to set records throughout the crisis, but all fuels – and global CO_2 emissions – are set to bounce back strongly in 2021

Note: TES = total energy supply; 2021e = estimated values for 2021.

- Worldwide energy demand in 2021 is set to regain all of the ground lost in 2020 due to the pandemic (Figure 2.1). The resultant upswing in demand for all fuels and technologies has contributed to sharp rises in gas, coal and electricity prices. This is overshadowing signs of more structural changes, such as the continuing rapid rise of renewables and electric vehicles. Global CO_2 emissions in 2021 are on track for their second-largest rise in history.
- Government recovery spending includes some USD 380 billion worldwide for sustainable energy, which is boosting investment in renewables, grids, energy efficiency and areas such as low-carbon hydrogen and carbon capture, utilisation and storage (CCUS). However, the boost that this provides is only around one-third of

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what would be required to secure an early peak in emissions. There is a major geographical imbalance in spending, with many emerging market and developing economies facing severe constraints on their ability to mobilise capital for recovery and energy transitions.

- After falling by around 1% in 2020, global electricity demand has come roaring back in 2021, outpacing the rise in low-emissions generation even in another record year for renewables. This is leading to increased output from coal-fired plants to meet demand, especially in Asia. The effects of the pandemic are more visible in the transport sector, where oil demand in 2021 is set to remain well below 2019 levels. Natural gas demand is expected to bounce back more quickly, driven mainly by an increase in industrial use.
- Governments, municipalities, companies and financial institutions are making increasingly ambitious pledges to curb emissions in the run-up to the crucial COP26 meeting in Glasgow. As of mid-2021, countries pledging to reach net zero emissions account for 60-70% of today's global GDP and energy-related CO_2 emissions, and around one-third of energy-related methane emissions.
- Our new *Outlook* does not include a forecast for the future of global energy, but offers scenarios that explore the implications of different policy choices, investment trends and technology dynamics.
- The main normative scenario is the **Net Zero Emissions by 2050 Scenario**, which outlines a narrow but achievable pathway to a 1.5 °C stabilisation in global average temperatures. There are also two exploratory scenarios. The **Announced Pledges Scenario** examines where all today's announced energy and climate commitments – including net zero pledges – would take the energy sector if implemented in full and on time. The **Stated Policies Scenario** does not take full implementation of these pledges for granted, but takes a more granular, sector-by-sector look at existing policies and measures as well as those that are under development, and assesses where they lead the energy sector.
- Most global commodity prices have rallied in 2021 as economic activity picked up, underlining that the affordability of energy remains a major concern for households, businesses and policy makers. While we do not, for the moment, anticipate a prolonged pan-commodity upswing in price levels, investment imbalances could well herald a period of greater volatility. Fuel price rises have led to a sharp increase in the estimated value of global fossil fuel consumption subsidies to USD 440 billion in 2021.
- The falling costs of key clean energy technologies offer a huge opportunity for all countries to chart a lower emissions pathway towards growth and prosperity. Renewable power companies have outperformed listed fossil fuel companies and public equity market indices in recent years. Patenting activity for low-carbon energy has likewise outstripped that for fossil fuels since 2000. Nevertheless, a new wave of innovation remains essential to accelerate the pace of transitions.

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2.1 Introduction

The warning signs are impossible to ignore. The stark conclusions on the physical science, produced as part of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, are reinforced on a startlingly regular basis by headlines of new extreme weather events from all around the world. Since the energy sector is responsible for almost 75% of global greenhouse gas emissions, it is firmly in the spotlight. There are signs of a response, both in deployment trends for some clean energy technologies and in the increasingly ambitious pledges to curb emissions made by governments, municipalities, companies, investors, financial institutions and others in the run-up to the crucial meeting of the United Nations Framework Convention on Climate Change Conference of the Parties (COP26). However, the latest energy and emissions trends are a reminder that changes in the way that we use and consume energy have a long way to go: the world's partial recovery from the Covid-19 pandemic has been enough to push up demand for all fuels and technologies, leading to a sharp rebound in prices and in carbon dioxide (CO_2) emissions.

The ways in which policy commitments and technological change must drive real changes in energy markets is a central theme of this *World Energy Outlook 2021*. The level of commitment to tackle climate change has never been higher, but there remains a large gap between the data coming from markets and the statements coming from policy makers. In this new *Outlook*, we explore how and when this gap might narrow, as it must if the world is to get serious about addressing climate change, by focusing on:

- **Recovery:** With different rates of vaccination and the spread of more transmissible variants of the virus, how widespread is the recovery from Covid-19? Are the policies and investment coming through going to make it a sustainable recovery?
- **Ambition:** How close do current pledges get the world towards the target of limiting global warming to 1.5 °C while meeting other energy-related sustainable development goals? What more needs to be done and in which parts of the energy system?
- **Implementation:** To what extent are governments and others backing their new commitments with the required actions to stimulate investments?
- **Consequences:** What does this all mean, in various scenarios, for demand for different fuels and technologies, and for capital and trade flows? What are the implications for people and jobs, and for the security and affordability of energy supply? And what does each scenario imply for emissions and for the rise in global temperatures?

This chapter sets the scene. Its first-half examines our starting point in 2021, the continued uncertainties created by the pandemic, the regional differences in outcomes and responses, and what the latest data for energy, investment, prices and emissions tell us about the forces shaping today's energy sector. Its second-half describes the scenarios used in this year's analysis, discusses how and why they differ from each other, looks at the underlying economic and demographic drivers, the outlook for energy and carbon prices, and the dynamic role played by energy technology development and innovation.

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2.2 Energy and the Covid-19 pandemic

Last year's edition of the *World Energy Outlook* surveyed the disruption caused to the energy sector by the Covid-19 pandemic and concluded that "it is too soon to say whether today's crisis represents a setback for efforts to bring about a more secure and sustainable energy system or a catalyst that accelerates the pace of change". One year on, many uncertainties remain, but some of the contours of the recovery, in different parts of the world, are more clearly visible.

In the *World Energy Outlook-2020*, we posited three possible ways out of the crisis, based on different assumptions about the severity and duration of the public health emergency, its economic impact and the response from policy makers:

- The Stated Policies Scenario (STEPS) assumed that the pandemic would be brought under control by the end of 2021, bringing a relatively robust economic recovery. This scenario did not assume any dramatic change in policy orientation in favour of a more sustainable recovery, beyond measures already announced.
- The Delayed Recovery Scenario (DRS) assumed more prolonged outbreaks of Covid-19, with deeper economic impacts. Like the STEPS, the DRS did not foresee additional policy changes affecting the nature of the eventual recovery.
- By contrast, the Net Zero Emissions by 2050 (NZE) case and the Sustainable Development Scenario relied on a wholesale shift in policy focus and investment in support of a sustainable recovery, aided by a relatively rapid improvement in public health and the economy.

One year on, our assessment of the starting point for this *Outlook* reveals a mixture of these elements. Some parts of the world, notably those with ready access to vaccines, are seeing a robust economic rebound, and some advanced economies are taking steps to promote sustainability in their recovery strategies. However, the picture in many emerging market and developing economies is significantly less encouraging: public health and economic indicators point towards a delayed recovery, and many countries lack both the finance and the policy momentum to mobilise a much-needed increase in clean energy investment. The sharp uptick in commodity prices in the second half of 2021 could cast a shadow over the global economic recovery.

2.2.1 Economy and public health

Public health indicators are still flashing red in many parts of the world. Many countries have experienced multiple waves of infections from Covid-19, and new variants have brought additional challenges. While some countries appear to be on track to get the virus under control over the course of 2021, many others – including most developing economies – are vulnerable to prolonged outbreaks with damaging economic impacts.

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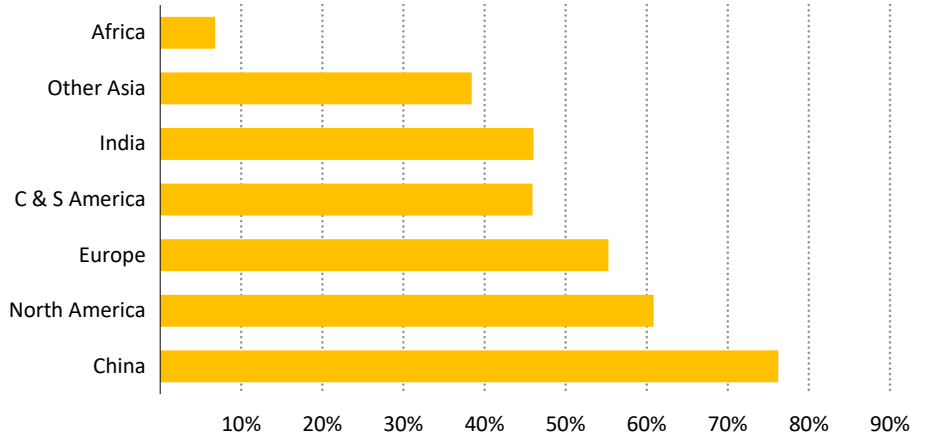
Data for infections are incomplete and do not provide a full picture. A more telling indication of country and regional differences is provided by the data on vaccinations (Figure 2.2). Most emerging market and developing economies, especially those in Africa, have not yet had the means or opportunity to start mass vaccination campaigns in earnest and remain very vulnerable to the spread of more transmissible variants of Covid-19.

Figure 2.2 ▷ Share of population with at least one dose of Covid-19 vaccine



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The pace of vaccination varies widely between countries, and this shapes future downside risks from the pandemic

Notes: C & S America = Central and South America. Data for all countries are from 1 October 2021, except China which is from 18 September 2021.

Source: Official data collected by Our World in Data website (2021).

A speedier roll-out of vaccines and continued fiscal support have facilitated the rebound in economic activity in many advanced economies and in China (Figure 2.3). But economic indicators in other emerging market and developing economies have lagged, especially in Eurasia, Latin America, the Middle East and Africa (many developing economies in Asia have fared slightly better).

One of the effects of the pandemic has been a faster increase in levels of debt (Figure 2.4). This is visible across the board, but advanced economies and China have better access to debt finance, at lower cost, than most other countries. Some emerging market and developing economies are starting to experience more difficult borrowing conditions, limiting their ability to mobilise funds for recovery (including for clean energy investments). Financial strains in 2020 were particularly visible among energy exporters, although these have been eased somewhat by a rally in commodity prices in 2021.

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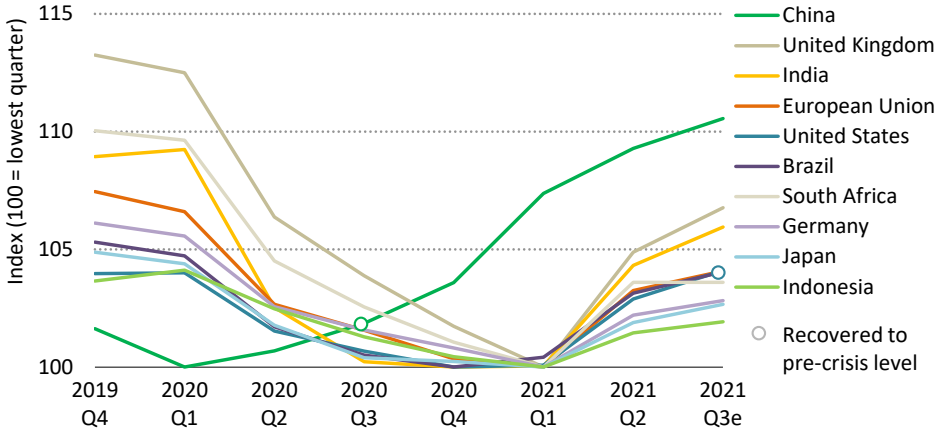
Figure 2.3 ▷ Change in GDP per capita by quarter for selected countries



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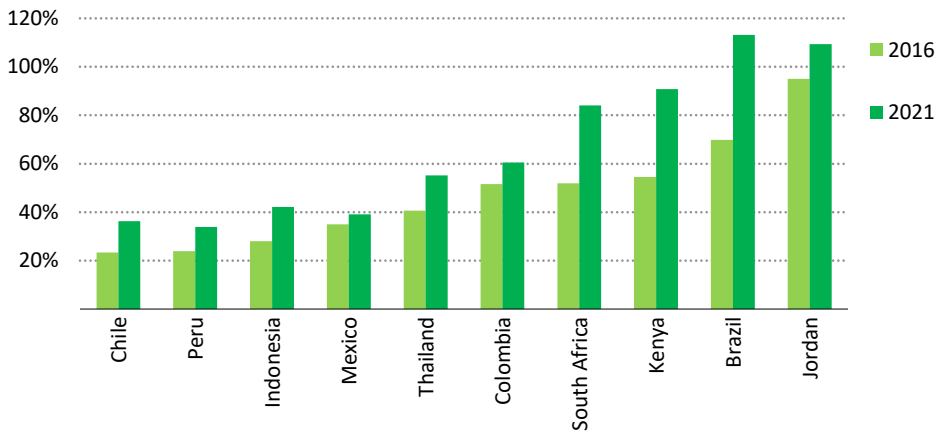
Economic impacts of the pandemic bottomed out in most countries in late 2020 or early 2021, but several months earlier in China

Notes: 2021 Q3e = estimated value for the third quarter of 2021. Change in GDP = annualised year-over-year change by quarter.

Source: IEA analysis based on Oxford Economics (2021).

Figure 2.4 ▷ Government debt-to-GDP ratios for selected emerging market and developing economies



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Debts in many emerging market and developing economies have risen significantly, and are expensive to service

Note: Debt positions in 2021 represent the latest month of available data in the first half of the year.

Source: Calculations based on TheGlobalEconomy.com (2021).

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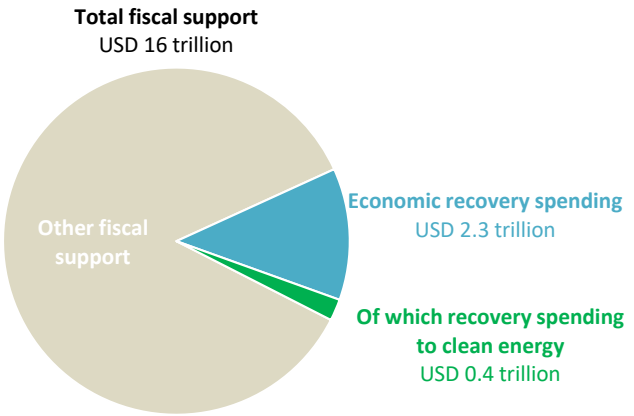
2.2.2 Recovery spending and energy investment

The ability of governments to mobilise fiscal support has helped households and companies to weather the immediate crisis, and will be equally important in shaping the speed and sustainability of the recovery. Most of the cumulative support provided, over USD 16 trillion as of mid-2021, has been aimed at providing near-term emergency and economic relief (IMF, 2021a).[1] Of this, around USD 2.3 trillion has been directed to economic recovery, which is defined as spending that goes to new investments, including spending that could be directed to clean energy infrastructure (Global Recovery Observatory, 2021). As of July 2021, we estimate that USD 380 billion is going to sustainable energy (IEA, 2021a) (Figure 2.5).

Figure 2.5 ▷ Breakdown of global Covid-19 pandemic-related fiscal support



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As of mid-2021, governments had spent around USD 380 billion on sustainable recovery measures as part of their response to the pandemic, around 2% of the total fiscal response

Note: Other fiscal support includes non-energy sector fiscal support, including near-term economic relief for companies and households, as well as emergency health measures.

Source: IEA Sustainable Recovery Tracker (2021a).

This funding support for clean energy is set to be delivered over the next few years – 70% of it by 2023 – and along the way it also leverages additional spending from the private sector. Our assessment of the multiplier effects by country and sector suggests that this could mean an additional USD 1 trillion in sustainable recovery investment over the period to 2023.

Some signs of this are already visible in our tracking of energy investment data and anticipated spending in 2021 (Figure 2.6). Overall investment in all parts of the energy sector is expected to rebound in 2021 by some 10% to USD 1.9 trillion, making up most of the decline seen in 2020. Spending on electricity networks is set to rise in 2021 after four years of decline, thanks in part to higher infrastructure spending in China, Europe and United

[1] Some of this support has translated into higher savings, especially in advanced economies. When these savings are spent – and what they are spent on – is an important near-term variable for the economic outlook.

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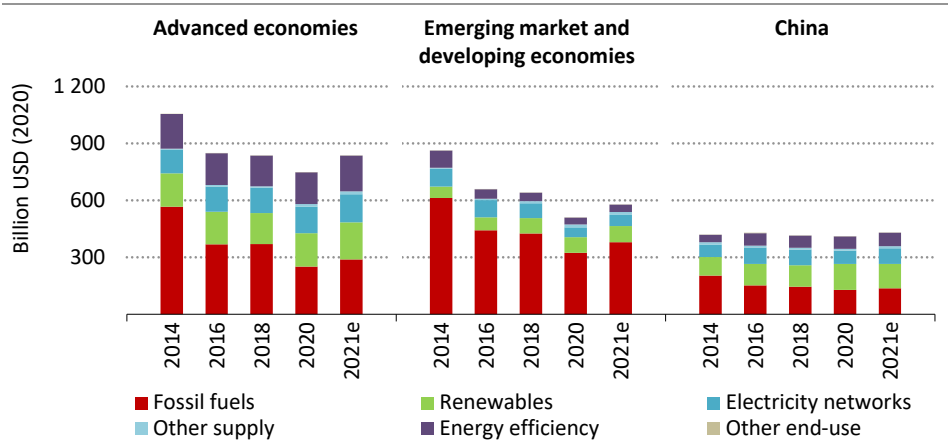
States. Spending on energy efficiency improvements is anticipated to increase in 2021 by nearly 10%, in response to renewed economic growth and the initial effects of recovery programmes. Policies and stimulus spending are also spurring projects in new areas such as low-carbon hydrogen and carbon capture, utilisation and storage (CCUS).

However, the amounts that are being dedicated to sustainable recoveries are far from sufficient to jolt the global energy system onto a different track. The additional USD 1 trillion over the period to 2023 is only around one-third of the amount that we estimate would be needed to secure an early peak and rapid subsequent reduction in global emissions (see *Sustainable Recovery* report [IEA, 2020a]). Overall clean energy investment would need to double in the 2020s to be consistent with limiting the rise in global average temperatures to "well below 2 °C" and it would need to more than triple in order to keep the door open to a 1.5 °C stabilisation.

There is a huge geographical imbalance in recovery spending and in clean energy investment. Although advanced economies are only committing around 60% of the global public and private spending envisaged in the *Sustainable Recovery* report (IEA, 2020a), the available funds are much larger than in developing economies, which already face a large infrastructure deficit. This reflects some worrying trends in clean energy investment and finance: if China is excluded, then emerging market and developing economies account for only one-fifth of the amounts being spent worldwide on clean energy, despite needing to find ways to meet the rapidly rising energy needs of two-thirds of the world's population.

Figure 2.6 ▷ Energy investment trends by region



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Emerging market and developing economies need to boost clean energy investment but often have limited fiscal space and constrained access to finance

Notes: Emerging market and developing economies aggregate excludes China in this figure. 2021e = estimated values for 2021.

The falling cost of key clean energy technologies offers a huge opportunity for all countries to chart a new, lower emissions pathway towards economic growth and prosperity. Clean

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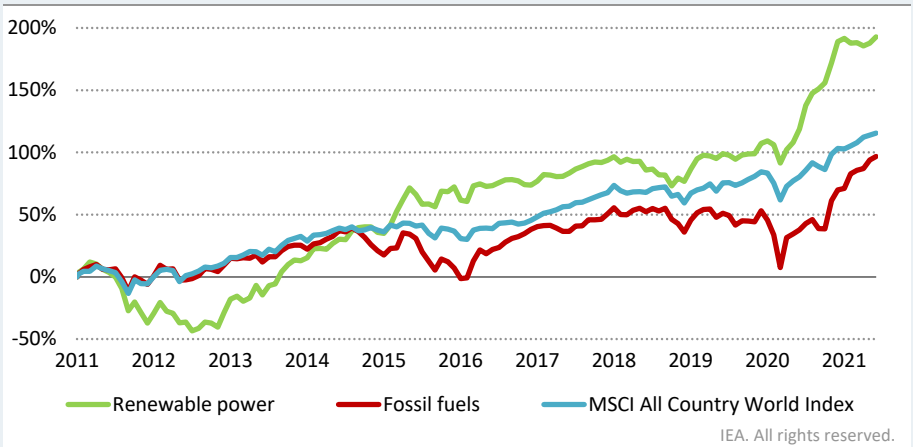
energy companies around the world have done well on financial markets, with listed renewable power companies outperforming fossil fuel companies and public equity market indices in recent years. However, clean energy investment still remains far short of what is required to put the energy system on a sustainable track. At the same time, the amount being spent on oil and natural gas is also short of what would be required to maintain current consumption trends. A surge in clean energy spending is the obvious way out of this impasse, but something has to change quickly or global energy markets face a turbulent period ahead.

Box 2.1 ▷ Fossil fuels or renewables: Which energy companies have delivered the strongest financial returns?

Does investing in energy transitions make financial sense? To answer this question, the IEA teamed up with Imperial College in the United Kingdom to examine structural trends in the historical financial performance of energy companies around the world (Figure 2.7). The analysis, updated to June 2021, showed that a publicly traded renewable power portfolio generated generally higher investment returns, higher diversification benefits (meaning that performance was less correlated to the overall market) and lower volatility than a portfolio consisting of fossil fuel suppliers. These findings held in all markets examined, but the overall performance gap was widest within advanced economies and China (IEA, 2021b).

Figure 2.7 ▷ Ten-year returns of a global market benchmark versus publicly traded renewable power and fossil fuel portfolios



Since late 2014 a renewable power equity portfolio has generated higher investment returns than one consisting of fossil fuel suppliers

Notes: The analysis compiled portfolios of different firms engaged in renewable power and fossil fuel supply and calculated total return and annualised volatility over five- and ten-year periods since 2011. The total return for each company is calculated in the local currency to produce a unit-less return. The portfolio construction methodologies and further analysis on credit conditions and commodity prices are available on the IEA website.

Source: IEA analysis based on Bloomberg (2021).

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Renewable power companies have reaped the rewards of huge improvements in cost competitiveness in recent years. They have also benefited from low interest rates, which are an important consideration for companies that are typically two-to-three-times more leveraged than fossil fuel companies. They weathered the initial storm of the pandemic considerably better than their fossil fuel counterparts, with a record-breaking market rally during 2020, though the most recent data for 2021 show a slightly changed picture: indices for fossil fuel are picking up as economic recovery boosts demand and prices.

What are the implications of this analysis for investors? It remains the case that investment opportunities in renewables lack scale and liquidity in most parts of the world, meaning that they are not always readily accessible. But the historical record does show that, with growing policy momentum and cost advantages, renewables have the potential to generate competitive risk-adjusted returns.

2.2.3 Energy demand and supply

Worldwide energy demand in 2021 is set to recover the ground that was lost the previous year, with a 4% increase returning global energy demand to pre-pandemic levels. The pickup in economic activity as countries gradually emerged from lockdowns has meant an upswing in demand for all fuels and technologies. These effects are overshadowing the signs of more structural changes in the energy sector, notably the rise of renewables for power generation and electric vehicles for personal mobility.

The pandemic was a setback for the pace of improvements in energy efficiency: strains on corporate and household budgets, uncertainties about the pace of recovery, and lower fuel prices in 2020 delayed spending on more efficient equipment and vehicles. The amount of energy required to generate a unit of global GDP has been steadily coming down over time, but the rate of improvement has slowed noticeably in recent years and was only 0.5% in 2020. This is well below the 3-4% annual figure needed to achieve global climate and sustainability goals. Investments in energy efficiency are set to pick up in 2021, although growth is likely to be heavily concentrated in markets and sectors with supportive government policies, such as the buildings sector in Europe.

Electricity

After declining in 2020, electricity demand is expected to increase by more than 1 000 terawatt-hours (TWh) in 2021, pushing consumption well above pre-pandemic levels. The increase in China is particularly striking, with demand already around 10% higher than in 2019. The worldwide rise in demand is set to outpace the expansion of low-carbon generation and much of the residual increase is being met by increased output from coal-fired plants in Asia.

In recent years, higher output from renewables has accounted for most of the growth in global electricity generation. Together with coal-to-gas switching, notably in the United

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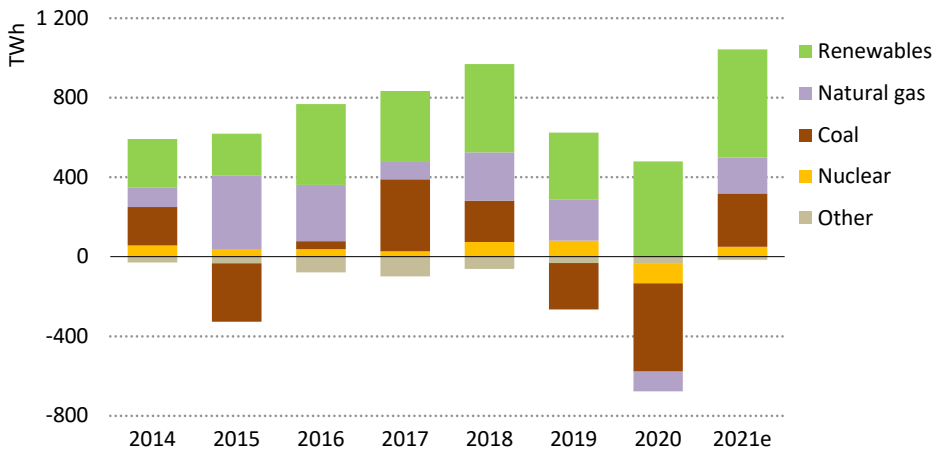
States, this has stemmed the rise in energy-related CO_2 emissions from the power sector. In 2020, record growth in renewables coincided with a fall in electricity demand, resulting in a big jump in the share of renewables in total generation, which rose to 28%, and a squeeze on generation from non-renewable sources. The result was a fall in global power sector emissions of around 3% – the largest relative and absolute decline on record. Another record rise in renewables is in the cards for 2021, but this is set to fall well short of the surge in demand (Figure 2.8).

Figure 2.8 ▷ Change in global electricity generation, 2014-2021



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Another record year for renewables in 2021 is not enough to cover the rise in electricity demand, leaving an opening for coal-fired generation – and higher emissions

Note: 2021e = estimated values for 2021.

Liquid fuels

The impacts of the pandemic are lasting longer in the transport sector than they are for electricity. Oil demand in 2021 is set to rise by around 5.2 million barrels per day (mb/d), but this only covers part of the 8.7 mb/d decline from the previous year (Figure 2.9). Consumption of aviation fuels remains well below pre-pandemic levels: most of the immediate reasons are related to restrictions on international travel and limited progress with vaccinations in many developing economies, but the pandemic may also have changed some air travel patterns for good. Road transport demand is rebounding faster, with both diesel and gasoline expected to be back within touching distance of pre-pandemic levels early in 2022, but continued public health risks, teleworking (especially in advanced economies), higher electric vehicle sales and increased efficiencies for new models are all constraining growth.

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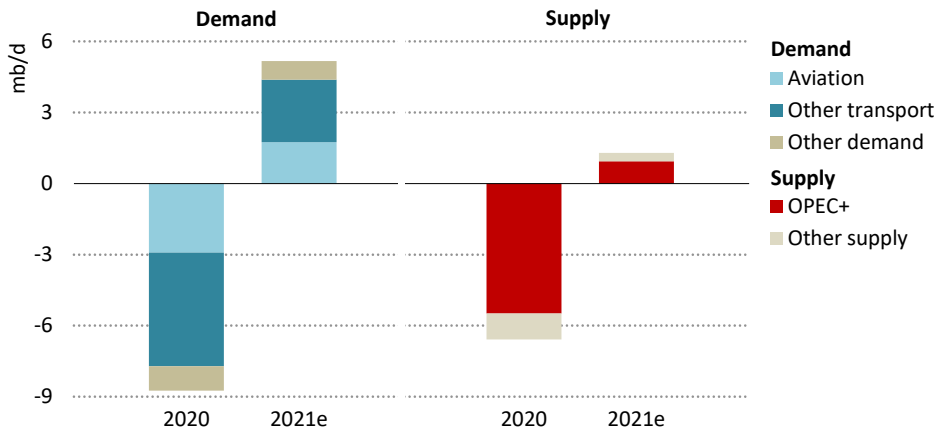
Figure 2.9 ▷ Annual change in oil demand and supply, 2020 and 2021



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Oil demand is rebounding in 2021, but remains well below 2019 levels. OPEC+ countries absorbed most of the supply shock in 2020 and are now gradually unwinding these cuts

Notes: 2021e = estimated values for 2021. The differences between supply and demand reflect changes in stocks.

Rising demand and prices make a case for the OPEC+[2] group to unwind some of the cuts in oil supply that they implemented in 2020, but uncertainties concerning demand have not all disappeared, and there are questions about the allocation of output among key producers. Producers outside the OPEC+ group meanwhile are set to get close to pre-crisis levels of production in 2021 and to surpass them in 2022, despite mounting social and environmental pressures on many oil companies and increased scrutiny of their investment plans.

Compared with traditional oil supply, the volumes of low-carbon liquid fuels coming to market are relatively small – around 1.9 million barrels of oil equivalent per day (mboe/d) in 2020. However, policies are giving a boost in some areas: production capacity for hydrotreated vegetable oil (HVO) – a renewable diesel fuel – is expected to nearly double over the next two years, significantly expanding the capacity to produce biofuels from waste and residue feedstocks.

Gaseous fuels

Unlike oil, natural gas demand in 2021 is rising well above pre-pandemic levels and this has created strains in gas markets, contributing to a spike in prices in the third-quarter of 2021 that has fed through into higher wholesale electricity prices in many markets. The broad-based increase in natural gas consumption has been accompanied by a series of planned and unplanned outages on the supply side. Although industrial users have led the recovery,

[2] The OPEC+ group includes the 13 Organization of the Petroleum Exporting Countries (OPEC) members and ten other oil producing countries including Azerbaijan, Bahrain, Brunei Darussalam, Kazakhstan, Malaysia, Mexico, Oman, Russia, South Sudan and Sudan.

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weather-related factors, including an extended heating season and low wind generation in Europe, limited hydropower production in Brazil and heatwaves in Asia, have also played a role in boosting demand from the power and buildings sectors.

On the supply side, exporters in Russia and Central Asia bore the brunt of the demand slump in 2020 and are capturing some of the rebound in 2021, mostly via increased pipeline deliveries. Liquefied natural gas (LNG) supply, by contrast, saw less downside in 2020 and continues to see a steady increase in seaborne gas trade. Asian countries now account for nearly three-quarters of global LNG imports.

As with liquids, low-carbon gases account for only a small share of total supply (currently below 1%), but demand for these gases is growing rapidly. Preliminary data show a double-digit rise in global biomethane production in 2020 to more than 5 billion cubic metres (bcm), largely due to supportive policies in Europe and North America, and a further large increase is anticipated in 2021. Low-carbon hydrogen is another fuel enjoying a surge of interest and investment, although for the moment the vast majority of global production comes from fossil-based hydrogen (including carbon capture without permanent sequestration).

Solid fuels

The 4% decline in global coal demand in 2020 was the largest drop in more than 70 years, but growing electricity demand and the pickup in industrial activity are behind the rebound in 2021, around 80% of which is coming from Asia. China is by far the world's largest producer and consumer of coal, and is instrumental in setting the global trend, but is far from alone in seeing higher coal demand in 2021. The increases, for the most part, are a reaction to the upswing in activity, but they are also a strong indication that the pace of structural change in the energy sector is far from sufficient.

Low-carbon solid fuels count for more in the energy mix than their liquid or gaseous counterparts: almost 90% of the bioenergy used today is in solid form. Some of this solid bioenergy is used in modern technologies to provide electricity and heat, while helping to reduce emissions. A larger share of it is for traditional use as a cooking and heating fuel in developing economies – an unsustainable and inefficient form of energy consumption that is a major cause of indoor air pollution and related adverse health impacts.

2.2.4 Emissions

Global energy-related CO_2 emissions are on track to rise by 1.2 billion tonnes in 2021, erasing two-thirds of the pandemic-related reduction seen in 2020 (Figure 2.10). A rise of this size would represent a 4% increase and the second largest absolute rise in history. The spike in electricity demand coupled with an increase in coal use is responsible for nearly 30% of this increase. Emissions from transport are also set to rise substantially in 2021, although continued limitations on air travel prevent them from rising past 2019 levels. Emerging market and developing economies generally have much lower per capita emissions than elsewhere, but overall account for around 60% of global CO_2 emissions. Emissions in advanced economies have been in gradual structural decline, but the rebound in economic activity is set to produce a rise of around 3% in 2021.

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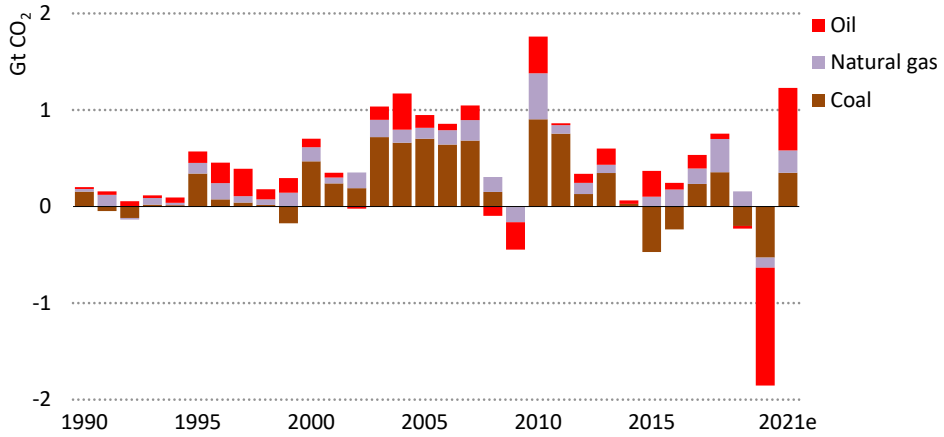
Figure 2.10 ▷ Annual change in energy-related CO_2 emissions



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Global CO_2 emissions are set to see one of the largest rises in history in 2021, erasing most of the gains realised during the pandemic

Note: 2021e = estimated values for 2021.

2.3 Where do we go from here?

2.3.1 Climate pledges

A key variable in determining where we go from here is what governments commit to do, and whether they are successful in realising their ambitions. Pledges made by governments are central to the architecture of the Paris Agreement and the fight against climate change, and the last year has been a particularly busy one for new climate policy announcements. This *World Energy Outlook* considers all pledges and commitments made as of mid-2021, including formal Nationally Determined Contributions (NDCs) as well as other announced ambitions, including longer term net zero targets (Figure 2.11).

In the context of the Paris Agreement, NDCs are meant to be updated every five years, becoming more ambitious over time. Most countries in the world have submitted a first NDC, although only around 60% of that number, so far, have formally submitted new or updated versions. The current crop of NDCs is typically focused on targets for 2030, but an increasing number of countries are putting their actions on emissions in the context of long-term strategies and net zero emissions targets.

If the world is to stem the rise in global average temperatures, it has to bring emissions down to a point where any residual emissions from human activity are balanced by removals of emissions from the atmosphere. That is why net zero targets – and the consistency of interim goals with these targets – have become a central focus of the climate debate. As of September 2021, 53 countries and the European Union have pledged to meet net zero

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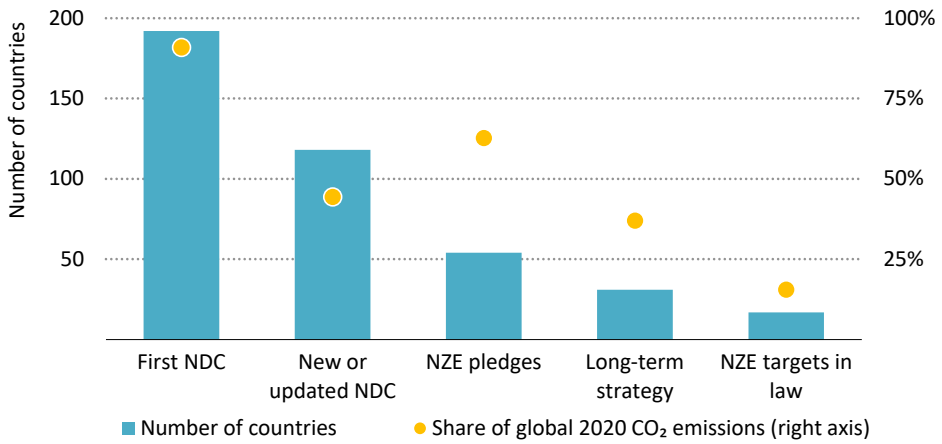
emissions targets; in total they account for 60-70% of today's global GDP and energy-related CO_2 emissions, and around one-third of energy-related methane emissions, the other main greenhouse gas.

The urgency of addressing climate change requires ambition from policy makers, but in practice there is not a single standard against which to judge the adequacy of their pledges. Countries are not starting the journey to net zero from the same place, and they should not be expected to finish it at the same time: there is a strong case for advanced economies to reach net zero before emerging market and developing economies (each of which has its distinctive circumstances) and assist others in getting there. The context for company pledges likewise varies depending on their operations: it is much easier for firms reliant on electricity, such as technology companies, to take on ambitious targets than it is for those in logistics or heavy industrial sectors.

Figure 2.11 ▷ Number of countries with NDCs, long-term strategies and net zero pledges, and their shares of global CO_2 emissions in 2020



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Net zero pledges by countries, sub-national jurisdictions, coalitions and companies have become a keystone of the global push to tackle climate change

Note: Submitted NDCs and their updated or new versions as defined by the United Nations Framework Convention on Climate Change (UNFCCC), as of 24 September 2021.

That said, beyond the headline level of ambition, there are several important questions to ask when assessing pledges:

- What does the pledge cover? Some national commitments focus only on certain sectors and exclude others. Some cover all greenhouse gases and others only CO_2. Company pledges also vary in scope: some include emissions from operations, but not indirect emissions in their value chain.

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- Are there conditions attached? If so, what are the conditions that have to be met in order for the commitment (or parts of it) to be realised? In the case of country pledges, the most common conditions relate to financial support. In practice, many commitments are implicitly reliant on measures to strengthen institutional capacity.
- Does the pledge rely on carbon dioxide removal (CDR) or offsets? This is an increasingly important consideration. CDR technologies include natural CO_2 sinks, such as forests and soils, as well as technological solutions, such as direct air capture or bioenergy with carbon capture and storage. Reliance on these solutions can be justified in areas where emissions reductions are extremely difficult to achieve, but broad reliance on offsets is often an indication of a lack of stringency.
- Are there mechanisms in place to track progress and ensure compliance? These are vital to ensure that the emissions reductions are robust, and that governments are held accountable for performance against their targets.

2.3.2 WEO-2021 scenarios

This *World Energy Outlook* (*WEO*) explores various scenarios, each of which is built on a different set of underlying assumptions about how the energy system might evolve. These scenarios are not predictions – the IEA does not have, and has never had, a single view about what the long-term future might hold. Instead, what the scenarios seek to do is to enable readers to compare different possible versions of the future and the levers and actions that produce them, with the aim of stimulating insights about the future of global energy.

These scenarios highlight the importance of government policies in determining the future of the global energy system: decisions made by governments are the main differentiating factor explaining the variations in outcomes across our scenarios. However, we also take into account other elements and influences, notably the economic and demographic context, technology costs and learning, energy prices and affordability, corporate sustainability commitments, and social and behavioural factors.

This *World Energy Outlook 2021* assesses three main scenarios. One is normative, in that it is designed to achieve a specific outcome and shows a pathway to reach it. Two scenarios are exploratory, in that they define a set of starting conditions and then see where they lead. In contrast to the 2020 edition of the *WEO*, we do not vary the assumptions about public health across the scenarios; we assume in each scenario that the pandemic is largely brought under control by the end of 2021 in advanced economies and China, but that this takes longer in many emerging market and developing economies.

The scenarios are:

- The **Net Zero Emissions by 2050 Scenario (NZE).** This is a normative IEA scenario that shows a narrow but achievable pathway for the global energy sector to achieve net zero CO_2 emissions by 2050, with advanced economies reaching net zero emissions in advance of others. This scenario also meets key energy-related United Nations Sustainable Development Goals (SDGs), in particular by achieving universal energy

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access by 2030 and major improvements in air quality. The NZE does not rely on emissions reductions from outside the energy sector to achieve its goals, but assumes that non-energy emissions will be reduced in the same proportion as energy emissions. It is consistent with limiting the global temperature rise to 1.5 °C without a temperature overshoot (with a 50% probability).

- The **Announced Pledges Scenario (APS)** appears for the first time in this *WEO*. It takes account of all of the climate commitments made by governments around the world, including NDCs as well as longer term net zero targets, and assumes that they will be met in full and on time. The global trends in this scenario represent the cumulative extent of the world's ambition to tackle climate change as of mid-2021. The remaining difference in global emissions between the outcome in the APS and the normative goals in the NZE or the Sustainable Development Scenario shows the "ambition gap" that needs to be closed to achieve the goals agreed at Paris in 2015.

- The **Stated Policies Scenario (STEPS)** provides a more conservative benchmark for the future, because it does not take it for granted that governments will reach all announced goals. Instead, it takes a more granular, sector-by-sector look at what has actually been put in place to reach these and other energy-related objectives, taking account not just of existing policies and measures but also of those that are under development. For example, the new Fit for 55 package of measures announced by the European Commission in July 2021 provides the detailed underpinnings for the European Union to reach its new 2030 emissions reduction target (a 55% reduction in emissions by 2030 compared with 1990 levels), and this is sufficient to bring the near-term EU trajectory in the STEPS close to that in the APS. The STEPS explores where the energy system might go without a major additional steer from policy makers. As with the APS, it is not designed to achieve a particular outcome.

An additional scenario referenced in the text is the **Sustainable Development Scenario (SDS)**. As a "well below 2 °C" pathway, the SDS represents a gateway to the outcomes targeted by the Paris Agreement. Like the NZE, the SDS is based on a surge in clean energy policies and investment that puts the energy system on track for key SDGs. In this scenario, all current net zero pledges are achieved in full and there are extensive efforts to realise near-term emissions reductions; advanced economies reach net zero emissions by 2050, China around 2060, and all other countries by 2070 at the latest. Without assuming any net negative emissions, this scenario is consistent with limiting the global temperature rise to 1.65 °C (with a 50% probability). With some level of net negative emissions after 2070, the temperature rise could be reduced to 1.5 °C in 2100.

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2.4 Inputs to the scenarios

2.4.1 Economic and population assumptions

The global **economy** is assumed to grow by around 3% per year on average over the period to 2050, with large variations by country, by region and over time (Table 2.1). The assumed rates of economic growth are held constant across the scenarios, which allows for a comparison of the effects of different energy and climate choices against a common backdrop. We recognise that the pace and nature of change in the energy system will have economic repercussions, both positive and negative: these impacts have been assessed in other reports, including the *Net Zero by 2050: A Roadmap for the Global Energy Sector* (IEA, 2021d). Joint analysis with the International Monetary Fund (IMF) which was featured in the *Roadmap* suggests that the surge in energy investment needed to get the world on track in the NZE would add 0.4 percentage points to yearly global growth over the next decade.

Table 2.1 ▷ Real GDP average growth assumptions by region

	Compound average annual growth rate			
	2010-2020	2020-2030	2030-2050	2020-2050
North America	1.6%	2.4%	2.0%	2.1%
United States	1.7%	2.3%	1.9%	2.1%
Central and South America	0.3%	2.8%	2.6%	2.7%
Brazil	0.3%	2.3%	2.7%	2.5%
Europe	1.1%	2.3%	1.5%	1.8%
European Union	0.8%	2.1%	1.3%	1.5%
Africa	2.5%	4.2%	4.2%	4.2%
Middle East	1.7%	2.6%	3.1%	2.9%
Eurasia	1.8%	2.5%	1.6%	1.9%
Russia	1.3%	2.2%	1.1%	1.4%
Asia Pacific	4.7%	4.9%	3.1%	3.7%
China	6.7%	5.2%	2.9%	3.6%
India	5.1%	7.1%	4.4%	5.3%
Japan	0.4%	1.1%	0.7%	0.8%
Southeast Asia	4.2%	4.9%	3.2%	3.8%
World	**2.6%**	**3.6%**	**2.7%**	**3.0%**

Note: Calculated based on GDP expressed in year-2020 US dollars in purchasing power parity terms.

Sources: IEA analysis based on Oxford Economics (2021); IMF (2021b).

Experience thus far indicates that – when Covid-19 is brought under control and the restrictions are removed – the trajectory for economic recovery is relatively rapid, especially in countries that have mobilised strong fiscal support. Recoveries have been led by industry and retail, while other sectors such as tourism and transport have lagged. However, some major near-term uncertainties remain. As noted, there are continued downside risks from a prolonged pandemic, with the spread of variants posing particular threats to emerging

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market and developing countries with low vaccination rates. There are also questions about the extent and duration of government support, with rising debt burdens limiting fiscal leeway in many countries; developing economies are again more vulnerable in this respect. In addition, there are uncertainties about the near-term impact on the broader economy following the sharp increases seen in energy prices in 2021.

Over the longer term, emerging market and developing economies are the main drivers of an expanding global economy, although a steady slowdown in population growth, the possibility of a further retreat from globalisation and a gradual moderation in growth in China all dampen the advance of global GDP over time. Higher public debt arising from the pandemic may be managed in practice by central bank tolerance for slightly higher inflation. The main energy-related uncertainties for the economic outlook relate to the impact of price volatility, the size of any near-term surge in clean energy investment, the extent of productivity gains associated with the deployment of new energy technologies, and the pressure exerted by energy transitions on major hydrocarbon-rich economies.

The global **population** is assumed to rise from just under 8 billion today to 8.5 billion in 2030 and 9.7 billion in 2050, an increase of just over 25% in 30 years.[3] The rate of growth continues to slow over time, despite a near doubling of the population in sub-Saharan Africa. Although its effects are likely to be transient, the pandemic appears to have slightly slowed population growth, with China and many advanced economies registering fewer births during the pandemic. Other short-term impacts of the pandemic include a fall in life expectancy in a number of advanced economies and a significant fall in international migration: the number of new visas and residence permits issued by Organisation for Economic Co-operation and Development (OECD) countries fell by 46% in the first-half of 2020 compared with the same period in 2019.

A rising share of older people in the global population is an increasingly important demographic trend. This has not been a major issue at global level: the share of the global population aged 65 and above increased from about 5% in 1960 to 9% in 2019. However, it is already a noticeable trend in high income countries, and becomes increasingly relevant over time in China and other middle income economies. Aside from the economic implications, older populations also affect patterns of energy use, with higher residential consumption offset by a lower propensity to travel.

Urbanisation is a key driver of our energy projections. Some 56% of the global population lived in cities and towns in 2020, and they accounted for two-thirds of global energy consumption and over 70% of CO_2 emissions, despite the fact that approximately one-in-three urban inhabitants dwell in informal settlements and slum households without adequate access to basic services (Ritchie and Roser, 2019). The share of the global population living in towns and cities is expected to rise to almost 70% in 2050, and to grow especially fast in sub-Saharan Africa and South Asia.

[3] This is in line with the median variant of the United Nations projections (United Nations Department of Economic and Social Affairs, 2019).

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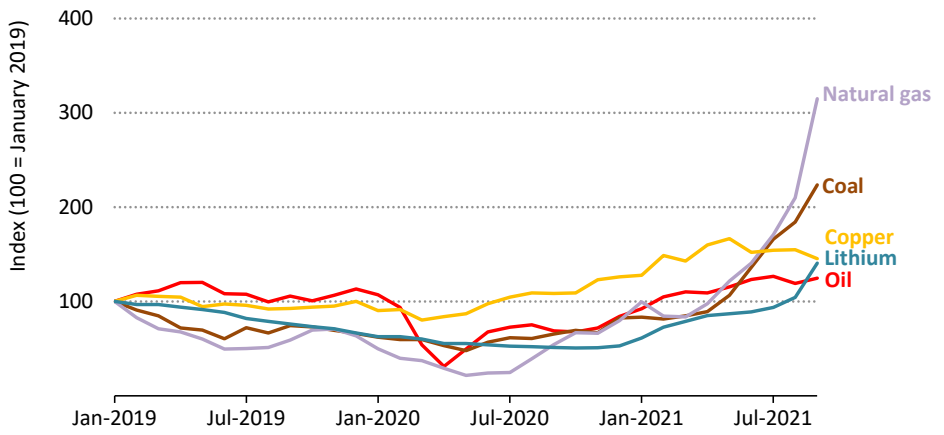
The model of urban development that is followed will have major consequences for the energy outlook, in particular the demand for energy-intensive construction materials such as steel and cement. In some advanced economies, the pandemic led to major cities such as London, Paris, Madrid, Milan and Berlin experiencing population declines as inhabitants sought easier living conditions further afield during lockdowns. It is an open question whether the experience of remote working will affect the balance between urban and rural populations in the future.

2.4.2 Energy prices

The economic recovery in 2021 has tightened commodity markets and put sharp upward pressure on prices (Figure 2.12). Looking beyond the immediate factors that have contributed to market tightness, some analysts have posited that the world may be entering a new super cycle, i.e. a prolonged period during which strong demand and some constraints on supply lead to high prices for energy and other commodities. The readiness of governments to spend on new infrastructure, a pickup in broader business investment and the increased mineral intensity of clean energy transitions could all support such a thesis. Indeed, the IEA has highlighted the importance of copper, lithium, nickel, cobalt and rare earth elements to a secure and rapid transformation of the global energy sector, and pointed to a looming mismatch between the world's strengthened climate ambitions and the availability of critical minerals that are essential to realising those ambitions (IEA, 2021d).

Figure 2.12 ▷ Monthly price indicators for selected commodities



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Most global commodity prices rallied in 2021 as economic activity picked up, but this does not necessarily mean a prolonged upswing in price levels

Note: Natural gas = Netherlands TTF natural gas forward one month; oil = Europe Brent spot price FOB; coal = Northwest Europe (ARA) CIF; copper = LME-Copper grade A; lithium = lithium carbonate global average.

Sources: IEA analysis based on Bloomberg (2021), IHS Markit (2021) and S&P Capital IQ (2021).

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The scope for a broad-based super cycle that encompasses energy markets as well as other commodities can be overstated. There is no visible equivalent today to the role in the previous upswing played by China, whose breakneck urbanisation and industrialisation drove markets in the early part of the 2000s. There are also trade-offs between different commodity types: to the extent that there is a surge in demand for minerals and metals for solar arrays, wind turbines, power lines and electric motors, this should ultimately ease pressure on traditional fuel markets. In addition, as noted, there are clouds on the economic horizon that could hold back the speed of recovery, especially in emerging market and developing economies. For these reasons, we do not anticipate an extended pan-commodity period of high prices, but there is still ample scope for price volatility and price spikes, given the multiple mismatches between current investment trends and possible patterns of demand.

The impact of changes in the energy sector on consumers is naturally a matter of political concern, especially when it comes to lower income households and certain energy-intensive industries. The scope and level of carbon pricing is one aspect of this, but there are also regulatory interventions that push in the other direction by holding the price paid for certain fossil fuels below their market value. After a sharp fall in 2020, the estimated value of these fossil fuel consumption subsidies is set to rise again in 2021 (Box 2.2).

Box 2.2 ▻ As prices and demand bounce back, so do fossil fuel consumption subsidies

The continued prevalence of taxes and regulated prices that favour fossil fuels makes the journey towards a sustainable energy future considerably more difficult. These market distortions dilute the case for more efficient and cleaner investments. The IEA has been a longstanding supporter of efforts to phase them out. Fossil fuel consumption subsidies are one important element of these market distortions, and occur when prices paid by consumers for fuels or electricity are lower than reference prices reflecting their full market value. These subsidies fell to a record low of USD 180 billion in 2020, but higher fuel prices and energy use, coupled with hesitancy on pricing reforms, are set to push this amount to an estimated USD 440 billion in 2021 (Figure 2.13).

This rebound to well above pre-pandemic levels is worrying at a time when countries need to be redoubling efforts to cut wasteful consumption and accelerate clean energy transitions. Subsidies to oil products remain the largest component of the total, but subsidies to natural gas and electricity have been the fastest rising. The increase in the subsidy burden adds to the fiscal pressures in many emerging market and developing economies, especially where subsidies are a specific incurred cost (typically where the fuel in question is imported) rather than foregone revenue (from potential sale of domestic output at a market price). Pricing reform is politically challenging but economically and environmentally essential to put the world on track for a more sustainable future.

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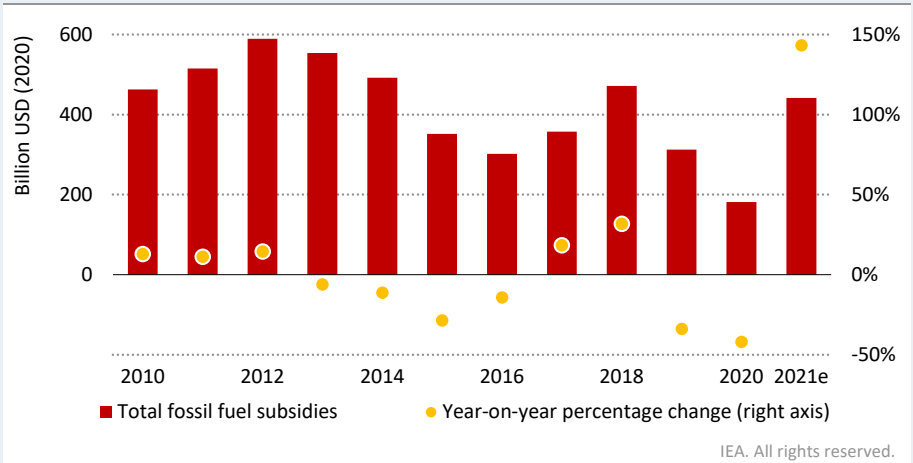
Figure 2.13 ▷ Global fossil fuel consumption subsidies, 2010-2021



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After their biggest ever percentage fall in 2020, fossil fuel consumption subsidies are set for their highest ever rise in 2021 as fuel prices and consumption rebound

Note: 2021e = estimated values for 2021.

Oil

In the STEPS, oil demand rebounds quite rapidly and reaches pre-pandemic levels by 2023 (Table 2.2). This maintains some support for prices compared with the low levels of 2020. Prices range between USD 60-90 per barrel in the STEPS, rising slowly over time and then plateauing. OPEC members continue to purse market management efforts, while shale producers maintain a more cautious stance on output growth than in the past. This reduces the peak in tight oil production in the STEPS compared with *WEO-2020*, but means the subsequent decline from the peak is also less pronounced.

In the APS, global oil demand peaks sooner than in the STEPS and then starts to decline, as do prices. Net zero pledges implemented by countries in this scenario do not include targets on production, but do imply stringent efforts to minimise emissions from oil and gas operations. This tends to increase slightly the production costs in these countries relative to other producers: since these countries are generally the marginal producers, it also offers some support at the margin for global prices.

In the NZE, the rapid drop in oil and natural gas demand means that no fossil fuel exploration is required and no new oil and natural gas fields are required beyond those that have already been approved for development. Prices are increasingly set by the operating costs of the marginal project required to meet demand. Resource-rich governments are assumed to restrict investment in new fields. If they were to opt to increase production so as to capture a larger share of the market, prices would be much lower.

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Natural gas

Natural gas has experienced an even sharper increase in prices in 2021 than oil, driven by a combination of circumstances that included a strong recovery in demand in Asia and Europe (leading to strong LNG demand from Asia), unseasonal weather and planned and unplanned capacity outages. As in the case of oil, the immediate period of higher prices is expected to be temporary, not least because of the planned expansion of LNG export capacity following a record year for project final investment decisions in 2019, but the potential for supply-demand imbalances and price volatility in the coming years remains strong.

Table 2.2▷ Fossil fuel prices by scenario

			Net Zero Emissions by 2050		Sustainable Development		Announced Pledges		Stated Policies	
Real terms (USD 2020)	2010	2020	2030	2050	2030	2050	2030	2050	2030	2050
IEA crude oil (USD/barrel)	92	42	36	24	56	50	67	64	77	88
Natural gas (USD/MBtu)										
United States	5.2	2.0	1.9	2.0	1.9	2.0	3.1	2.0	3.6	4.3
European Union	8.8	4.2	3.9	3.6	4.2	4.5	6.5	6.5	7.7	8.3
China	7.9	6.3	5.3	4.7	6.3	6.3	8.5	8.1	8.6	8.9
Japan	13.0	7.9	4.4	4.2	5.4	5.3	7.6	6.8	8.5	8.9
Steam coal (USD/tonne)										
United States	60	43	24	22	24	22	25	25	39	38
European Union	109	50	52	44	58	55	66	56	67	63
Japan	127	69	58	50	67	63	73	63	77	70
Coastal China	137	89	61	51	72	66	77	65	83	74

Notes: MBtu = million British thermal units. The IEA crude oil price is a weighted average import price among IEA member countries. Natural gas prices are weighted averages expressed on a gross calorific-value basis. The US natural gas price reflects the wholesale price prevailing on the domestic market. The European Union and China natural gas prices reflect a balance of pipeline and LNG imports, while the Japan gas price is solely LNG imports. The LNG prices used are those at the customs border, prior to regasification. Steam coal prices are weighted averages adjusted to 6 000 kilocalories per kilogramme. The US steam coal price reflects mine mouth prices plus transport and handling cost. Coastal China steam coal price reflects a balance of imports and domestic sales, while the European Union and Japanese steam coal prices are solely for imports.

In the STEPS, higher natural gas demand and the rise in oil prices (for oil-indexed supply contracts) exerts some upward pressure on natural gas prices. Demand growth in China, India and elsewhere in Southeast Asia continues to support prices in those regions through to 2050, giving signals for incremental export capacity growth to established producing regions such as Australia and the Middle East as well as to emerging exporters in East Africa. In Europe, near-term prices are buoyed somewhat by headwinds facing competing sources, with the retirement of coal and nuclear plants.

In the APS, the pursuit of net zero targets translates into a sharper decline in natural gas demand in several major gas importers such as Japan, Korea and the European Union, leading to a flat or declining gas price trajectory in those regions. Henry Hub prices stay in the

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USD 2-3 per million British thermal units (MBtu) range as domestic demand in the United States falls sharply, while a small upside from coal-to-gas switching in Europe quickly dissipates as prices settle around USD 6.50/MBtu. The surplus in internationally traded gas that results from lower European import requirements means that prices do not rise as strongly as they otherwise would in places such as China.

In the NZE, no new fields or export projects are developed, and natural gas prices fall to the marginal cost of delivering LNG from existing and under-construction projects, which require ongoing investment to sustain the required output. There is some temporary price support for gas as oil demand falls away more quickly than in the STEPS or APS and reduces the volumes of associated gas reaching the market. Natural gas becomes the largest fossil fuel in the energy mix by the late 2040s, and its discount to oil prices is progressively eroded.

Coal

International coal prices in 2021 reached levels not seen for more than ten years as demand rose in parts of Asia, especially for power generation and industrial uses in China, accompanied by some disruption and logistical issues on the supply side. This is not a harbinger for the future, however, and coal markets balance at lower prices in our scenarios. The difficulty of obtaining funding for new coal supply projects and infrastructure gives some support to prices in the STEPS. In the much more constrained demand environment of the APS and even more so the NZE (where no new coal mines or mine extensions are required) prices simply gravitate towards the operating costs of existing projects. In contrast to oil and gas, operating costs make up the largest share of coal supply costs.

Critical minerals

Many mineral commodities started 2021 with strong price rallies, with some reaching multi-year highs. Copper prices broke the symbolic USD 10 000/tonne barrier in May 2021, hitting an all-time high, and nickel prices rose by 50% from pre-pandemic levels, reaching their highest level since 2012. Lithium and cobalt prices are also resuming an upward trajectory. The recent price rallies were mainly driven by a combination of demand recovering faster than supply, stock building activities, ultra-loose monetary policies and expectations for strong future demand growth as a result of accelerated energy transitions.

The outlook for prices for many energy transition minerals depends on the pace of economic growth and on supply responses to that growth. It also depends to a large extent on how the world's decarbonisation pathway evolves. In the STEPS, the markets for many mineral resources may not necessarily be in deficit and may not tighten rapidly, given that investment is showing signs of a rebound. In the NZE, however, the projected level of demand growth is unprecedented, and this is bound to put substantial upward pressure on prices. The level of prices in these scenarios will be determined by the extent to which industry and governments ensure adequate investment in new supply well before the imbalances emerge, and also by how far consumers respond to rising prices by reducing demand and switching to substitute materials.

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2.4.3 Carbon prices

An increasing range and variety of carbon pricing schemes are coming into operation around the world. The main development since the *WEO-2020* has been the launch of China's national emissions trading system (ETS), which immediately became the world's largest carbon market (by volume) covering over 4 gigatonnes CO_2 emissions. There have been other developments such as various reforms to strengthen the European Union ETS, the launch of national carbon markets in the United Kingdom, and extensions to the scope of the ETS in Korea and Germany. Carbon taxes were also introduced in the Netherlands and Luxembourg.

The STEPS includes only existing and announced initiatives, whereas in the APS, SDS and NZE additional measures of varying stringency and scope are assumed to be introduced. In the NZE, for example, carbon prices are in place in all regions, rising by 2050 to an average of USD 250/tonne CO_2 in advanced economies, to USD 200/tonne CO_2 in other major economies (in China, Brazil, Russia and South Africa), and to lower levels elsewhere. As with other policy measures, CO_2 prices need to be introduced carefully, with a view to the likely consequences and distributional impacts.

The level of CO_2 prices included in the scenarios should be interpreted with caution. The scenarios include a number of other energy policies and accompanying measures designed to reduce emissions, and this means that the CO_2 prices shown are not the marginal costs of abatement as is often the case in other modelling approaches (NGFS, 2021). For example, many emerging market and developing economies in the NZE are assumed to pursue a variety of direct policies to adapt and transform their energy systems and so the level of CO_2 prices is lower there than elsewhere. Nonetheless, CO_2 prices provide an important backstop for fuel switching and for some investment decisions in sectors and countries that have few other policies to reduce emissions. It is also assumed that parallel policies are introduced to avoid differences in CO_2 price levels leading to the relocation of industrial (and other) activities. CO_2 prices are applied to other non-CO_2 emissions, such as methane.

The CO_2 prices used in our World Energy Model are applied at the point where the emissions occur and so are not directly included in the wholesale fossil fuel prices discussed in section 2.4.2. Nonetheless, they could indirectly impact fossil fuel prices via the effects on demand and also due to their application on emissions resulting from the direct activities of the fossil fuel industry, such as the energy required to extract oil and gas from the ground. This additional cost, or the measures adopted to reduce the emissions intensity of production, could raise total production costs.

2.4.4 Technology innovation, deployment and costs

The *World Energy Outlook* includes a very broad and dynamic representation of various energy technologies and their costs. The model which it uses incorporates the latest data on current costs for all technologies, and then builds in the effects on costs of continued research, economies of scale, and improvements in manufacturing and installation from learning-by-doing. As a result, technologies across the energy sector – including key

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renewable electricity production and storage technologies – get progressively cheaper over time. The pace at which this happens varies by scenario as cost reductions are linked to cumulative deployment: the more a technology is deployed, the larger the assumed reductions in costs. Policies play a crucial role in this process, particularly in determining how quickly new, innovative clean technologies are scaled up in sectors such as shipping, aviation and heavy industry (Box 2.3).

The speed of scaling up is particularly important in the NZE, which relies on a much more rapid pace of technology innovation than has typically been achieved in the past. The time from first prototype to market introduction in the NZE for technologies such as solid-state batteries, small modular nuclear reactors, ammonia-fuelled ships, or direct air capture, on average, is 20% faster than the fastest energy technology developments in the past, and around 40% faster than was the case for solar photovoltaics (PV). The speed at which new technologies are developed is crucial: almost half of the emissions reductions needed in 2050 in the NZE come from technologies that are today at the prototype or demonstration state, i.e. they are not yet readily available on the market.

Box 2.3 ▷ Energy patents start to pivot towards low-carbon technologies

Energy-related patent applications around the world can provide a good leading indicator of future technology trends. Joint analysis of the historical data by the IEA and the European Patent Office (IEA, 2021e) shows a clear divergence since 2015 between a continued rise in patents for low-carbon technologies and a decline in patenting for fossil fuels.[4] However, the pace of growth in clean energy patenting has slowed compared with a decade ago – a finding that reinforces the IEA's call for a new wave of innovation, accompanied by concerted policy support to accelerate the pace of clean energy transitions (Figure 2.14).

Alongside these headline findings, the composition of patents in the area of clean energy also contains some more granular insights. The market maturity of some low-carbon energy supply technologies, such as solar PV, in reflected in an initial period of heightened patenting activity that has tailed off since 2012. Most patents in recent years have been related to end-use sectors. Transport has been a particularly active sector for innovation. So has industry, with a focus on energy-efficient technologies for industrial production, including in some of the hard-to-abate sub-sectors such as iron and steel. Meanwhile, the overall growth trend since 2017 is being led by invention in cross-cutting technologies that enable higher levels of clean energy, such as batteries, hydrogen, smart grids and CCUS.

[4] The analysis focuses on international patent families, each representing a high value invention for which patent applications have been filed at a regional patent office or in at least two jurisdictions worldwide.

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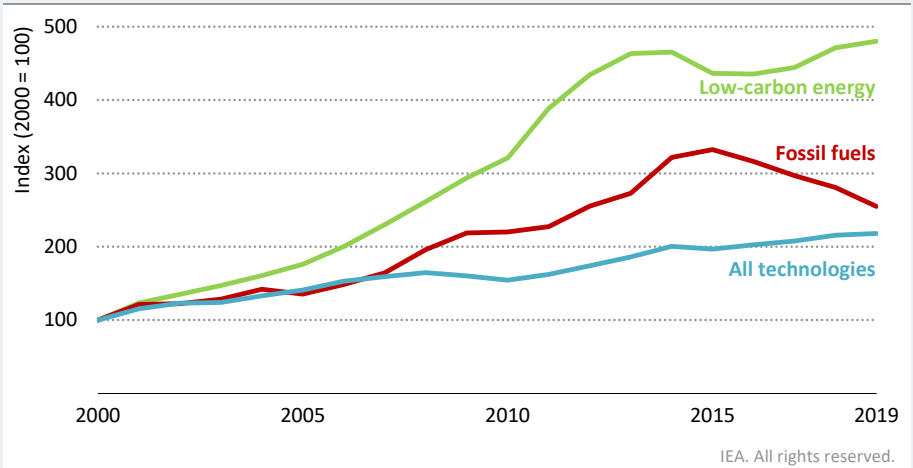
Figure 2.14 ▷ Global patenting for low-carbon energy technologies versus fossil fuel and other technologies, 2000-2019



Patenting activity for low-carbon energy technologies has risen faster than for fossil fuels since 2000, but a new wave of innovation remains essential

Source: Joint analysis by IEA and European Patent Office (2021e).

The very rapid pace of clean energy innovation assumed in the NZE depends on governments putting research, development, demonstration and deployment at the core of their energy and climate policies. There are some positive signs in this respect. Public spending on energy research and development continued to rise in 2020, and low-carbon technologies accounted for 80% of this. Innovation features in many of the stimulus packages announced by governments, with about USD 25 billion already committed to major demonstration projects for large-scale low-carbon energy technologies, including CCUS and other ways to mitigate industrial emissions. This figure could double based on recent announcements. However, this still falls far short of the USD 90 billion of public money that needs to be mobilised to complete a full portfolio of demonstration projects over the coming decade. Moreover, the international collaboration that plays an important part in accelerating knowledge transfer and supporting rapid diffusion of new technologies cannot be taken for granted.

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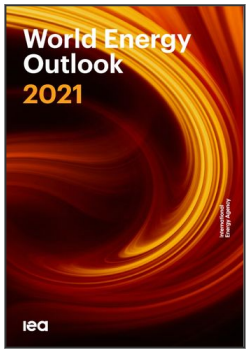

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