Atradius
Managing risk, enabling trade

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A glimmer of hope

Atradius Energy Outlook

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Executive summary

1 Off track?

- Against the backdrop of the hottest year on record, the COP28 stocktake summit of the Paris Agreement provided a gloomy picture. As though the energy transition is off track.
- It is not (yet). We see firming acceleration of the energy transition after the Russian invasion, with stepped-up government intervention, energy efficiency and lower CO2 emissions.
- Bright spots are visible: China taking up a major role in the energy transition, investments significantly picking up, technology costs continuing to fall, and clean energy becoming increasingly competitive.

2 Bright spots improve scenarios

- These bright spots translate into an improved scenario. Fossil fuel demand peaks earlier, the momentum in deploying renewables, especially solar PV, continues as China turns to clean energy.
- Advanced economies are leading with lower and cleaner energy demand, helped by strong policy support. The emerging economies, excluding China, need commitments, policies, and funding.
- The gap between announced and implemented policies is closing, firming up the scenario of Net Zero Emissions (NZE) by 2050 as well. But the gap remains wide.
- One should therefore make no mistake. The call for implementation and funding is as loud as ever.

3 Renewable energy outlook

- 2023 was a record year for adding renewable capacity. The ongoing high prices for oil and gas, energy security, combined with declining costs, especially for solar, contributed to this. Besides, supportive policy initiatives aid the renewables momentum.
- China is adding the most renewable capacity, both solar and wind. Large investments in solar manufacturing contributed to a drop in local solar modules prices, improving the competitiveness of solar energy. China is expected to add the most capacity towards 2030 and in the longer term to 2050.
- In our baseline scenario demand for electricity will grow strongly, especially in emerging and developing countries driven by economic development, the increasing population and rising incomes. Particularly in the transport sector, electrification will take off. Additional electricity demand will be entirely met by low-emissions sources, with renewables becoming the dominant electricity source. Solar PV will become the most dominant electricity source. In the NZE scenario these developments are even more pronounced.
- Large investments in the electricity sector are needed to keep the electricity supply reliable and stable. In order to keep up with the strong growth in renewables, investments in the grid are crucial. Just like speeding up the permissions process is.

4 Oil market outlook

- The volatility that characterised oil markets after the pandemic eased in 2023. The short-term outlook is more balanced. Global demand growth is muted as the global economy is slowing and demand-targeting policies are taking effect. Strong production growth in the Americas is largely offsetting OPEC+ production cuts.
- Global oil demand is expected to peak s and begin declining in the second half of the 2020s. More decisive energy transition policies, especially in Europe and North America targeting the electrification of the vehicle fleet, are the key drivers to declining demand. Lower demand will drive production to low-cost sources. OPEC+ will therefore increase its share of a smaller oil market.
- The future price of oil is consequently substantially lower than the levels around USD 80 per barrel today. We forecast the price to ease to USD 74 per barrel in 2030 and further to USD 60 in 2050. Volatility remains, especially in the event of an escalation of geopolitical conflicts. Still, the risk of sharp upward spikes is lower.
- In the NZE scenario, oil demand will fall much more rapidly due to significantly more aggressive energy transition policies, especially in EMEs. Oil production will be even more concentrated in resource-rich countries with lower operating costs, further driving op OPEC + market share. The oil price may fall to USD 25 per barrel in 2050.

5 Gas market outlook

- Gas markets have gradually rebalanced in 2023, after the high stress following Russia's invasion of Ukraine. Gas prices are now 68% lower year-on-year in the US, 39% lower in Asia and 54% lower in Europe.
- We expect global gas demand to peak soon and to be 7% lower in 2030 and even 42% lower in 2050. Robust policy support will reduce the share of gas in the energy supply by 2030 in the power sector and then increasingly in buildings and industry.
- Demand for gas is expected to grow in Asia-Pacific, Middle East and Africa until 2030 and then start to decline The US and Europe are projected to see a decline in gas demand both in the medium and long term.
- Russia is expected to be the largest gas supplier in 2050, whereas currently this is the US. But Russian supply will be almost 40% lower. The global surplus of LNG leaves Russia with fewer options to diversify into non-European markets. The Middle East remains the largest near-term source of supply growth.
- The gas price is trending down in all three regions (US, Europe, Asia). Gas prices will stay somewhat elevated until the middle of the decade, as global gas markets continue to adjust to the loss of Russian pipeline gas supply to Europe. This has knock-on effects on prices in other importing regions.

1. Energy transition off track?

1.1 2023: Hottest year on record

In our last Energy Outlook, we already highlighted the severity of climate change, naming it an existential threat. Events in 2023 pressed home the message that this was no exaggeration. Global warming has reached new heights. Last year, the warmest calendar year since 1850, the temperature hit 1.48 degrees Celsius above the pre-industrial average. This was 0.17 degrees above the previous highest annual value in 2016 as well.

Mere data could perhaps be ignored, extreme weather events not. Large scale flooding occurred due to monsoon rainfall and tropical cyclones, such as in California, Mexico and the Mediterranean. Droughts hit Mexico and South America. Heatwaves struck in Europe, North Africa and parts of North America and Asia, often breaking local temperature levels, such as the 47 degrees Celsius in Italy and 52.2 in China. This coincided with extensive wildfires, like in California, pushing up carbon emissions from these by 30% compared to 2022. Other parts of the world, such as Western Europe, witnessed severe precipitation, unprecedented in length and intensity. Furthermore, in 2023, Antarctic Sea ice reached record low levels, spending 8 months below the previous 25-year average. On the other side of the globe, the annual March peak of Arctic Sea ice extent was the fourth lowest. Meanwhile sea levels keep on rising as ocean surface temperatures pass all previously recorded levels. We are getting closer to a situation where the Earth's eco systems struggle to adapt and some places approach the limits of human survivability in summertime.

These figures and events are arguably not a reflection of climate change only. Indeed, the occurrence of El Niño, the natural process of Pacific Ocean water, has amplified the temperature rise. Even taking that into account, the rise is still large. A comprehensive attribution of factors other than climate change and El Niño is still not available. Suggested factors such as the January 2022 eruption of the Hunga Tonga-Hunga Ha'apai volcano, reduced aerosols due to lower sulphur dioxide emissions by shipping and the approach of the solar cycle to its peak are probably limited.[1]

Against this backdrop, nearly 200 countries assembled at the COP28 climate talks in Dubai in late November and early December. The summit was framed as the first global stocktake of progress made by the world towards the 2015 Paris Climate goals of 1.5 degrees Celsius warming with limited or no overshoot. This is the (longer term) temperature rise that is hoped to prevent years such as 2023 becoming the rule rather than the exception. The prospects are not looking good. COP28 provided a gloomy picture with the recognition that, despite a lot of positive developments, ambitions and intentions, the world is set for global warming of 2.4 to 2.6 degrees Celsius by the end of the century. Unless urgent action is taken and support provided to reduce CO2 emissions by 43% in 2030 and 60% by 2050,[2] it looks as if the world is off track.

Is it? In this Outlook we will take a closer look at where we are in the energy transition. We will consider the developments, plans and intentions countries in the world currently have. And what is needed to achieve the Paris climate goals. It will be argued in more detail that we are moving too slowly. And, consequently, that the track to achieve these goals is rapidly narrowing. But we refrain from being (too) negative. All is not lost. There is a glimmer of hope.

We will elaborate on this theme by first, in the remainder of this chapter, sketching the developments and outlook in the energy sector, particularly the energy mix, since our last Energy Outlook. In chapter 2, we follow this by describing the IEA's forecast scenarios for the energy mix in more detail. That is followed in chapter 3 by a discussion of the renewables, whereas chapters 4 and 5 look at the oil and natural gas sector respectively.

1.2 2030: a milestone year

In this Outlook we once again provide a forecast for the period up to 2050. There is a simple reason for this - all IEA scenarios are using that date as a reference. Nonetheless, as opposed to previous years, we will place the emphasis considerably more on the short term, focussing on the period until 2030.

Why up to 2030? The reason, in a nutshell, is that this period is the crucial time in which the foundations for a successful energy transition to 2050 are laid. If these are lacking, the transition from 2030 on will be on much weaker ground, and reaching Net Zero Emissions by 2050, or even coming close

1 Copernicus (2014), Global Climate Highlights 2023 https://climate.copernicus.eu/global-climate-highlights-2023.

2 For more details on the outcome of COP28 see The Oxford Institute for Energy Studies (2024), Ten key conclusions from COP28: a farewell to fossil fuels? https://www.oxfordenergy.org/publications/ten-key-conclusions-from-cop28-a-farewell-to-fossil-fuels

to it, will be very difficult if not impossible. It is therefore crucial that the world is on track in the coming years.[3 4]

Looking closer, we see several arguments underlying this broad picture. First, there is only a limited remaining amount of CO2 that can still be emitted to limit the global warming to the Paris Agreement objective of 1.5 degrees, as compared to the pre- industrial level. This so-called CO2 budget is critical to avoid levels of global warming that could lead to irreversible climate change, where polar ice caps melt, ecosystems collapse, and food and water supplies are severely disrupted. This means that there is no time to lose with the energy transition. Every year counts.

Second, whilst energy transition up to 2030 is necessary, it is also critical for the period after 2030. As from then, the energy transition needs to accelerate, based on what happened in the previous decade. This period up to 2030 is when large investments, especially in renewables and infrastructure including the electricity grid, are made. As this takes time, so does reaping the benefit in terms of CO2 emissions. Therefore, a delay or reduction of investment will be perceivable in a constrained energy transition after 2030.

Third, whilst these investments are based on existing and commercially viable technology, for Net Zero by 2050 to be achieved, more is needed. In particular, technology needs to develop from a demonstration or prototype stage today into being widely employed in the 2030s. Moreover, innovation is needed to decarbonise heavy industrial sectors and long-distance transport by sea and air. Technologies such as direct air capture, low carbon fuels, hydrogen electrolysers and advanced batteries are promising, but need time and funding. Options like electronic trucks and industrial CCUS (Carbon Capture Usage and Storage) can then only make substantial inroads after 2030, with deployment before that date nevertheless critical to lower cost and allow the necessary scaling up. Deploying existing technology is necessary but not sufficient to achieve Net Zero by 2050. New technology needs to be deployed on a large scale.

In brief, energy transition is a race against time. There is only a limited CO2 emission budget left for avoiding irreversible global warming threshold levels. Immediately reducing emission levels as well as investments in infrastructure and technology are critical for this. And the year 2030 is a milestone. That is why we opt for emphasising it.

1.3 Energy transition drivers

As in previous outlooks we use two IEA Energy Outlook based scenarios,[5] against the background of the prevailing direction of the energy transition. The latter scenario is captured by the Stated Policies Scenario (STEPS), in which current policies of countries, in place or announced, are evaluated. They are projected to lead to a temperature rise of 2.4 degrees Celsius in 2100 (with 50% probability). This is the world that was discussed at the COP28 summit in Dubai. It is not the one that we see ultimately playing out. For that, climate change is too pressing as we have witnessed in the weather extremes during last year. Therefore, as in our last Energy Outlook, we think that besides current policies, the climate-related pledges in nationally determined contributions (NDCs) and commitments in related areas such as energy access will be put in place. This moves the world to the so-called Announced Pledges Scenario (APS), in which the temperature rise is limited to 1.7 degrees. This, of course, is not enough given the Paris Agreement objective of 1.5 degrees. To reach that, more needs to be done. Indeed, the world needs to achieve net-zero CO2 emissions by 2050, as the Net Zero Emissions by 2050 Scenario (NZE) that we will describe as a normative scenario, is the one that the world should strive for. In such a world, key energy-related UN Sustainable Development Goals, such as universal access to reliable modern energy services (by 2030) and major improvements in air quality, are met as well. As argued above, each passing year of high emissions and limited progress towards these also makes Net Zero by 2050 more difficult to achieve. But these goals are not out of reach (yet).

The above scenarios differ in outcome, especially in the potential effect on climate change. But they also have a lot in common. One can even see similar trends playing out, but with a different intensity.

What are these trends? We see broadly three. First, energy efficiency, meaning saving energy. This implies, for example, using insulation to reduce the use of energy for home heating, without loss of heat. Second, electrification. The reduction of energy demand may be further spurred by electric heating rather than gas heating. Moreover, as electricity is increasingly generated by solar PV, wind or hydropower, the energy mix will be cleaner as well. Electrification of transport via electric vehicles (EVs) is another example. Third, there is a move away from fossil fuels in a twofold way. We see a large-scale power generation shift from, particularly, coal and gas driven plants to renewables. Furthermore, where electrification is not feasible, a shift to clean fuels is taking place, away from fossil fuels. This is visible in road traffic, sea transport and aviation. Cleaner fuels such as biofuels are mixed with fossil fuels.

What drives these trends and their intensity? Again, three major factors can be distinguished. First, government intervention and support. This is where it starts. Policy should be designed and laid out in clear, legislated plans, with set implementation deadlines and monitoring, including budgetary support in the form of subsidies (or

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3 This is echoed in the 2021 World Energy Outlook, p. 16 '...The APS sees a doubling of clean energy investment

and financing over the next decade, but this acceleration is not sufficient to overcome the inertia of today's energy system. In particular, over the crucial period to 2030,...'

4 Using a familiar metaphor, think of the energy transition as being a large tanker, the largest possibly imaginable. If the mega ship is to reach its destination, it needs to steer accurately and timely. Failure may lead to a disaster.

5 Our outlook draws on the IEA publication of October 2023. As we have argued in previous outlooks this publication reflects the best comprehensive analysis available in the market. The IEA is arguably the most reputable international think tank in the energy world.

taxes). This is not only related to energy- and climate-related policies, such as the EU Emissions Trading System in which CO2 emissions can be traded between companies. It also includes the industrial policies aimed at clean energy manufacturing, for example the US Inflation Reduction Act of 2022 and the EU Green Deal Industrial Plan. Second, funding, not only by governments, but also the private sector needs to be involved to finance the energy transition. Daunting amounts are involved: US$ 4.2trillion in 2030 in NetZero for example. To put this into perspective this amounts to some 50% of current global GDP. Third, technological progress. This is key to the energy transition as well. As mentioned above, commercially viable technology should be scaled up. Technology that is still in prototype phase such as CCUS is to be developed to be commercially viable and then, as a next step, scaled up.

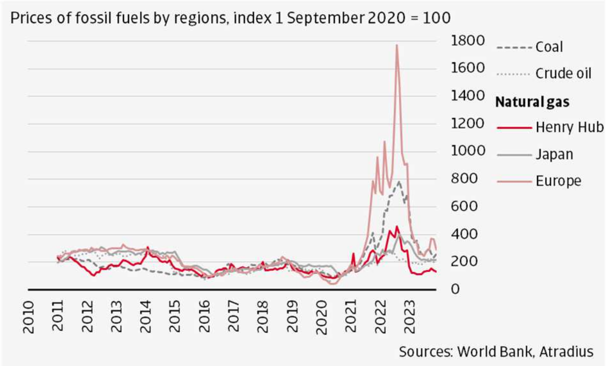
In the scenarios we sketch in this Outlook for the NZE, government intervention is more effective, funding amply available, from both public and private sources, and technology available timewise and at more competitive prices than in the APS. This leads to higher energy efficiency, more electrification and a far more pronounced shift from fossil fuels to renewables in the NZE scenario.

1.4 After the crisis

These figures were recorded in the second year after the Russian invasion of Ukraine in February 2022. The event, as we argued in our previous Outlook, shocked the energy system and put it in crisis mode. Russia was, and is, the largest fossil fuel producer in the world. No wonder fears of supply shortages sent prices of fossil fuels up - in the case of European gas even sky high - with spillovers to the rest of the world. The event triggered a wave of gas-to-coal switching in Asia and, to a lesser extent, in Europe. The negative impact for CO2 emissions was taken for granted. It was energy security first. The higher energy prices had two major implications. Energy savings were boosted, especially in the EU, with a positive impact on CO2 emissions. Moreover, higher energy prices triggered price rises across the economy, that is to say: inflation. This affected the global economy through a range of channels. The result was central banks across the globe hiking interest rates, considerable pressure on global economic activity, and subsequently on energy demand.

Now, after another year has elapsed since the energy crisis erupted, without further shocks, we observe that the turmoil has evaporated (figure 1.1). Fossil fuel prices have calmed down and are no longer subject to extreme volatility and price levels have come down accordingly. They have remained above pre-crisis levels though, especially those for natural gas. After peaking at USD 130 per barrel of Brent in early 2022, oil now trades in the range of USD 70-80. This reflects muted expectations of economic developments as well as the fact that Russian oil has kept flowing despite sanctions imposed by the US, UK, EU and a number of other countries supporting Ukraine. Production cuts by OPEC+ (that includes Russia) attempt to put a floor under the price. As to natural gas, after the extraordinary spike of USD50 per British thermal unit in Europe – equivalent to more than USD 250 per barrel of oil – in late 2022 the price is now back at around USD 10. The market has rebalanced after Russian pipeline gas exports to Europe almost stopped. LNG trade has filled the gap and has become the marginal supply, and thus setting the price. But with its liquification and gasification steps in between, LNG is considerably dearer. Prices are therefore set to remain higher. Coal prices peaked at USD 400 per tonne and are now back at around USD 150. In brief, fossil fuel prices have reached new equilibrium values. With that, a major source of inflation has faded, and thus that source of pressure on economic activity and energy demand. The energy crisis is abating.

Figure 1.1 Energy prices have calmed down



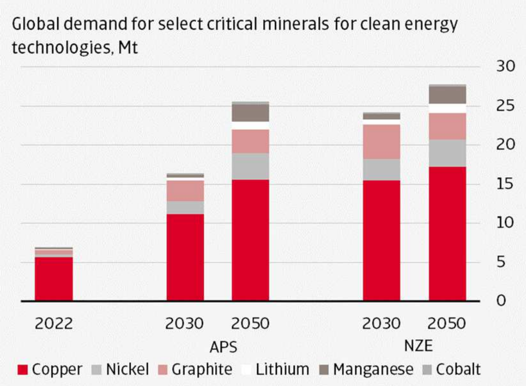
Does this mean that the energy transition is now back on the pre-crisis pathway? The answer is no. Why? The first point here is Russia's invasion has created fractures in the global political and security landscape. Europe, for example, had an extensive pre-crisis energy trade relationship with Russia. That has now dried up and has been replaced by others, such as Qatar and the US for LNG. Setting up these and other relationships is now factored in, taking into account political and energy security arguments. This not only concerns energy but clean energy as well. In value chains of the latter, concentrations have developed, such as for the production of critical minerals like lithium, nickel, cobalt and copper that can potentially create new security vulnerabilities (see focus box on next page). Diversifying away from that, or plainly put, doing it yourself as a country or region like the EU, implies higher production costs, otherwise it would have already been done in the first place. This presses the message home that energy security has a price.

The second point, and closely related to the former, is that government intervention is being further stepped up. We have seen that during the energy crisis, governments in the EU poured USD 550 billion into firms and households to alleviate the impact of the crisis. That short-term intervention is now being replaced by more structural policies. These are used to fast track the deployment of clean energy, as is the case with the Inflation Reduction Act in the US, more ambitious near-term targets and support measures in Europe and strong support for clean energy in China, India and Brazil.

In focus: critical minerals

The world needs to shift from an energy system powered by fossil fuels to one dominated by clean electricity to meet the climate goals. To generate, transport and store this electricity, massive amounts of solar panels, wind turbines, electrical cables and batteries are required. All these clean electricity-related technologies are generally more mineral intensive than their hydrocarbon counterparts. An onshore wind farm for instance requires nine times more mineral resources than a gas-fired power plant (IEA, 2021). The demand for critical minerals such as copper and aluminium (key materials for electric wires and networks), cobalt, graphite, lithium, manganese, nickel and tin (major battery metals), zinc (important for wind and solar power and batteries) and rare earth elements such as neodymium (essential for magnets required by electric vehicles and wind turbines) is thus set to increase rapidly. The IEA (2023) estimates demand for these minerals to double or almost quadruple by 2050 depending on the scenario. The main drivers of demand growth are electric vehicles and batteries, followed by electricity networks. Achieving the climate goals thus requires a global mining boom.

Reaching the climate goals requires a mining boom



Sources: IEA Critical Minerals Market Review 2023, Atradius

As inflation is coming down with the lower energy cost, central banks are likely to cut rates in 2024 and 2025. At the same time, it is clear that these central banks are unlikely to cut rates to pre-crisis levels. Consequently, borrowing costs may go down, but will remain higher than before the energy crisis.

The fourth point concerns energy efficiency that was given a boost by the higher energy prices, driving down energy demand. True, as energy has become cheaper, the pressure on saving energy is lower. At the same time, as prices, especially of natural gas, are likely to settle at higher levels than pre-crisis, a lasting positive impact will remain. This is supported by the behavioural change of more energy (price) consciousness in households; it has become clear to them they will not be freezing if the heating is at 19 degrees Celsius.

The fifth, and final, point looks at CO2 emissions. After all, that is what it ultimately boils down to. With an estimated growth of around 1% in 2022 and 2023, after a 6% growth in the last pandemic year 2021, the suggestion is a conversion point is nigh. This is supported by the COP28 agreement between 155 countries to reduce their methane emissions by 70% in 2030.[6] That is badly needed, as the amount of CO2 that can still be emitted, the so-called CO2 budget, is being raced through. For example, Lamboll et al. (2023) estimate that the remaining budget to stay within the 1.5 degrees Celsius limit of the Paris Agreement (with 50% probability) is 250 gigatonnes as of January 2023.[7] For the boundary of 2% it is 1,200 gigatonnes. To put this in perspective, energy sector-related CO2 emissions amounted to 42 gigatonnes in 2022.

1.5 Acceleration needed

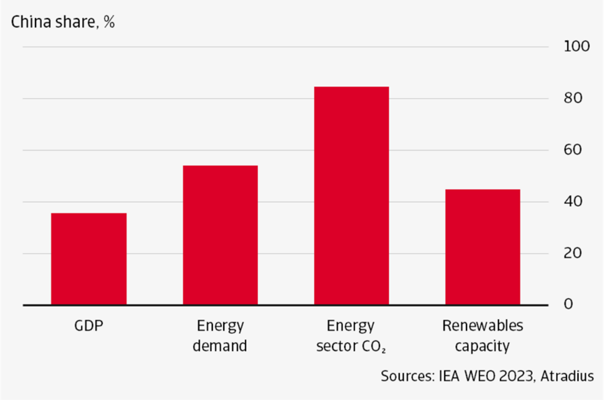
Against this backdrop, various major developments with a lasting impact on the energy world are taking shape. While they point in the right direction there is still a (long) way to go.

First, developments in China, both on the supply and demand side, are supportive. This country has a major share in the energy world (figure 1.2). It is going through a transition, which is two pronged, reflecting the demand as well as supply side of the energy world. First, the demand side: The Chinese economic model is changing. Its focus on property and infrastructure is waning, simply because there are now sufficient buildings, roads, bridges, airports and harbours. As a result, the Chinese economy will rely more on consumption. That will slow energy demand growth significantly as will China's CO2 emissions. On the supply side, matters are changing as well. The Chinese authorities have moved to the energy sector to support the economic transition. The country is investing heavily in high tech manufacturing, including solar PV and electric vehicles. How the Chinese transition will play out is not certain. But it is clear that, given China's size in the global energy domain, it will have a considerable impact.

6 Methane emissions are 10% of total CO2 emissions. See https://www.iea.org/reports/co2-emissions-in-2022.

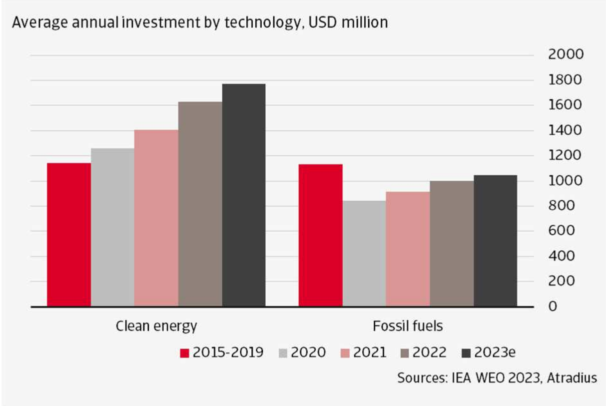
7 Lambol, R.D., Zebedee, R.J., Smith, C.J., Kikstra, J.S., Byers, E. and Rogelh, J. (2023), Assessing the size and uncertainty of remaining carbon budgets, Nature Climate Change, 1360-1367

Figure 1.2 China's share in the change to selected global economic and energy indicators, 2012-2022



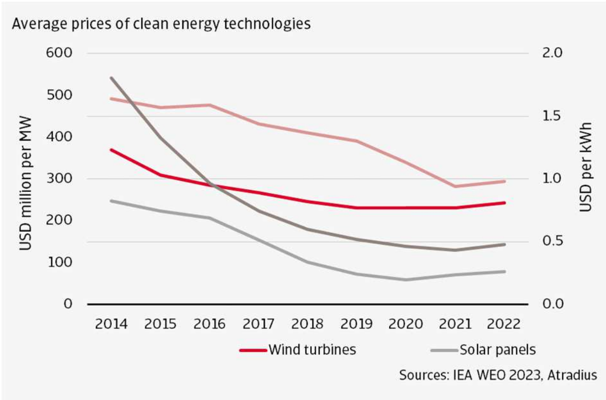
Second, investments are picking up after the slump from the Covid-19 pandemic (figure 1.3). The Russian invasion and its accompanying (energy) security issues have accelerated the momentum behind clean energy, just as it triggered a scramble for oil and - in particular – gas supply. In 2023 an estimated USD 2.8 trillion was invested, of which the majority, USD 1.7 trillion, went into clean energy. This includes renewable power, nuclear, grids, storage, low emission fuels, efficiency improvements and electrification. The remainder of slightly above USD 1 trillion went to fossil fuel supply and power, of which around 15% to coal and the rest to oil and gas. There is a marked acceleration in investments in clean energy, particularly in renewable power and EVs, with batteries, heat pumps and nuclear power also contributing. Investment in low emission power accounts for 90% of the investment in electricity generation, with solar PV the major contributor (USD 380 billion). For solar PV the investment level already matches the amount required to be on track for a 1.5 degrees Celsius stabilisation. China, in particular, is investing heavily in clean energy, at USD 180 billion p.a. on average since 2019, followed by the EU (USD 154 billion) and the US (USD 95 billion). Apart from this bright solar spot, current investment levels need to be ramped up, predominantly in clean energy, to USD 3.8 trillion in 2030 in our baseline APS scenario and USD 4.7 trillion in the NZE scenario. The increase is needed particularly in emerging and developing economies. Currently 90% of clean energy investment is taking place in China and the advanced economies. The present investment level in fossil fuels is not sustainable. Indeed, at the COP28 it was agreed to 'transition away' from fossil.[8]

Figure 1.3 Investment levels renewables continue to rise



Third, technology costs are no longer decreasing. After a long period of decline, costs for key clean energy technology have come under some upward pressure (figure 1.4). This has stabilised and, in some cases, even increased prices. It is largely due to higher input prices for critical minerals, semiconductors and bulk materials like steel and cement. Prices for Solar PV modules eased significantly during 2023 due to overcapacity in China. Wind turbine costs remained high in 2023 at 35% above levels of early 2020. Higher interest costs and permissions were concerns for investors and financiers, especially for electricity grid infrastructure. Despite cost stabilisation, clean energy remained competitive versus fossil fuels, where downward pressure on costs from technology learning is offset by moving towards geologically more challenging sources.

Figure 1.4 Recent cost developments for selected clean energy technologies



Competitiveness of clean energy is a precondition for the energy transition. Higher levels of deployment should generate scale benefits that translate into lower prices. Apart from scale, technology innovation, material substitution and efficiency improvements should further drive down costs. Lower prices for clean energy should then lead demand away from fossil fuels, reducing the costs of clean energy and so forth. For this virtuous cycle to accelerate, or even happen, investments and government support are critical. There is some way to go here.

8 See e.g. The Oxford Institute for Energy Studies (2024), Ten conclusions from COP28: a farewell to fossil fuels? Energy Insights 143.

2. Bright spots improve scenarios

2.1 Bright spots

Against the background of the developments sketched in chapter 1, the APS as well as the NZE scenario have changed versus 2022. To highlight these, we take a closer look at the implications for the scenarios based on the implemented, rather than announced, policies.[9] This implies that both the APS and the NZE scenario have improved, especially in terms of likelihood to play out. The developments are as follows (figure 2.1).

Figure 2.1 Demand for renewables strongly up since last year

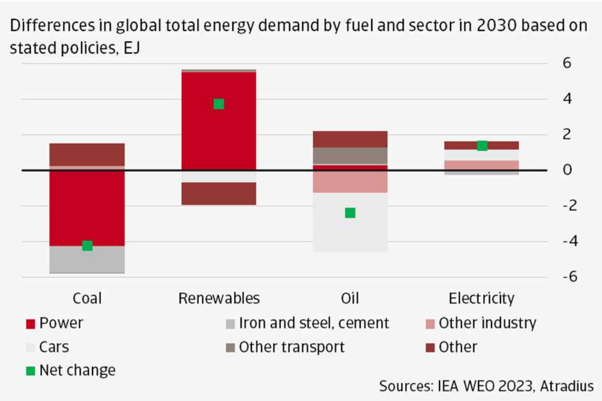
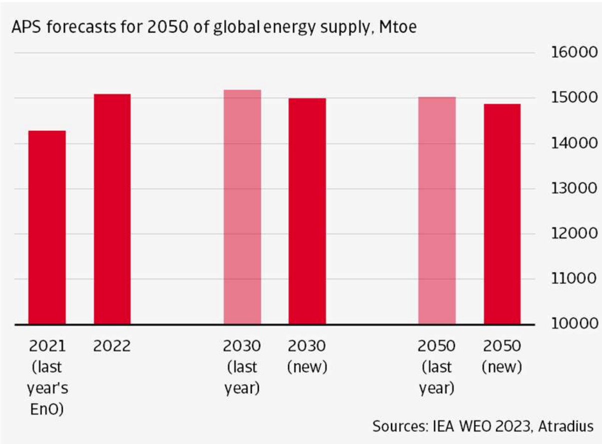


Figure 2.2 Overall energy demand slightly lower than last forecast



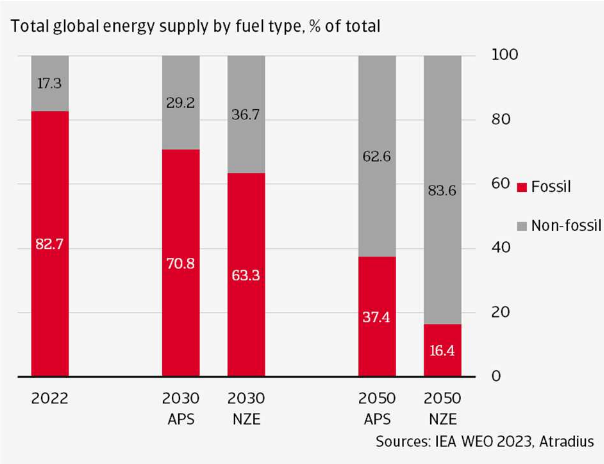
- **Peak fossil.** The three fossil fuels are expected to peak by 2030 as are energy-related CO2 emissions. Coal decline reflects reduced capacity additions of both coal-fired power and coal fired iron and steel production. Coal fired power has increasing become a backup fuel for power generation as renewables dominate the expansion in power. Iron and steel production is changing through the use of electric arc furnaces, reducing coal use intensity. Oil demand is changing because of the rise in EVs. These are estimated to reach a share in new car sales of 18% worldwide, mostly in China and other advanced economies. A continued rise in demand from shipping and aviation will not be sufficient to prevent a peak in oil demand before 2030. Gas demand is under pressure because of muted demand from power and buildings. Demand saw a brief rise in 2021 after which it started to decline, reflecting a switch to renewables in power generation, increased use of heat pumps and Europe's accelerated energy savings and shift away from gas following the Russian invasion in Ukraine.
- **Renewables momentum**. Closely related to the peak in fossil, is the continued momentum in renewables deployment. Higher interest rates and supply chain constraints create difficulties, but the overall picture is one of acceleration of deployment. Solar PV in particular is rising more than in previous versions, due to ample solar PV manufacturing capacity. It is mirrored in lower power generation from gas and coal. The strength of wind and solar reflects a number of factors already referred to: a) higher policy ambitions backed up by funding, in China, the EU, India, Japan and the US; b) cost reduction, such as the cost of electricity from solar (90% lower than in 2010), onshore (70%) and offshore wind (60%), with recent cost increases muted by scaling and innovation; c) manufacturing capacity and related industrial policies, helping solar PV in particular; and d) policy and regulatory frameworks that have helped reduce financing costs by providing operators with a high degree of revenue certainty, usually using long term contracts. That said, the recent rise in borrowing costs is a reason for concern.
- **China transition.** The transition of China, on the supply and demand side of the economy, that we have mentioned above is also included. This has an impact on all fossil fuel and on coal demand in particular, which is now significantly lower. As we saw, China is also heavily investing in renewables. Moreover, the rise in EV use, very prominent in China as well, has led to a projected 20% higher number of these vehicles by 2030. This will depress oil demand by around 1 million barrels per day, boosting electricity demand, also by 2030.

9 The reader may observe that this underlying APS scenario is STEPS mentioned earlier. For the purpose of simplicity, this reference is left out.

2.2 APS reinforced

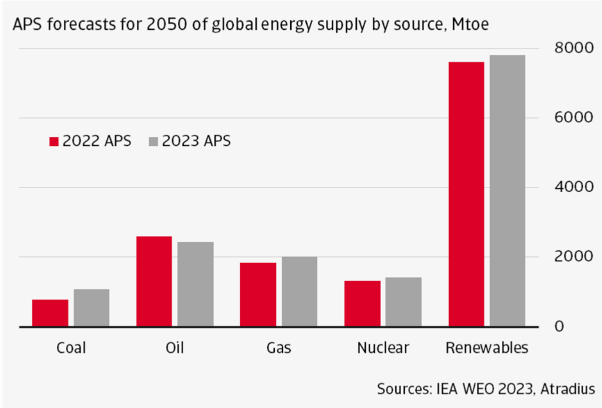
Against the backdrop that we have sketched above we now describe the developments in our main scenario, the Announced Policies Scenario. As mentioned earlier, this is the state of the world in which, besides the policies already implemented, those that are announced, however vague, are included. It is assumed that they will indeed be implemented, and in time. This may be seen as a bold assumption. But we continue to believe that, given the clear signs of climate change and the impact it is already having, countries will ultimately live up to their announced policies and implement them. What we are saying is that the so-called implementation gap will be closed.

Figure 2.3 Rapidly declining share of fossil fuels in APS



The main message as to the APS in this Energy Outlook is that the changes that we described in our 2023 Outlook are reinforced. These occurred in 2022 but did not stop at the end of that calendar year, thus firming up the picture in this Outlook. They play out while the fossil fuel prices have calmed. We essentially see two shifts. First, lower energy demand due to lower disposable income, and relatively more expensive energy that comes with the higher prices.[10] This leads to a more energy-efficient world, meaning energy is saved. This will be especially observable after 2030 and is already more pronounced now compared to the previous Outlook (figure 2.3).[11] Second, there is an impact on the energy mix, as renewables become more competitive relative to gas and other fossil fuels. This drives an accelerated shift in the energy demand towards renewables. This acceleration has been reinforced, as governments, faced with energy security issues, have taken a more active role in accelerating investments in renewables such as wind and solar PV but also nuclear power for energy generation.[12] The higher renewables investments support their increased competitiveness versus fossil fuels, as scale benefits are reaped. A comparison of the APS in our last Outlook with the current one confirms this picture (figure 2.4), albeit with some nuance.

Figure 2.4 Energy mix in 2050: APS 2022 vs APS 2023



The decline in oil demand by 2050 is indeed reinforced, as EV use will grow faster than previously envisaged. For gas and coal there is a (minor) upward adjustment. This is due to price rises during the crisis, and the envisaged higher levels post crisis have prompted additional investments which leads to production that is supposed to find its way to the market. These adjustments do not affect the overall picture of the sharply declining share of fossil fuels in the APS. Still, the decline is now even more pronounced as compared to the 2022 APS.

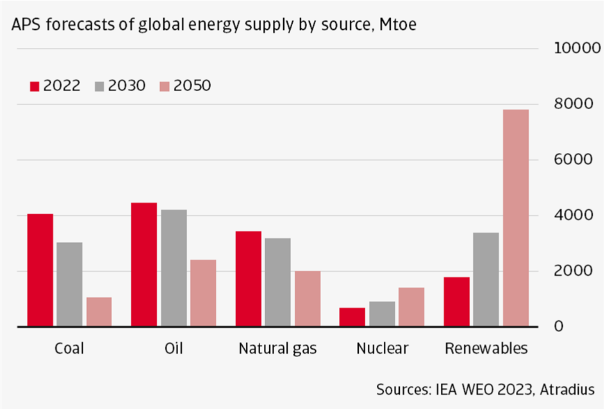
In the APS, total energy demand rises until the mid-2020s and then declines gradually, ending 3% lower than the 2022 level. All fossil fuels peak before 2030, coming out lower at that date than currently (figure 2.5). They then further decline after 2030. Renewables continue to grow and will come out five times higher than in 2022. Oil demand declines due to the rise of EV sales of passenger cars and trucks, outweighing the rise in aviation and petrochemicals. Robust support for clean energies reduces the demand for natural gas in the power sector and increasingly in buildings and industry as well. Gas gets a standby role in the power sector, a process reinforced by other options such as batteries that allow electricity buffering. The rise of renewables increasingly weighs in especially after 2030. Coal demand, with peaks in India and China in the mid-2020s, will decline, to 25% below its current level in 2030 and 75% below it in 2050. Solar PV and wind are leading the charge of the renewables, the use of which is projected to rise twofold by 2030 and more than eightfold in 2050. Other renewables such as bioenergy, geothermal, concentrating solar and marine power, likewise all have a part to play in the transition. Nuclear rises by 40% by 2030 and more than doubles in 2050, although from a relatively low level now.

10 These are the so-called income and substitution effects of a rise in energy prices.

11 The decline after 2030 as such is due to additional retrofit targets and updated energy codes kicking in, such as more stringent economy standards in transport and upgrades to industrial processes. Electrification is another source, as heat pumps and EVs provide more efficient energy use.

12 Coal as well, but that is temporary.

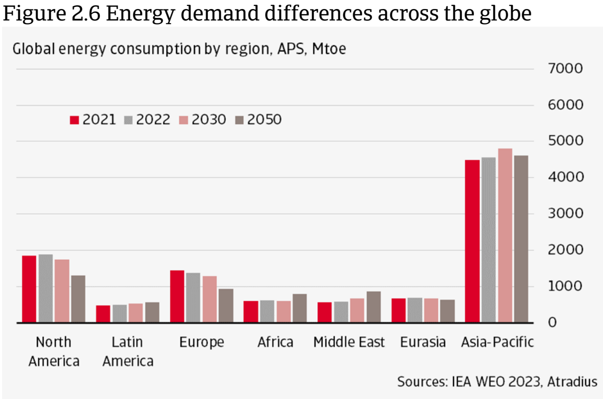
Figure 2.5 Renewables lead the charge



Advanced economies are leading the charge in reducing energy demand and changing its mix. Energy demand in the advanced economies is declining, helped by strong policy support. In the US the principal legislative vehicles are the Bipartisan Infrastructure Investment and Jobs Act of 2021, which invests around USD190bn for clean energy (and mass transit) and the Inflation Reduction Act of 2022, with an estimated USD390bn for energy security and climate change combat. This impacts mostly the power sector, but also transport and industry, stepping up the use of solar PV and wind in particular. The EU raised its clean energy ambitions in response to the energy crisis, with a strong emphasis on energy security. National and EU level packages were put in place for an amount of USD 500bn, achieving a 55% reduction of emissions and full independence from Russian natural gas in 2030. Electrification comes in parallel with decarbonisation of the power sector; EVs will account for 90% of all vehicles on the road in 2050 whereas the building sector is also electrified by the use of heat pumps.

In the emerging economies, energy demand continues to rise in the APS, simply because of the increase in the number of inhabitants and growth of the economies. Strong commitments and policies are needed make the energy transition happen. China and India have these ambitions, with objectives to be carbon neutral by 2060 and 2070 respectively. China is the largest producer and consumer of coal in the world, a major consumer of oil and gas, emitting one third of global CO2. But it is also the largest user of many clean energy technologies, with large shares in EVs sales, wind and solar as well as nuclear capacity. The country has updated its so-called Nationally Determined Contribution (NDC), reflecting faster progress in the energy transition. That includes an earlier peak of coal use, a faster curb on oil demand and use of natural gas to peak around 2030. India has adopted the net zero 2070 target in its updated NDC as well. This is backed up by regulation and tripling of the current investment level in clean energy by 2030. This leads to over 50% of non-fossil power generation already in that year, driving fast growth in electromobility, low emissions of hydrogen, grid expansion and other clean energy infrastructure. In Latin America and the Caribbean, representing over 60% of CO2 emissions in the region, half of the countries have pledged to achieve net zero ambitions by 2050 or earlier. Energy efficiency plays a key role, especially in moderating electricity demand in the building sector and further electrification of transport. This should help reduce the share of fossil fuels to below 60% in 2030 (from 67% today). In the Middle East, Saudi Arabia, Bahrain and Kuwait have set net zero targets by 2060; the UAE and Oman for 2050. Living up to these commitments implies a fourfold increase in clean energy investment by 2030, taking the share of these investment to half the total. Renewables, especially solar PV, will then account for 15% of power generation by 2030, accelerating to 67% in 2050. EV sales will amount to 15% of the total in 2030. Other regions have so far shown less ambition, partly due to lack of funding. In Africa 40% of the population still lack access to energy, 70% to clean cooking. As that is expected to change, energy demand will surge, initially relying on fossil fuels. Key policy initiatives can only be found in Senegal and South Africa. The economy in Eurasia, which includes Russia and the Caspian region, largely depends on fossil fuels. This is only changing gradually, ending at 75% in 2050, with limited policy initiatives in place so far.

Figure 2.6 Energy demand differences across the globe



2.3 Smaller implementation gap remains wide

The above picture of our baseline scenario, improved versus that presented in our earlier outlook due to various policy initiatives, leads to lower CO2 emissions as well. More specifically, it goes down from 12 gt to 10.9 gt in 2050 bringing us more firmly below the 2 degrees Celsius Paris Agreement threshold. A small step, but significant nonetheless. Still, there is no reason to celebrate. The reason for this is what we call the implementation gap. This gap, representing the difference between announced and implemented policies (as represented in the STEPS scenario), remains wide, especially after 2030. Under the APS, the CO2 emissions decline to 37.4 gt in 2050, a reduction of 26.5 gt compared to now. Of this reduction 60%, or 15.9 gt, represents the implementation gap (figure 2.7). This is large. The call for further action to close this gap therefore remains loud. As mentioned, we continue to believe that this will happen, although time is running out.

Figure 2.7 Implementation and ambition gaps remain wide

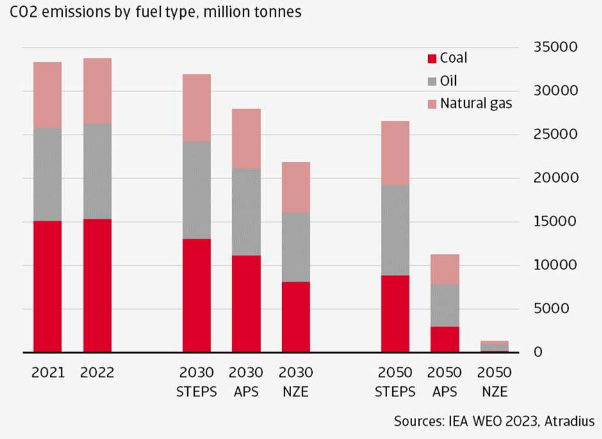
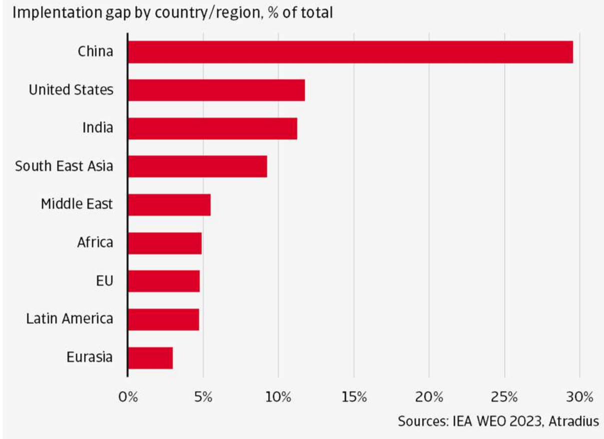


Figure 2.8 Implementation gap largest in emerging economies



How can this gap be closed? Of course, in general by backing up (vague) commitments with concrete policy measures. Of these we see several revolving around the themes mentioned in section 3. First, scale up technologies aiming at decarbonisation. This will involve the enhanced use of renewables, EVs and retrofits for existing power stations and efficient industrial processes. Existing technologies can be used for this. Until now less developed technologies will be needed as well, in particular for long haul transport and industry sectors such as steel. Second, electrification will have to be boosted even further, including for freight transport, industrial processes and heating in buildings. Third, apart from decarbonisation and electrification, energy efficiency measures need to be scaled up even more prominently. Fourth, bioenergy, solar thermal and geothermal sources supplementing existing renewables are to be developed. Finally, remaining CO2 emissions should be neutralised using carbon capture, utilisation and storage (CCUS).[13]

The largest challenge of the implementation gap is predominantly in the emerging economies, most significantly in China and India (figure 2.8). Of the global implementation gap of 15.9 gt, just under 50% has to come from these countries. If other emerging economies such as in southeast Asia, Latin America and the Eurasian region are added this figure easily climbs to 75%. Of the advanced economies, the implementation gap is still relatively large in the US at around 13% of the global total; the EU with an economy of a similar size, has a gap that is currently at about less than half this level.[14] Therefore, the EU is arguably leading the charge in the energy transition in the advanced economies. The emerging economies need to step up their efforts.

2.4 Net Zero by 2050 not out of sight (yet)

With the sizable effort required to close the implementation gap we are not there yet. In the APS scenario 10.9 gt CO2 emissions would remain in 2050, implying a temperature rise of 1.7 degrees Celsius. This is already a long way towards the 1.5 degrees Celsius temperature rise of the Paris Agreement, let alone the 2.6-2.8 degrees warming that we mentioned in section 1. The difference between the two figures seems small, so why bother? The point is, it is small but nevertheless highly significant. In view of what we are currently experiencing with the climate, every tenth of a degree of reduction of global warming is worth pursuing. Moreover, it is in line with what the IPCC calls a 'low or no overshoot scenario'.[15] The latter means that prolonged periods where a higher temperature hardly occur. It is simply a more desirable and more comforting outcome. Such a world is described in the Net Zero Emissions by 2050 scenario (NZE).

It is a world in which net CO2 emissions, as the name suggests, are brought back to zero. For this to be achieved, another gap needs to be closed. This is called the ambition gap, the difference between the APS and NZE. It involves the elimination of all (net) CO2 emissions by 2050. To achieve this, a further reduction of CO2 emissions by 10.3 gt in 2050 is needed. In 2030, CO2 emissions already need to be 5.8 gt lower than in the APS. This requires only announced ambitions by countries, not policies to back these up. But they are lacking so far. There is some progress, still. This is simply because there is progress under the APS in terms of reduction of CO2. The lower CO2 emissions figure under the APS means that the ambition gap is lower as well. We are on firmer ground in the NZE scenario as well.

13 To get a feel for the challenge, the IEA has estimated that there is a need for CCUS capacity of 1.6 gt by 2030 and 6-8 gt by 2050. Current capacity under construction and development is just 360 mt by 2030 if all completed.

14 These are our estimates based on the IEA Energy Outlook.

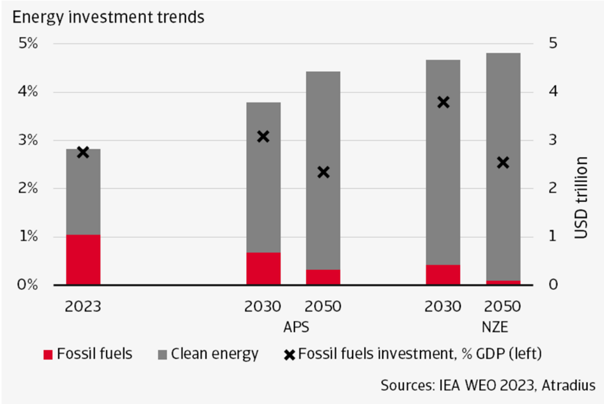
15 IPCC stands for the United Nations' Intergovernmental Panel on Climate Change.

The size of the implementation gap nevertheless remains significant. To close it, net zero commitments are needed. These commitments indeed need to be backed up with policy measures. They evolve around the themes already discussed above.

First, clean electricity generation, and more specifically a decline in the use of coal in the NZE that is much more pronounced than in the APS. In the emerging economies, where coal is still dominant in the power sector a lot more needs to be done. In the NZE scenario, low emission sources are used, as well as expansion and modernising of grids. Energy storage is ramped up. Second, efficiency improvements are combined in the NZE with materials efficiency and behavioural changes such as working from home, carpooling and less (business) travel. The result is a 5.5% decline in energy use by 2030, versus an increase by 2% in the APS. Third, electrification of end-users, in all sectors of the economy. Fossil fuel does not disappear, not even in the NZE but its importance wanes: 16.4% of total energy demand by 2050 as compared to 37.4% in the APS. It is replaced by electricity. By 2030 more than 60% of new car sales are electric (more than 40% in the APS). In the emerging economies electrification in transport focusses on two/three wheelers and urban buses. Biofuels, hydrogen and hydrogen fuels come into play in aviation, shipping and long-haul freight transport. In the industrial sector, continued demand for industrial materials, such as steel and cement, for industrialisation and urbanisation continue. Stringent emission standards in the NZE help support the transition for efficient use of these, such as additional support for enhanced and even untested technologies. Fourth, other greenhouse gases, such as methane fall steeply in the NZE. In particular, energy related emissions drop. This is compounded by lower fossil energy supply as well as deployment of emission reduction technologies in the fossil fuel sector. The agreement on methane reduction during the COP28 helps us to view this as realistic and will lower the CO2 emissions in the APS as well. Fifth, low emissions technology is increased significantly. This concerns battery capacity for the expansion of EVs, with critical metals such as lithium being available. In the industrial sector, hydrogen production from fossil fuel is largely replaced by electrolyse. Already in 2030, in the NZE, 69mt low emission hydrogen is available (25 mt in the APS). CCUS technologies in the NZE scenario countries adopt the best available technology to mitigate emissions from industrial plants to meet global demand for low emissions hydrogen. In 2030, 1gt CO2 is captured, 250% more than in the APS.

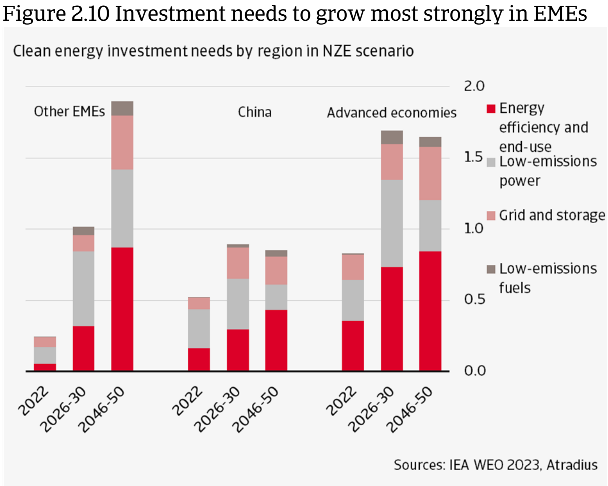
Closing the ambition gap requires levels of investment in comparison to which the level of USD 2.8 trillion in 2023 pales. By 2030 the amount should go up from 2.8% of GDP in 2023 to 3.8% or USD 4.6 trillion. Only around USD 400 billion comes from fossil investment in 2030, the rest from investments in clean energy. This is to be brought down further to USD 250 billion in 2050 under the NZE. Indeed, the complement of this development is a huge investment in clean energy, to the tune of USD 4.4 trillion in 2030 and USD 4.8 trillion in 2050 in the NZE (figure 2.9).

Figure 2.9 Investments in fossil fuels to drop from 2030 to 2050



The bulk of the increase in investments is to come from the emerging economies, especially those other than China, where the levels are to increase fourfold in 2030 and sevenfold in 2050. To compare, current investment levels in these countries are at about USD 250 billion per annum, whereas in China and the advanced economies amounts of USD 500 billion and USD 800 billion per annum respectively have been reached. These levels of investment are to increase by a factor of 1.5 and 2 respectively under the NZE. This is not peanuts, but quite some progress has been made. Not so in the emerging economies other than China, reemphasising that these countries have a long way to go. The bulk of the financing resources should indeed go to these countries (figure 2.10).

Figure 2.10 Investment needs to grow most strongly in EMEs



The picture is not fundamentally different in the APS, albeit that the amount and percentage of GDP for fossil is somewhat higher and those for clean energy somewhat lower.

3. Renewable energy outlook

2023 was a very good year for renewables. Benefitting from ongoing high prices for oil and gas, geopolitical risks fuelling energy security and declining costs especially for solar, a record year for adding renewable capacity was achieved. Particularly in China, the increases in renewable capacity were impressive. Here, supportive policies and low costs for solar energy boosted renewables. Pledges at the COP28 will boost investments in clean energy and efficiency. In our base scenario, the Announced Pledges Scenario (APS), it is assumed that governments will meet all announced national energy and climate targets. In that case renewables will increase strongly towards 2050, with solar PV becoming the dominant energy source. In the Net Zero Emissions by 2050 Scenario (NZE) more is required to limit the temperature rise to 1.5 degrees Celsius.

3.1 COP28 pledges provide boost

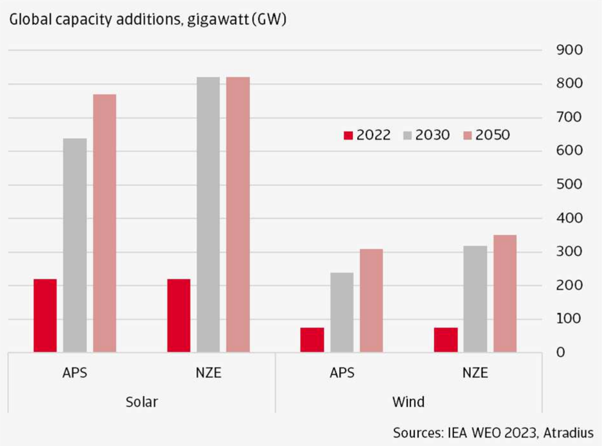
Capacity additions of solar PV and wind reached a record high in 2023. All-time highs were hit in Europe, the United States and Brazil, but the increase in capacity in China was the most impressive. In 2023, China added as much solar PV as the entire world did in 2022 and it increased its wind capacity by a stunning 66%. Continuous policy support around the globe and declining costs contributed to this impressive growth in renewables. This strong growth is expected to continue as the IEA revised its forecast upwards in its Renewables 2023 report. In most countries and regions, the increase reflects policy changes and improved economics for large-scale wind and solar PV projects. But consumers also play a role as they are adopting solar PV systems faster due to the higher electricity prices. Although renewables will increase faster in most countries, it is especially China that is responsible for the upward revision. Thanks to the sharp increase in solar PV manufacturing capacity, it created a supply glut and was responsible for a decline of local module prices by almost 50% from January 2023 to December 2023, thereby increasing the economic attractiveness of both utility scale and distributed solar PV projects and making solar more affordable than investing in new and existing coal- and gas-fired power generation. That said, trade measures against Chinese cells and modules means not all countries could benefit from the lower costs for solar PV.

- **Sharp increase in solar manufacturing.** Large-scale investment has led to strong growth in China's solar PV manufacturing capacity. This currently exceeds both local and global demand and is responsible for a sharp decline in module prices and has made solar installations more competitive. Solar manufacturing is highly concentrated, with only five countries accounting for over 90% of global capacity. Of these five China is by far the largest, representing around 80% of global solar manufacturing capacity. China is the largest exporter of solar panels, and consequently actually facilitates the expansion of renewable energy around the world. China is planning to add more manufacturing capacity in the coming years, thereby remaining the primary exporter of solar panels. Other countries are also planning to add manufacturing capacity, but this might be solely for covering domestic demand. An exception is India, which is planning to add more capacity to meet both domestic needs and for exports. In the US, investments in production capacity are set to rise, supported by the Inflation Reduction Act. But here, as in the European Union, solar manufacturing domestically will not cover the fast-growing solar PV deployment. The EU and the US will remain large importers of solar panels. If all planned increases in global solar manufacturing capacity go ahead, it could potentially match the level of solar deployment reached in 2030 in the NZE scenario.
- **COP28 pledges will boost renewables.** Almost 200 governments have agreed to triple renewables in the power sector from 2022 by 2030. This would bring the global renewable capacity in the power sector in 2030 in line with the NZE scenario. In the latest Renewables 2023 report, the IEA stated, however, that we are not yet there. Under existing policies and market conditions global renewable capacity will increase strongly but falls short of the tripling target. It is up to governments to reach this target through accelerating the implementation of existing policies and overcoming some challenges. The IEA signals a number of challenges, but these vary by country and region. First are the policy uncertainties and delayed policy responses to the new macroeconomic environment. Second are the insufficient investments in the grid infrastructure. The third challenge concerns administrative barriers and permitting procedures. Last but not least the insufficient financing in emerging markets and developing countries.

3.1.1 Solar leads renewables addition

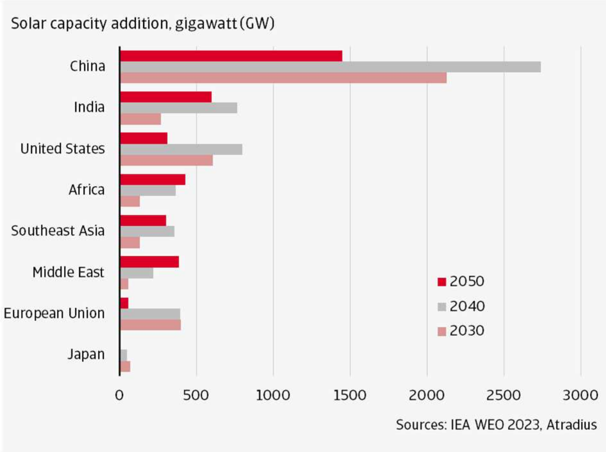
Supportive policies around the world and declining costs, especially for solar, facilitate the strong growth in renewables. Global solar PV capacity additions have reached record levels year on year. In the World Energy Outlook 2023 the IEA announced that around 220 GW was amended in 2022, and this is expected to increase to 640 GW in 2030 in the APS. In the NZE, capacity additions will rise even faster, reaching 820 GW in 2030. These solar PV capacity additions include rooftop solar and utility-scale projects. The global wind market is facing some challenges, and this led to a drop in capacity addition in 2022 to 75 GW. It is, however, expected to recover and falling costs and improving technology will result in increased capacity of 240 GW in the APS by 2030, in comparison with 320 GW in the NZE scenario. Far behind the yearly capacity additions of solar.

Figure 3.1 Falling costs boost solar PV



As in previous years, China will lead the growth in renewable capacity. China is expected to add the most capacity, both solar and wind, towards 2030 and in the longer term to 2050. Despite the phasing out of wind and solar subsidies in 2020 and 2021, solar PV and onshore wind capacity is increasing thanks to its economic attractiveness and supportive policy environments providing long-term contracts. China's Net Zero by 2060 and its 14th Five-Year Plan (2021-2025) are boosting renewables, enhanced by the ample availability of local manufacturing capacity and low-cost financing. Currently, generation costs for new utility-scale solar PV and onshore wind systems are lower than for coal in almost all provinces[16]. This provides provinces the opportunity to move away from coal. China is expected to reach its national 2030 target for wind and solar PV installations already this year.

Figure 3.2 APS: China leads renewables growth



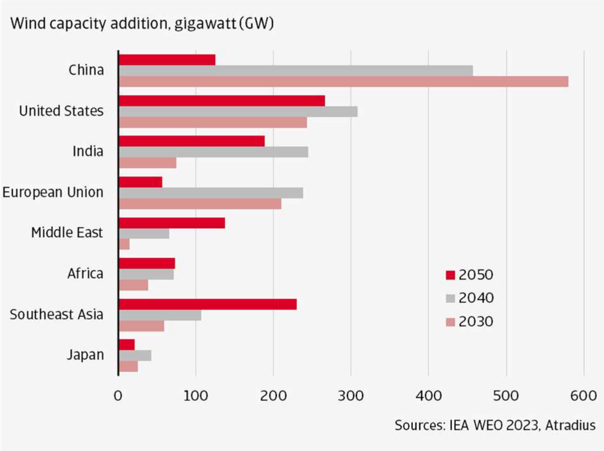
Other countries where solar PV and wind energy will grow strongly are the US, the EU, India and Brazil. Important drivers are the supportive policy environments and the economic attractiveness of solar PV and onshore wind. In the **US**, the Inflation reduction Act is boosting the use of renewables. This legislation, announced in August 2022, will support the energy transition in the US. The largest impact of this government support will be visible in the power sector due to the tax credits that will accelerate the deployment of solar PV and onshore wind in the coming years. In the near term there are, however, some market challenges. Supply chain constraints have led to project delays of both solar and wind, and complying with trade regulations could cause delays of solar modules. The forecasts for offshore wind have been revised downwards by more than 60% because developers are delaying or cancelling projects due to the challenging market conditions.

In the **European Union** the energy crisis led to an increase in clean energy ambitions, with energy security as an important pillar in the energy transition. Large legislative packages and many national and EU-level incentives have been announced to accelerate the move to renewables and reduce dependency on fossil fuels. In the APS scenario, most targets in the Fit for 55 package will be met. This also envisages that the EU will meet the REPowerEU goal of eliminating dependence on Russian gas before 2030.

India will become the third largest market for renewables. Due to an expedited auction schedule for utility-scale onshore wind and solar PV, growth will accelerate in this market. Especially between 2030 and 2040 when it is progressing towards NetZero in 2070, solar and wind capacity are expected to grow strongly. As in the EU, in **Brazil** rooftop solar PV in particular is expected to increase strongly, outpacing the large-scale plants, because consumers want to reduce their electricity bills.

16 Renewables report 2023, IEA

Figure 3.3 APS: Wind faces challenges



Wind capacity will also increase strongly, but much less than solar. Particularly in China, wind capacity will grow considerably. Towards 2030, the US and the European Union will follow second and third. Outside of China, the wind industry is facing challenges due to the changing macro-economic conditions. Inflation has resulted in rising equipment costs for onshore and offshore wind. In addition, the higher interest rates have increased the financing costs of capital-intensive variable renewables. Because governments were late with policy responses to these higher costs and permitting challenges, several auctions, especially in Europe, were undersubscribed. Even developers whose power purchase contracts were signed prior to the economic changes have cancelled their projects. Therefore, the short-term outlook for wind is less optimistic than that of solar and is the reason for the IEA to revise downwards its forecast for wind capacity expansion, especially for offshore wind, outside China. Most large Western manufacturers have reported losses over the past two years. Project development has been slower in most countries. In the European Union long permitting waiting times, supply chain challenges and higher equipment and financial costs have reduced onshore wind deployments. This is also especially visible in the US and the UK, two large markets for offshore wind, where the changing economic conditions resulted in delays or where projects are even at risk of being cancelled.

3.2 Electricity

While global energy demand will decline in the coming decades, demand for electricity will grow strongly. This increasing demand is mainly driven by emerging and developing countries where economic development, the increasing population and rising income are responsible for this strong growth. In both scenarios, APS and NZE, these countries will account for around three-quarters of the global electricity demand. Demand for household appliances, air conditioning and heating will increase strongly in these markets. In advanced economies, electricity demand will grow less rapidly, because efficiency gains in household appliances and heating and cooling systems will temper demand in these countries. In the advanced economies, it is especially the transport sector that is responsible for the strong growth as the sale of electric cars will increase considerably. Overall, by 2050 electricity demand will be 120% higher than nowadays in the APS. In the NZE, electricity demand will be 150% higher in 2050, because the electrification of end-users will be faster. In all sectors demand for electricity will increase.

This higher additional electricity demand will be entirely met by low-emissions sources of electricity; renewables will become the dominant electricity source. Globally, solar PV will become the most dominating electricity source, but regionally the most predominant source can differ. For instance, in the European Union, wind will be the main renewable energy source, whereas solar will become the leading technology in China.

3.2.1 Electrification will take off

In 2022, electricity in the global energy final consumption was around 20%. In the next 8 years this share will only increase marginally. In the APS, electricity will account for 24% in 2030, in comparison with 28% in the NZE scenario. Towards 2050, the electricity share will accelerate - to 41% in the APS and 50% in the NZE scenario. In both scenarios this is attributed to the sharp increase in electric cars. In the NZE scenario, the expected increase in residential and industrial heat pumps is also contributing to the rise of electricity use.

Particularly in the **transport sector,** electrification will take off. Although nowadays oil is still the dominant fuel source used in transport, accounting for around 90% of consumption, this will decline in both the APS and NZE scenario. Especially in the NZE scenario, the decarbonisation of the transport sector will accelerate. In the lead up to 2030, electrification will mainly take place in road transport as the sale of electric vehicles will accelerate due to widespread policy support. Other transport sub-sectors like aviation and shipping will take more time to decarbonise. The use of electricity in the transport sector will increase from only 1% in 2022 to 5% in 2030 and 27% in 2050 in the APS. In the NZE scenario, electricity will account for 8% in 2030 and accelerate to 51% of the energy consumption in 2050. In contrast to the APS, in the NZE scenario the use of oil will drop sharply between 2030 and 2050. Hydrogen is expected to accelerate mainly after 2030, increasing from nil in 2022 to a share of 14% of energy consumption in 2050. Especially in aviation and shipping, the use of biofuels, hydrogen and hydrogen-based fuels will increase.

Around 50 countries have policies in place to incentivise the use of EVs. For example, countries have set target dates to phase out internal combustion engine vehicles. Also supporting the sale of EVs is the fact that car manufacturers have plans to release new electric car models in the coming years or have themselves net zero targets. Local EV manufacturing hubs have been established in large consumer markets like India, Indonesia, and Thailand. Already China is an important hub for EV manufacturing, providing a boost for the sale of EVs. In China, the sales of electric cars are also supported by tax exemptions. In 2022, electric cars accounted for 29% of total cars sold. In Europe the sale of electric cars is also accelerating. In 2022, around 20% of total cars sold were electric and it is expected that due to the CO2 standards adopted for passenger cars this share will increase sharply towards 2030. Although in the US the share of EVs is still limited at 8% of total cars sold, there is strong growth in sales supported by tax credits for electric cars and investments in charging infrastructure. Overall, electric cars accounted for 14% of new car sales in 2022. This will increase to around 44% by 2030 in APS, compared to 66% in the NZE Scenario. To support the strong growth in EVs it is important that investments take place in charging infrastructure and enhancing electricity networks so that the infrastructure can support this expansion.

In other energy consuming sectors like **industry** and **buildings**, electricity is already broadly used. Currently, around 23% of the energy used in this sector is electricity. As industry is the most energy consuming (including iron and steel, chemicals) and CO2-emitting sector, the decarbonisation progress should accelerate. Fossil fuels still account for 35% of energy consumption in this sector, with coal still the largest. Progress in greening this sector is slow, as is improving efficiency. Only a few companies have set targets to produce low-emissions materials. It is expected that in both scenarios, electrification will accelerate through direct electrification or through the use of hydrogen produced using electrolysers. In several countries there are plans for greening the industry.

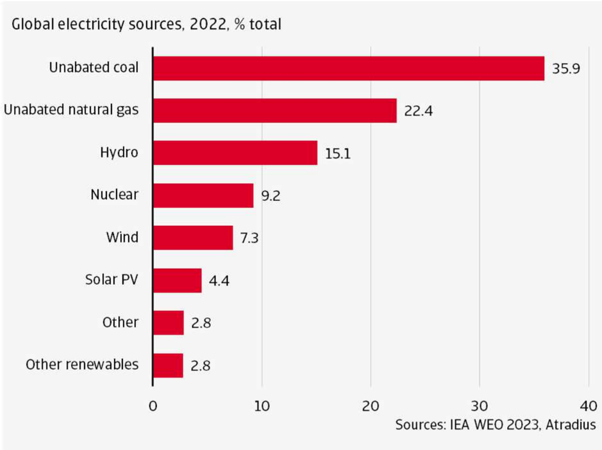
Hydrogen investment projects have been announced, are promising, but progress is slow. In 2022 investment projects reached USD 1 billion, and last year the world largest operational electrolyser plant in China switched to hydrogen from natural gas. A major project in Saudi Arabia reached final investment decision. Around the world projects are increasingly being planned. If all projects in the pipeline are realised, more than 400GW of electrolysis could be operational by 2030. This would be good news as it is in line with targets in the APS scenario. That is, if all plans go ahead, because cost inflation, supply chain bottlenecks and policy uncertainty could hamper this progress.

3.2.2 Greening the power sector

Electricity supply differs between countries, depending on the available resources, policy choices and the relative economic competitiveness of various power generation technologies. Looking at the energy sources in the global electricity generation sector, coal with a share of 36%, is still the dominant energy source. It is however, as soon as 2025, to be overtaken by renewables.

In 2022, the share of renewables in electricity generation was around 30%. The largest sources within renewables are hydropower, solar and wind. Nowadays, hydropower is still the largest with a share of 15% of electricity generation, followed by wind (7%) and solar (4%). Although hydropower will remain an important source for electricity generation, its role within the decarbonisation of the power sector is limited because hydropower is already a mature technology and therefore has limited room to grow. Owing to its vulnerability for weather conditions and climate change, its annual output can vary widely. Besides, the high upfront capital costs and limitations on development of favourable sites constrain further growth prospects. Therefore, its share in electricity generation will decline towards 2050.

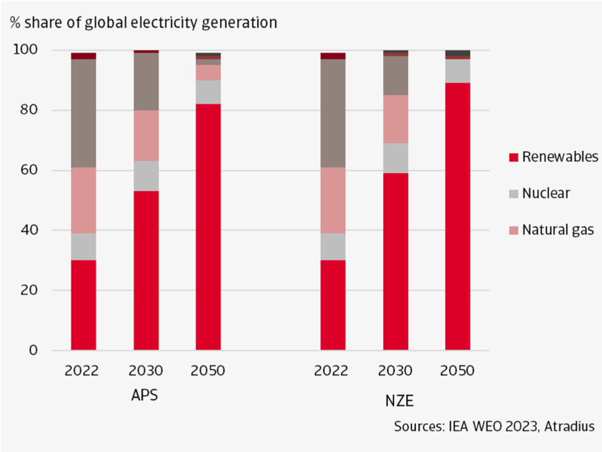
Figure 3.4 Coal still the dominant electricity source



Another low-emissions power, nuclear, also a large share and is currently far larger than the use of solar and wind. Especially in advanced economies, nuclear is the largest low-emissions electricity source. A changing political landscape will support the use of nuclear power in the coming years. Particularly in China and other emerging markets, nuclear will grow. In advanced markets, countries will extend the lifetime of existing nuclear reactors (Japan, Korea, and USA) and look for new projects (Canada, UK, US).

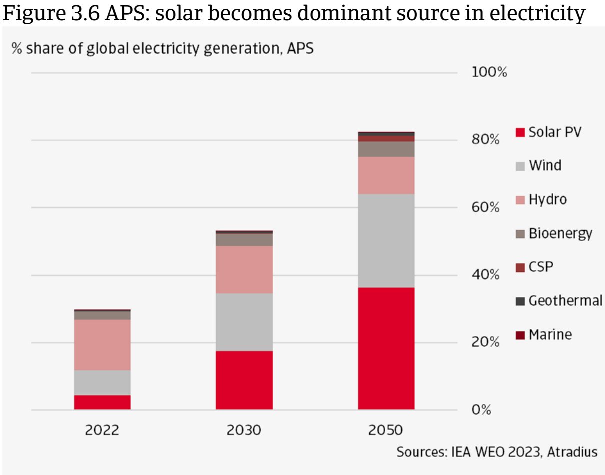
Supported by policy enhancements to accelerate the energy transition, renewables will grow strongly in the power sector and will soon become the main source. In the wake of the energy crisis, there is a strong momentum for renewables as they can address security challenges while accelerating the energy transition. Many countries have policies in place and have updated their Nationally Determined Contribution (China, India) that will support renewables in the power sector. Declining costs for solar, wind and batteries, technology innovation and progress will facilitate the strong growth in renewables. In APS, renewables will account for 53% of electricity generation in 2030 and 82% in 2050. In the NZE scenario, renewables will grow even faster and will have a share of 59% in 2030 and 89% in 2050.

Figure 3.5 Renewables grow strongly



Solar will keep the momentum of previous years and grow strongly in the coming years. Supported by declining costs it will be the fastest growing renewable in the coming years. The outlook for solar is even better than forecast last year. In 2022, solar had a share of 4% in total electricity generation. In the APS this will grow to 18% in 2030 and accelerate to 36% in 2050. Solar will thereby surpass wind and hydropower by 2030 and outpace these two sources considerably by 2050. Wind will also increase sharply, from 7% in 2022 to 17% in 2030 and 28% in 2050. In the NZE scenario, solar and wind are expected to increase to 21% and 19% respectively in 2030. Towards 2050 this share will increase to 41% for solar and 31% for wind. Other renewable sources like geothermal and bioenergy will have limited shares in electricity generation.

Figure 3.6 APS: solar becomes dominant source in electricity



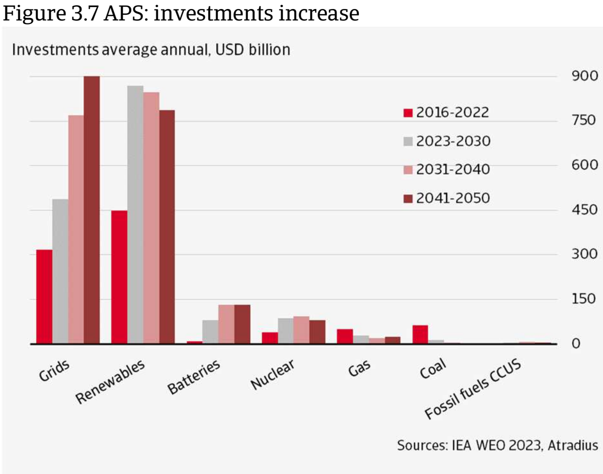
With solar and wind becoming so important in the power sector, investment in a reliable stable electricity supply and flexibility of the sector is crucial. In order to avoid delaying the strong increase of solar and wind it is crucial to speed up permitting and grid expansion. It can take years to modernise, digitalise and reinforce existing electricity networks, so streamlining permitting and licensing processes is necessary. Already in many advanced economies, like Spain, the UK and the US there are grid connection queues for wind and solar projects. Moreover, long term planning and the scaling up of investment is crucial. The IEA foresees that hydropower and thermal sources will also play a central part in providing seasonal flexibility.

3.3 Investments in the power sector

Most investments taking place in the power sector will be directed to the deployment of renewables and the grid. In the APS scenario, total world investments in the power sector are expected to increase to an annual average of USD 1.6 trillion in 2022-2030 - almost double the amount invested annually between 2016 and 2022.

In the APS, investments in renewables account for almost half of total investments in the next decade. Investments in renewables will remain high in subsequent years but are expected to decline. This is in contrast to investments in the grid, where increasingly more money is needed to make the electricity networks ready for the rising use of variable electricity sources and the strong growth in electricity demand. In 2023, annual investment in grids was expected to reach USD 330 billion and this needs to climb to USD 620 billion in 2030 in the APS and to USD 680 in the NZE scenario.

Figure 3.7 APS: investments increase



A stable and reliable grid will facilitate strong growth in renewables. Power generators will need to be more agile, consumers need to be more connected and responsive, and the grid infrastructure will need to be strengthened and digitalised to support the more dynamic flows of electricity and information. An important factor for meeting short-term flexibility needs, especially after 2030, concerns battery storage and demand response. In the APS scenario, investments in batteries will increase from an annual average of US 8 billion in 2016-2022 to USD 80 billion by 2030. Most investments will take place in advanced economies and China. Investments in other emerging and developing markets are lagging due to the relatively high cost of capital and lack of capital.

4. Oil market outlook

Oil markets have stabilised after years of volatility following the pandemic and Russia's invasion of Ukraine. Demand for oil is muted in part thanks to targeted policies, in part due to slower economic growth. Supply on the other hand has proven more resilient than expected, with strong growth from the Americas in particular. As such, the short-term outlook is much more stable and more resilient in the face of geopolitical risk.

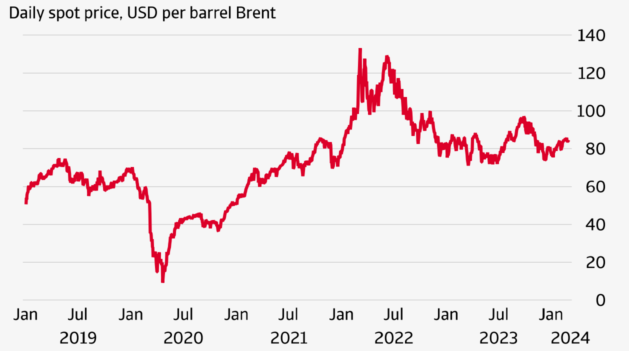
Following the IEA's Announce Pledges scenario (APS), we expect the weaker trend in demand to continue, bringing it 4% lower in 2030 compared to 2022. The pace of decline will accelerate from 2030 to 2050, bringing global demand down 43% by 2050. Under the Net Zero emissions by 2050 scenario (NZE), the decline in demand is much more precipitous, falling by 20% in 2030 already and by 74.8% in 2050. In our baseline scenario (APS), the electrification of the road transport sector, especially in advanced economies and in the longer term, China, will drive the decline in demand. Demand for oil in EMEs in Africa will continue to rise to 2050 and be flat in Eurasia and the Middle East. The chance of moving to an NZE future is largely dependent on EMEs reversing this trend. On the supply side, the US will remain one of the world's largest oil producers next to Saudi Arabia, but the market share of OPEC+ members will rise to 44.6%, increasing the cartel's market influence. Prices will decrease as demand wanes, but ongoing investment is needed to ensure supply is sufficient.

4.1 Key developments: Russia defies sanctions

The exceptional volatility that hit the oil market in the wake of the pandemic receded in 2023. After gradually recovering from the collapse in demand in 2020, prices spiked above USD 130 per barrel of Brent crude in February 2022, following Russia's invasion of Ukraine. 2022 saw several more upward swings due to inflexible supply side dynamics. But market tensions eased in 2023 as slowing global economic growth weighed on demand which was more than met by global supply with record US production alongside higher-than-expected Russian output. Prices eased to USD 82 per barrel from USD 101 in 2022.

On the demand side, demand for oil recovered to 2019 levels in 2023. The reason for the slow recovery was rising inflation around the world and slowing global GDP growth that persisted through 2023. Higher consumer prices compounded by rising interest rates slowed consumer spending and consequently demand for oil. US consumer spending has defied expectations and the US economy has remained buoyant despite rapid monetary tightening from the Federal Reserve. This has sustained relative US dollar strength as well, as the nominal USD index against a basket of currencies fell 1.7% in 2023, after a nearly 10% bull run since the pandemic. Given that global oil sales are denominated in US dollars, oil imports remained relatively more expensive for other countries, especially emerging market economies, further weighing on demand.

Figure 4.1 Oil prices stabilised in 2023



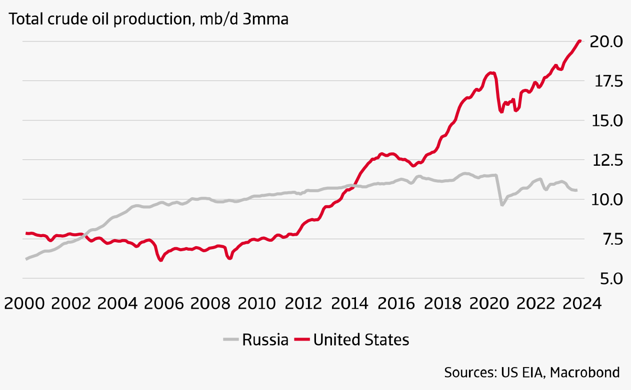
Source: Macrobond

China's demand recovery is largely behind the global demand recovery to pre-pandemic levels. China is one of the world's largest oil consumers, accounting for 15% of global demand. Oil demand recovered through 2023 following the scrapping of its 'zero Covid' policy in December 2022, accounting for more than half of global demand growth in 2023. On the industry side, aviation was the main driver of global demand growth. The aviation sector was the last major sector to bounce back from the pandemic as global growth remained muted; but there are also limited alternative fuel sources to oil.

On the supply side, OPEC+ has continued to prioritise supply management to keep prices elevated. OPEC member countries and other major oil producers including Russia introduced a series of production cuts in response to concerns about weaker global demand and lower prices. In June 2023, OPEC+ agreed after long negotiations to extend their production cuts of 3.66 mb/d (about 5% of daily global demand) until the end of 2024. Then in November, OPEC+ members agreed to further individual voluntary cuts instead of groupwide cuts, totalling around 2.2 mb/d, led by Saudi Arabia (1 mb/d). OPEC+ announced that Brazil would join the alliance from January 2024, but Brazil has not committed to any production cuts. Russia also pledged cuts of 0.2 mb/d of fuel export reductions. While Russia has agreed to voluntary production cuts to support OPEC+ in keeping prices elevated, its overall output has been one of the upside surprises for 2023.

Despite Western sanctions, Russia has continued to export large volumes of oil, helping keep supply sufficient to prevent more upward price swings over the past year. The latest data show that Russia still produced 10.7 mb/d in October 2023, down just 0.6 mb/d from 11.3 mb/d in February 2022 when it invaded Ukraine (see figure 4.2). Russia has broadly managed to avoid the EU and G7-imposed price cap by redirecting exports from the EU to third countries like India, China and Turkey which are able to purchase Russian oil at a discount.

Figure 4.2 Russian production stable while US reaches new highs



The OPEC+ production cuts have been largely offset by higher output elsewhere in 2023. The US has led this increase with field production there reaching an all-time high of 13.3 mb/d in January 2024. Including petroleum products, as presented in figure 3.2, total US supply has reached 20 mb/d. Following years of declining investment, exacerbated by the pandemic-induced slide in output, production growth has surged in the US, growing 6.9% y-o-y in 2022 and 8.5% y-o-y in 2023. This has increased the US's influence on global oil prices again, undermining OPEC+ efforts to manipulate prices. Remarkably, this surge in US output comes despite a decrease in the number of active oil rigs. According to Baker Hughes data, there were 500 active oil rigs as of the end of 2023, down from 618 at the start of the year and a peak above 1,600 during the shale boom of 2014. As shale producers account for two-thirds of US output, the growth is driven by efficiency improvements, such as drilling longer horizontally and concentrating rigs in the highest-yield locations.

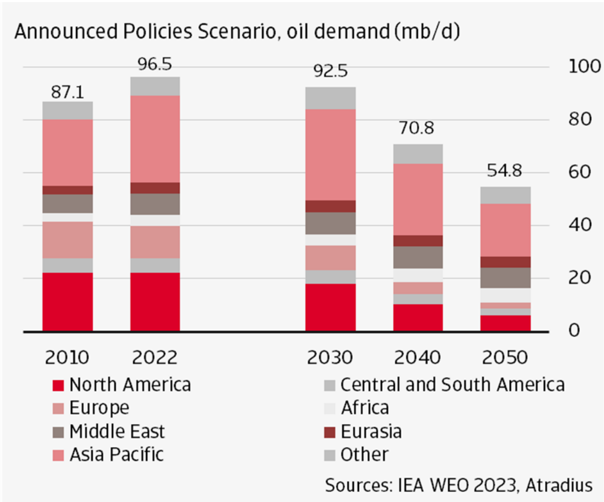
4.2 Oil demand: peak comes earlier

Peak oil is in sight in the coming years, and we expect to see demand for oil decrease thereafter. The trajectory for oil demand and the underlying trends is broadly in line with the APS pathway presented last year. Global demand for oil is estimated to have increased by 2.3 mb/d in 2023, surpassing 2019 levels for the first time. But the pace of growth is expected to halve in 2024 to 1.2 mb/d as GDP growth slows and the gains from the post-Covid recovery fall away. Moreover, electrification of the vehicle fleet and energy efficiency improvements are increasingly weighing on demand growth. These trends will continue over the forecast horizon, causing global demand to begin decreasing in the second half of this decade.

Global demand for oil is set to decline on average 0.5% per year from now to 2030, primarily thanks to the road transport sector. Road transport accounts for 45% of global oil demand, far more than the next biggest sector, petrochemicals (15%). But the share of oil in road transport's total energy demand mix is expected to drop from 92% today to 84% in 2030 as the sector moves towards electromobility and the increased use of biofuels. Demand for oil in the industrial sector will continue to increase over this period, but only by 0.8 mb/d as a result of policies targeting oil demand like bans on single-use plastics and the widespread collection of plastics.

This global decline is concentrated in advanced economies, which lead the electrification of car fleets. OECD countries, which account for 43% of global oil demand today, already saw their demand peak in 2005. This downward trend will continue, with demand declining a further 8.4 mb/d by 2030. This translates to an average decline in demand of 2.8% per year. The largest absolute decline will come from North America: 4.1 mb/d bringing annual consumption there to 18.1 mb/d in 2030. The pace of decline will be the highest though in Europe (-3.7% vs. -2.5% per year in North America).

Figure 4.3 Oil demand to fall in coming decades



Emerging market economies will continue to see increasing oil consumption to 2030. Non-OECD countries consume 50% of global oil today[17]. That share will rise to 56% in 2030 as EMEs add a further 3.1 mb/d to their demand. The largest absolute increase in consumption will come from Asia-Pacific where consumption will increase by 1.7 mb/d to 34.6 mb/d in 2030, driven by rising demand in China. The pace of growth is slowing sharply though, from 2.3% average annual

17 The 7% remaining of global oil consumption not consumed by OECD or non-OECD countries is consumed by international ships and aircraft.

growth from 2010 to 2022 down to only 0.6% annualised growth. Among EME regions, Central & South America are bucking the trend of increasing demand in this decade. The region is already a relatively small consumer, accounting for only 5% of global demand, and is forecast to see consumption decrease another 0.4 mb/d to 5.1 mb/d in 2030. Africa, with an even smaller share of global oil consumption (4%) sees annual demand rise 1.5% to 2030, the fastest average annual growth rate among regions due to rapid economic development, population growth and urbanisation.

From 2030 to 2050, the decline in global oil demand will be much more pronounced than in the current decade, falling on average 2.6% per year. Should countries adhere to the climate pledges they've already made, demand for oil would fall by 41.7 mb/d to 58.4 mb/d in 2050. It would also be more geographically spread. After China's oil demand peaks before 2030, Asia-Pacific will begin to see demand declining on average 2.7% per year to 20.1 mb/d in 2050. This region will remain the biggest global consumer (37%), but it will also contribute the largest absolute decline in oil demand, shaving off 14.5 mb/d. North America will follow with a reduction of 12.1 mb/d, followed by a 6.8 mb/d reduction in Europe. The only region that will continue to see growth in oil consumption is Africa, growing at a slightly slower pace of 0.9% per year from 2030 to 2050. Overall, OECD countries become significantly less important for the global oil market as their shared demand falls to 10.4 mb/d in 2050 - 19% of global consumption. Non-OECD markets on the other hand see their share of global consumption rise from half to 69%.

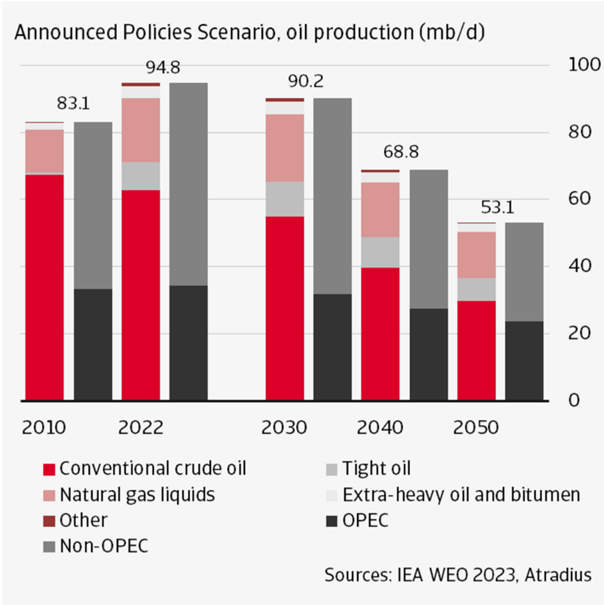
4.3 Oil supply: risk of underinvestment has receded

The short-term oil supply outlook is robust as demand continues to ease. Global oil supply is expected to exceed global oil demand by 3.5 mb/d this year, led by strong growth in the Americas, namely the US, Canada, Brazil and Guyana. This should be sufficient to offset some production cuts from OPEC+ countries, but supply concerns remain a risk. While supply bottlenecks have calmed in the past year, new concerns have arisen, associated with rising geopolitical tensions in the Middle East. 7% of world oil supplies pass through the Red Sea and the Suez Canal, so this poses a significant risk for supply disruptions. While an increasing number of tankers are redirecting their trade routes, extending voyages by up to two weeks and increasing costs, there has been limited impact on oil supplies so far. IEA member countries also hold substantial oil stocks to offer a buffer to any major disruptions. Thus, barring any major escalation of Middle East tensions or OPEC+ production cuts, the short-term supply outlook is strong.

Global oil production will decline substantially in the second half of this decade, in line with falling demand[18]. From 2022 to 2030, world production falls on average 0.6% per year down to 90.2 mb/d. Production in the US will peak before 2030 and we expect total production there to stand at 19.0 mb/d in 2030. The US will thus maintain its role as a major world oil producer, which should offer a buffer to any market shocks from a supply shock. But it is clear that the US shale sector is no longer the dynamic swing producer it was a decade ago. Overall, non-OPEC production will fall 2.1 mb/d to 58.3 mb/d in 2030. Guyana, which first began producing oil in 2019, sees production increase by over 1 mb/d to 2030, the largest increase of any country in the APS. Brazil is the runner-up country with production growing just under 1 mb/d with the oil produced being almost fully exported.

OPEC production is expected to fall slightly further by 2.5 mb/d to 31.9 mb/d in 2030. This will bring OPEC's market share to 35.4%, from about 36% now. We expect OPEC policy to continue to prioritise market management strategies. Accordingly, conventional crude oil will be the production source with by far the greatest decline, falling 7.9 mb/d to 54.9 mb/d in 2030. The Russian outlook is expected to decline slightly, but less than last year's forecast. Russian oil production is expected to stand at 9.9 mb/d in 2030, 1.4 mb/d higher than projected for 2030 last year.

Figure 4.4 Oil production to be drawn down by non-OPEC and non-conventional sources



Sources: IEA WEO 2023, Atradius

The decline in oil production is much more pronounced from 2030 to 2050. Global production is forecast to fall 41.7 mb/d under the APS scenario. The largest decline will come from North America where production falls to 14.2 mb/d after peaking before 2030. Central and South America will also see production decline by 3 mb/d between 2030 and 2050 to 5.2 mb/d as their relatively more expensive sources, especially deep sea, prove less feasible in the increasingly

18 For the remainder of this section, we refer to oil production which differs slightly from oil supply due to processing gains where the volumetric amount of total output is greater than input. For instance, in 2022, total oil production was 94.8 mb/d, with 2.3 mb/d added in processing gains to provide 97.1 mb/d of supply, meeting demand.

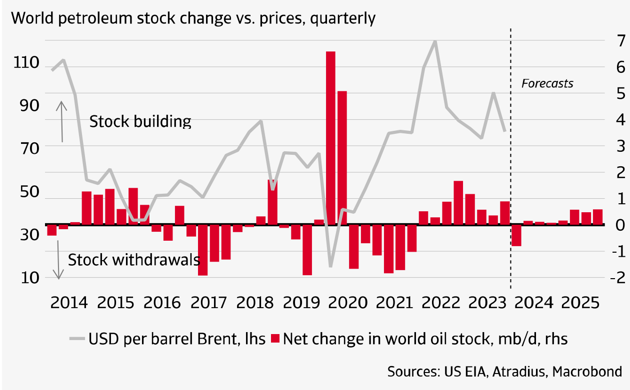
lower demand environment. The pace of decline from Russian oil fields will accelerate, with production there plummeting to only 3.5 mb/d in 2050 as it struggles to maintain output from existing fields or invest in developing new ones. Overall, OPEC production is set to fall a further 8.2 mb/d between 2030 and 2050, bringing its output to 23.7 mb/d. This points to increasing influence of OPEC in global oil supplies as it will contribute 44.6% of global supply, compared to 36% today. However, given the expectation that total oil demand will be only 56% of 2022 levels, the influence of the markets will be more limited. Saudi Arabia's oil production will decline by about 2 mb/d from 2030 to 2050, bringing its output to 10.3 mb/d or one-fifth of global production – almost exactly in line with the US.

The supply outlook is vulnerable to investment trends but the risk of underinvestment, flagged in our past outlooks, has decreased. As global oil supply more than satisfies demand in the coming years, global investment appears sufficient despite remaining below the pre-pandemic level. Instead, the risk is rising that large investments in oil exploration and exploitation may challenge the global economy's transition away from oil consumption. Still, the supply from existing sources would decline too sharply in the absence of continued investment to meet global demand, even as it declines. The average annual investment in new and existing oil fields needed to 2050 is lower than previously expected with an average of USD 308 billion needed per year, compared to USD 337 billion of required investment projected last year. We still expect investment to be higher in the 2030s before declining from there. While investments in the oil sector need to be decreased over the coming decades, some level of ongoing investment is critical to ensure energy supply can meet global demand and avoid volatile price swings and energy insecurity through the energy transition.

4.4 Oil price on a downward trajectory

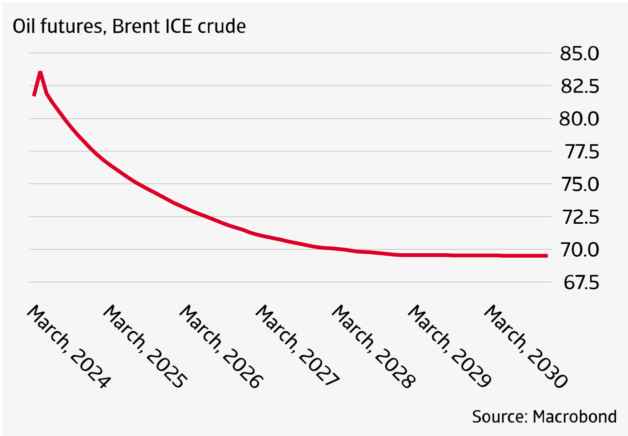
As the oil market appears more securely balanced in the short term, with global demand growth slowing and ample supply, especially from the Americas, the price of oil is also expected to remain relatively stable at around USD 80 per barrel this year and next. This balance can be seen in figure 4.5 where aside from a small deficit expected this quarter due to OPEC+'s supply management, we expect global oil stocks to be stable and gradually grow next year. This is of course barring any more significant disruption to oil flows which could spur more upward spikes and price volatility.

Figure 4.5 Oil market in relative balance to 2025



Market expectations also support this outlook, as signalled by the oil price futures curve. Immediate supply concerns surrounding geopolitical tensions and the extended OPEC+ productions cuts could push prices slightly upwards in the coming months, but overall, the market is in backwardation, meaning prices are expected to fall, not rise, to around (nominal) USD 70 per barrel in 2030. Medium-term market expectations are broadly in line with the outlook last year except that the slope of the curve has narrowed, further indicating that the expected decline in prices will be more gradual.

Figure 4.6 Markets anticipate steady decline in oil prices

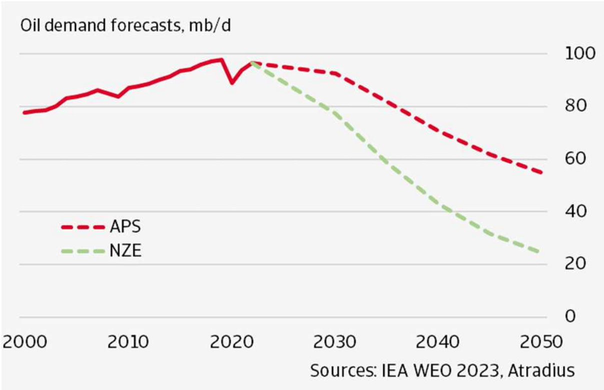


This is broadly in line with the IEA's own price forecast trajectory, which falls to USD 74 per barrel in 2030, in real 2022 US dollar terms. The gradual decline in prices reflects the anticipated peak and slow decline in demand for oil expected in the rest of the 2020s. As the policy focus under the APS scenario is to curb oil demand, the market equilibrium price will in turn be lower. Effective policies that allow for stable substitution of oil in the energy mix should prevent an increase in demand for oil in response to the lower price environment. International oil prices fall further to USD 60 per barrel in 2050 as the market price falls to the marginal cost of oil production. The equilibrium price is lower thanks to innovation and efficiency gains, but this is partially offset by the effects of moving to more geologically challenging resources.

4.5 OPEC becomes even more dominant in NZE

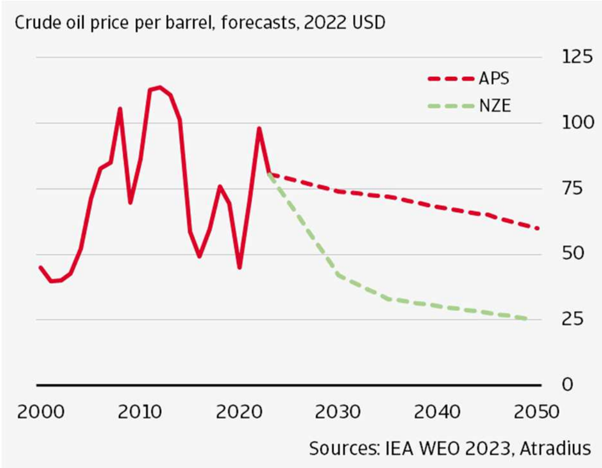
The outlook for the oil market is much less buoyant under the Net Zero emissions by 2050 scenario. Considering oil demand reached pre-crisis levels last year, the prediction that peak oil demand was already behind us as envisioned in last year's NZE was optimistic, underpinning the following of APS as a baseline. But the demand outlook is remarkably lower than in APS thanks to the implementation of more aggressive policy mandates required to reach the climate goals for 2050. The pace of demand contraction is twice as rapid from now to 2050 under NZE than APS, falling on average 4.8% per year. The significant demand reductions under this scenario come from EMEs, whereas the outlook for advanced economies is relatively similar to the APS. Worldwide, the precipitous drop in oil demand is primarily due to the shift in demand for road transport.

Figure 4.7 Demand for oil to fall to 25% current levels in 2050 under NZE



On the supply side, production is projected to fall across all regions over the coming decades. Beyond 2030, the rapid decline in demand would cause a number of higher cost projects to close before they reach the end of their technical lifetimes. Investments will still be needed to ensure a stable energy transition even in this scenario, but it would only be needed in existing fields so that supply does not decline more quickly than demand. No conventional long lead-time projects would be developed from now on, so investment can be significantly lower than today. As such, the role of OPEC members in the Middle East would increase in the global crude oil markets. With large reserves and slow decline rates of their existing fields, minimal investment is needed there to continue to garner output gains. OPEC's share of world oil production would reach 53% in 2050, its highest level ever. The market oil price would fall further in line with the operating cost of this marginal project, estimated at only USD 25 per barrel in 2050.

Figure 4.8 Oil price plummets to USD 25 under NZE



5. Gas market outlook

Gas markets have gradually rebalanced after the shock that followed Russia's invasion of Ukraine in February 2022. For this study, we used the Announced Pledges scenario (APS) from the IEA to predict future gas supply and demand. We expect, based on IEA's APS, global gas demand to soon peak and that it will be 7% lower in 2030 compared to 2022, the base year of this study. The decline will continue in the years after 2030, until gas demand in 2050 is 42% lower than in 2022. In the alternative Net Zero Emissions (NZE) scenario, demand starts to decline sooner and the level drops even lower in 2050 compared to APS, to a level that is 78% lower than in 2022.

The share of gas in the energy mix is expected to decline as renewables gain market share, but less so than oil. Asia (especially China and India) and the Middle East remain the main sources of demand growth in the coming decades, while Europe, Japan and the United States see a contraction of demand. On the supply side, Russia is still expected to be the largest gas supplier by the end of the forecast horizon (2050), but its role will likely be diminished. The supply increases that are still needed in the medium term are mainly coming from the Middle East. In all other major gas producing regions, supply is expected to decline in both the medium (up to 2030) and long term (up to 2050). Gas prices are likely to remain elevated relative to pre-crisis levels until the middle of the decade. After 2025, a wave of new LNG export capacity will ease gas market balances, reducing gas prices in all major regions.

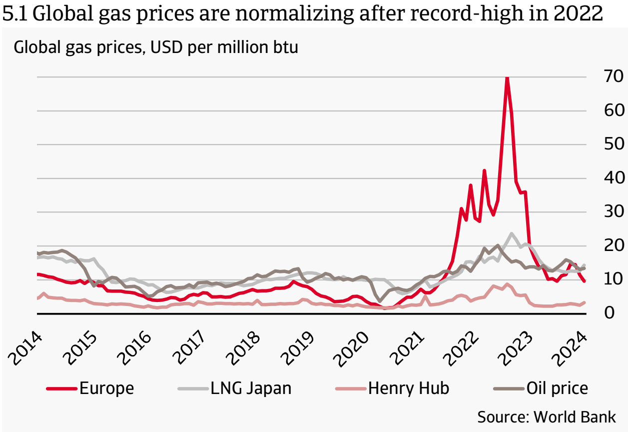
5.1 Key developments: US becomes first

Natural gas markets have moved towards a gradual rebalancing after the shock that followed Russia's invasion of Ukraine. This was due in no small part to effective decision-making and a relatively warm winter. As a result, gas prices in all three major markets – North America, Asia and Europe – have decreased. These markets traditionally each have their own pricing mechanism.[19]

Russia's invasion of Ukraine triggered a major energy crisis in 2022. Dramatically reduced Russian supply drove European gas prices – and indirectly Asian spot LNG prices – to record highs in that year. Gas markets moved towards a gradual rebalancing in 2023. After a 60% increase in 2022, Europe's LNG imports declined marginally in 2023, as lower gas demand and high storage levels eased the pull on LNG imports. The US remains by far the largest LNG supplier to Europe. Russia's piped gas supplies to Europe almost halved in 2023. Russian pipeline gas supplies to Europe are at their lowest level since the early 1970s. Russian pipeline imports were 8% of total EU imports in 2023.

As gas markets rebalanced, prices came down significantly in 2023, despite still tight supply fundamentals. In December 2023, gas prices were 68% lower year-on-year in the US, 39% lower in Asia and 54% lower in Europe. The TTF gas price (Europe) was USD 12 per million btu in December 2023, much lower than the previous peak in August 2022 (USD 70 per million btu). The Henry Hub (US) price also moved significantly lower and was USD 2.5 per million btu in December 2023. Strong domestic production together with milder winter temperatures moderated natural gas prices. The price of LNG gas in Japan reached USD 13 per million btu in December 2023, compared to USD 20 at the start of the year (figure 5.1).

5.1 Global gas prices are normalizing after record-high in 2022



Despite the overall price decline in all three major regions, volatility in prices remained high due to tight gas supplies and geopolitical tensions. Gas prices are also still well above their historical averages, both in Asia and Europe. LNG is traditionally a mix between oil indexation and spot pricing, but spot prices have become dominant in recent years. The relevant pricing mechanism is the Netherlands Title Transfer Facility (TTF), which is Europe's biggest (market-based) gas benchmark.

19 In North America, the gas price is determined according to the free market principle, with multiple buyers and sellers interacting in a spot market ("gas-on-gas" competition). The reference price is that of Henry Hub, a distribution hub in the US pipeline system in Louisiana. The dominant pricing mechanism in Asia remains oil indexation. Gas prices in Europe are

now playing the role of marginal supply to Europe. Any news of a tightening of the global LNG market is bound to impact European prices.

Global LNG trade expanded by 2% year-on-year in 2023. This was the slowest growth rate since 2014, barring the exceptional contraction in 2020. The Asia-Pacific region led LNG demand growth, accounting for virtually all incremental imports. The Asia-Pacific region saw LNG imports expanding by 4% year-on-year in 2023. This was primarily driven by China, Thailand and India. China regained its position as the world's largest LNG importer in 2023. In contrast, LNG imports declined sharply in the mature markets of Asia, principally Japan (down 8%) and South Korea (down 3%). European LNG import growth was muted in 2023, falling by 1.5% amid persistently low demand and reduced storage injection needs compared to 2022.

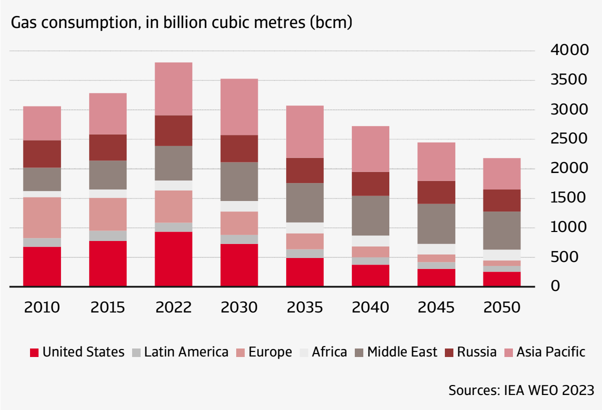
On the supply side, growth in LNG in 2023 was driven primarily by the United States, which accounted for 87% of incremental global LNG volumes. The US recorded a remarkable 10% y-o-y increase (or 10 billion cubic metres (bcm)) in LNG exports, driven by the restart of Freeport LNG and the continued commissioning of the Calcasieu Pass. From a supply perspective, the top three LNG exporters remained the same. In 2023 the United States moved to take first place for the very first time, exporting 116 bcm, surpassing both Australia and Qatar, tied at 106 bcm. Together, these three exporters account for more than 60% of global LNG supply.

5.2 Demand: gas heyday is over

The supply shock triggered by Russia casts a long shadow over gas markets. In the APS, global gas demand will soon peak and by 2030 will be 7% lower than in 2022 (figure 5.2). The decline continues in the years after 2030, until gas demand in 2050 is 42% lower than in 2022. Robust policy support reduces the demand for natural gas by 2030 in the power sector and then increasingly in buildings and industry. There is a continued need for gas to back up variable renewables, but gas is mostly reduced to a stand-by supply. Moreover, the role of gas in ensuring flexibility is complemented by other options such as batteries and demand response. After 2030, rapid growth of renewables in the power sector further reduces the market share of gas.

Three regions are expected to see growing gas demand between 2022 and 2030: Asia-Pacific, the Middle East and Africa. In Asia, gas demand will continue to grow by 54 bcm up to 2030, with growth mainly concentrated in China and India. Gas demand growth in China does slow considerably: annual growth drops to 1.3% in the period 2022-2030 compared to 11% in the previous decade. In India, gas demand is ramped up in the next decade, with 6% annual growth. Most of the growth comes from manufacturing and other industry, helped by the expansion of city gas distribution networks. Around 2040, demand in India will peak and after that slowly decline. In China, the peak of gas demand is somewhat earlier, in 2030.

5.2 Gas consumption in 2050 more than 40% lower than today



Besides Asia, the Middle East is an important source of demand, accounting for an additional 73 bcm up to 2030. This translates to an annual growth rate of 1.5%. Iran and Saudi Arabia are expected to account for around 75% of the incremental gas demand. The expansion of gas-intensive industries, together with the gradual phase-out of oil products from the power sector, is set to support this growth.

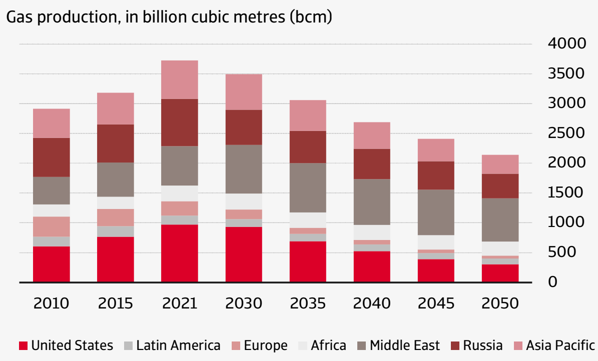
North America (particularly the US), Japan, Europe and Central and South America are projected to see a decline in gas demand both in the medium and long term. In the US – the world's largest natural gas consumer - gas demand falls by 2.6% annually between 2022 and 2030. The decline in gas demand is primarily due to lower gas burn in the power sector amid the continued expansion of renewables. Gas demand in the residential and commercial sectors is set for a decline amid energy efficiency gains enabled by retrofits. In the more distant future, after 2030, US gas demand will start to decline at an accelerated pace. Between 2030 and 2050, gas demand is expected to decline at an annual rate of 5.1%.

Europe is forecast to reduce gas demand by 155 bcm between 2022 and 2030, a total decline of 28% (corresponding to an annual decline of 4.1%). A relatively high gas price environment is set to weigh on demand recovery in industry, while gas-fired power plants are gradually replaced by renewables. In the residential and commercial sectors, energy efficiency gains together with more rapid installation of heat pumps are set to reduce gas use during the forecast period. The relocation of European industries to other regions – with a structurally lower cost of gas supply – remains a major downside risk to industrial gas demand in Europe.

5.3 Supply: LNG to take a more dominant role

In the APS, global gas supply declines by about 7% between now and 2030 and by 42% between now and 2050 (figure 5.3).[20] LNG is going to take a more prominent role in future gas supply. Currently, the US is the largest natural gas supplier. In the baseline scenario, the US will move to second place in 2050, delivering 700 bcm less gas than now (it currently supplies just over 1000 bcm annually). Russia moves from second place to first place in 2050, though it will supply 274 bcm less gas compared to 2022 (an almost 40% reduction). Qatar is projected to be the third-largest supplier in 2050 (currently this spot is occupied by Iran).

5.3 Gas production decline follows that of demand to balance gas markets



Sources: IEA WEO 2023

In the United States, gas production is reduced by about 75 bcm between 2022 and 2030. This translates to an annual production decline of nearly 1% between 2022 and 2030. The production decline is in stark contrast to the 4.7% growth rate in the previous decade (when the US increased its production by 402 bcm). The decline is driven by lower US domestic gas consumption. Even though total production is declining, the US does solidify its position as the world's largest gas exporter through to 2030. The US alone is set to contribute around half of incremental LNG supply up to 2030.

Total gas production in Russia fell by more than 100 bcm between 2021 and 2022. Between 2022 and 2050, roughly another 274 bcm decline is expected, to a total production level in 2050 of 415 bcm. Russia's gas transit contract with Ukraine is set to expire at the end of 2024. We assume that by 2025 only TurkStream 2 will supply Russian piped gas to the EU. Lower gas demand growth in China and a global surplus of LNG leaves Russia with few options to diversify into non-European markets. According to the baseline scenario, Russia's share of internationally traded gas, which stood at 30% in 2021, falls by 2030 to less than 15%.

The Middle East remains the largest near-term source of supply growth. The entire Middle East region is projected to add about 140 bcm in additional supply up to 2030. In the longer horizon up to 2050, the Middle East is the only region producing more gas than in 2022, even though after 2030, production volumes start to decline. Qatar is expected to step up its gas production by around 70 bcm up to 2030. This forecast is underpinned by rising LNG trade as Europe has significantly higher import needs after the Russian invasion of Ukraine. New supplies are being enabled by the expansion of the North Field in Qatar.[21] Saudi Arabia adds about 30 bcm in production up to 2030, but this is solely for domestic needs. The country with the largest gas reserves in the region, Iran, adds only 8 bcm in production, which is also mainly used to meet domestic demand.

Besides the Middle East, Africa is the only region that sees an increase of production up to 2030, due to the projected opening of a gas field in Mozambique. The other gas producing regions – Europe, Asia and Latin America – all see production declines. In Asia, the decrease mainly takes place in Southeast Asia. China and India are still ramping up production until 2030; and India even up to 2050. China emerges in the top-five largest natural gas producers, along with the US, Russia, Iran and Qatar.

5.4 Gas price adjusted downward

We align our baseline price forecast with the Announced Pledges Scenario (APS) from the IEA. The IEA scenarios model an energy system in equilibrium, in which energy prices follow a relatively smooth trajectory to balance supply and demand, and where energy markets, investment, technologies and policies all evolve in a mutually consistent direction. Unlike oil, there is no single global price for natural gas, but instead a set of regional prices that are increasingly interlinked by the ability of LNG tankers to seek out the most advantageous commercial destination. Figure 5.4 shows the gas price forecast under the APS and NZE scenarios.

Nevertheless, the gas market is increasingly functioning as a global market, with LNG taking a more prominent role at the cost of pipeline supply. As the US is the world's largest LNG exporter and given the contractual terms it uses (hub-indexed pricing mechanisms and destination-free shipping arrangements), the regional flexibility of LNG trade is set to increase, and markets are set to become increasingly interdependent.

Under the APS, the gas price is trending down in all three regions. Gas prices will stay somewhat elevated relative to pre-crisis levels until the middle of the decade as global gas markets continue to adjust following the loss of Russian pipeline gas supply to Europe, a loss that is assumed to be permanent. However, a wave of new LNG export capacity from 2025 eases gas market balances. The Henry Hub price,

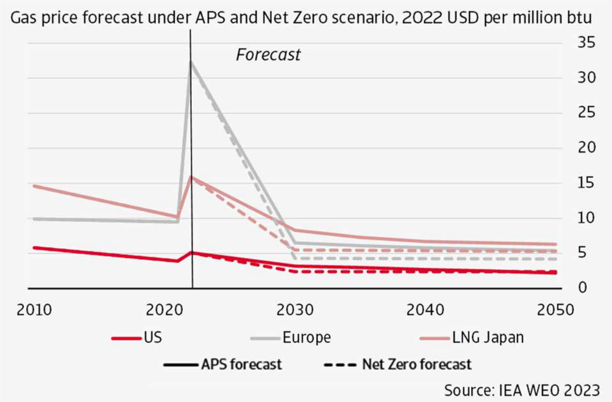
20 By definition, in the long term, global gas supply has to equal global demand.

21 The world's biggest single non-associated natural gas field, offshore north-east Qatar peninsula. The North Field represents the southern part of the giant natural gas field that is shared between Iran and Qatar.

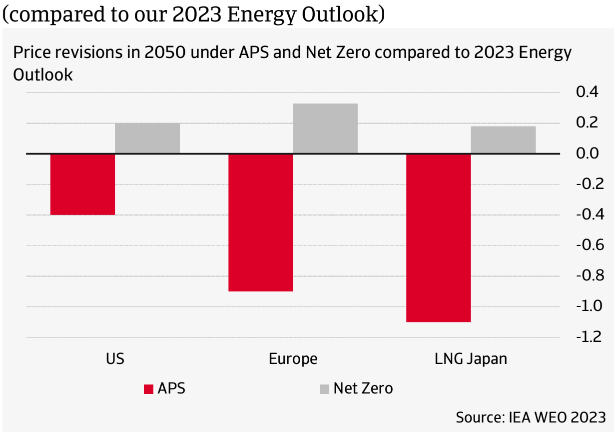
the marker for natural gas in the United States, declines slightly over the forecast horizon. The Asian LNG price and European gas price also decline up to 2030; the Asian price is once again above the European gas price in 2030, making it the premium market for LNG. Over the coming decades, LNG trade is expected to take a more prominent role, which reduces the price spread between Asian LNG and Henry Hub.

The EU still needs to attract additional non-Russian gas, keeping near-term gas prices elevated. This has knock-on effects on prices in other importing regions, although the effects in Asia are muted by the link to oil prices in many long-term contracts. Compared to our 2023 Energy Outlook, equilibrium prices in the long term (2050) are revised downwards in the APS. The downward revisions in the APS follow from additional pledges that countries have made, resulting in lower future gas demand, and putting a downward pressure on prices.

5.4 Gas prices decline under both the APS and Net Zero scenarios



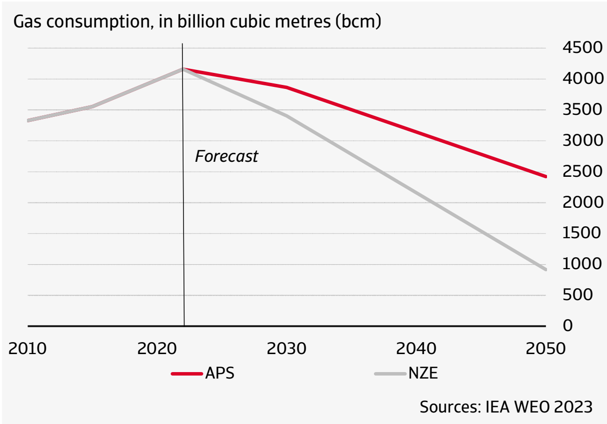
5.5 Price revisions in 2050 are particularly large in the APS (compared to our 2023 Energy Outlook)



5.5 NZE: stronger demand reduction

Under the Net Zero Emissions scenario, the decline in gas consumption is stronger than under the APS. Rapid electrification of heat demand and efficiency gains bring gas demand down to 300 bcm by 2050 in the NZE scenario. Gas demand in NZE is 750 bcm lower in 2030 than in 2022, a drop of almost 20% (whereas in the baseline the drop was 7%). Rapid growth of renewables in the power sector starts to rapidly reduce the market share of gas after 2030. By 2050, the level of demand is almost 80% lower than today. The position of gas in the total energy mix declines even more markedly than under APS, from 23% today to 4% in 2050 (compared to 10% in 2050 under APS). The rapid decline in gas production in NZE in all regions implies that some projects have to close before reaching the end of their technical lifetimes. Growing gas use for hydrogen production does slow the decline after 2040 in areas where hydrogen is exported, notably the Middle East and Australia.

5.6 Gas consumption declines even faster in NZE scenario



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