World Energy Investment 2024

INTERNATIONAL ENERGY AGENCY

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Abstract

This year's edition of the *World Energy Investment* provides a full update on the investment picture in 2023 and an initial reading of the emerging picture for 2024.

The report provides a global benchmark for tracking capital flows in the energy sector and examines how investors are assessing risks and opportunities across all areas of fuel and electricity supply, critical minerals, efficiency, research and development and energy finance.

The report highlights several key aspects of the current investment landscape, including persistent cost and interest rates pressures, the new industrial strategies being adopted by major economies to boost clean energy manufacturing, and the policies that support incentives for clean energy spending, notably from the increasingly important viewpoints of energy security and affordability.

This year's edition provides an expanded analysis on the sources of investment and sources of finance in the energy sector, including new insights on the role of development finance institutions in energy investments across emerging and developing economies. It will also look at how investment trends in clean energy compare with those in fossil fuels, as well as the geographic distribution of these investments.

The report also includes a new regional section covering 10 major economies and regions. It also assesses additional efforts needed to meet the COP28 goals to transition away from fossil fuels, triple renewable capacity and double the rate of improvements in energy efficiency by 2030.

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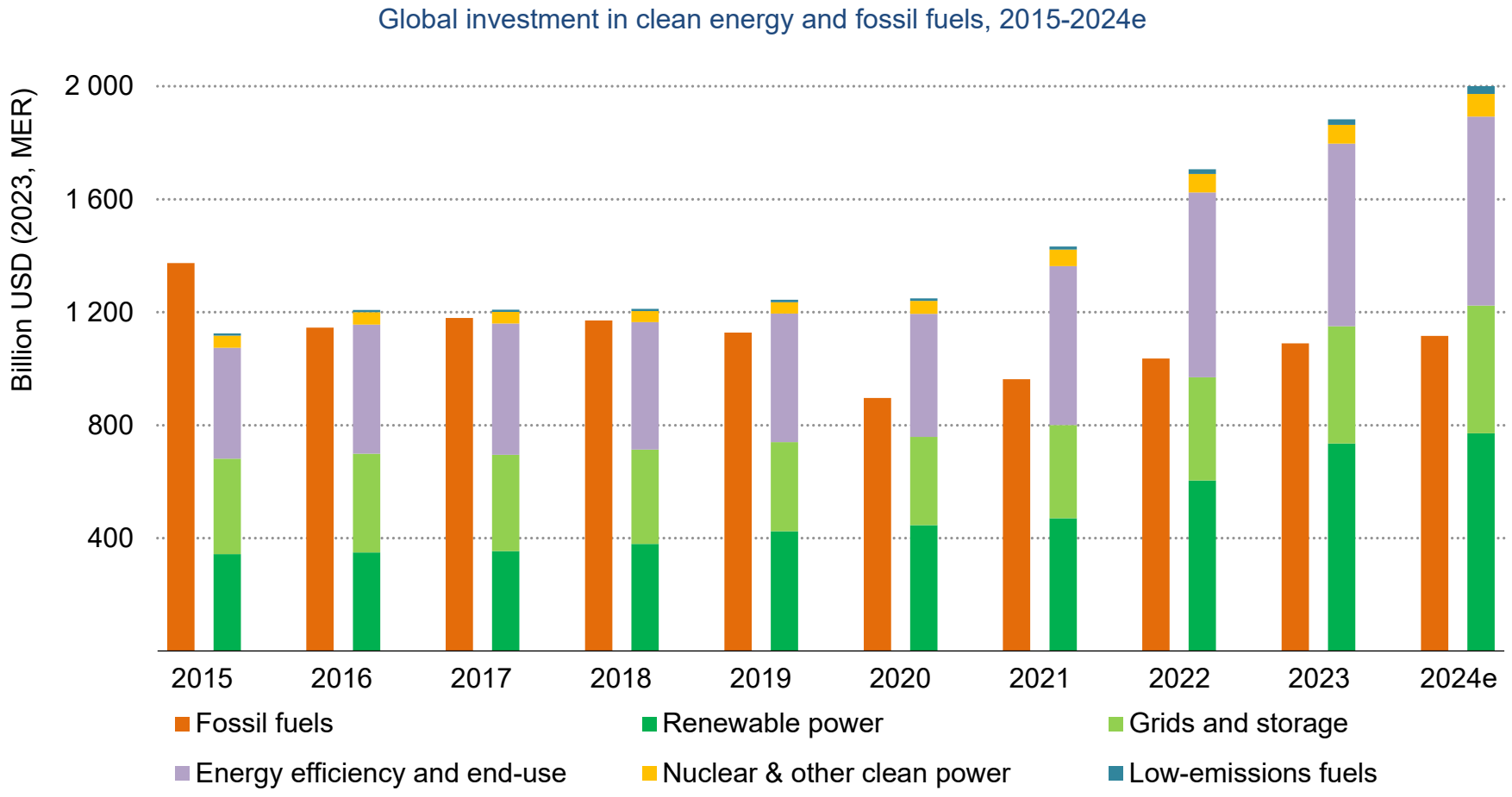
Overview and key findings

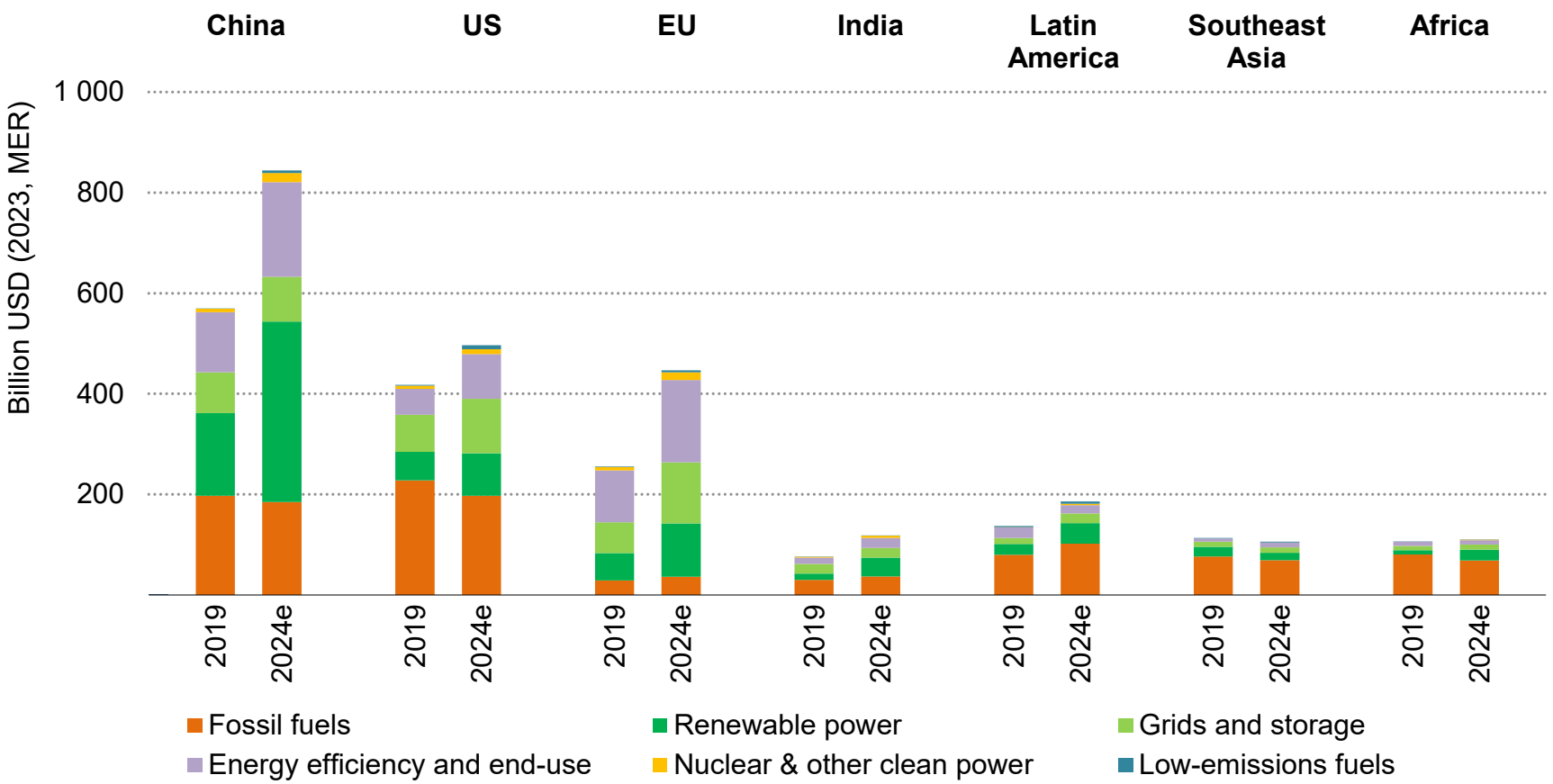
The world now invests almost twice as much in clean energy as it does in fossil fuels…



Note: Other clean power = fossil fuel power with CCUS, hydrogen, ammonia, and large-scale heat pumps. Low-emissions fuels = modern bioenergy, low-emissions H_2 based fuels, and CCUS associated with fossil fuels and also includes direct air capture. 2024e = estimated values for 2024.

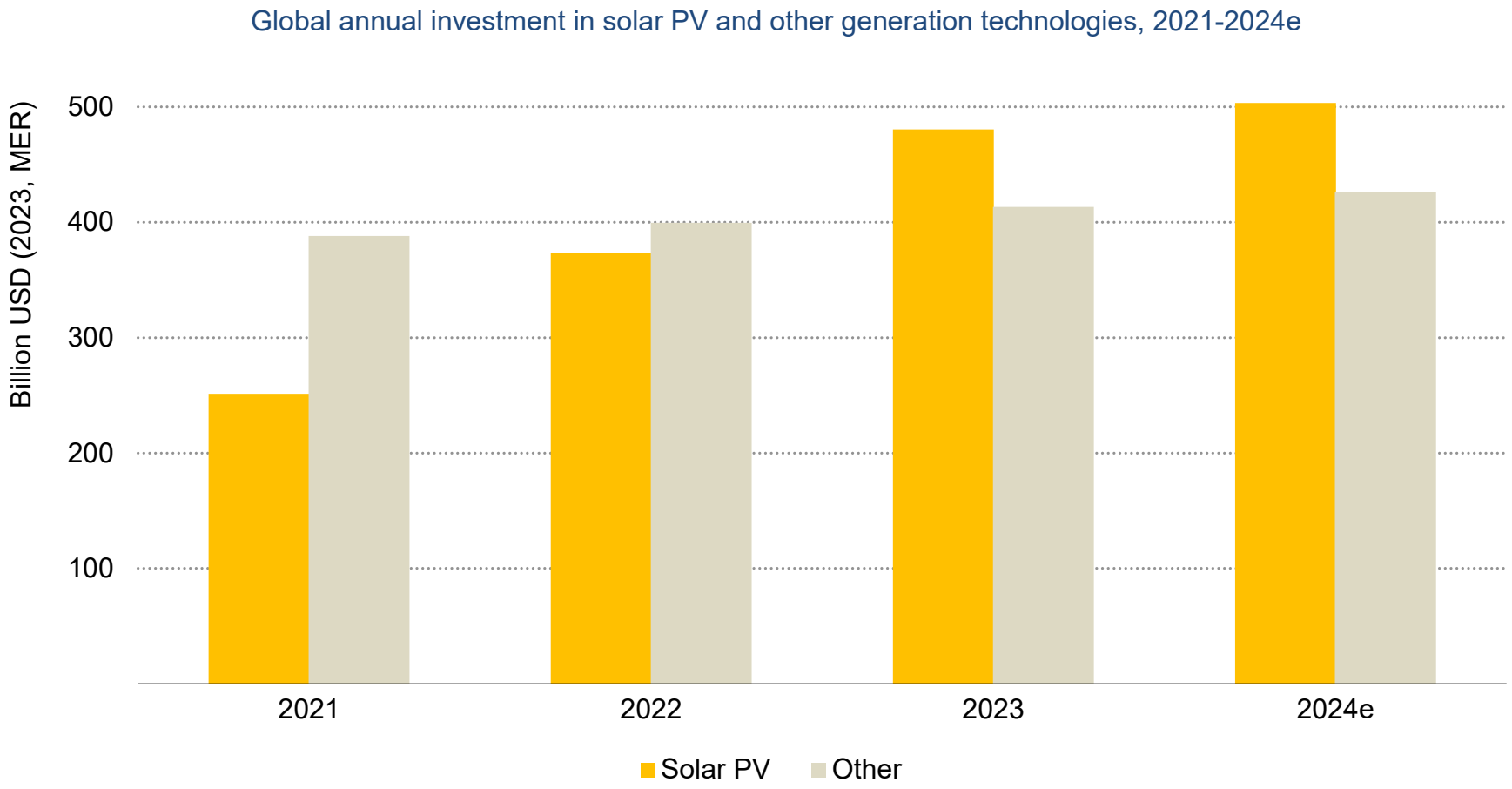
…but there are major imbalances in investment, and Emerging Market and Developing Economies (EMDE) outside China account for only around 15% of global clean energy spending

Annual energy investment by selected country and region, 2019 and 2024e



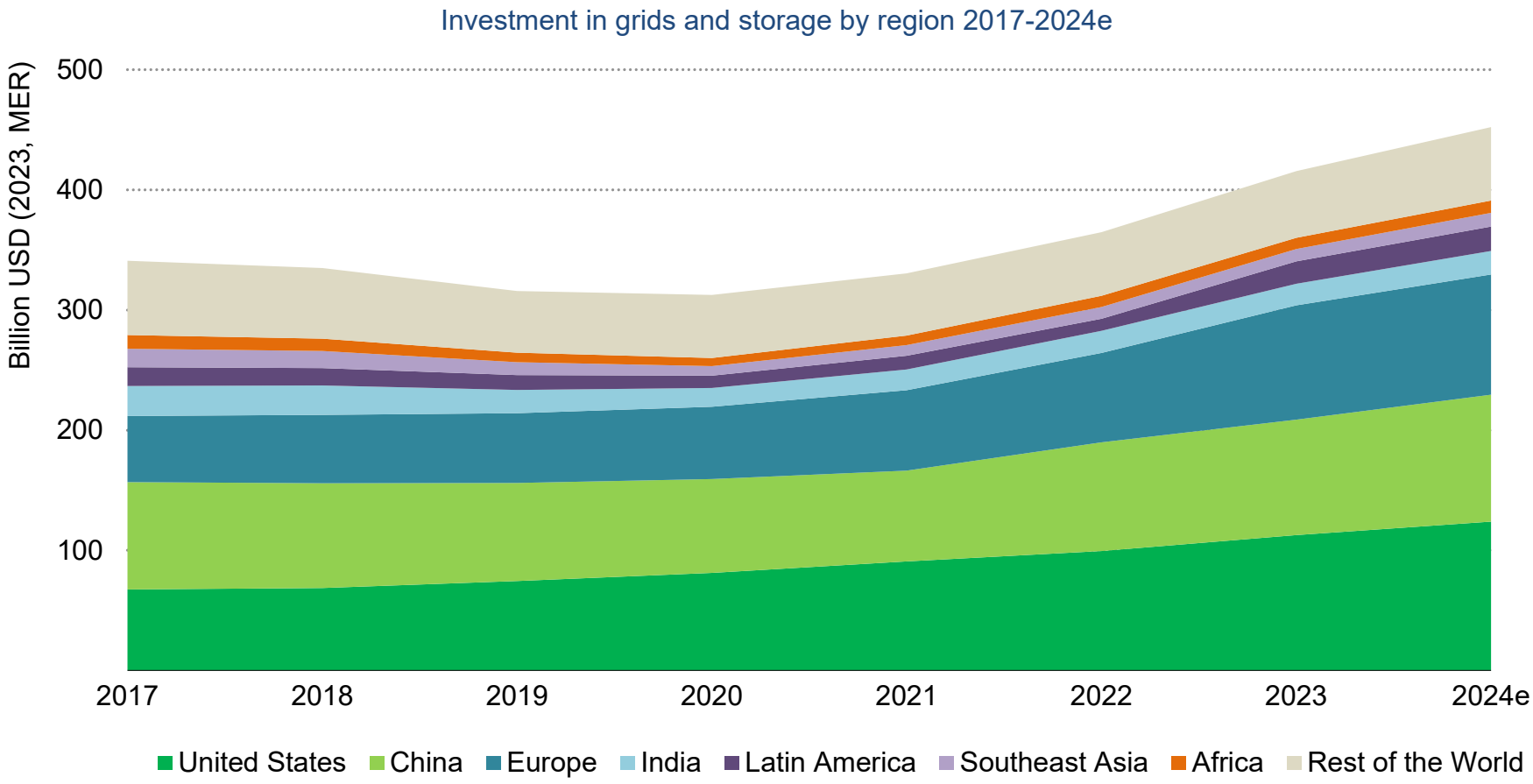
Note: 2024e = estimated values for 2024. US = United States. EU = European Union.

Investment in solar PV now surpasses all other generation technologies combined



Note: 2024e = estimated values for 2024. Other = electricity generation from all other technologies including coal, oil, natural gas, wind, hydro and nuclear.

The integration of renewables and upgrades to existing infrastructure have sparked a recovery in spending on grids and storage



Note: 2024e = estimated values for 2024.

Rising investments in clean energy push overall energy investment above USD 3 trillion for the first time

Global energy investment is set to exceed USD 3 trillion for the first time in 2024, with USD 2 trillion going to clean energy technologies and infrastructure. Investment in clean energy has accelerated since 2020, and spending on renewable power, grids and storage is now higher than total spending on oil, gas, and coal.

As the era of cheap borrowing comes to an end, certain kinds of investment are being held back by higher financing costs. However, the impact on project economics has been partially offset by easing supply chain pressures and falling prices. Solar panel costs have decreased by 30% over the last two years, and prices for minerals and metals crucial for energy transitions have also sharply dropped, especially the metals required for batteries.

The annual World Energy Investment report has consistently warned of energy investment flow imbalances, particularly insufficient clean energy investments in EMDE outside China. There are tentative signs of a pick-up in these investments: in our assessment, clean energy investments are set to approach USD 320 billion in 2024, up by more 50% since 2020. This is similar to the growth seen in advanced economies (+50%), although trailing China (+75%). The gains primarily come from higher investments in renewable power, now representing half of all power sector investments in these economies. Progress in India, Brazil, parts of Southeast Asia and Africa reflects new policy initiatives, well-managed public tenders, and improved grid infrastructure. Africa's clean energy investments in 2024, at over USD 40 billion, are nearly double those in 2020.

Yet much more needs to be done. In most cases, this growth comes from a very low base and many of the least-developed economies are being left behind (several face acute problems servicing high levels of debt). In 2024, the share of global clean energy investment in EMDE outside China is expected to remain around 15% of the total. Both in terms of volume and share, this is far below the amounts that are required to ensure full access to modern energy and to meet rising energy demand in a sustainable way.

Power sector investment in solar photovoltaic (PV) technology is projected to exceed USD 500 billion in 2024, surpassing all other generation sources combined. Though growth may moderate slightly in 2024 due to falling PV module prices, solar remains central to the power sector's transformation. In 2023, each dollar invested in wind and solar PV yielded 2.5 times more energy output than a dollar spent on the same technologies a decade prior.

In 2015, the ratio of clean power to unabated fossil fuel power investments was roughly 2:1. In 2024, this ratio is set to reach 10:1. The rise in solar and wind deployment has driven wholesale prices

down in some countries, occasionally below zero, particularly during peak periods of wind and solar generation. This lowers the potential for spot market earnings for producers and highlights the need for complementary investments in flexibility and storage capacity.

Investments in nuclear power are expected to pick up in 2024, with its share (9%) in clean power investments rising after two consecutive years of decline. Total investment in nuclear is projected to reach USD 80 billion in 2024, nearly double the 2018 level, which was the lowest point in a decade.

Grids have become a bottleneck for energy transitions, but investment is rising. After stagnating around USD 300 billion per year since 2015, spending is expected to hit USD 400 billion in 2024, driven by new policies and funding in Europe, the United States, China, and parts of Latin America. Advanced economies and China account for 80% of global grid spending. Investment in Latin America has almost doubled since 2021, notably in Colombia, Chile, and Brazil, where spending doubled in 2023 alone. However, investment remains worryingly low elsewhere.

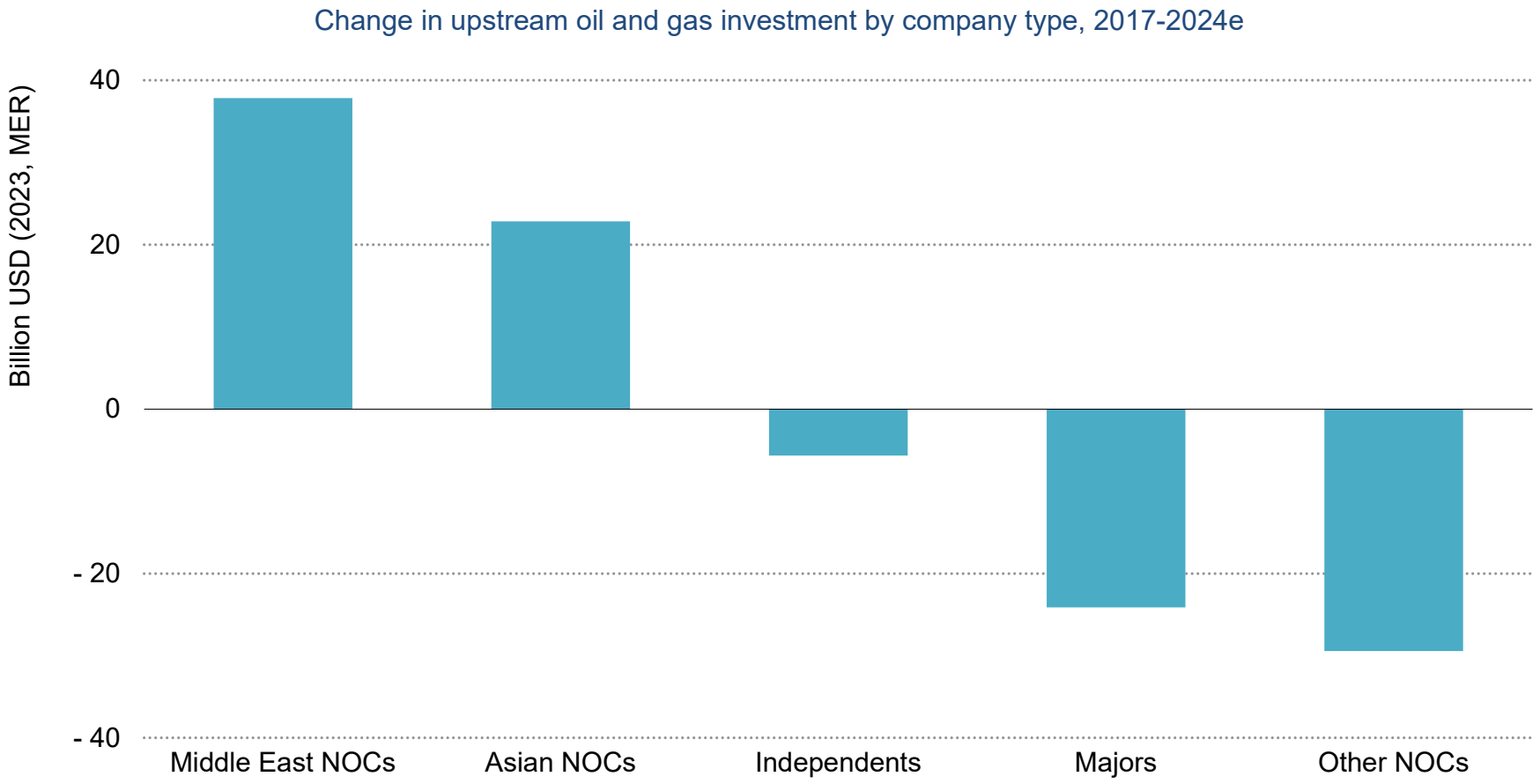
Investments in battery storage are ramping up and are set to exceed USD 50 billion in 2024. But spending is highly concentrated. In 2023, for every dollar invested in battery storage in advanced economies and China, only one cent was invested in other EMDE.

Investment in energy efficiency and electrification in buildings and industry has been quite resilient, despite the economic headwinds. But most of the dynamism in the end-use sectors is coming from transport, where investment is set to reach new highs in 2024 (+8% compared to 2023), driven by strong electric vehicle (EV) sales.

The rise in clean energy spending is underpinned by emissions reduction goals, technological gains, energy security imperatives (particularly in the European Union), and an additional strategic element: major economies are deploying new industrial strategies to spur clean energy manufacturing and establish stronger market positions. Such policies can bring local benefits, although gaining a cost-competitive foothold in sectors with ample global capacity like solar PV can be challenging. Policy makers need to balance the costs and benefits of these programmes so that they increase the resilience of clean energy supply chains while maintaining gains from trade.

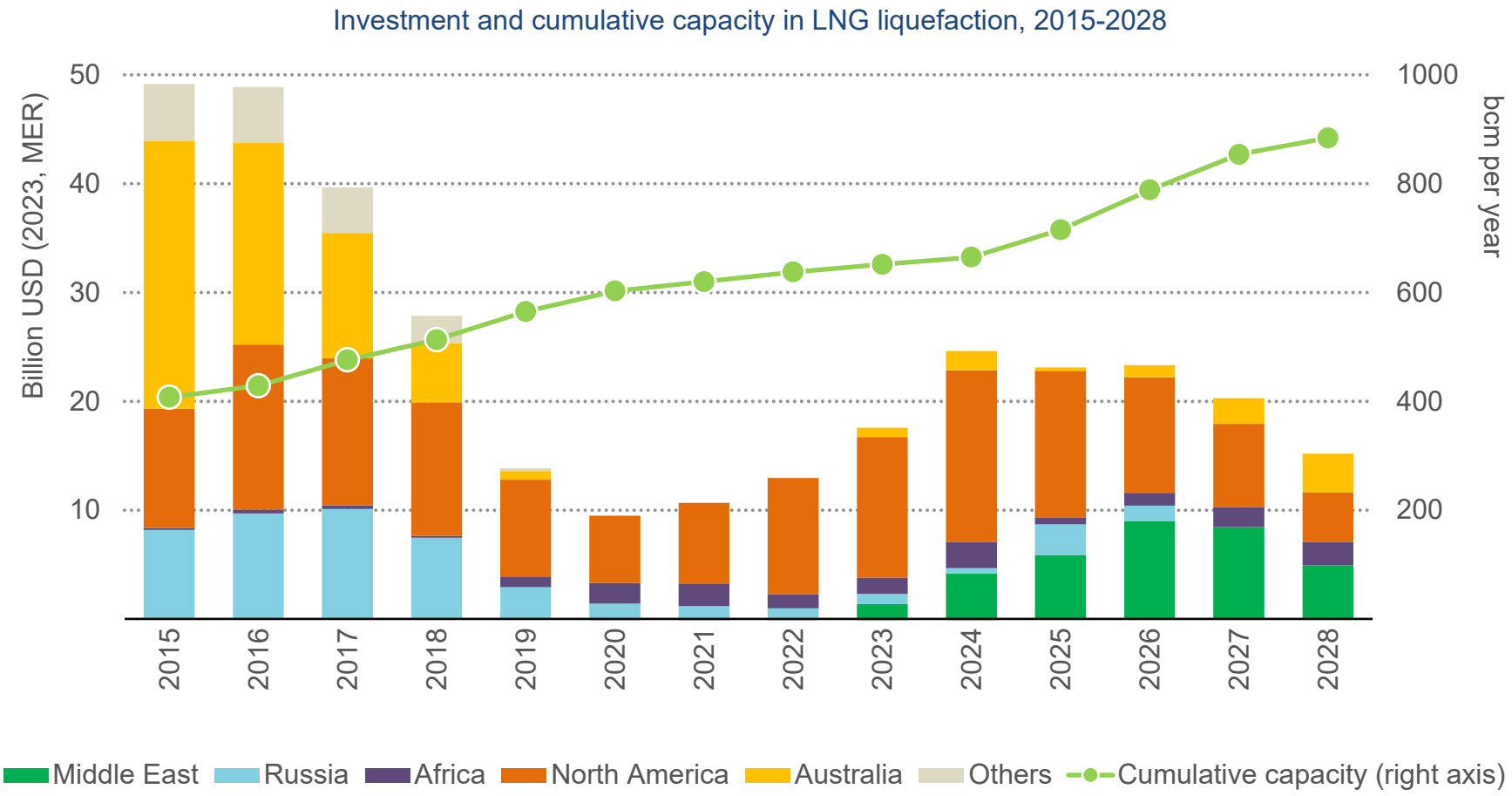
In the United States, investment in clean energy increases to an estimated more than USD 300 billion in 2024, 1.6 times the 2020 level and well ahead of the amount invested in fossil fuels. The European Union spends USD 370 billion on clean energy today, while China is set to spend almost USD 680 billion in 2024, supported by its large domestic market and rapid growth in the so-called “new three” industries: solar cells, lithium battery production and EV manufacturing.

Overall upstream oil and gas investment in 2024 is set to return to 2017 levels, but companies in the Middle East and Asia now account for a much larger share of the total



Note: 2024e = estimated values for 2024. NOC = national oil companies. Majors include bp, Chevron, ConocoPhillips, ENI, ExxonMobil, Shell and TotalEnergies.
Sources: IEA calculations based on S&P, Bloomberg LP, Rystad and annual reports. Includes reported capital expenditure and 2024 guidance for 73 companies accounting for about 70% of global production.

Newly approved LNG projects, led by the United States and Qatar, bring a new wave of investment that could boost global LNG export capacity by 50%



Note: Newly approved LNG projects in the United States and Qatar are expected to boost capacity by 50% between 2015 and 2026. Bcm = billion cubic metres.

Investment in fuel supply remains largely dominated by fossil fuels, although interest in low-emissions fuels is growing fast from a low base

Upstream oil and gas investment is expected to increase by 7% in 2024 to reach USD 570 billion, following a 9% rise in 2023. This is being led by Middle East and Asian NOCs, which have increased their investments in oil and gas by over 50% since 2017, and which account for almost the entire rise in spending for 2023-2024.

Lower cost inflation means that the headline rise in spending results in an even larger rise in activity, by approximately 25% compared with 2022. Existing fields account for around 40% total oil and gas upstream investment, while another 33% goes to new fields and exploration. The remainder goes to tight oil and shale gas.

Most of the huge influx of cashflows to the oil and gas industry in 2022-2023 was either returned to shareholders, used to buy back shares or to pay down debt; these uses exceeded capital expenditure again in 2023. A surge in profits has also spurred a wave of mergers and acquisitions (M&A), especially among US shale companies, which represented 75% of M&A activity in 2023. Clean energy spending by oil and gas companies grew to around USD 30 billion in 2023 (of which just USD 1.5 billion was by NOCs), but this represents less than 4% of global capital investment on clean energy.

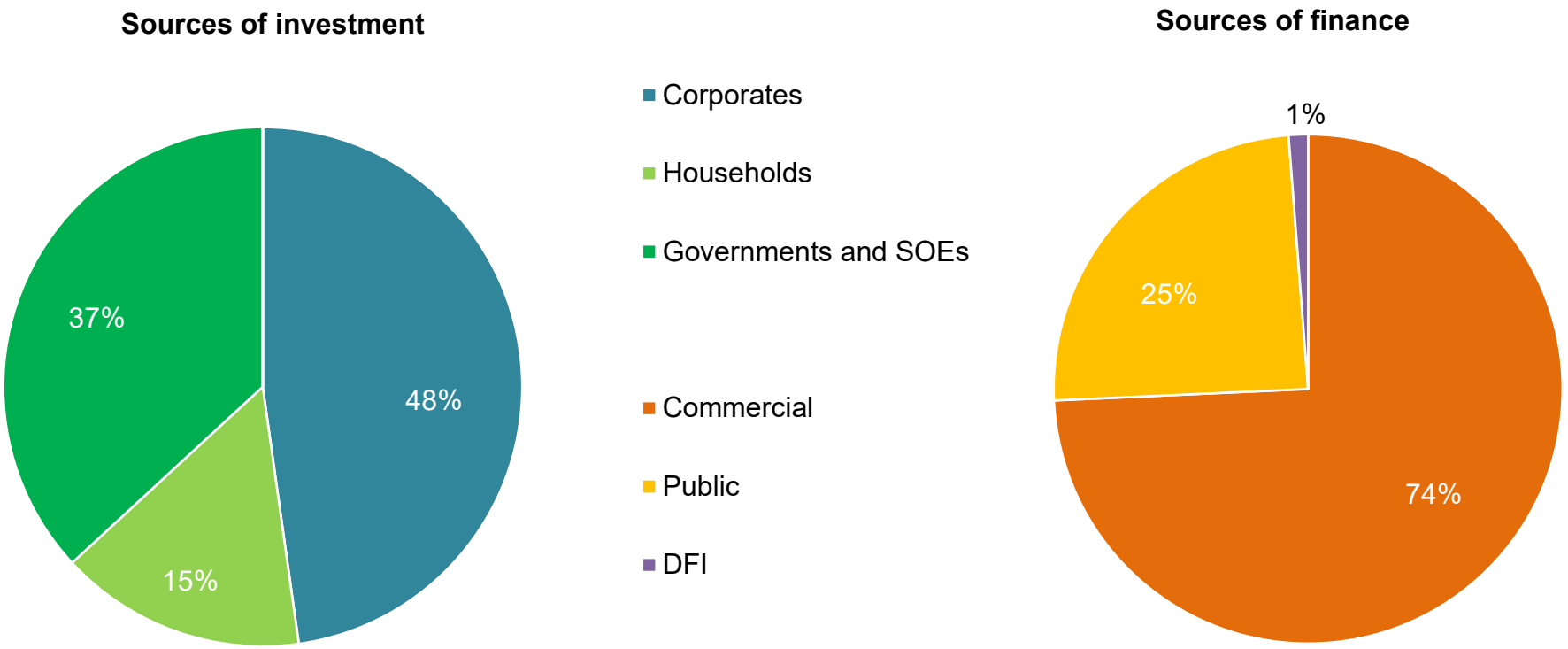
A significant wave of new investment is expected in LNG in the coming years as new liquefaction plants are built, primarily in the United States and Qatar. The concentration of projects looking to start operation in the second half of this decade could increase competition and raise costs for the limited number of specialised contractors in this area. For the moment, the prospect of ample gas supplies has not triggered a major reaction further down the value chain. The amount of new gas-fired power capacity being approved and coming online remains stable at around 50-60 GW per year.

Investment in coal has been rising steadily in recent years, and more than 50 GW of unabated coal-fired power generation was approved in 2023, the most since 2015, and almost all of this was in China.

Investment in low-emissions fuels is only 1.4% of the amount spent on fossil fuels (compared to about 0.5% a decade ago). There are some fast-growing areas. Investments in hydrogen electrolysers have risen to around USD 3 billion per year, although they remain constrained by uncertainty about demand and a lack of reliable off-takers. Investments in sustainable aviation fuels have reached USD 1 billion, while USD 800 million is going to direct air capture projects (a 140% increase from 2023). Some 20 commercial-scale carbon capture utilisation and storage (CCUS) projects in seven countries reached final investment decision (FID) in 2023; according to company announcements, another 110 capture facilities, transport and storage projects could do the same in 2024.

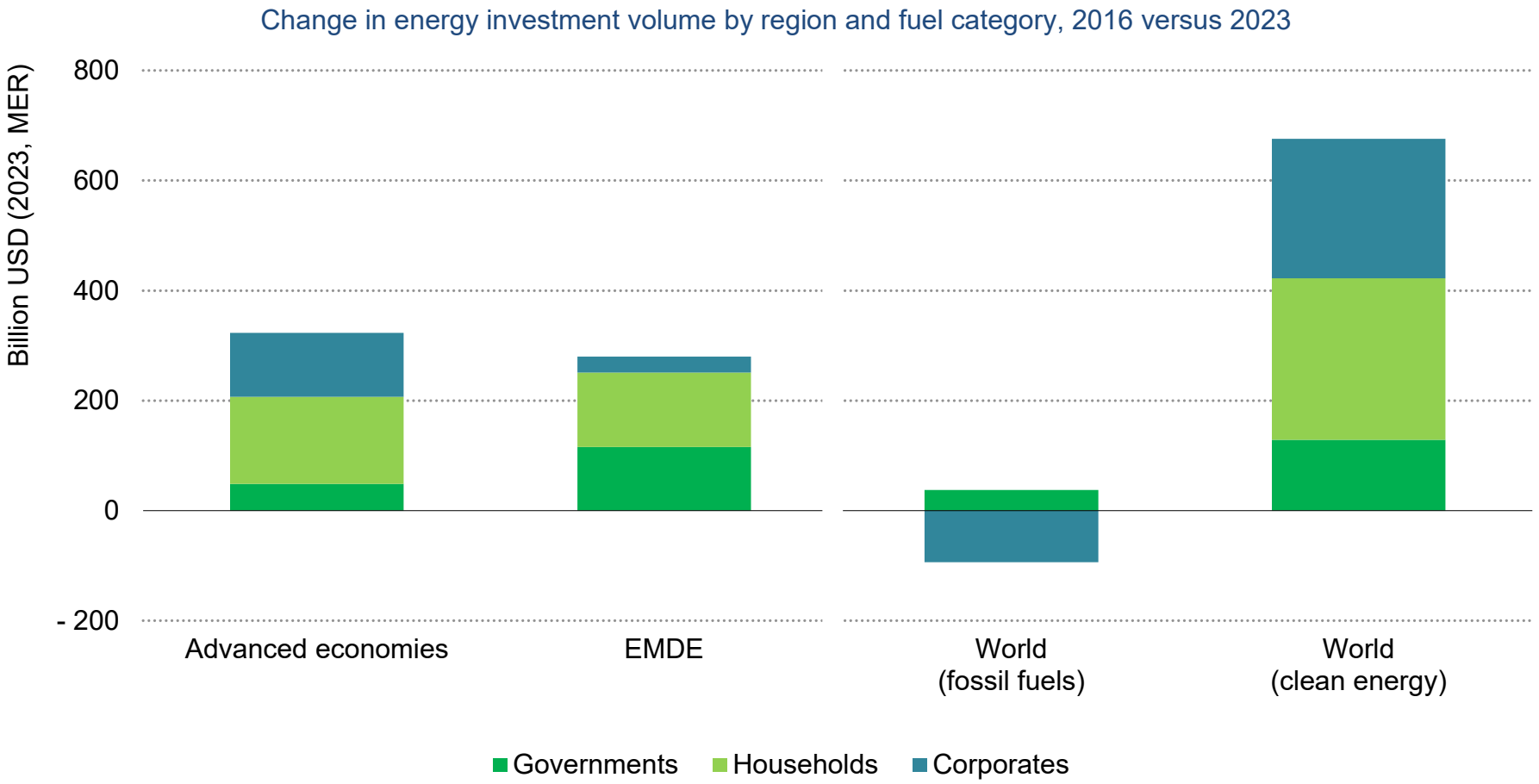
Energy investment decisions are primarily driven and financed by the private sector, but governments have essential direct and indirect roles in shaping capital flows

Sources of finance and investment in the energy sector, average 2018-2023



Note: Sources of investment refers to the entities investing in assets, regardless of the provider or origin of the funds. It includes state-owned enterprises (SOEs), corporates, and households. Sources of finance refers to the entities supplying the funds; this includes government funds (both equity in SOEs and subsidies), Development Finance Institutions (DFI) and commercial finance provided by corporates and households, as well as private debt.

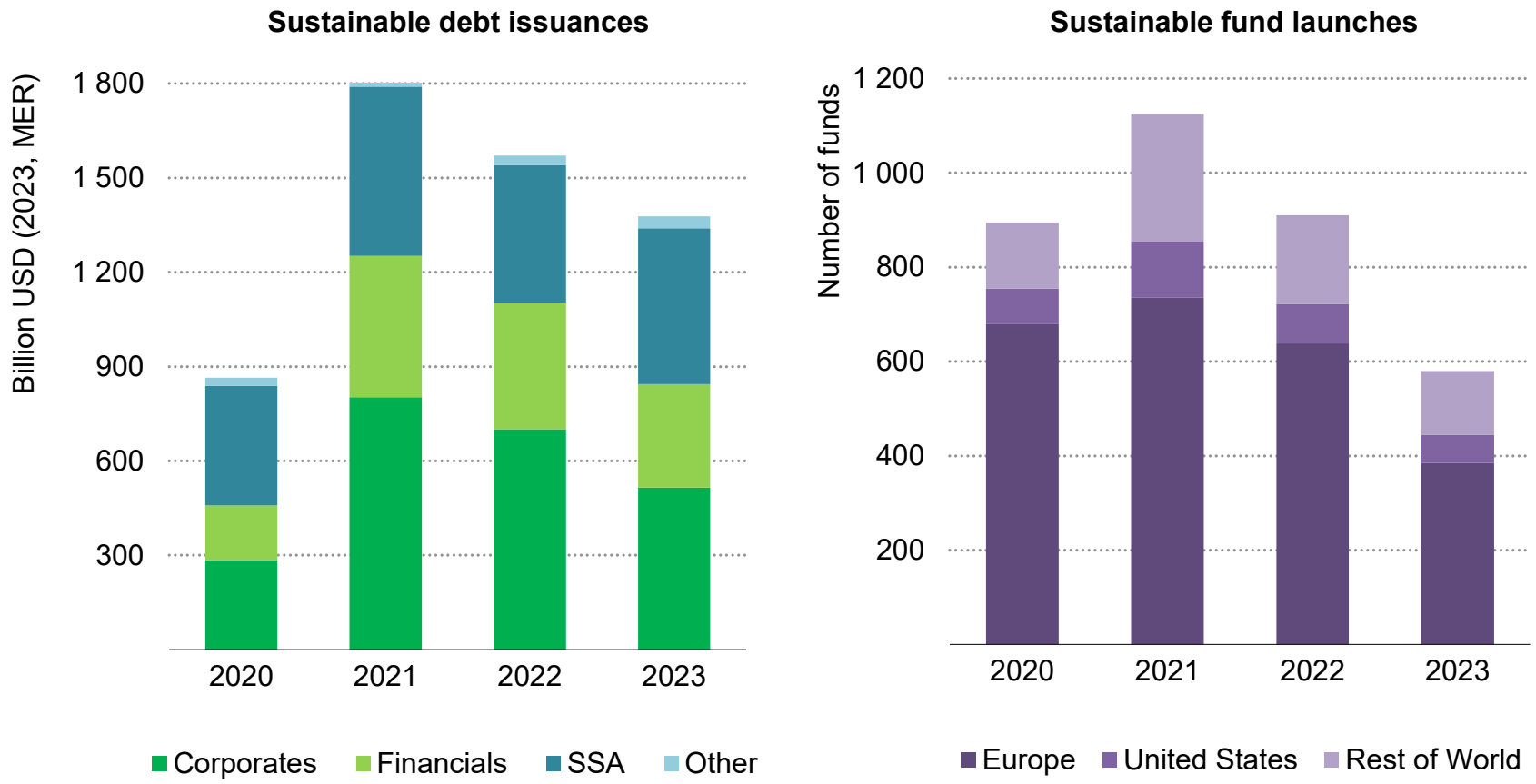
Households are emerging as important actors for consumer-facing clean energy investments, highlighting the importance of affordability and access to capital



Note: EMDE includes China.

Market sentiment around sustainable finance is down from the high point in 2021, with lower levels of sustainable debt issuances and inflows into sustainable funds

Sustainable debt issuances and sustainable fund launches, 2020-2023



Note: SSA = Sovereign, Supranational and Agency.

Source: IEA analysis based on Bloomberg New Energy Finance and Morningstar.

Energy transitions are reshaping how energy investment decisions are made, and by whom

This year's World Energy Investment report contains new analysis on sources of investments and sources of finance, making a clear distinction between those making investment decisions (governments, often via state-owned enterprises (SOEs), private firms and households) and the institutions providing the capital (the public sector, commercial lenders, and development finance institutions) to finance these investments.

Overall, most investments in the energy sector are made by corporates, with firms accounting for the largest share of investments in both the fossil fuel and clean energy sectors. However, there are significant country-by-country variations: half of all energy investments in EMDE are made by governments or SOEs, compared with just 15% in advanced economies. Investments by state-owned enterprises come mainly from national oil companies, notably in the Middle East and Asia where they have risen substantially in recent years, and among some state-owned utilities. The financial sustainability, investment strategies and the ability for SOEs to attract private capital therefore become a central issue for secure and affordable transitions.

The share of total energy investments made or decided by private households (if not necessarily financed by them directly) has doubled from 9% in 2015 to 18% today, thanks to the combined growth in rooftop solar installations, investments in buildings efficiency and electric vehicle purchases. For the moment, these investments are mainly made by wealthier households – and well-designed policies are essential to making clean energy technologies more accessible to all. A comparison shows that households have contributed to more than 40% of the increase in investment in clean energy spending since 2016 – by far the largest share. It was particularly pronounced in advanced economies, where, because of strong policy support, households accounted for nearly 60% of the growth in energy investments.

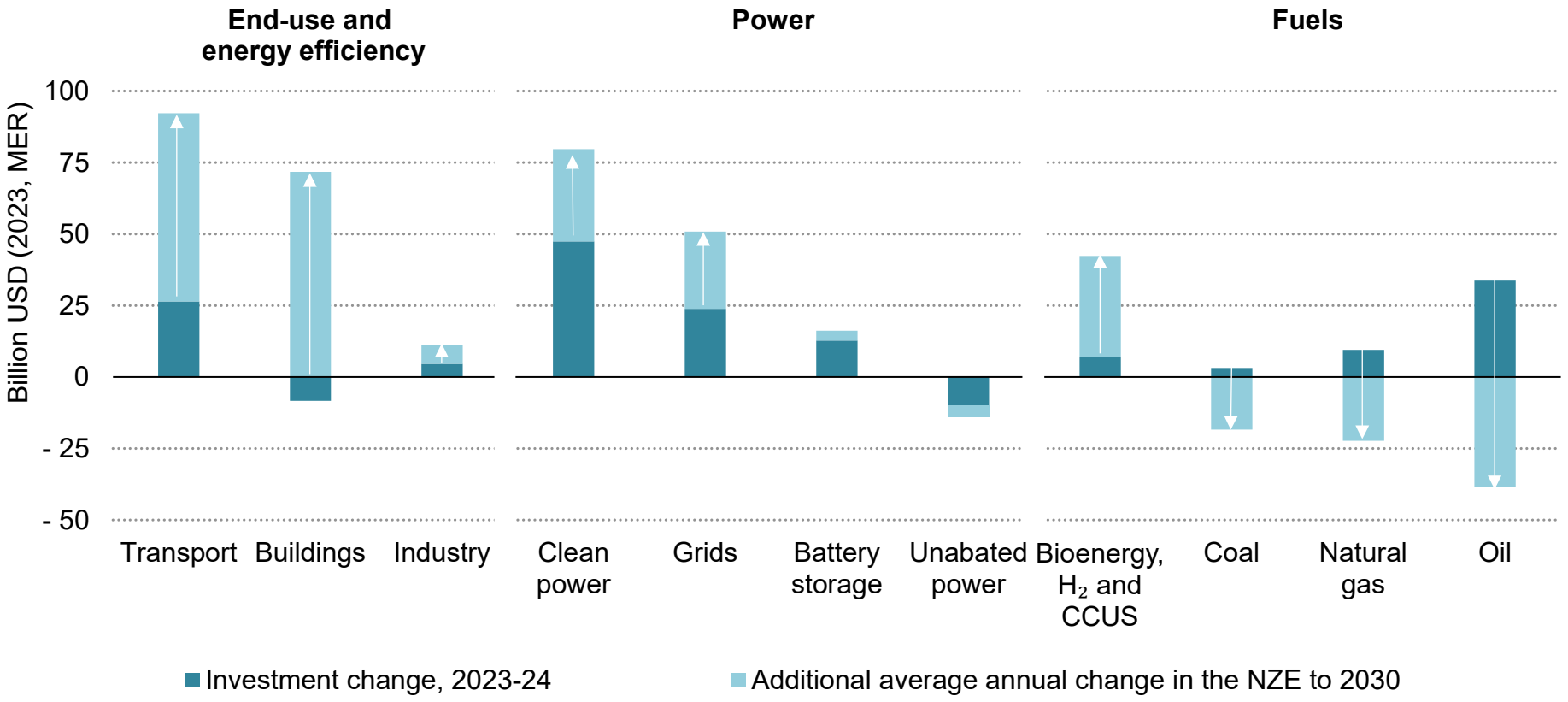
Three quarters of global energy investments today are funded from private and commercial sources, and around 25% from public finance, and just 1% from national and international development finance institutions (DFIs).

Other financing options for energy transition have faced challenges and are focused on advanced economies. In 2023, sustainable debt issuances exceeded USD 1 trillion for the third consecutive year, but were still 25% below their 2021 peak, as rising coupon rates dampened issuers' borrowing appetite. Market sentiment for sustainable finance is wavering, with flows to ESG funds decreasing in 2023, due to potential higher returns elsewhere and credibility concerns. Transition finance is emerging to mobilise capital for high-emitting sectors, but greater harmonisation and credible standards are required for these instruments to reach scale.

Tracking COP28 Progress

A secure and affordable transitioning away from fossil fuels requires a major rebalancing of investments

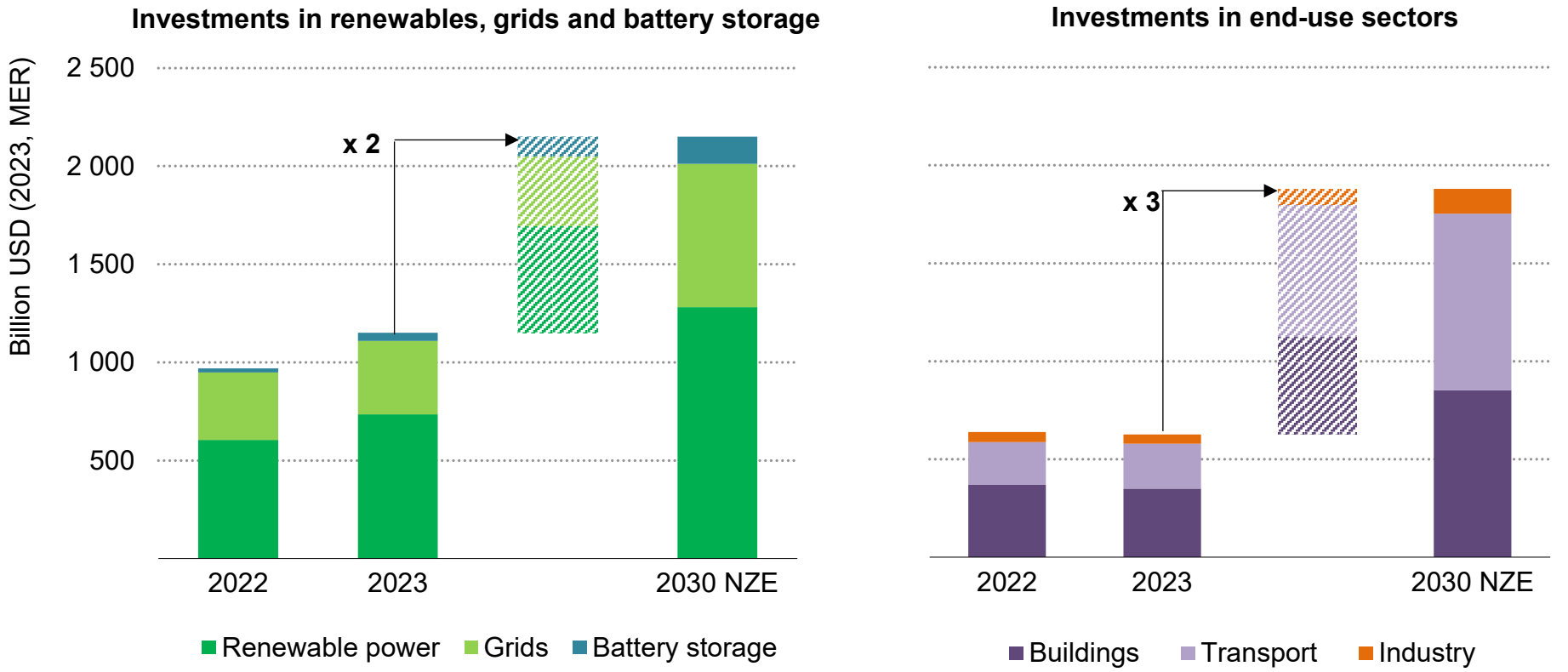
Investment change in 2023-2024, and additional average annual change in investment in the NZE Scenario, 2023-2030



Note: CCUS = carbon capture, utilisation, and storage. Low-emissions generation includes modern bioenergy, low-emissions hydrogen, hydrogen-based fuels and CCUS associated with fossil fuels. NZE = Net Zero Emissions by 2050 Scenario.

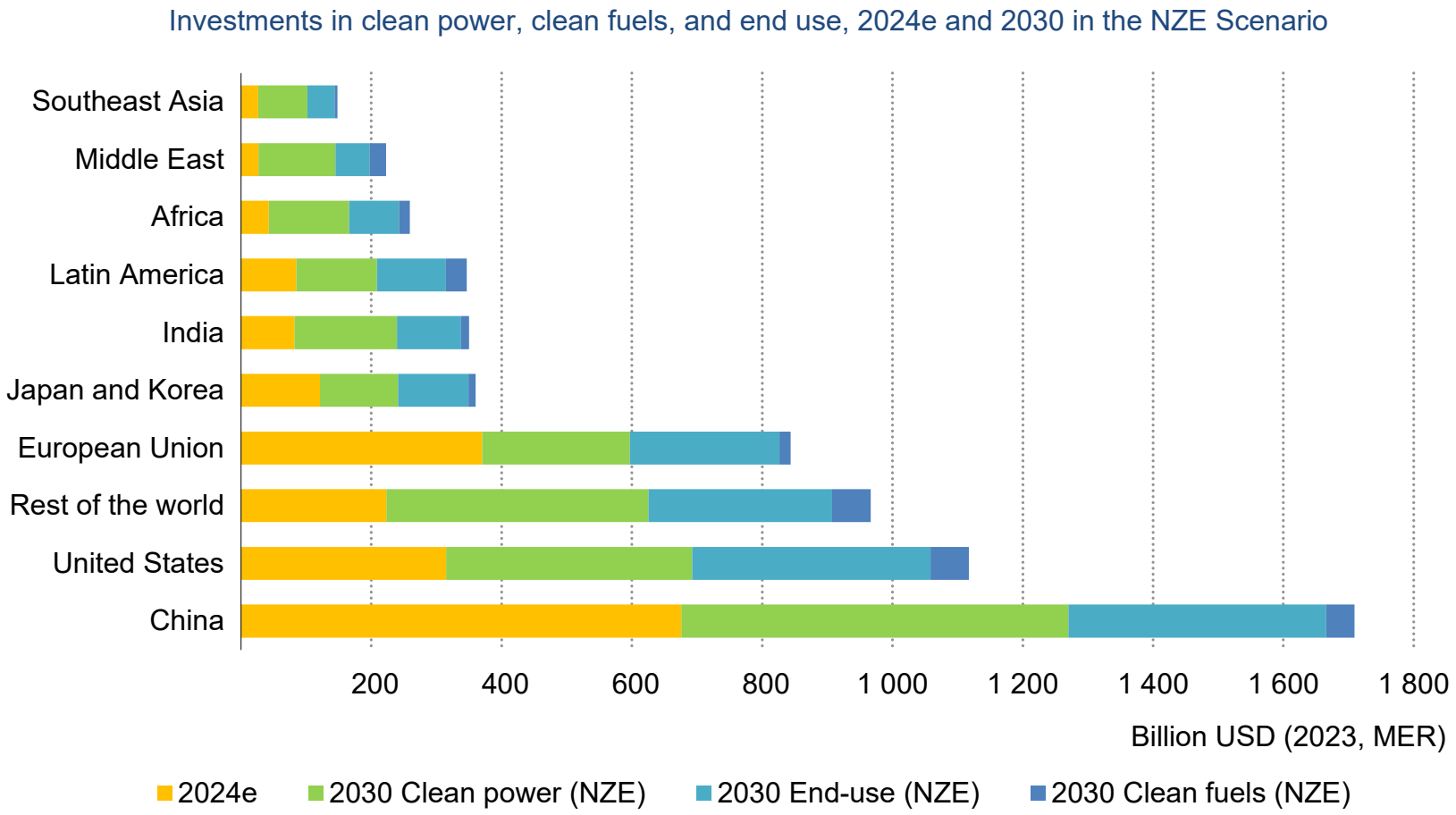
A doubling of investments to triple renewables capacity and a tripling of spending to double efficiency: a steep hill needs climbing to keep 1.5 °C within reach

Investments in renewable power, grids, and battery storage, as well as end-use sectors, today versus 2030 in the NZE Scenario



Note: Investments in end-use sectors include energy efficiency, electrification, and renewables for end use. NZE = Net Zero Emissions by 2050 Scenario.

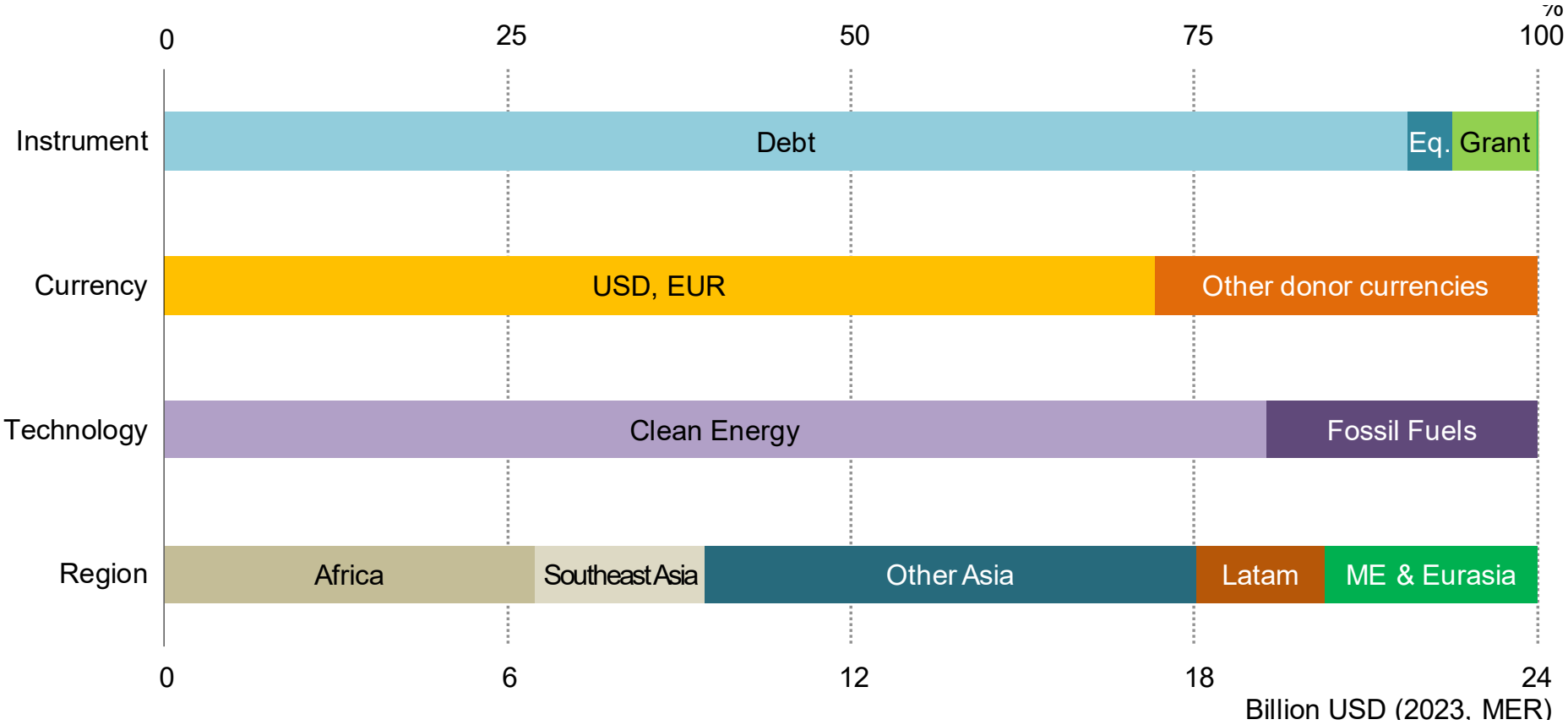
Meeting COP28 goals requires a doubling of clean energy investment by 2030 worldwide, and a quadrupling in EMDE outside China



Note: NZE = Net Zero Emissions by 2050 Scenario. End use includes energy efficiency and electrification.

Mobilising additional, affordable financing is the key to a safer and more sustainable future

Breakdown of DFI financing by instrument, currency, technology, and region, average 2019-2022



Note: DFI = Development Finance Institutions, excluding China-based DFIs. Eq. = Equity. The volume of DFI financing in the OECD Creditor Reporting System (CRS) database is typically reported in donor currency.

Source: IEA analysis based on total reported disbursements from the OECD CRS database.

Much greater efforts are needed to get on track to meet energy & climate goals, including those agreed at COP28

Today's investment trends are not aligned with the levels necessary for the world to have a chance of limiting global warming to 1.5 °C above pre-industrial levels and to achieve the interim goals agreed at COP28. The current momentum behind renewable power is impressive, and if the current spending trend continues, it would cover approximately two-thirds of the total investment needed to triple renewable capacity by 2030. But an extra USD 500 billion per year is required in the IEA's Net Zero Emissions by 2050 Scenario (NZE Scenario) to fill the gap completely (including spending for grids and battery storage). This equates to a doubling of current annual spending on renewable power generation, grids, and storage in 2030, in order to triple renewable capacity.

The goal of doubling the pace of energy efficiency improvement requires an even greater additional effort. While investment in the electrification of transport is relatively strong and brings important efficiency gains, investment in other efficiency measures – notably building retrofits – is well below where it needs to be: efficiency investments in buildings fell in 2023 and are expected to decline further in 2024. A tripling in the current annual rate of spending on efficiency and electrification – to about USD 1.9 trillion in 2030 – is needed to double the rate of energy efficiency improvements.

Anticipated oil and gas investment in 2024 is broadly in line with the level of investment required in 2030 in the Stated Policies Scenario, a scenario which sees oil and natural gas demand levelling off before 2030. However, global spare oil production capacity is already close to 6 million barrels per day (excluding Iran and Russia) and there is a shift expected in the coming years towards a buyers' market for LNG. Against this backdrop, the risk of over-investment would be strong if the world moves swiftly to meet the net zero pledges and climate goals in the Announced Pledges Scenario (APS) and the NZE Scenario.

The NZE Scenario sees a major rebalancing of investments in fuel supply, away from fossil fuels and towards low-emissions fuels, such as bioenergy and low-emissions hydrogen, as well as CCUS. Achieving net zero emissions globally by 2050 would mean annual investment in oil, gas, and coal falls by more than half, from just over USD 1 trillion in 2024 to below USD 450 billion per year in 2030, while spending on low-emissions fuels increases tenfold, to about USD 200 billion in 2030 from just under USD 20 billion today.

The required increase in clean energy investments in the NZE Scenario is particularly steep in many emerging and developing economies. The cost of capital remains one of the largest barriers to

investment in clean energy projects and infrastructure in many EMDE, with financing costs at least twice as high as in advanced economies as well as China. Macroeconomic and country-specific factors are the major contributors to the high cost of capital for clean energy projects, but so, too, are risks specific to the energy sector. Alongside actions by national policy makers, enhanced support from DFIs can play a major role in lowering financing costs and bringing in much larger volumes of private capital.

Targeted concessional support is particularly important for the least-developed countries that will otherwise struggle to access adequate capital. Our analysis shows cumulative financing for energy projects by DFIs was USD 470 billion between 2013 and 2021, with China-based DFIs accounting for slightly over half of the total. There was a significant reduction in financing for fossil fuel projects over this period, largely because of reduced Chinese support. However, this was not accompanied by a surge in support for clean energy projects. DFI support was provided almost exclusively (more than 90%) as debt (not all concessional) with only about 3% reported as equity financing and about 6% as grants. This debt was provided in hard currency or in the currency of donors, with almost no local-currency financing being reported.

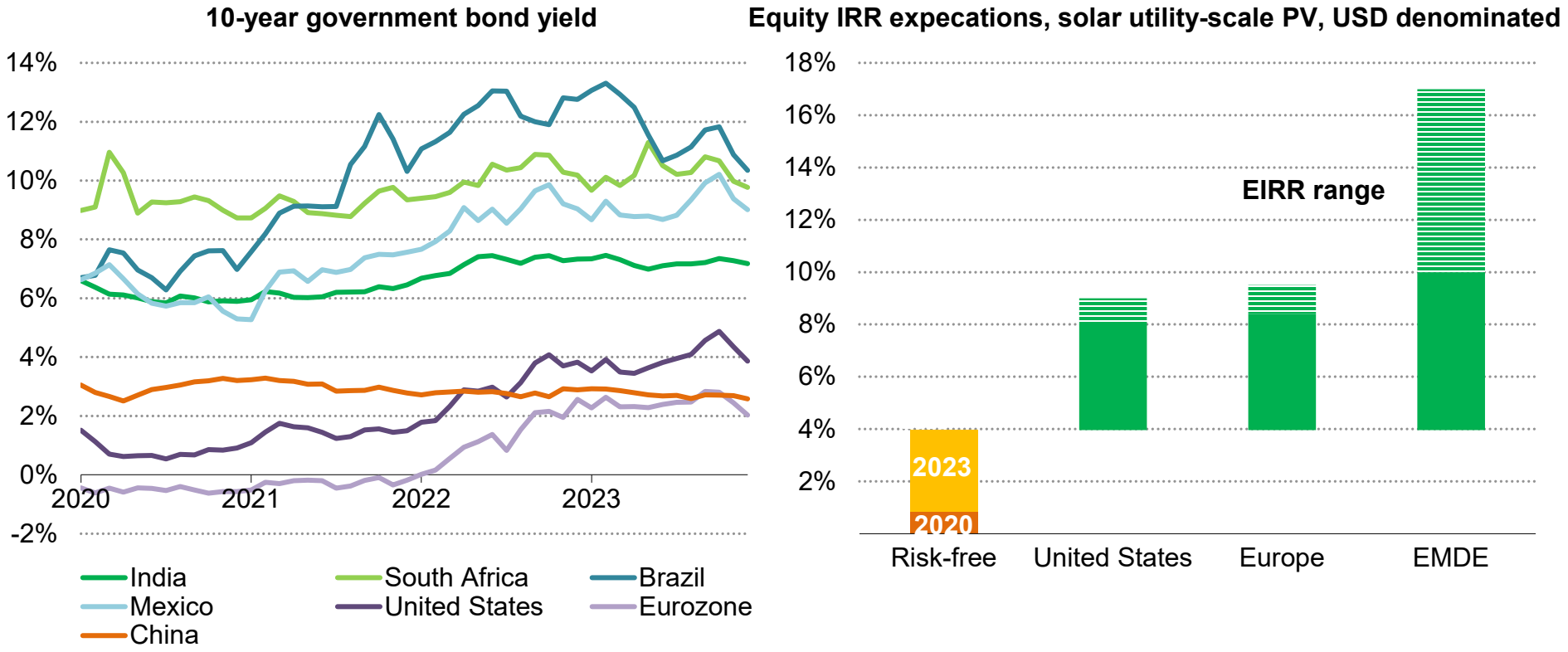
The lack of local-currency lending pushes up borrowing costs and in many cases is the primary reason behind the much higher cost of capital in EMDE compared to advanced economies. High hedging costs often make this financing unaffordable to many of the least-developed countries and raises questions of debt sustainability. More attention is needed from DFIs to focus interventions on project de-risking that can mobilise much higher multiples of private capital.

Finance

Overview

The cost of capital has increased across most of the world, with emerging and developing economies outside China facing much higher financing costs

Indicators of local-currency, economy-wide cost of debt and USD-based equity ranges for utility-scale solar PV in selected regions



Note: Data on government bond yields includes information until end-2023. EIRR = expected equity internal rate of return. The shaded bars do not reflect an increase, but rather the range of EIRR for 2023. For emerging market and developing economies (EMDE, which excludes China), this range is wider because risk perceptions for solar PV projects vary significantly by country.

Source: IEA analysis based on Refinitiv (2023) and IEA (2023), Cost of Capital Observatory.

Rising finance costs shape today's energy investment climate

Meeting the targets for sustainable development, climate and energy security will require a substantial increase in capital investment in energy. As these investments scale up globally, it is increasingly important to understand the prevailing trends affecting capital-allocation decisions across various finance providers, which is why this year's World Energy Investment report begins with a chapter on finance.

This chapter provides an overview of current financing trends. It makes a distinction between the notions of *investment* – understood as a capital expenditure used to build or acquire an asset – and *finance*, which encompasses the origin of the funds supporting an investment, as well as the form it takes and who is providing it. Within the energy finance ecosystem, we explore the different roles played by *capital providers* – the ones who make the investment decisions (e.g. governments, households and the private sector), also known as "sources of investment" – and *finance providers*. This second group includes development finance institutions as well as other public and private sources capital – which we refer to as "sources of finance." We also look at emerging themes such as transition finance and consider how the development of transition plans by financial institutions and corporations can support access to capital for hard-to-abate sectors. The role of carbon markets and carbon pricing is also discussed.

The year 2023 was marked by a spike in interest rates across many countries – including advanced economies where relatively low inflation and low interest rates had prevailed for more than a decade in the wake of the 2008 financial crisis. While the 2020-2022 pandemic drove interest rates sharply lower across much of the world, inflation pressures mounted in 2022, changing this trajectory. Compounding this trend, the invasion of Ukraine by the Russian Federation ("Russia" hereafter) in early 2022 – as well as other geopolitical conflicts across the world – increased political risks, driving up the cost of capital. Interest rates on long-term, local-currency government bonds – a benchmark indicator for the cost of capital in a country – rose considerably in many countries, with the notable exception of the People's Republic of China ("China" hereafter). Yields on ten-year United States Treasury bonds, for example, increased by about three percentage points between 2020 and 2023, with even larger differences in the US overnight interbank lending rate (the short-term rate). A similar trend was seen in bonds issued by European governments. Sharp increases in US interest rates have a significant knock-on effect for capital investments worldwide – including in emerging market and developing economies (EMDE) – because the assets held by most large international investors, asset managers and financiers are valued in US dollars (USD) and most major projects, regardless of geography, are also

priced in USD. On top of this, local-currency financing has also become more expensive in many EMDE, including Brazil, Mexico, India and South Africa.

In addition to raising borrowing costs, higher interest rates also affect the cost of equity, which is estimated as the sum of the *risk-free rate* (e.g. the return on a bond issued by a low-risk country like the United States) and the *equity risk premium* (the additional return that compensates investors for taking on the higher risk of equity). The expected equity internal rate of return (EIRR) of utility-scale solar photovoltaic (PV) projects in the United States, for example, has soared in recent years, reaching between 8% and 9% in 2023. But these USD rates of return are still about half of what foreign investors require to finance a similar project in some EMDE. Although the variations in both EIRR and the cost of capital vary widely among EMDE, developing and emerging economies face higher costs of capital in general due to the greater risks – real or perceived – of investing in a particular jurisdiction and/or industrial sector. This remains a significant barrier to increased levels of investment in these regions.

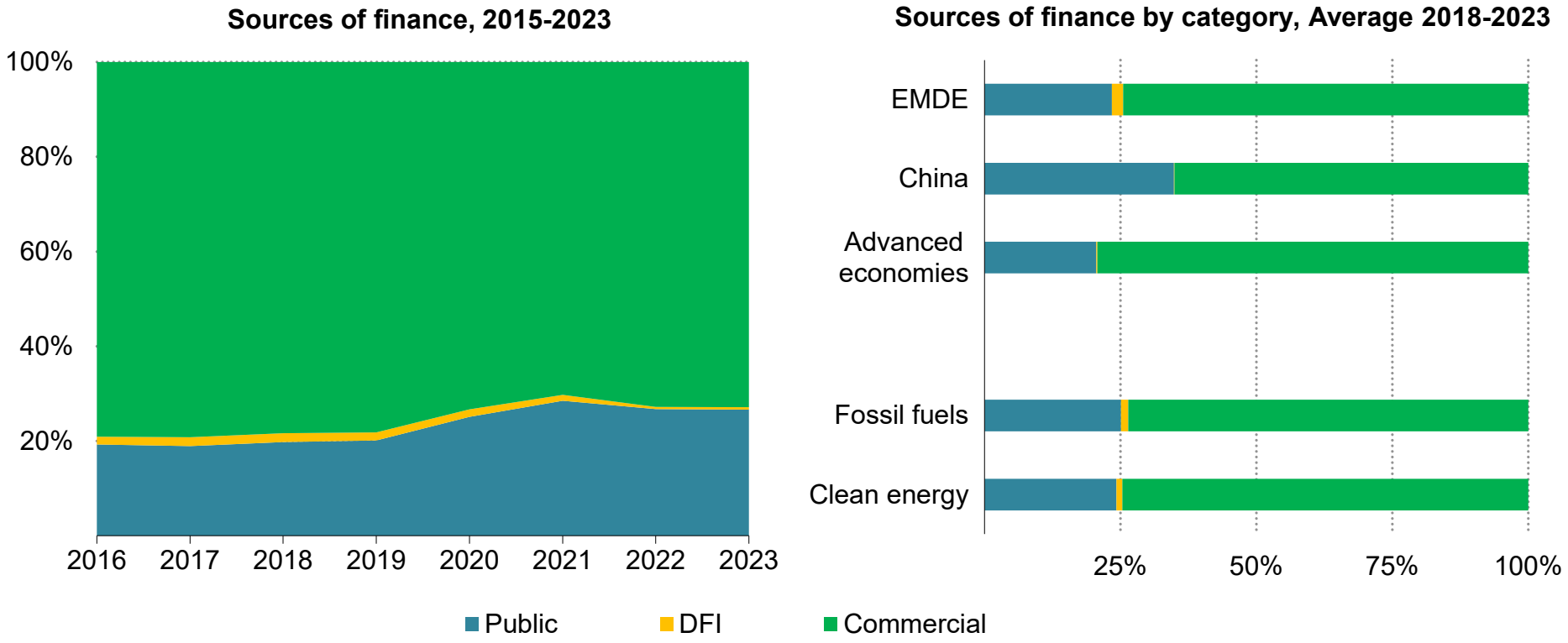
A higher cost of capital – the weighted average of the costs associated with raising funds for investments – makes it much more difficult to generate attractive risk-adjusted returns. This is especially true for relatively capital-intensive clean energy technologies that require a large upfront investment, that are generally more dependent on debt financing (compared to the oil and gas industry) and where operating expenses tend to represent a relatively small share of total project costs. Although ambitious government policies, technological advancements and declining cost trends (all key factors in determining energy project costs) have helped offset some of the rise in capital costs, the general rise in interest rates and a stronger USD are not good news for investment anywhere.

The picture in China is somewhat different. China did not suffer inflation pressures in the wake of the pandemic, but it has been battling relatively low economic growth and weakness in the property sector, with knock-on effects for local banks. This is why, unlike most of the world, China has kept benchmark lending rates low.

Elsewhere, there are signs that benchmark interest rates may not remain high for long. There is ample debate on when and how fast they may come down, though most experts agree that the exceptional period of near-zero interest rates is probably over. The US Federal Reserve (Fed) has indicated that it plans to cut its short-term benchmark by 75 basis points in 2024, although this expected rate-cutting cycle has been delayed repeatedly because US inflation remains stuck above the Fed's 2% target. These movements are beyond the remit of energy policy makers, but will be important for determining the pace of the energy transition over the next years.

Finance from commercial sources supports roughly 73% of energy investments overall, although public finance plays a larger role in China and some other EMDE countries …

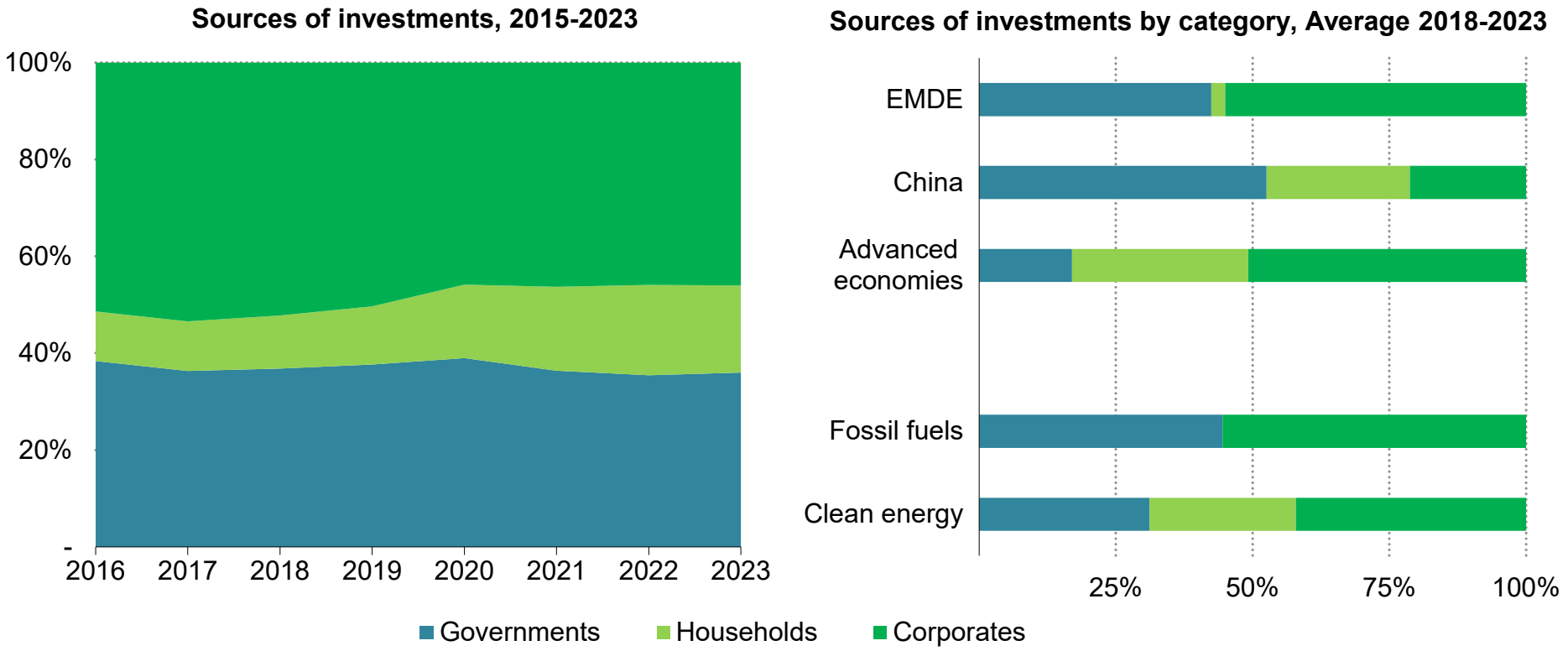
Changes in finance providers over time and by category



Note: “Commercial finance” includes equity investments made by private enterprises and households, alongside debt from financial institutions. It also includes some finance from state-owned banks, sovereign wealth funds and pension funds, although this includes a degree of state-directed lending, especially in emerging economies with strong industrial policies. “Public finance” includes public equity stakes in private corporations and state-owned enterprises, state subsidies and tax incentives and finance from export credit agencies as well as central banks. “DFI” refers to Development Finance Institutions that have a development mandate.
Source: IEA analysis based on data from S&P Capital IQ, IJGlobal, Rystad, World Bank, OECD, CRS, China Aid data.

… meanwhile the entities making the investments have evolved, with households gradually taking on a larger share through spending on efficiency, electric vehicles and rooftop solar

Changes in sources of investment over time and by category

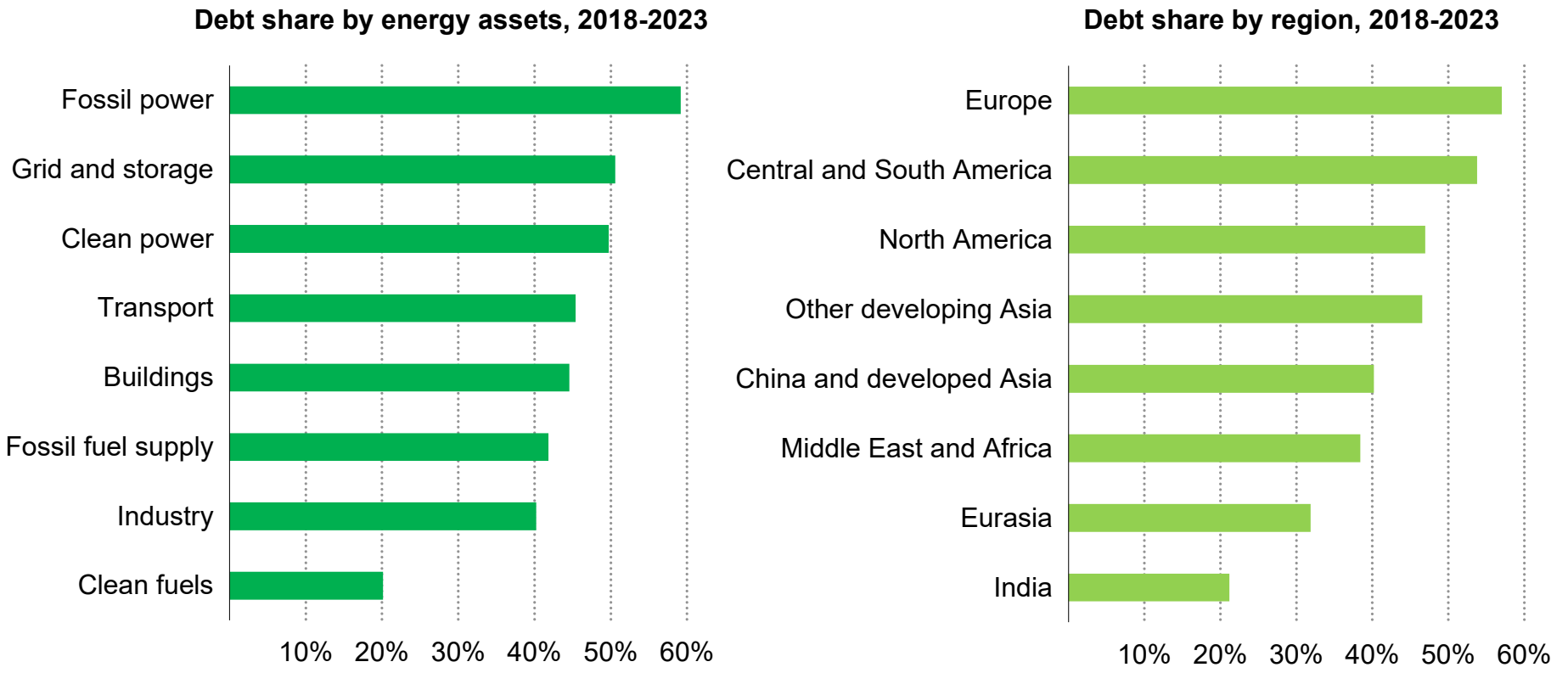


Note: “Government” refers to stated-owned companies and state-owned assets (in the case of buildings for example). “Corporates” refer to private and publicly listed companies.

Source: IEA analysis based on data from S&P Capital IQ, IJGlobal, Rystad, World Bank, OECD.

Debt financing is more prominently used in power, grids and developed markets, while larger equity stakes are seen in emerging and end-use technologies, fossil fuel supply and EMDE

Capital structure by energy assets and regions



Source: IEA analysis based on data from S&P Capital IQ, IJGlobal, Rystad, World Bank, OECD.

Clean energy is reshaping the role played by the private sector, including households, while government funding still plays a large role in China and in supporting fossil fuels in EMDE

Since 2016, there has been a significant change in the types of energy assets being financed, but less of a change in where capital has come from. Between 2016 and 2023, clean energy's share of total energy investment increased from around 50% to 63%. Throughout this period, private sources of finance made up the bulk of spending, accounting for 73% in 2023. While this share remains roughly the same by 2030 in the NZE Scenario, in absolute terms it represents an increase of USD 1.5 trillion in private sector spending.

The role of public financing – i.e. state-owned enterprises (SOEs), equity stakes in public assets such as government buildings and public vehicle fleets, as well as various subsidies and tax incentives – has decreased slightly. Public finance plays a larger role in EMDE, accounting for 32% of spending between 2016 and 2023, compared with 14% in advanced economies. Debt sustainability has become a growing concern across EMDE – three quarters of all developing economies have debt-to-GDP ratios of at least 75% – so mobilising a greater share of private finance in these markets will be essential.

Government investment in global energy assets has remained broadly stable at around 37% of assets for the 2015-2023 period. The government plays a particularly prominent role in fossil fuel asset ownership, meaning they are most involved in the energy sector in regions with high fossil fuel production such as the Middle East, Russia and the Caspian states. As these economies respond to the energy transition, many SOEs will remain responsible for electricity networks and utility-scale power generation, while policy makers are increasingly positioning their SOEs to be key players in the energy transition. Still, the role of SOEs in global energy financing is expected to decrease over time as end-use sectors gradually take on a larger share of total investment.

In China, government ownership accounts for 60% of all energy assets and is particularly evident in fossil fuels, where nearly all of assets are government owned. China has taken steps to support large SOEs and state-owned banks to increase clean energy finance, including through the development of sustainable finance regulations and incentives, so state ownership is expected to remain prominent even as clean energy becomes a larger part of the energy mix.

As energy transitions have gained momentum in recent years, we have seen a rise in investments made by households. Their share of new spending has doubled from 9% in 2015 to 18% in 2023. This is due to growth in rooftop solar, energy efficiency in buildings and the purchase of electric vehicles. With households taking on a higher share of energy investment, affordability and cost-of-living concerns may act as potential brakes on investment in the coming year. Unlike corporations or governments, consumer finance operates under

different constraints – use-of-proceeds, application processes, interest rates and fees, etc. – requiring unique policies and financing instruments. The financial institutions supporting consumers with financing also have a different profile compared to financial institutions lending to utility-scale projects. This fundamental shift in the system emphasises the need for tailored approaches to support households in their transition towards sustainable energy practices.

Capital structure – i.e. the combination of debt and equity used to finance energy assets – has remained fairly stable over the last 8 years at around 46% debt. This varies significantly between energy assets and regions. Fossil fuels have the lowest share of debt at around 40%. The last two years saw large repayments by oil and gas companies; prior to that, a period of low commodity prices ate into fossil fuel companies' profitability, limiting their use of retained earnings to pay back debt. For clean power, the share of debt is closer to 50% – down from 60% in the late 2010s – driven by the need for high upfront capital investment. This change is partly due to better growth opportunities for the sector and lower equipment costs, but also to the contractual repayment of debt used for the upfront capital of previously installed clean power. Meanwhile, the share of debt financing in the end-use sectors – with higher household participation – is 45%, close to the average for all energy assets.

Reducing the uncertainty on debt financing availability is crucial for the energy transition. Under the NZE Scenario, around 45% of investments in clean energy relies on debt – particularly in grid investment, where debt accounts for more than 50% of capital spending. This trend will feed into the concerns about countries' capacity to sustain high levels of borrowing, particularly in EMDE. Whether debt is provided on a corporate or project finance basis also matters. Grids are typically financed on a corporate basis while solar PV and wind are increasingly on a project finance basis. This ends up being particularly important in EMDE, where lending on a corporate basis to utilities is challenging without tackling the fundamental financial health of the utility.

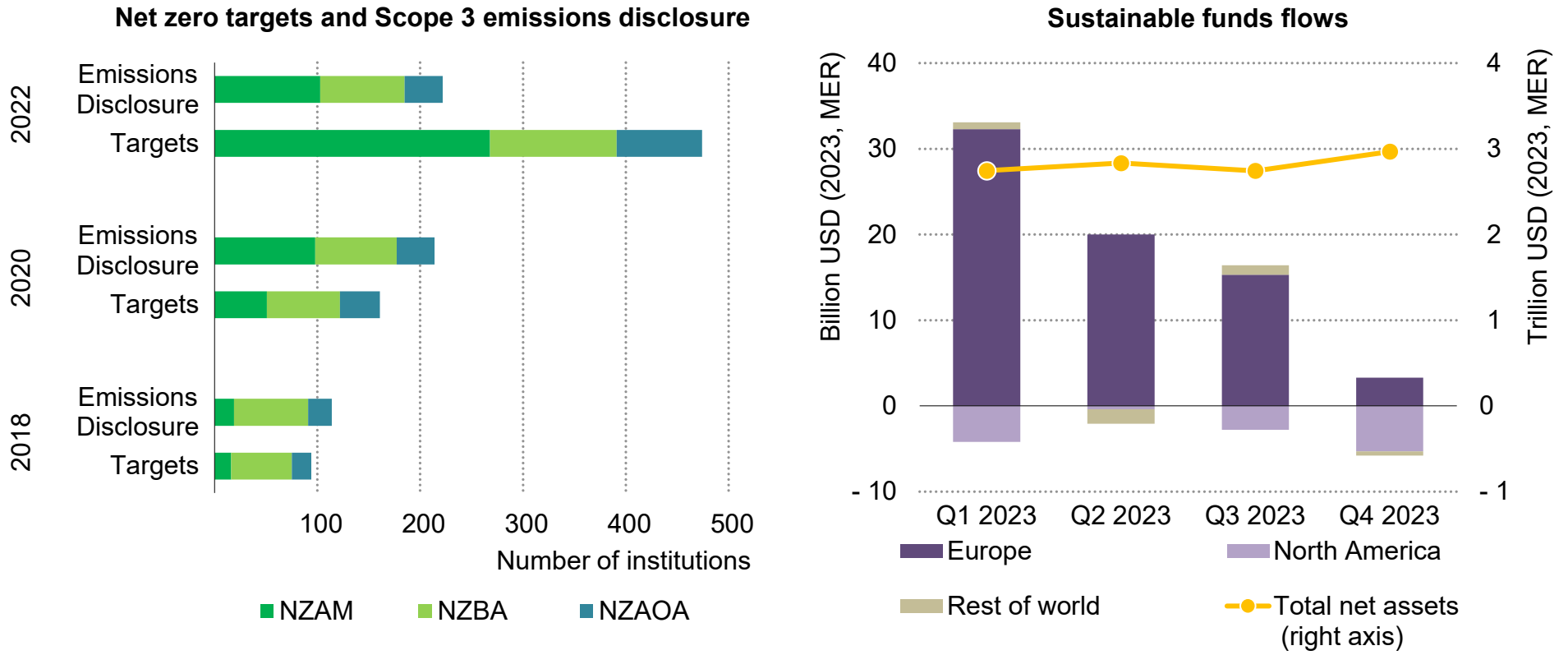
Meanwhile, equity financing plays a key role in funding clean energy technologies with high upfront risks – such as geothermal or hydro – or less mature technologies like battery storage, carbon capture, and low-carbon hydrogen. As these technologies mature, the risks should fall, allowing more debt to be used. Long construction timelines, such as for grid and nuclear, also increase the technology risks.

Equally, in less mature markets, even established technologies can count on a larger share of equity to take on the risks in development and construction phase. As newer technologies and markets establish a track record, there is potential for the share of debt to increase as governments implement supportive policies to bolster business models with stable cash flows. This can be particularly important in some EMDE, where a limited supply of equity (e.g. in Africa) acts as a brake on the development of bankable projects. This is where Development Finance Institutions (DFI) could step in to provide funds without increasing the debt burden in EMDE countries.

Trends for financial market actors

Financial institutions continued to announce net zero targets or emission disclosure plans, but reduced inflows to sustainable funds in 2023 reflected wavering market sentiment

Trends in sustainable finance investing



Notes: NZBA = Net-Zero Banking Alliance; NZAM = Net-Zero Asset Managers Initiative; NZAOA = Net-Zero Asset Owner Alliance. ‘’Targets” tracks the institutions that have either adopted net-zero targets or met most minimum conditions for targets. ‘’Emissions Disclosure” tracks the institutions that have committed to Scope 3 emissions disclosure, or that track or disclose a portion of portfolio emissions. The institutions covered are those tracked by the Climate Policy Initiative.

Source: Climate Policy Initiative (2023), Morningstar (2023).

Sustainable funds rebounded in early 2024, while interest is growing for financial industry engagement to focus on credible transition plans as opposed to emissions disclosure

Sustainable finance regulations have recently provided a tailwind for clean energy investments, but 2023 was a challenging year for sustainable investment practices. For the first time, sustainable funds saw a net outflow in the fourth quarter, notably including in Europe – home to 84% of sustainable funds by value. Outflows have become common in the United States, occurring for the last five quarters as environmental, social and governance (ESG) issues become increasingly politicised. Meanwhile, in Europe, sustainable funds consistently attracted larger proportional inflows than conventional funds, but the two have gradually converged in 2023 and as the market tightened, actively managed sustainable funds saw outflows for the first time. This is likely due to a combination of factors, with many fund managers increasing their allocations to government bonds, and concern growing over the classification of sustainable funds. Despite these concerns, the value of sustainable funds globally increased by 8% in 2023, driven by a rally in growth stocks (those that focus on long-term potential).

The pushback against ESG in the United States had an impact beyond sustainable funds. In February, two of the largest US-based asset managers – JPMorgan Chase and State Street – withdrew from Climate Action 100+ (CA100+), an investor-led initiative designed to encourage decarbonisation by large emitters. Blackrock also scaled back its involvement in the initiative, transferring participation from their US business to the smaller, international arm. CA100+ has also seen withdrawals from Europe, including Swiss Re in March 2024, with most firms arguing that they can achieve similar goals through independent engagement with emitters. Analysis of proxy voting patterns in 2024 indicates that support for climate-related resolutions remains strong, but most of these are focused on emissions disclosure. The departures from CA100+ came at a time when the initiative aimed to increase their focus on enactment of climate transition plans, as well as the continued push for improved disclosure.

There has been a growing emphasis on moving beyond disclosures to implementing transition plans, particularly among asset owners, who play a key role in the financing chain due to their ability to influence both corporate strategy and the approach of asset managers. In December 2023, the UN-Convened Net Zero Asset Owners Alliance (NZAOA) released guidance on how to strengthen engagement on transition planning, alongside development of credible plans for their own activities. Several months later, the NZAOA also published guidelines for asset managers on how to support their asset owner clients through strengthened climate stewardship.

The banking sector is also wrestling with how to adhere to tighter climate disclosure regulations without slowing real economic growth by restricting to key sectors

Banks play a particularly important role in the financing of energy projects because of their large pools of capital (primarily for debt financing) and because they provide funding at both the project and corporate level as well as to households, who play an increasing role in energy supply under the NZE Scenario. Banks can support energy transitions through the design of sustainable loan products and engagement with the companies they finance. Similarly, banks can create tailored consumer loan offerings to incentivise clean energy spending at the household level with products like green mortgages.

There is significant diversity within the banking sector, and the role of banks in the energy transition is likely to vary by their size and by region. The UN-convened Net Zero Banking Alliance (NZBA) plays a leadership role, working across the sector to promote approaches to decarbonise lending, develop transition finance tools and facilitate the managed phase-out of fossil fuels. Currently, more than 140 banks are NZBA members, and around 40% of global banking assets are held by banks with net-zero commitments. Despite this, data from Bloomberg indicate that the ratio of clean energy funding (including debt and equity underwriting) compared to fossil fuels has slightly worsened: For every 1 USD loaned to the fossil fuel sector in 2021, 75 cents went to clean energy companies. By 2022, the ratio had fallen to 73 cents (latest available data).

Sustainable finance regulations for the banking sector are primarily focused on improving disclosure. For example, in November 2023, the Basel Committee published a draft climate disclosure framework for consultation aimed at improving the tracking of banks' progress on climate-related activities. However, several banks have expressed concerns about the metrics used to measure these activities. Currently, the main metric used is financed emissions (i.e. banks' Scope 3 emissions) but these emissions are not widely reported by companies and are hard to estimate accurately. Furthermore, there is still debate over whether financed emissions are the best proxy for climate risk, with banks arguing for the use of multiple metrics, including a calculation related to transition finance.

Tighter regulations increase the risk that businesses in hard-to-abate sectors can no longer access financing from banks in markets with stricter climate regulations. This forces those businesses to raise capital in markets with more lax environments, where banks are also less likely to engage with companies over transition plans. This practice – financial carbon leakage – could delay change in the real economy. Avoiding this outcome means increasing the number of banks committed to net zero, while also ensuring that sustainable finance regulation considers transition financing.

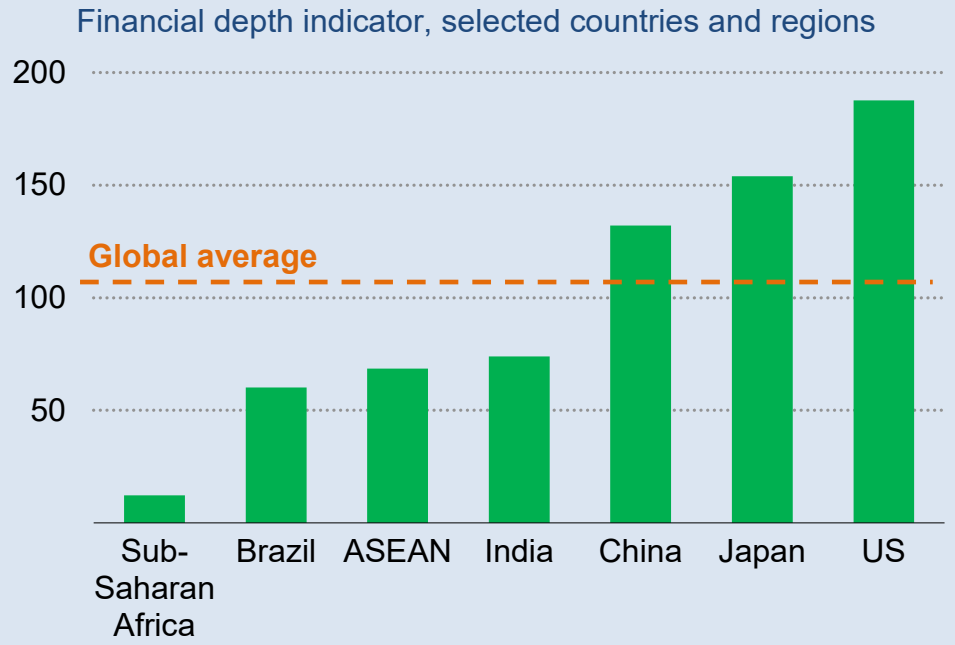
Box 1.1. Growing domestic private financial sector involvement in clean energy in EMDE

Currency risk is often cited as one of the primary drivers of high financing costs for energy projects, while also contributing to the growing debt problem in EMDE countries. Given the scale of investment needs, funding from advanced economies will remain important. Solutions such as hedging products allow hard currency funders to lend in local currencies, but these can add complexity and cost to financing arrangements. Domestic financial institutions, which lend in local currency and are less subject to external shocks, also therefore play a key role.

There is currently significant variation in the role of domestic capital in energy financing based on the depth of local markets. Domestic financing dominates in some of the larger EMDE, such as India and Brazil, or regions with well-developed financial sectors such as ASEAN. In these markets, various approaches allow local capital providers to invest in energy projects at an affordable rate, including tools like sustainable debt issuance, as in ASEAN, or mechanisms where the government absorbs some costs of commercial lenders, as in India.

In EMDE where the financial sector is less deep (e.g. sub-Saharan Africa) institutional investors such as pension funds often primarily invest in government securities, with limited familiarity with other investment classes such as infrastructure.

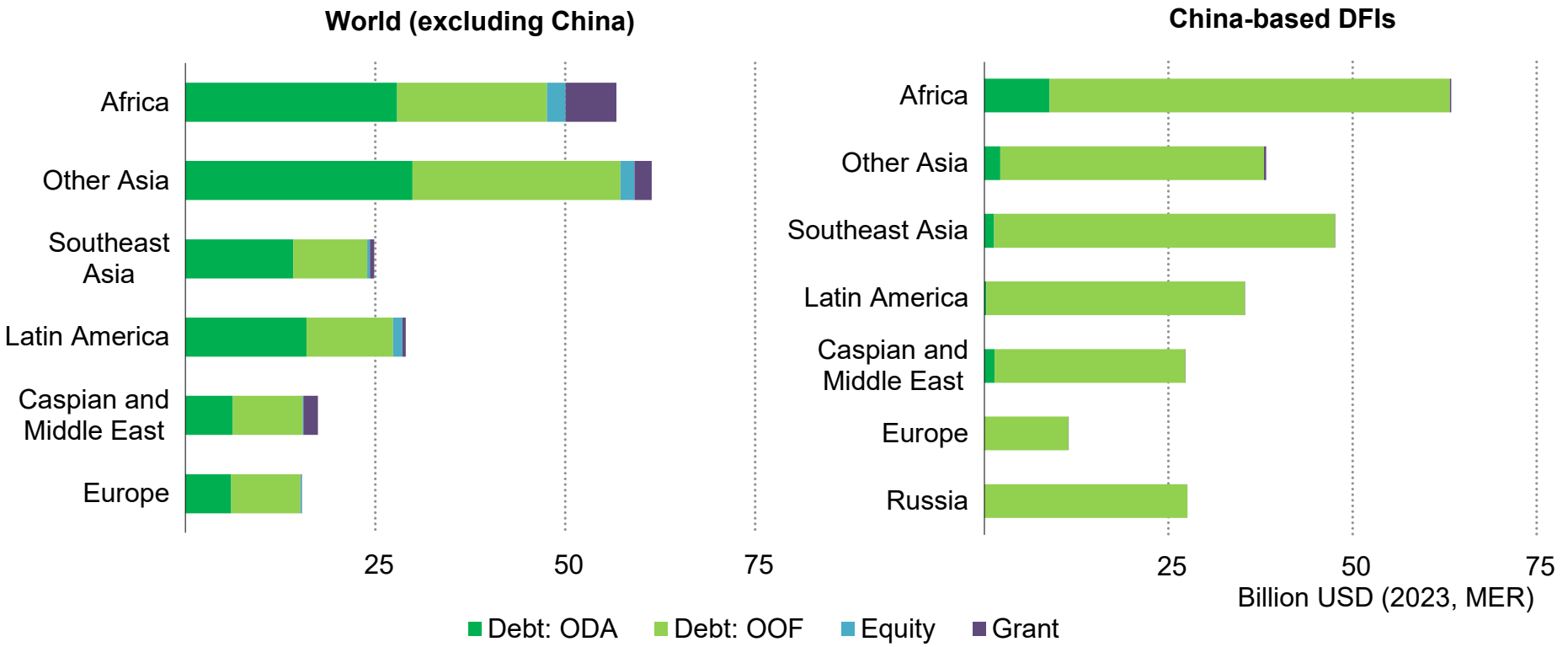
New mechanisms are emerging to tap into this capital source. For example, in Nigeria, InfraCredit – a local currency guarantee provider – has helped 19 local pension funds enter the energy sector, mobilising USD 206 million over the last five years. This group of investors is most likely to invest in operational assets, including via refinancing structures that help free up development capital for greenfield assets.



Source: IEA analysis based on World Bank data on domestic credit to the private sector and the market capitalisation of listed domestic companies.

Development finance institutions primarily provide debt financing, and are making progress in mobilising private capital for renewable power projects

Development finance provided to different regions by financial instrument, 2013-2021

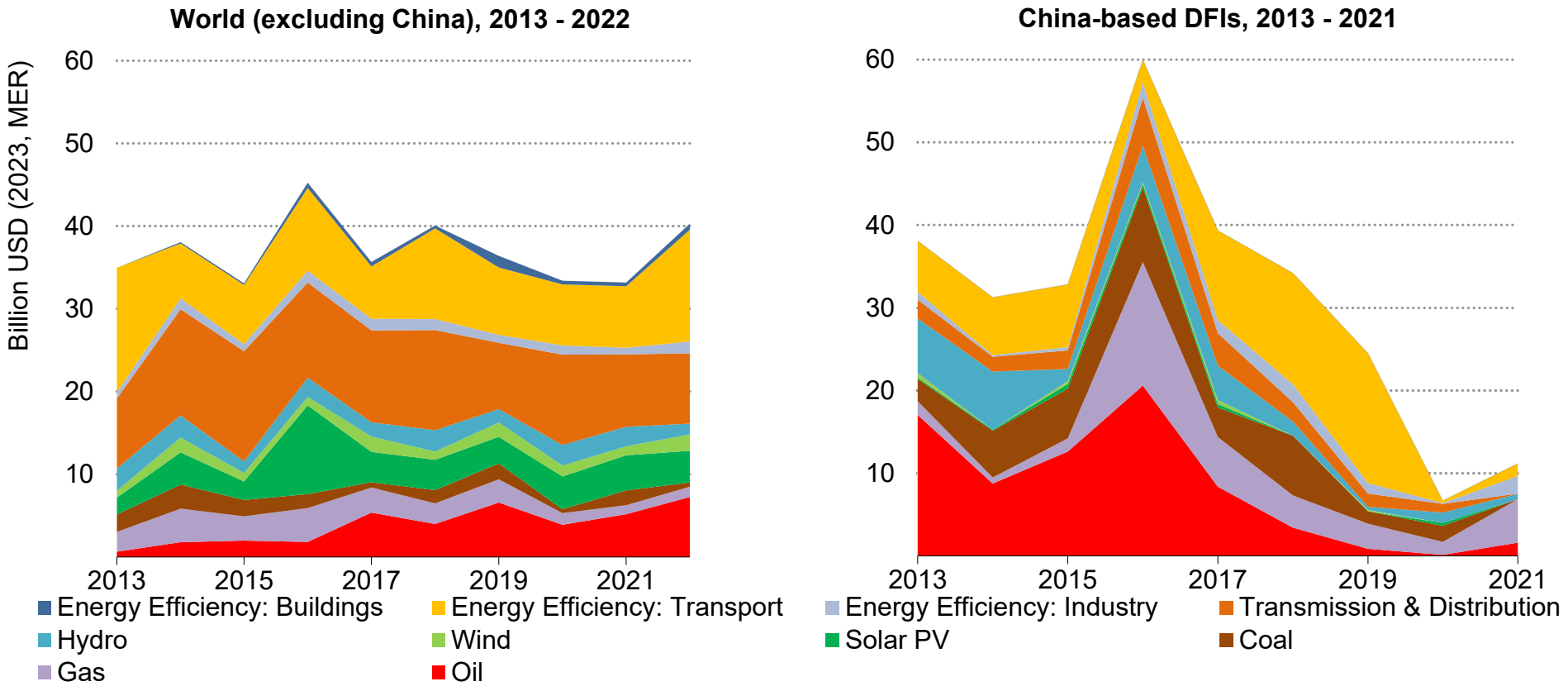


Note: Based on reported total disbursements. ODA = Official Development Assistance – concessional funds that meet the ODA grant equivalent threshold with economic development and welfare as the main objective; OOF = Other Official Flows that do not meet ODA criteria, excluding export credits. All equity financing is counted as ODA. "China-based DFIs" refer to China Development Bank and the Export-Import Bank of China, which do not report to the OECD Development Assistance Committee; hence its financing should be understood as ODA or OOF-*like*.

Source: IEA calculations based on OECD CRS and AidData's Global Chinese Development Finance Dataset, Version 3.0.

Development finance institutions have reduced their support for fossil fuel activities, notably from China, but this has not been accompanied by a surge in financing for clean energy

DFI financing by technology



Note: Based on yearly commitments. Oil, gas and coal include fuel supply and power generation. All Chinese financing covered in this analysis refers to overseas flows. Analysis of domestic investment trends is covered in more detail in Chapter 7, Regional Deep Dive.

Source: IEA calculations based on OECD CRS and AidData's Global Chinese Development Finance Dataset, Version 3.0.

DFIs play a crucial and unique role due to their ability to take on higher-risk projects, but they are facing pressure to ramp up financing and to scale up private sector mobilisation

Development finance institutions (DFIs) are uniquely positioned to catalyse investment flows towards sustainable and resilient energy infrastructure, particularly in EMDE. Along with direct financing, DFIs can provide policy support, capacity building, and concessional capital focused on de-risking projects to mobilise private capital into otherwise high-risk markets or technologies.

From 2013 to 2021, cumulative DFI financing reached approximately USD 468 billion globally, with China-based DFIs and other DFIs accounting for 56% and 44%, respectively. While energy financing from China's DFIs has fallen from its peak in 2016 – averaging around USD 27 billion in annual disbursements – other DFIs have been fairly constant in their financing, averaging USD 21 billion annually. DFI financing was disbursed across regions, with Africa being the largest recipient, followed by Asia Pacific and Latin America. Russia has also consistently received global energy financing through China's DFIs.

In terms of financial instruments, DFIs primarily provide debt, followed by significantly smaller amounts of grant and equity financing. Less than half of the total debt financing is provided on highly-concessional terms, or in the form of Official Development Assistance (ODA), where at least 10-45% of the loan is a grant-equivalent. The rest is provided under less-concessional terms, and mostly from China. It is also notable that nearly 80% of global DFI financing is reported to be provided in USD and EUR and limited amounts of local currency lending was available from DFIs excluding China. This highlights the need to better construct development finance instruments that are more preferential and are better suited to the needs of EMDE borrowers.

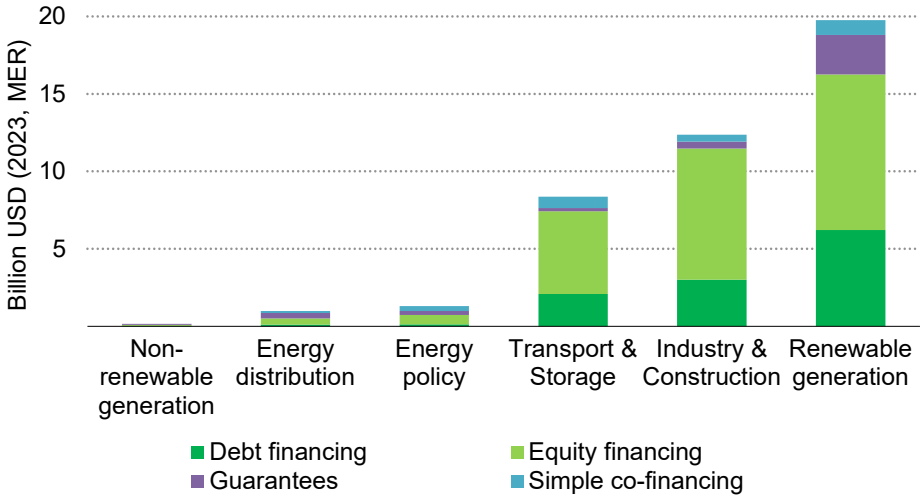
With regard to technology, around 65% of DFI financing was directed towards clean energy, with investments in energy efficiency in transport and transmission and distribution grids accounting for more than 40%. Notably, financing for fossil fuels continues, albeit from a smaller group of providers. This includes Chinese DFIs which, in line with their pledge in 2021, have stopped financing new coal projects abroad, but do still provide funding to oil and gas projects.

Several signals point to increased participation by DFIs in energy financing. According to the latest data, financing for energy-related sectors from DFIs outside of China reached a record high of USD 31 billion in disbursements in 2022, an increase of more than 50% from the previous year. A 2017 pledge by multilateral development banks (MDBs) to Paris align their financial flows took effect in 2023, culminating in a joint MDB assessment framework for Paris alignment. China's development finance in energy is also showing signs of revitalisation, with major announcements being made in the 3rd Belt and Road Forum in October 2023, such as the

pledge to inject nearly USD 48 billion each to China Development Bank and the Export-Import Bank of China to finance “small yet smart” projects, with an emphasis on green investments, as well as a USD 11 billion replenishment of the Silk Road Fund, the main investment platform for the Belt and Road Initiative. It is also notable that China has increasingly expanded its financing through state-owned commercial banks, such as the Bank of China and the Industrial and Commercial Bank of China, especially through syndicated loans alongside various multilateral institutions, including the European Bank for Reconstruction and Development (EBRD).

While it is important for DFIs to continue to channel their own capital into EMDE, including by acting as implementation partners for development aid from their donor governments, it is crucial to ensure that such resources also lead to effective mobilisation of the private sector. From 2012 to 2022, an average of USD 12 billion was mobilised for climate from the private sector annually – of which nearly USD 8 billion went to energy, industry, construction and transport. The Latin America and Caribbean region was the largest recipient of mobilised private finance (34%), followed by Asia (29%) and Africa (22%), demonstrating how middle-income countries are more likely to be the destination for private sector financing. Under the NZE Scenario, private finance increases across all EMDE regions by 2030. So finding solutions that can utilise DFI capital to de-risk private investments in lower-income countries will be essential to meet investment goals.

Mobilised private finance for climate in energy-relevant sectors, 2020-2022 (average)

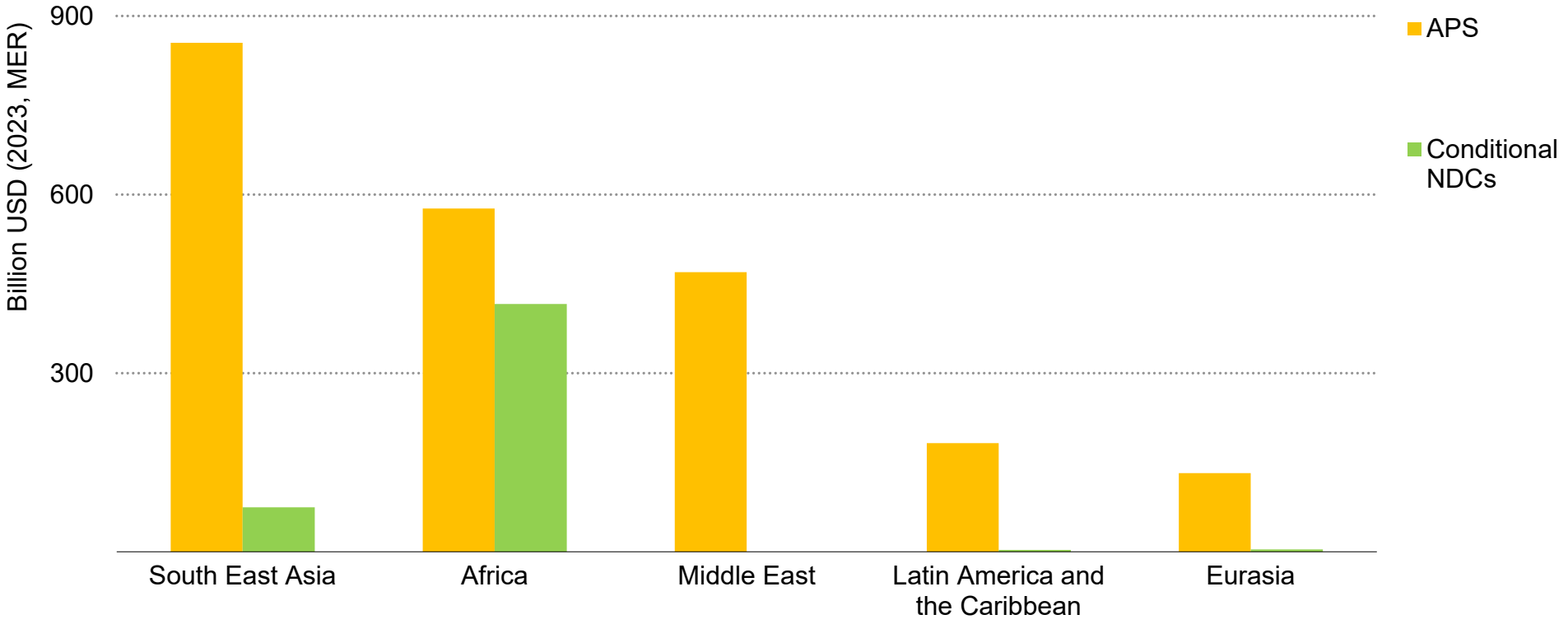


Note: Non-renewable generation includes carbon capture and storage. Debt financing includes syndicated loans and credit lines. Equity financing includes shares in collective investment vehicles and direct investment in companies and special purpose vehicles. Industry classification in this figure differs from the IEA’s definition.

Source: IEA calculations based on OECD CRS.

Requests for financial support included in current NDCs from EMDE are well below the levels of clean energy investment needed to meet their 2030 targets …

Investment in clean energy in APS and financial support requests for energy mitigation in conditional NDCs, 2020-2030



Note: APS = Announced Pledges Scenario; NDCs = National Determined Contributions. The conditional components of NDCs are contingent upon a range of possible conditions, such as receiving enhanced financial resources, technology transfer, technical co-operation and capacity building. Financial support requests from the conditional NDCs consider those that explicitly put forward a request for the energy sector.

Source: IEA analysis of conditional NDCs as of December 2023.

… but the next round of NDCs, expected by 2025, allows EMDE to reflect on their investment needs, providing greater clarity on where climate finance should be channelled

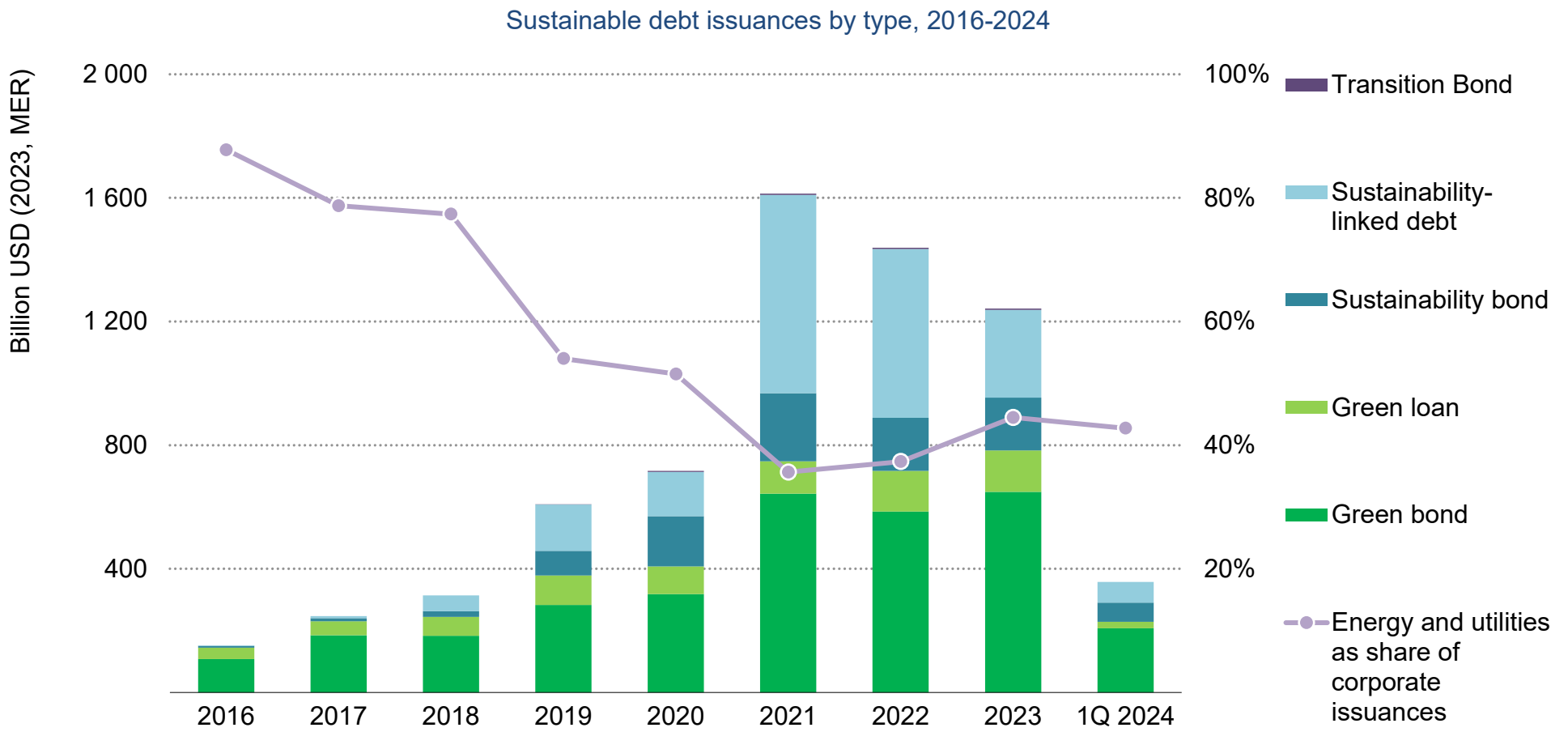
Increasing global co-operation on climate change can support clean energy investment via climate finance flows to EMDE. Countries put forward their short- to medium-term climate commitments in Nationally Determined Contributions (NDCs). The majority of NDCs have a target covering the energy sector. Around 70% of current NDCs contain a conditional component, the implementation of which is contingent on a range of possible conditions. These include financial, technical and capacity-building support. Some countries specify the level of financial support they would need to receive to implement their conditional NDC component; this can help increase clarity, transparency and understanding of these commitments.

However, estimating the financial support needed for clean energy investments reported in NDCs is difficult to analyse due to fragmented and unstandardised data. Overall, the level reported falls short of what countries need to invest to meet their own 2030 clean energy targets. In the first United Nations Framework Convention on Climate Change (UNFCCC) report in 2021 on the determination of needs of EMDE (which will be updated in 2024) the Standing Committee on Finance also concluded that there were significant gaps in the requests for investment support across the nine types of national reports to the UNFCCC. This discrepancy could be attributed to several factors. For instance, some EMDE might not need international financial support to implement their own proposed mitigation measures (e.g. some high-income, high-emitting countries do not have a conditional NDC component). Some NDCs may not fully capture the necessary clean energy investments, potentially also due to a lack of detailed planning. Another factor could be the limited availability of data or a limited capacity to estimate clean energy investment needs. African countries stand out for including estimates of financial support requirements in their NDCs that are closely aligned with the IEA's Announced Pledges Scenario (APS).

The next round of NDCs, expected by early 2025, presents a crucial opportunity for countries to act on the outcomes of the first Global Stocktake (GST), a process that culminated at COP28 and evaluated the collective progress towards the goals of the Paris Agreement. It will also be an opportunity to enhance the clarity and transparency of their assessment of clean energy investment needs to achieve the 2030 and 2035 NDC targets. In this light, Brazil's presidencies of the G20 and COP30 have made it a priority to support countries to transform their next round of NDCs into investable plans. A clearer assessment of financial support needed in NDCs would have also been important input for the discussions of the New Collective Quantified Goal (NCQG) on climate finance, which will replace the USD 100 billion goal set in 2009. Current discussions around the NCQG address its potential quantum, scope and structure, and will culminate at COP29.

Trends for financial instruments

Rising interest rates have contributed to a 14% decline in sustainable debt issuance since 2022, with investors' concerns triggering a drop in sustainability-linked debt financing …



Source: IEA analysis based on data from Bloomberg (2024).

… but new issues of "green" debt – particularly green bonds – have held steady and thanks to sovereign issuances, indications from early 2024 are positive

Sustainable debt issuances reached approximately USD 1.2 trillion in 2023, exceeding USD 1 trillion for a third consecutive year. Nonetheless, this represents a 14% decline from 2022 levels, and a 23% drop from the peak in 2021. Over the last two years, rising interest rates have been a constraining factor, with both the number and size of issuances decreasing. During this period, debt issuance from energy and utilities companies also fell from a high of more than USD 280 billion in 2021 to USD 229 billion in 2023 – though it remains above 2020 levels.

The biggest declines have been concentrated mainly in sustainability-linked debt, which in 2023 registered a 50% drop from the previous year, reaching only USD 284 billion. By sector, real estate showed the biggest decrease, followed by utilities and automobiles manufacturing. Some of this decline is likely due to investors' concerns around the credibility of sustainability-linked debt as a tool to drive rapid transitions, as well as industry-specific drivers, such as the contraction of the US commercial real estate market. Meanwhile, new issuance of green bonds – the most mature sustainable debt instrument – reached a record USD 650 billion in 2023 and accounted for more than half of total issuances. The steady increase in green bond issuance mainly comes from sovereigns, notably China, the United Kingdom, Italy, and Germany.

Sustainable debt issuance remains concentrated in advanced economies, which account for over three-quarters, and China, which accounts for a further 11%. However, there are signs of growth within other EMDE, which saw their share of issuance rise to 14% in 2023 from 8% in 2020. This has been driven by broadening use cases, as seen with two large bond issuances for green hydrogen in Saudi Arabia, and the instruments, such as the sovereign sustainability-linked bond from the Chilean government. The EUR and USD remain the primary currencies for issuance, accounting for 38% and 28%, respectively. While this helps to attract international investors, it exposes issuers in EMDE to currency risks. With many EMDE grappling with rising debt levels, the borrowing at lower interest rates through sustainable debt instruments makes them an attractive tool, particularly for financing large public infrastructure projects.

Initial indications from 2024 have given a generally positive outlook for sustainable debt issuances for the year. Although there may be some volatility due to political events, the fundamentals of the market, particularly for green bonds, remain strong and growth is expected in areas such as transition finance (see below). Additionally, the European Green Bond Standard, which comes into force in 2024, is expected to increase market confidence by strengthening disclosure requirements.

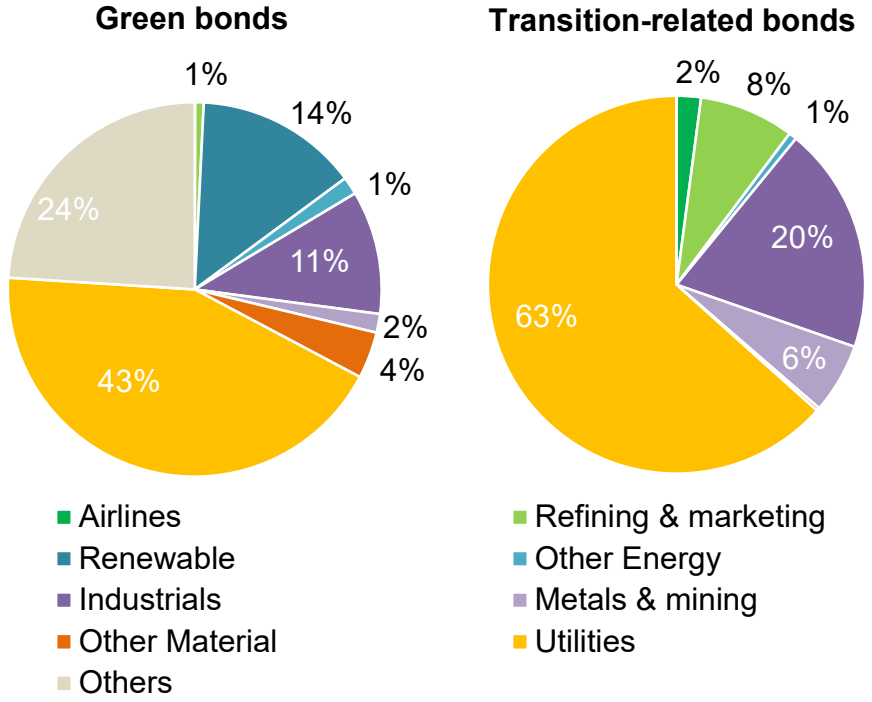
Transition finance tools are emerging as a promising means to drive more capital to high-emitting sectors, but further efforts to harmonise standards for transition plans are necessary

Achieving the NZE Scenario requires a broad range of investments. Some of these can easily be classified as clean energy, but many others are less easy to define. Under the NZE Scenario, technologies that could provide or enable zero emission energy or energy services account for 47% of spending in 2030, and those that provide emissions reductions but do not themselves deliver zero emissions energy or energy services account for 7%. Both categories struggle to attract financing earmarked for clean energy and are at risk of being excluded by investors seeking to decarbonise their portfolios.

Transition finance is a framework that can support these activities. Several organisations such as ICMA, CBI, GFANZ, OECD and others have developed transition finance guidance, covering activities such as retrofitting and substantiating assets, investment in alternatives to fossil fuel use, and the role of engagement by financial institutions. Despite these guidelines, there is still significant variation in transition finance methodologies, with ICMA finding three overlapping definitions ranging from economy-wide to only hard-to-abate sectors.

Transition-related bonds have been a preferred labelled tool for hard-to-abate sectors. Oil refining and marketing, industrials and metals and mining accounted for 34% of issuances in the last three years; these sectors accounted for only 15% of green bonds over the same period. Transition-related bonds issuances in 2023 accounted for just USD 3.5 billion – less than 1% of all sustainable debt issuances and are geographically concentrated in Japan, Italy and China.

Share of corporates issuances by industry 2021-2023

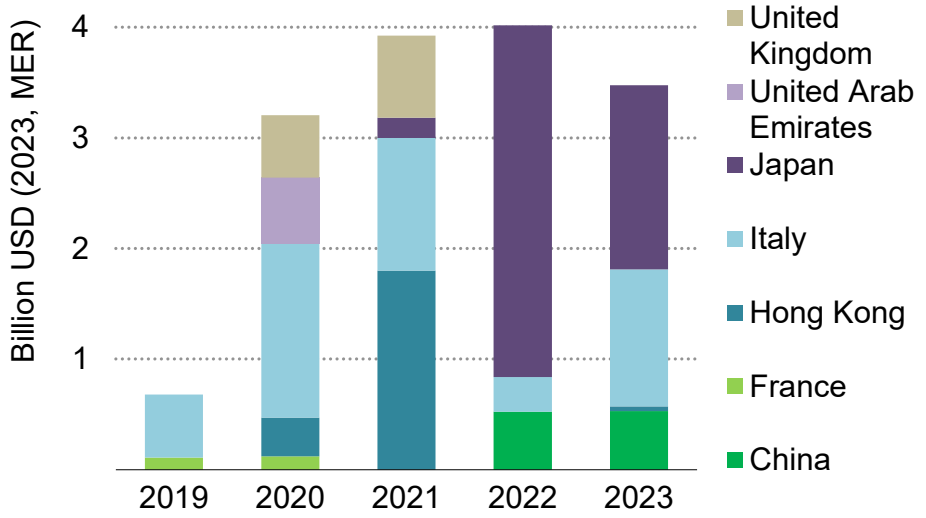


Note: “Other material” includes chemicals. “Others” includes consumer discretionary, consumer services, technology, and other business sectors.
Source: IEA analysis based on data from Bloomberg (2024).

Establishing viable, science-based transition plans is a vital first step to expanding the use of transition debt instruments. Transition plans are generally understood as aligning with the Paris Agreement, and spelling out transition pathways, actions and interim targets. These elements are fundamental for engagement between corporates and investors, as well as tracking progress. Governments and regulators have taken different approaches to establishing transition activities. For example, Europe and Singapore are using taxonomies to define transition activities, while Japan has created industry roadmaps. Coverage can vary based on the regional methodologies, but both taxonomies and roadmaps can support an increase in funding, including from advanced economies where investors may be subject to stricter rules covering sustainable finance.

Even with the provision of stronger transition plans and roadmaps, some additional obstacles have been observed. For example, on the issuer side, especially in EMDE, the data necessary to create transition plans and track progress is not always available. External support may therefore be necessary to help the development of this type of financing and, at least initially, such instruments will only be viable for larger companies with the resources to develop this data. On the supply side, many EMDE have sovereign ratings that are below investment grade, making it hard to attract investment from capital markets via instruments such as bonds without de-risking support from concessional finance providers. Particularly in EMDE with fossil-fuel intensive energy mixes, this use of concessional financing could have a significant real-world impact – especially if it leads to a "crowding in" of private sector investors. A further challenge is that many investors have net zero targets that rely on financed emissions as one of their primary metrics. Even though transition activities may be in line with a taxonomy or roadmap, they generally have higher emissions than purely clean activities, which would risk skewed investors' efforts to reduce their financed emissions. Further consideration is needed on appropriate indicators that can monitor institutions' proper progress and acceleration of funding for future energy transition of real economy.

Transition-related bond issuances by country 2019-2023



Source: IEA analysis based on data from Bloomberg (2024).

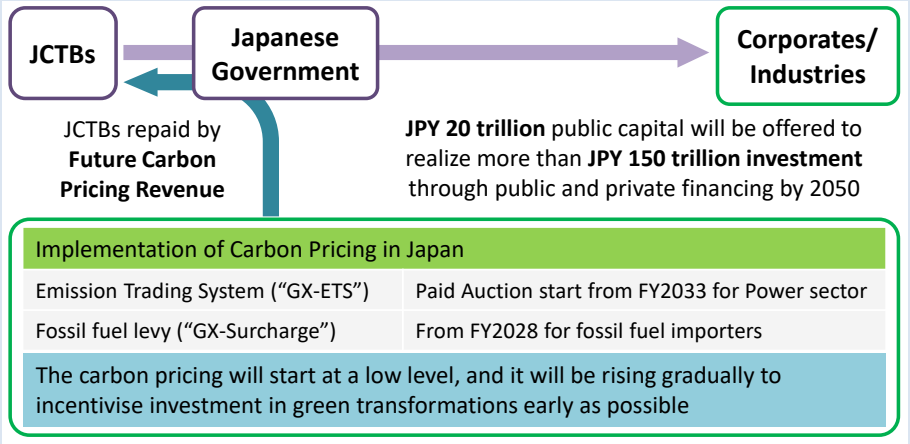
Box 2.1 The development of Climate Transition Bonds (JCTBs) in Japan

In February 2024, Japan issued the world's first sovereign transition bonds – Japan Climate Transition Bonds (JCTBs). Two offerings of JPY 800 billion (USD 5 billion) each were issued, with tenors of 5 and 10 years. The issuances are certificated by the Climate Bonds Initiative and based on Japan's national transition strategy.

Japan's Basic Policy for the Realization of Green Transformation, published in February 2023, includes a detailed investment plan for 22 industrial sectors to reach carbon neutrality by 2050, as well as a commitment to introduce carbon pricing. Under the investment plan, the government envisages JPY 20 trillion (USD 130 billion) of public capital to realise more than JPY 150 trillion (USD 1 trillion) in investment through public and private financing by 2050. The plan is accompanied by transition roadmaps for each sector, which were developed by expert committees of public and private stakeholders. These roadmaps allow investors to identify transition activities and can also be used by companies for internal transition planning. The investment plan also includes an emphasis on nascent technologies, which will receive over half of the proceeds of JCTBs.

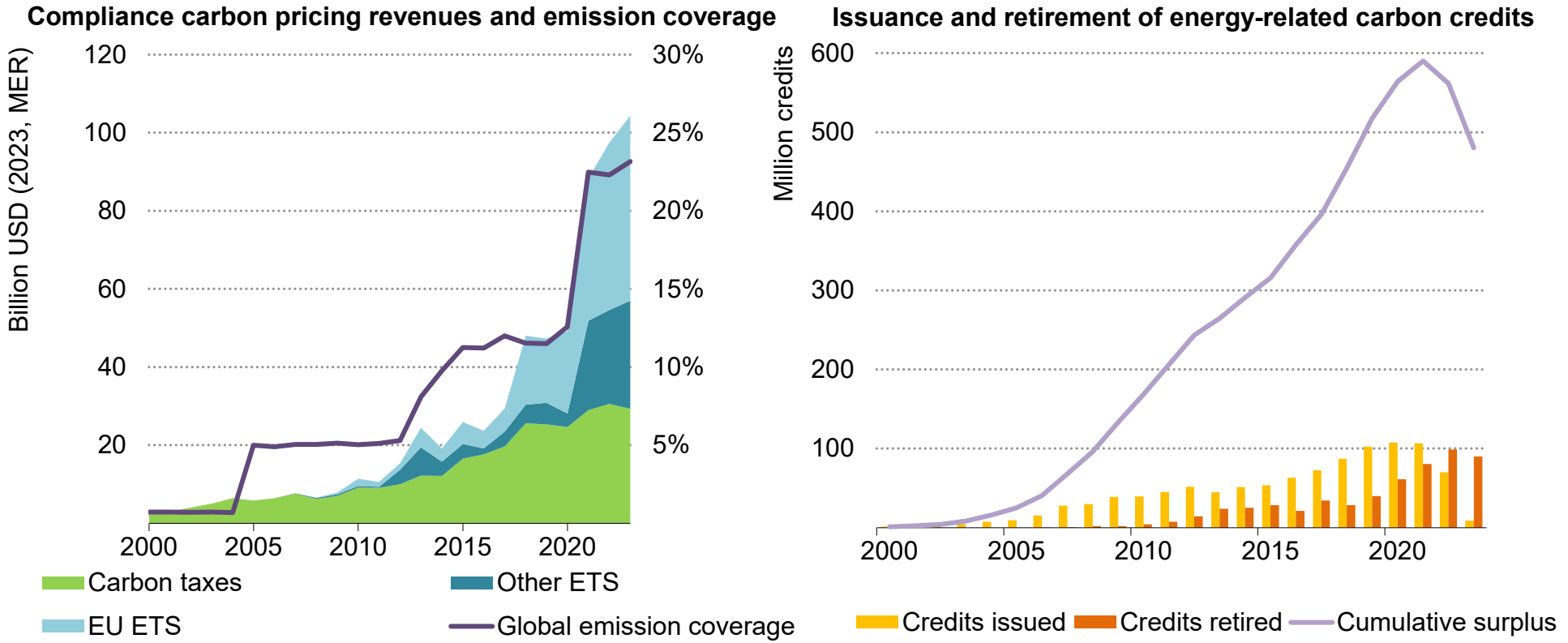
The JCTBs also include a novel approach to carbon pricing. Normally, revenue from carbon pricing can only fund future energy transition activity, i.e. after the carbon has been paid. This delays in the impact of the carbon pricing but Japan's approach was to build the future pricing revenue into the issuance, by assuming this is the capital government will use to make repayments on the bonds. This allows for the government to immediately take advantage of the assumed future revenue of carbon taxes.

Structure of Japan Climate Transition Bonds (JCTBs)



The JCTBs approach can potentially be repurposed for EMDE. With the government playing the role of credit intermediary, this could enhance corporates' creditworthiness and eliminate the complexity of financing for small-scale projects. Countries with sub-investment-grade credit ratings, may need additional credit enhancements – such as guarantees from DFIs – to help facilitate access to international capital markets.

Revenues from compliance carbon pricing hit record highs in 2023; in the voluntary markets, a large surplus of unused older credits weighed on prices and demand amid quality concerns



Note: Data on carbon credits relates to the following voluntary carbon markets registries: American Carbon Registry, Climate Action Reserve, Gold Standard, Verra's Verified Carbon Standard, California Air Resources Board, Washington State Climate Commitment Act. The categories considered under energy-related carbon credits are: renewable energy, industry, transport, energy efficiency, carbon capture and storage. ETS = Emissions Trading System.

Source: IEA analysis based on data from the World Bank, and Berkeley, 2024 .

Compliance carbon pricing instruments have seen further expansion and innovation in 2023, while voluntary carbon markets faced quality concerns

Carbon pricing is a key instrument for mitigating emissions, encouraging investment in low-carbon technologies and reducing demand for emissions-intensive activities. Carbon pricing instruments include compliance carbon pricing instruments (CCPIs), such as carbon taxes, emissions trading systems (ETS) or hybrids of the two, as well as baseline and credit systems, which generate carbon credits. These two types of carbon pricing instruments can contribute in different ways to financing the clean energy transition, depending on the specific local contexts.

As of May 2024, 75 CCPIs were in place worldwide. All CCPIs cover the energy sector and 23% of global greenhouse gas (GHG) emissions. Aggregate revenues from CCPIs hit a new record high in 2023 and, for the first time, revenues surpassed USD 100 billion – of which roughly half was generated by Europe's ETS. A few notable energy-sector related developments in CCPIs also took place: Canada introduced a regulatory framework for a federal cap-and-trade system for the oil and gas sector – its largest source of GHG emissions. Meanwhile, as part of a broader reform, the European Union extended the coverage of its ETS by including its domestic maritime sector, which represents 3% to 4% of total EU CO_2 emissions. Indonesia introduced a new intensity-based ETS for the power generation sector. Brazil passed a new draft law for cap-and-trade. Moreover, in October 2023, the EU Carbon Border Adjustment Mechanism (CBAM) also entered its transitional phase – introducing reporting requirements only – in preparation for a definitive regime that will start in 2026.

Voluntary carbon credit markets have come under particular scrutiny in 2023, with some projects being accused of over-crediting, of lacking additionality or of enabling human rights abuses. This, alongside inconclusive negotiations at COP28 on Article 6 rules, impacted the issuance of energy-related carbon credits in 2023. Retirements of credits remained high in 2023, after reaching a peak in 2022. However, a surplus of unsold legacy credits has been accumulating in recent years, reaching around 480 million credits in 2023. This keeps the costs of most energy-related carbon credits much lower than the real cost of mitigation. To address questions that some have raised on the integrity of some legacy credits, CORSIA has introduced cut-off dates for eligible credits. Recent initiatives were also set up to improve the quality of carbon credit supply (such as the Core Carbon Principles of the Integrity Council for Voluntary Carbon Markets) as well as demand (such as the Claims Code of Practice of the Voluntary Carbon Markets Integrity Initiative, the Nordic Code of best practice for the voluntary use of carbon credits, Finland's guide to good practices for voluntary carbon markets).

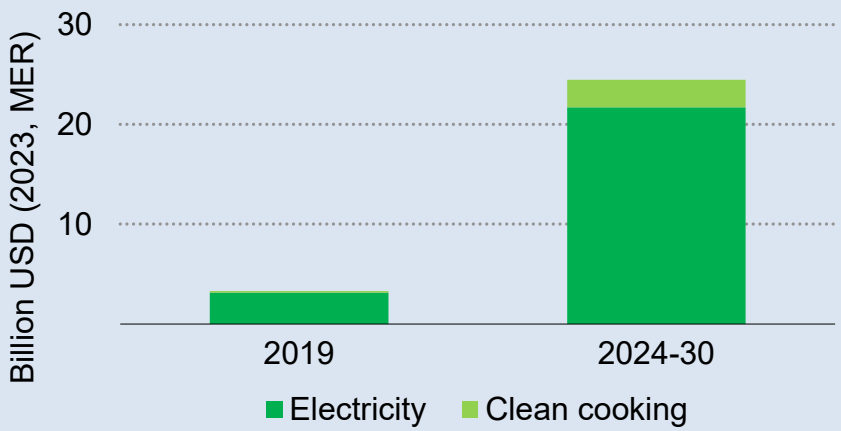
Box 2.3 Innovative financing solutions for energy access

There are still 750 million people living without access to electricity globally and more than 2 billion people without clean cooking solutions. Achieving the Sustainable Development Goal 7 – universal energy access by 2030 – will require annual spending of at least USD 42 billion beginning in 2024. This represents a massive increase in spending, particularly in Africa, where energy access projects have struggled to attract more than USD 5 billion annually.

Energy access investments are particularly challenging given that they are small scale, and the risks associated with the end user are often high. Mounting debt at utilities has slowed grid connections, challenges over demand stimulation have put pressure on mini-grid business models, and non-payment risks have impacted profitability for providers of home solar systems. Meanwhile, it is difficult to keep clean cooking solutions affordable for end users without the use of carbon credits, a market that has faced credibility concerns.

Financial aggregation solutions have emerged as a way to raise more private capital for access projects. In May 2023, Sun King, an off-grid electricity provider, finalised a securitisation deal led by Citi, the US-based bank. Worth USD 130 million and denominated in Kenyan shillings, the transaction is based on the future expected revenue of a million customers. Alongside DFIs, the structure included participation from commercial banks in the region. Similarly, in 2021, Winch Energy used a portfolio loan approach – combining successful tenders for mini-grid development in Uganda and Sierra Leone into one holding company – to raise USD 16 million for projects that were otherwise too small to access financial markets. Grants and concessional capital will still play a key role, particularly in rural areas and fragile and conflict-prone states, but aggregation can leverage private capital into some of the more commercial projects.

Annual energy access investment in Africa



Source: IEA, 2024.

Implications

To meet investment needs under the NZE Scenario, further evolution of today's financial architecture is needed, including tailored solutions for transition activities and for EMDE

Ensuring the availability of affordable capital will be vital for driving rapid energy transitions. It is critical not only for financing projects and companies, but also for supporting the enabling environment and facilitating necessary spending by households. Current market conditions – particularly the rising interest rate environment – have resulted in higher financing costs and highlight the need for innovative risk-mitigation instruments and support mechanisms, particularly for EMDE. Tightening market conditions have also contributed to a setback in sustainable finance instruments as more financial players voice concerns about regulations becoming overly stringent, especially when it comes to financing high-emitting, hard-to-abate sectors.

Clean energy projects should adopt a diversified financing strategy that leverages the strengths and risk appetites of each source of capital. While private sector investment is particularly dominant in advanced economies, growing domestic private financial sector financing in energy in EMDE is particularly important, as it reduces currency risk and reliance on external sources. Attention is also due for households, which have also become increasingly prominent as providers of capital, as observed by the near doubling of their share of energy asset ownership between 2015 and 2023. Given the increases in the cost of living, maintaining affordability of services will be vital over the course of 2024, which may require additional support from public sources. DFIs can also play a role in ensuring affordability and providing capital in higher risk markets and technologies.

Appropriate tools and systems need to be in place to direct finance towards energy investment in EMDE as a catalyst for clean energy transitions. This includes enhancing the credibility of carbon markets, which have faced criticism related to over-crediting, lack of additionality and enabling human rights abuses. Furthermore, improving transition finance mechanisms, and strengthening sustainable finance regulations, especially in the context of the potential impact on financing high-emitting, hard-to-abate sectors, can help ensure that financing supports the differing trajectories of EMDEs compared to advanced economies.

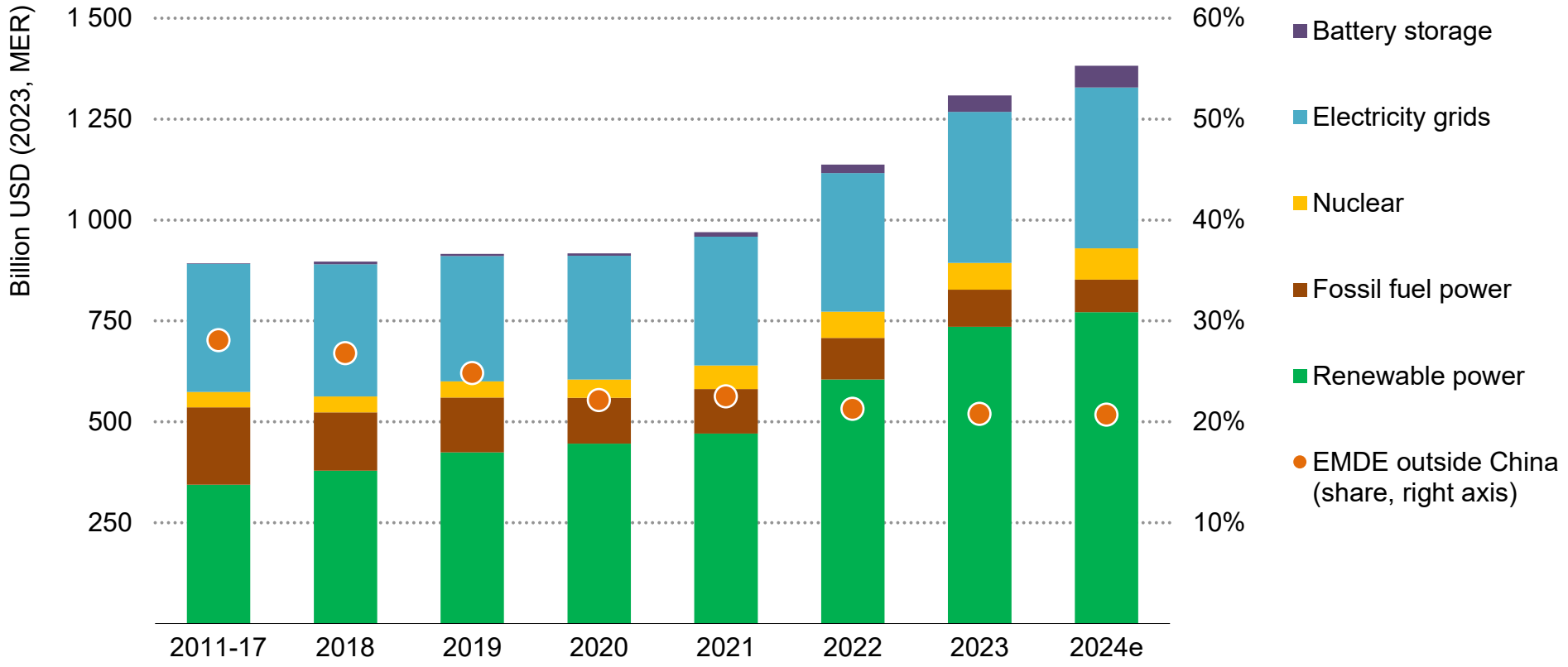
On the EMDE side, providing an accurate assessment of financial needs for clean energy investments around NDCs will be crucial. This can be used as a basis for engagement in some of the global efforts to accelerate financing for energy transitions, such as at the upcoming G20 discussions, or via initiatives such as the ongoing Bridgetown Initiative that aims to reform the global financial architecture to better support EMDE.

Power

Overview

Power sector investment increased by 15% in 2023 to USD 1.3 trillion, with the growth rate expected to slow in 2024 due to cost reductions for renewables and a decline in fossil fuels

Global annual investment in the power sector by category, 2011-2024e



Note: Investment throughout is measured as ongoing capital spending on new and existing power capacity. All numbers throughout are in 2023 USD. Fossil fuel power includes unabated and abated power. EMDE = emerging market and developing economies. 2024e = estimated values for 2024.

Spending on renewables and batteries continues to reach new highs even as costs for solar PV and batteries plummet, while unabated fossil fuel power maintains its downward trend

Global investment in the power sector grew by 15% in 2023, reaching a record USD 1.3 trillion. Concerns over high interest rates and the profitability of renewables firms were offset by lower prices for solar PV modules, coupled with rapid renewables deployment in major economies including China, the European Union and the United States. Growth is set to continue in 2024 but at a more modest pace.

Global spending on renewables also hit a new record of USD 735 billion, driven by solar PV and wind. China alone saw solar PV spending jump to USD 220 billion – almost half of global solar investment for the year – with capacity additions multiplying by a factor of 2.5 compared to 2022 thanks to falling module prices and pandemic recovery effects. As prices for solar modules and other key clean energy technologies continue to fall, we are now expecting the growth of spending for renewables to slow down – especially for distributed solar PV – and reach USD 770 billion in 2024. This does not reflect a slowdown in the renewable power capacity added, as price decreases allow for more capacity to be added per USD spent. Nonetheless, grid and curtailment concerns, permitting delays and land availability remain constraining factors.

As renewables expanded in 2023, capital expenditures on fossil fuel power decreased by 10%, to USD 90 billion, led by declines in coal-fired power. For 2024, we are expecting a similar decrease to USD 80 billion, again driven by coal (-30%) and to a smaller extent by gas-fired power (-8%). Spending on fossil fuel power with carbon capture utilisation and storage (CCUS) remained below USD 1 billion and was concentrated in China.

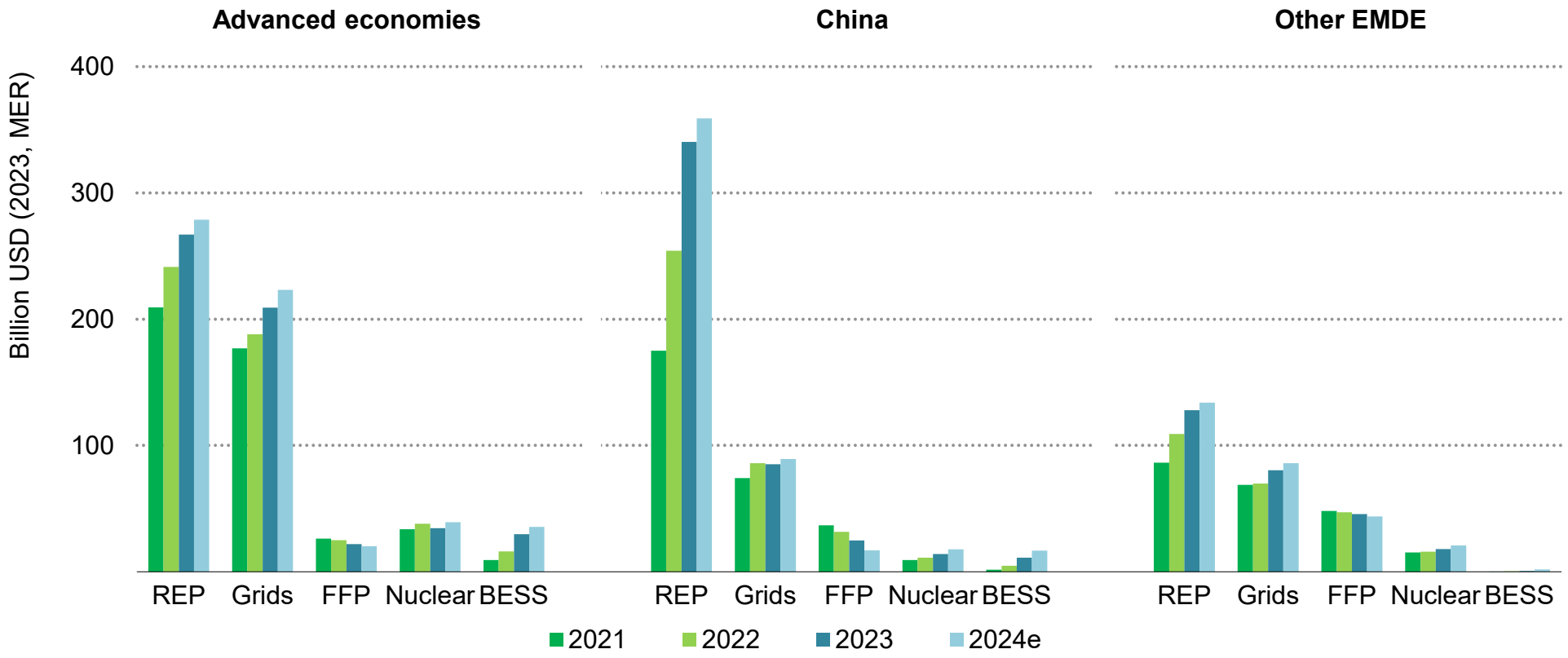
While investment in nuclear power remained largely unchanged in 2023, expected growth of around 20% in 2024 promises renewed momentum. However, most of this spending growth in the next few years will be driven by lifetime extensions rather than investment in new nuclear capacity. Investment in hydropower fell slightly and is expected to be even lower in 2024.

Investment in electricity grids reached USD 375 billion, translating to a 9% average growth rate globally. Notable success stories for grids were in advanced economies as well as China and Latin America. Investment by other emerging market and developing economies (EMDE) still lagged the global average, and even declined in some regions. Battery storage investment grew in line with our strong expectations, reaching USD 40 billion.

Final investment decisions (FIDs) continue to demonstrate a mixed picture. While FIDs for utility-scale renewables were at record highs, those for unabated coal-fired power plants also increased to levels not seen since 2015, with almost all of these made in China.

Investment in renewable power rose rapidly across the board, with promising momentum for spending on grids, nuclear and battery storage in 2024

Annual investment in the power sector by geography and category, 2021-2024e



Note: REP = renewable power. FFP = fossil fuel power. BESS = Battery Energy Storage System. Investment spending on BESS in other EMDE is so small (USD 2 billion in 2024e) that it can almost not be detected on the chart. 2024e = estimated values for 2024.

EMDE are slowly attracting more investment, but not at the scale required, while in advanced economies falling wholesale electricity prices create uncertainty for investors

While total power sector investment in EMDE outside China increased to USD 270 billion in 2023 – a record – its growth rate of 12% still lagged the 16% average for advanced economies and China. Renewable power spending rose by almost one-fifth and now represents half of total power sector investment in other EMDE regions. Investment in grids increased to USD 80 billion – the highest level since 2018 – with further growth expected for 2024. Spending on nuclear and batteries also increased, while investments in fossil fuel power generation dipped slightly.

Strong renewable power investment in EMDE outside China was driven by significant spending in India, Southeast Asia, Brazil and Africa, thanks to policy reforms and the introduction of well-organised public tenders, as well as grid improvements. The volume of renewable energy capacity that was auctioned in India, for example, topped 20 gigawatts (GW) in 2023 – more than double that of 2022 – with a particular focus on solar PV and projects that combine renewables with storage. Seeking to tackle its "state of disaster" in the electricity sector, South Africa also concluded its first battery procurement programme and is seeking to add an additional 5 GW of renewables and 600 megawatts (MW) of battery storage.

Latin America notably increased its spending on grids in 2023. Brazil led the way with a record USD 8 billion auction, while Colombia and Panama revived interconnection plans. On the other hand, investment in grids in Southeast Asia and Africa stalled.

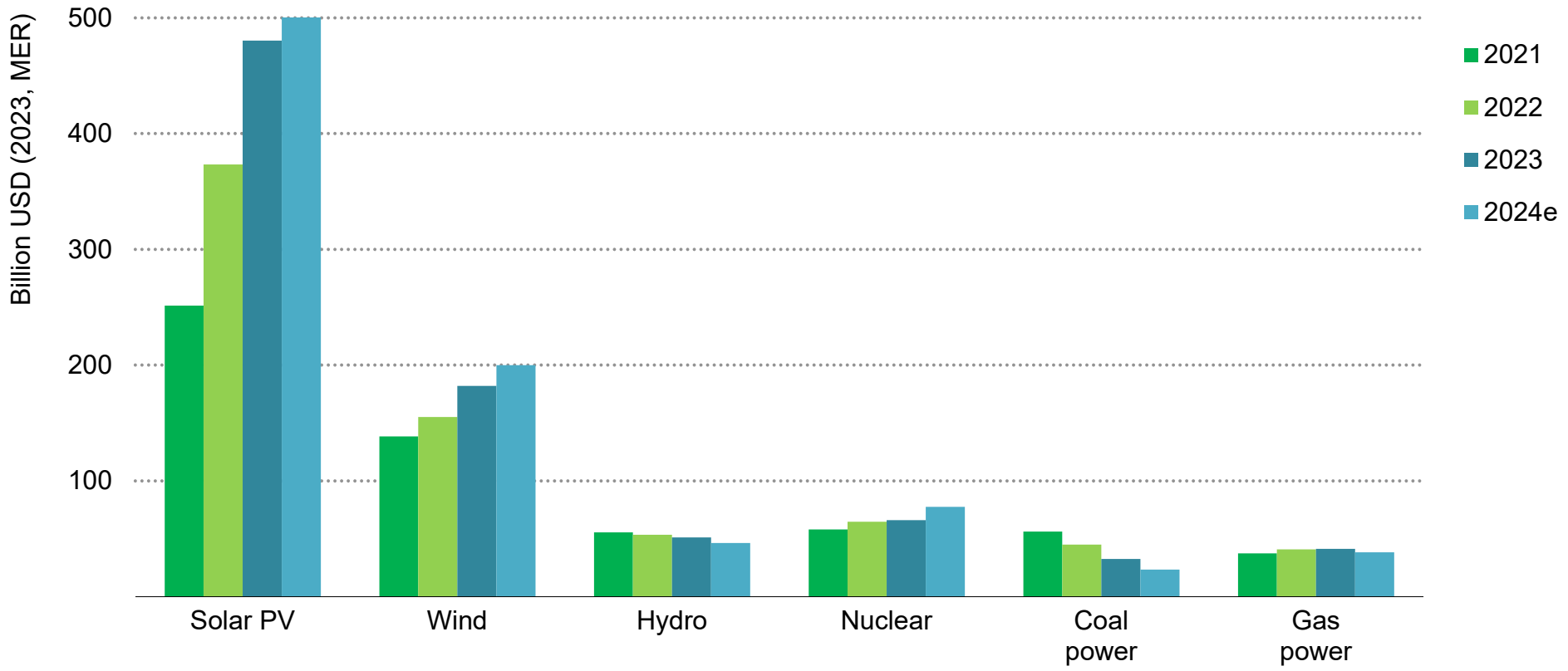
Overall, however, power sector investment in EMDE outside China still represented only around 20% of the global total, while advanced economies and China were responsible for more than USD 1 trillion in spending. We expect this trend to persist in 2024, which means that overall spending is still not on track to meet current climate and energy-access goals. One major reason for this is the high cost of capital for clean energy projects in EMDE regions outside China, which is often double or triple the cost in advanced economies.

While renewable companies in advanced economies saw improved profitability in 2023, lower prices for natural gas and deeper market penetration by low-cost renewables are starting to put pressure on wholesale electricity prices – creating uncertainties for their revenue streams. This, in turn, puts additional scrutiny on future investments – one reason we expect growth in renewable power investment to slow in 2024. In some European countries, for example, average wholesale electricity prices have fallen to their lowest levels since 2021 – and have regularly dipped into negative territory. This underscores the pressing need for greater investment in power grids, interconnectors and storage infrastructure as the share of intermittent renewables increases.

Generation

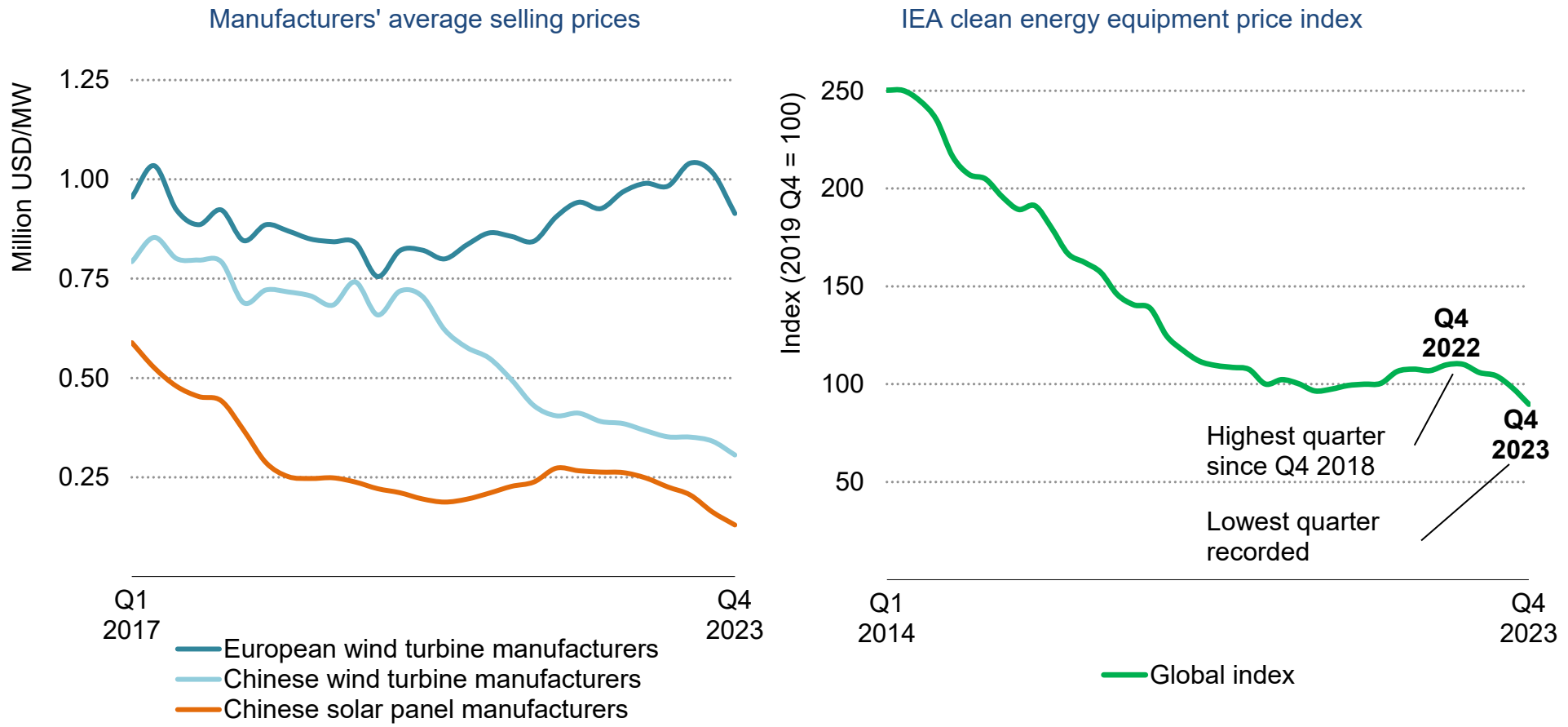
Solar PV attracted a record USD 480 billion in spending in 2023 – more than all other generation technologies combined – while investment in coal power has fallen by 40% since 2021

Global annual investment in power generation by selected technologies, 2021-2024e



Note: Gas-fired generation investment includes both large-scale plants and small-scale generating sets and engines. Hydropower includes pumped-hydro storage. 2024e = estimated values for 2024.

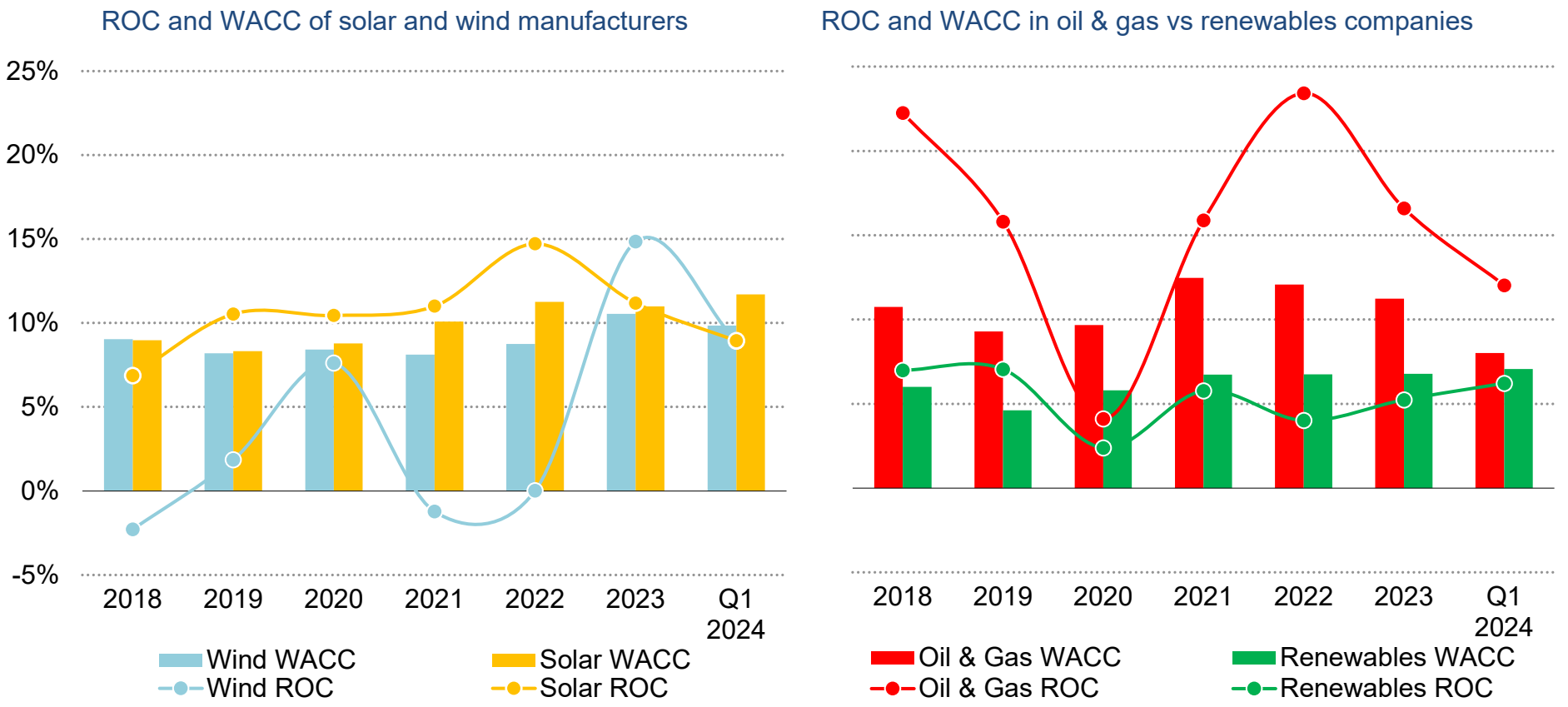
Price pressures in solar PV and wind equipment have eased, and capital costs edged lower in 2023, reaching record lows for solar PV and batteries



Note: The clean energy equipment price index, developed by the IEA, tracks price movements in a global basket of solar PV modules, wind turbines, lithium-ion batteries for electric vehicles (EVs) and utility-scale battery storage, weighted by shares of investment. Prices are in current USD, more details can be found here.

Source: IEA calculations based on companies' financial reports, Bloomberg data and BNEF.

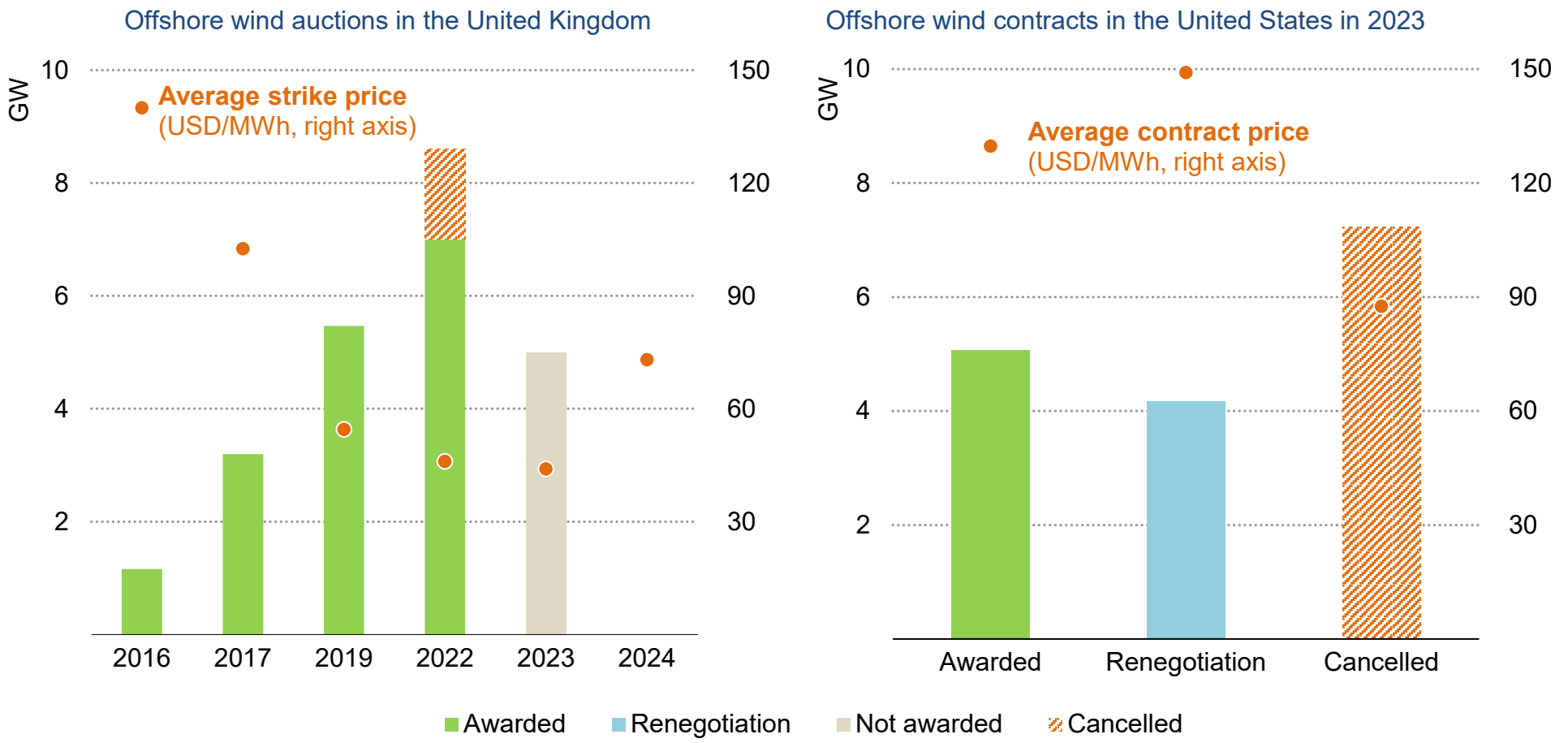
The profitability of renewable utilities improved as capital costs fell; solar manufacturing margins narrowed due to overcapacity, while challenges in wind manufacturing began to ease



Note: ROC = return on capital. WACC = weighted average cost of capital. Calculation based on the top 25 publicly listed companies in each sector according to production capacity, primarily concentrated in advanced economies and China. Renewable companies include utilities and manufacturers. WACC is based on implied market valuation. 2024 Q1 values based on obtainable data from companies.

Source: IEA analysis based on Bloomberg data and S&P Capital IQ.

Offshore wind developers face contract profitability issues as governments react to new market conditions by adjusting energy purchase prices



Note: UK average strike and US average contract prices are expressed in 2023 USD.
Source: IEA calculations based on UK Department of Energy and Change and company reports.

Renewables developers see improving profitability, while solar PV onshoring plans and wind manufacturers face challenges

Solar PV and wind projects continue to offer attractive investment prospects, despite profitability challenges in the manufacturing business. Renewable utility profitability is slowly returning to pre-pandemic levels, with returns on invested capital (ROIC) increasing by one-third in 2023 from a year earlier, thanks to falling solar and wind costs. ROIC is also notably more stable compared to the volatility of oil and gas companies in recent years. That said, the average cost of capital for renewable power firms has increased slightly in recent years, now hovering at around 7% of market value.

An exception to the trend of improving profitability was offshore wind. 2023 saw a range of contract cancellations due to previously agreed low prices that were no longer viable given supply chain challenges, cost increases and permitting delays. In the United States, for example, 7 GW of planned capacity was cancelled while another 4 GW are subject to contract renegotiations at prices that are on average around two times higher. There were multiple cancellations in the United Kingdom as well, with the 2023 auction not attracting a single offer, prompting an increase of the strike price by 165% for its 2024 auction. Nonetheless, successful contract renegotiations, adjustments in auctions and regulatory support such as the European Union's wind power package are all positive signs that demonstrate the need for regulators to remain responsive to changing market conditions.

On the manufacturing side, 2023 was dominated by significant price declines and concerns about overcapacity. As manufacturing capacity continues to grow within the Chinese solar PV sector, listed solar firms – dominated by Chinese entities – are starting to see their profit margins shrink. Despite government support for domestic manufacturing, cost pressures have led to some cancellations of expansion plans – and in some cases, existing plant closures – in Europe, the United States and India. That said, falling prices for solar modules led to a 5% drop in the global average levelised cost of electricity (LCOE) for solar PV last year.

Companies specialised in wind turbines – a sector dominated by European manufacturers – struggled for roughly two years with various supply chain, cost and technical issues. But by 2023, profitability had largely recovered, reaching similar levels as solar PV manufacturers. Wind turbines produced by Chinese companies continue to be around one-third the price of European-made turbines and have had some limited success in winning onshore wind auctions in Europe and Asia. However, overseas expansion plans by Chinese wind turbine producers face obstacles due to more complex logistics and higher operation and maintenance costs.

Investment in clean technology manufacturing is surging, driving price decreases but also creating overcapacity in solar PV and battery manufacturing

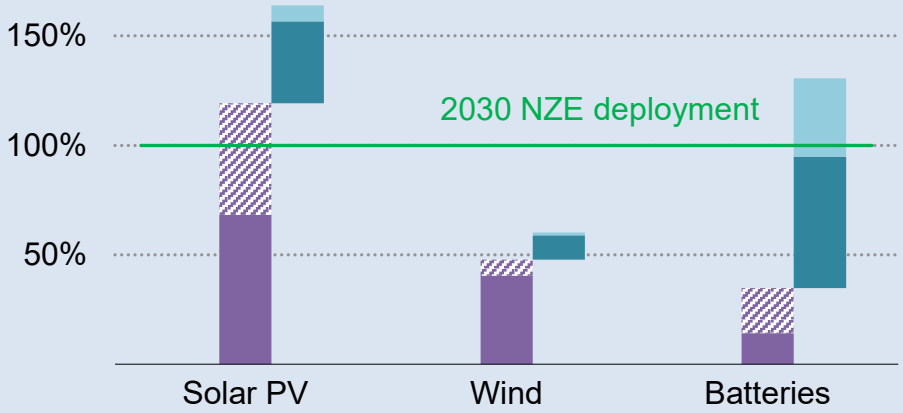
Clean technology manufacturing is surging: The sector accounted for 4% of global GDP growth in 2023. Clean technology manufacturing attracted almost USD 200 billion in investment last year – a 70% jump from 2022 – with solar PV and battery manufacturing plants leading the way. Investment in solar PV manufacturing more than doubled to around USD 80 billion, while investment in battery manufacturing stood at USD 110 billion. Together, both accounted for more than 90% of total spending on clean technology manufacturing in 2023.

China accounted for three-quarters of global clean technology manufacturing investment, down from 85% in 2022, as investment in the United States and Europe accelerated. This geographic concentration is set to continue to 2030, with China, the United States and the European Union together projected to account for around 80% to 90% of manufacturing capacity for solar PV, wind, battery, electrolyser and heat pumps.

This surge in clean technology manufacturing is, however, creating significant overcapacities – especially for solar PV and batteries. Existing capacity for solar modules and cells is already sufficient to meet demand under the NZE Scenario in 2030.

As a result, prices for solar PV modules and batteries have fallen to historic lows. However, these facilities are also seeing relatively low utilisation rates and profit margins are being compressed.

Output from existing and announced manufacturing capacity relative to NZE Scenario in 2030



Notes: Increased utilisation refers to the gap between 2023 production levels and existing capacity being utilised at 85%. A utilisation rate of 85% is used for both existing and announced manufacturing capacity in 2030.
Source: IEA (2024), Advancing Clean Technology Manufacturing.

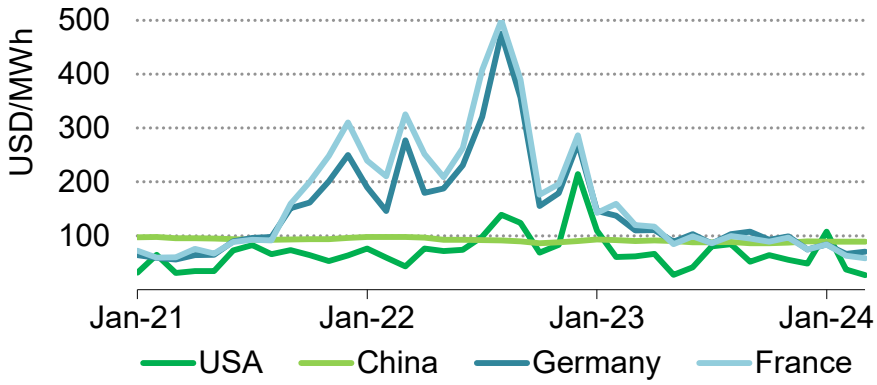
Volatile wholesale electricity prices create uncertainty for renewables companies over the impact on revenues and future investment, underlining the need for storage and grid expansion

Wholesale electricity prices in Europe are declining, with some reaching their lowest levels since 2021. Lower natural gas prices, increased hydro and nuclear output, and reduced demand, are all driving down wholesale prices. As renewable capacity grows, power production from these sources is also reaching unprecedented levels, occasionally resulting in negative prices and increased volatility. For instance, Spain achieved record-high solar power production in the first quarter of 2024 with prices averaging 43 USD/MWh – and sometimes approaching zero. Germany and the Netherlands also experienced brief periods of negative prices in March 2024. While electricity prices in the United States have been below those in Europe for a while (due to its domestic natural gas production), prices have dipped to record lows in recent months.

The rise in affordable electricity benefits consumers and is a welcome respite from the record highs during the energy crisis. At the same time, it increases uncertainty for renewables companies as revenue streams come under pressure and become more unpredictable – leading to greater scrutiny of the future growth prospects for renewables investments. Developers who choose not to co-locate their wind and solar PV power parks alongside battery storage or other sources of flexibility may see a drop in potential revenues during peak generation – hampering profits and discouraging investment.

Enhanced coordination between renewables production, storage and demand response is needed to manage the balance between price levels and growing volatility. Further grid expansion is also urgently needed to mitigate price swings in both directions. Increased interconnection in Europe offers an opportunity to optimise electricity flow, especially when prices differ between regions. During the energy crisis, for example, Spain and Portugal experienced lower power prices than the rest of Europe due to their ample electricity production from solar PV and wind, while a lack of interconnection constrained electricity flow to higher-price markets in central Europe.

Monthly wholesale electricity prices in selected regions

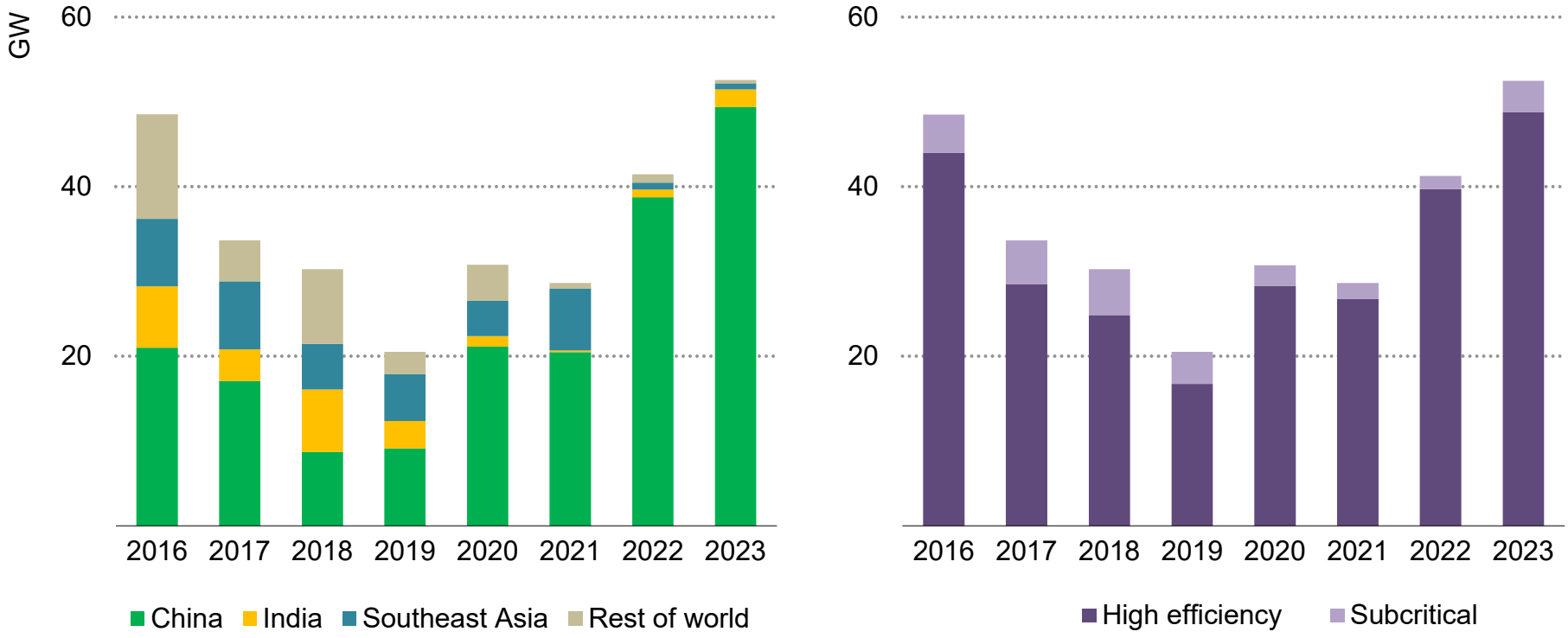


Source: IEA calculations based on EIA (2024), CEIC (2024), Ember (2024).

Final investment decisions (FIDs)

More than 50 GW of unabated coal-fired power generation was approved in 2023, the most since 2015, and almost all of this was in China, reflecting security priorities and strong demand

Coal-fired power generation capacity reaching FID by geography (left) and segment (right), 2016-2023

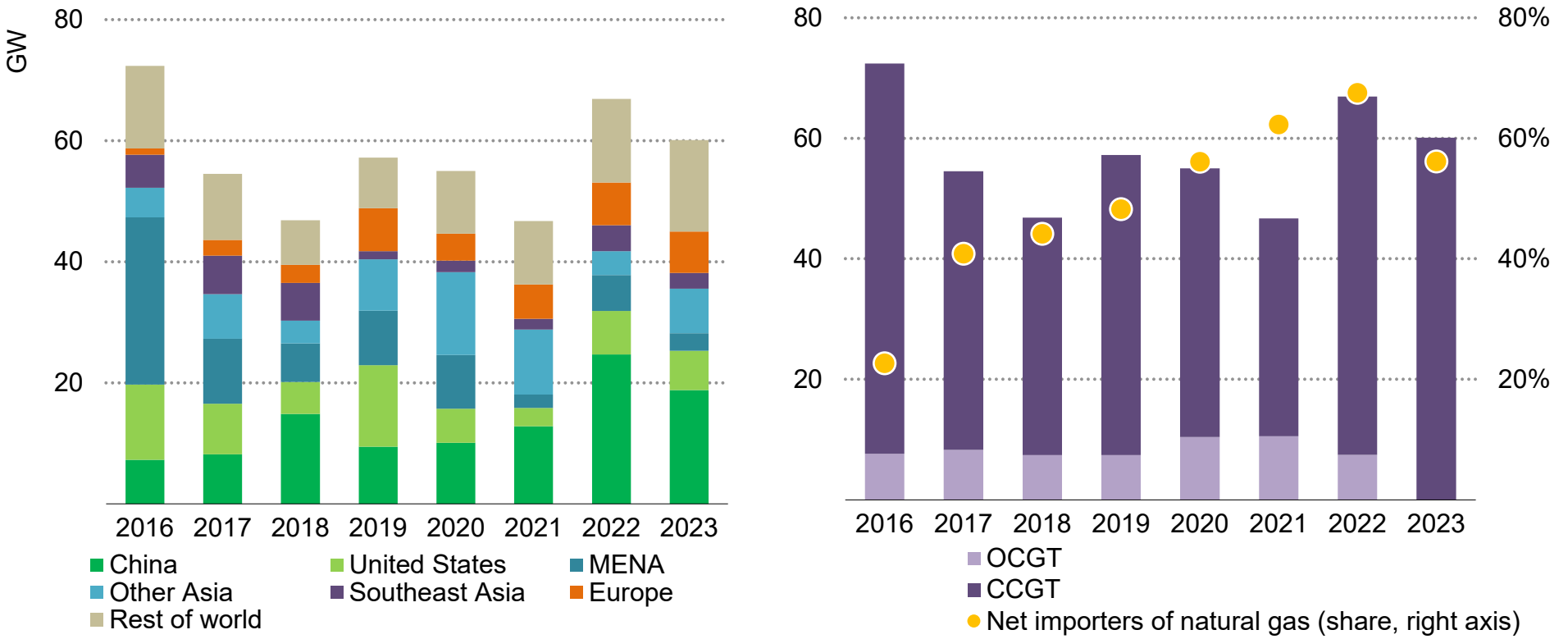


Note: FID = final investment decision. FIDs are an indication of the scale of future capacity to come online in the coming years. The IEA tracks projects that reach financial close or begin construction to provide a forward-looking indicator of future capacity additions and spending activity.

Source: IEA calculations based on McCoy Power Reports (2024).

FIDs for unabated gas-fired power generation declined by 10% in 2023 to 60 GW, still above the levels observed before the global energy crisis

Gas-fired power generation capacity reaching FID by geography (left) and segment (right), 2016-2023



Note: MENA = Middle East and North Africa. CCGT = combined-cycle gas turbine. OCGT = open-cycle gas turbine. Share of net importers of natural gas = share of gas power that has reached FID in countries that are net importers of natural gas. FIDs are an indication of the scale of future capacity to come online in the coming years. The IEA tracks projects that reach financial close or begin construction to provide a forward-looking indicator of future capacity additions and spending activity.

Source: IEA calculations based on McCoy Power Reports (2024).

FIDs for unabated fossil fuel generation rose above their already elevated 2022 levels, reaching more than 110 GW, driven by unabated coal-fired power

Despite a drop in the number of approvals for natural gas power plants, FIDs for unabated fossil fuel generation rose to 110 GW in 2023, driven by a 30% year-on-year increase in coal-fired capacity. Even as its contribution to natural gas FIDs declined significantly and clean power expanded drastically, China is still the source of the vast majority of this unabated fossil fuel-generated capacity, accounting for 95% of the world's coal-fired plants that reached financial close. In fact, if China were excluded, global approvals of unabated fossil fuel generation would have decreased by 3% last year.

The main drivers for this proposed capacity expansion are ongoing security of supply concerns amid the underperformance of hydropower in China, inflexible interprovincial electricity export contracts and rising electricity demand, as well as pressure on provincial governments to prioritise economic growth.

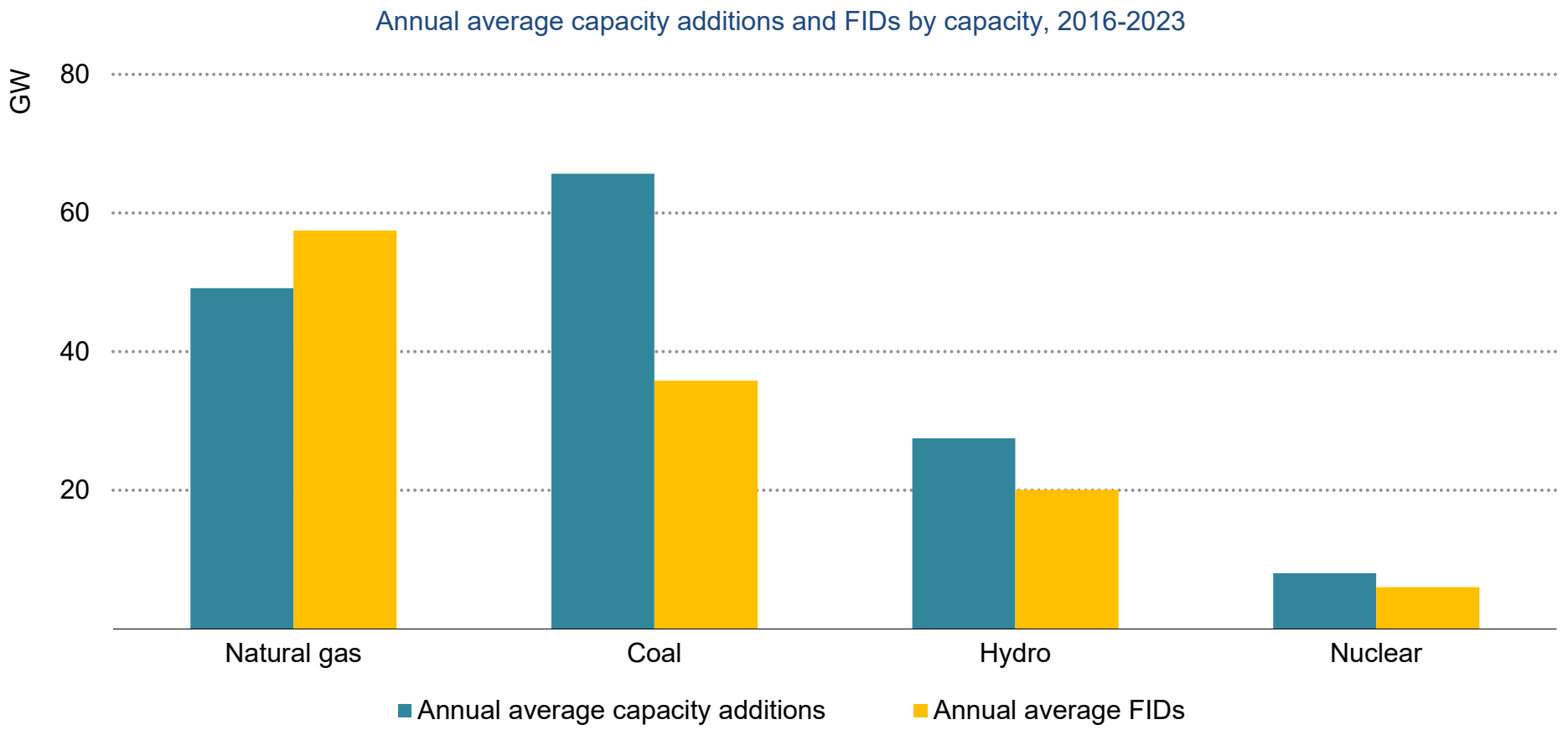
Against a backdrop of rapid expansion of renewables capacity in China, these new unabated fossil fuel power plants face the prospect of very low utilisation and reliance on capacity markets. It remains unclear whether this new capacity will be used primarily for flexibility purposes or for baseload generation, but the potential implications for China's emissions in the latter case are significant given the government's carbon intensity target.

In India, new coal FIDs doubled from a year earlier, to 2 GW in 2023 – their highest level since 2019 – as the country sought to meet higher-than-expected electricity demand. In the rest of the world, only two countries – Russia and the Philippines – approved meaningful increases in new coal-fired capacity for development. It appears, therefore, that most countries and financiers are following through with their pledges to stop supporting new coal-fired power plants.

In contrast to coal, FIDs for gas-fired power generation fell by 10% in 2023 – reaching 60 GW – although they remained above the average of recent years. China still approved the largest share of gas-fired plants, but the number dropped significantly, leading to a lower share of plants reaching financial close among net importers of natural gas. Elsewhere, FIDs for new gas plants increased in the Caspian region (Kazakhstan, Uzbekistan, and Azerbaijan) in particular, due to an influx of cheap Russian gas, while Nigeria has started to invest in gas-fired power stations using its domestic gas reserves.

Elsewhere, approvals of new gas FIDs in the United States, Europe and Asia in 2023 were in line with recent years. At the same time, new projects in the Middle East and North Africa (MENA) region fell by 50%. Moreover, all new gas FIDs were for combined-cycle gas turbine plants (CCGTs), which indicates that these new projects are looking for operating at higher utilisation rates.

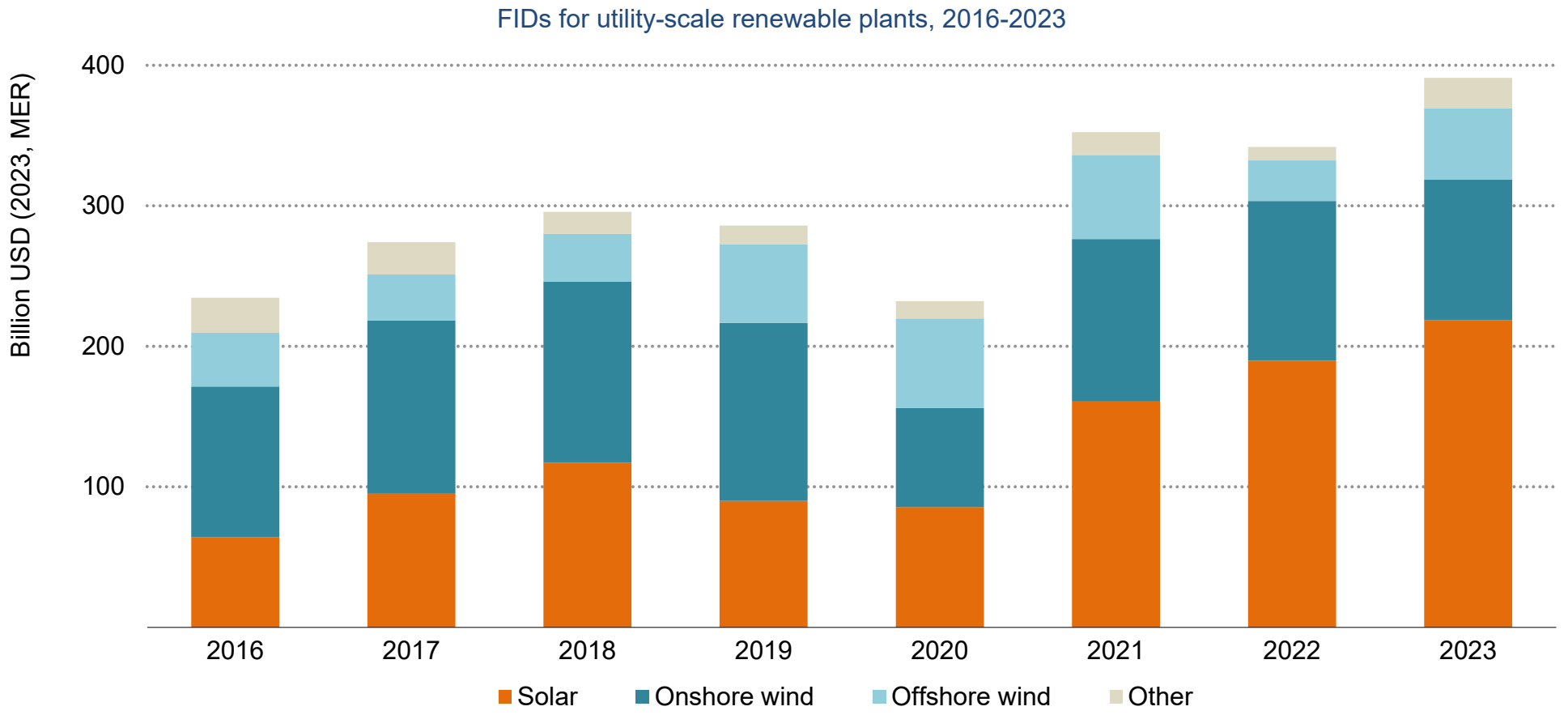
Despite the high levels of new coal FIDs, the pipeline of coal is still slowing; similarly, a good year for new hydropower has not offset the low number of approvals in recent years



Note: Annual average FIDs are an indication of the scale of future capacity to come online in the coming years and the time it takes for a new plant to go online can vary: A new natural gas plant might take three years, for example, while a new nuclear plant can take seven years.

Source: IEA calculations based on McCoy Power Reports (2024), S&P Global (2024), and IAEA (2024).

FIDs for utility-scale renewables climbed to record levels with solar leading the way, but offshore wind recovered strongly from its 2022 lows



Note: Excludes large hydropower. “Other” includes biomass, waste-to-energy, geothermal, small hydro and marine.
Source: IEA calculations based on Clean Energy Pipeline (2024).

Continued growth in solar and a rebound in offshore wind lifted FIDs for utility-scale renewables to an all-time high in 2023

FIDs for utility-scale renewable projects increased by 15% year-on-year to almost USD 400 billion in 2023, an all-time high. FIDs for solar plants represented more than half of the total at USD 220 billion – a new record and 2.5 times the amount approved in 2020. Wind power recovered somewhat from the previous year's drop due to a strong recovery in offshore FIDs, while fewer onshore wind projects were approved. The total numbers of utility-scale deals continued to increase significantly as the combined value of deals above USD 1 billion more than doubled.

Thanks to the European Union's "Fit-for-55" package, as well as improvements to the region's auctions and permitting, approvals of utility-scale renewable projects there rose by 50%, led by Germany, France and Poland. Similarly, the United States saw FIDs increase by 20%, with a bumper fourth quarter after details of the Inflation Reduction Act were disclosed. Elsewhere, notable jumps were also observed in Saudi Arabia and the Philippines.

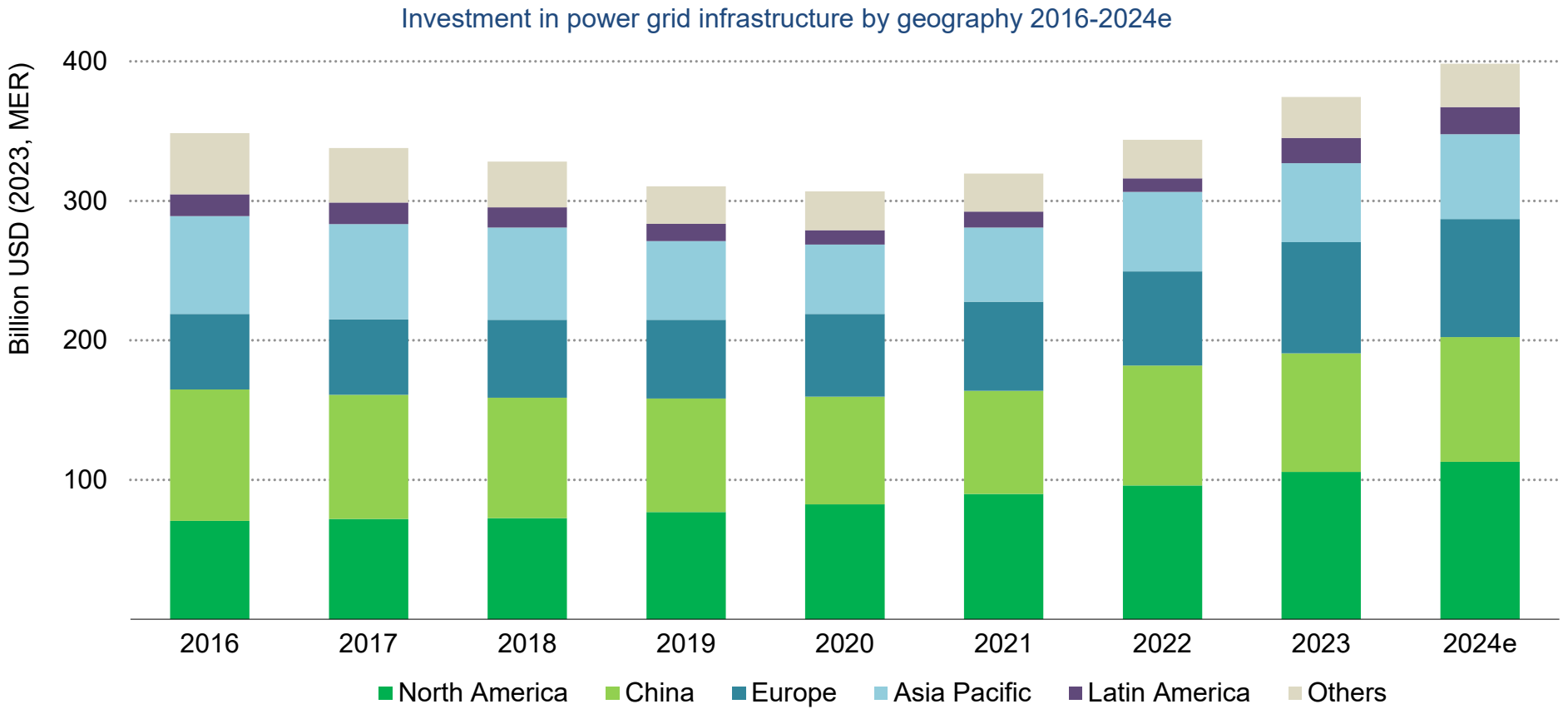
In a strong year for hydropower, FIDs for large-scale hydro plants increased to 32 GW from 14 GW in 2022. This was the highest level seen since 2017 – a promising sign for a technology that will play an important role in providing future baseload and energy storage services. China dominated approvals – which approved FIDs for more than 23 GW – India, Indonesia, Laos, Viet Nam and Angola. Pumped hydro – which can serve as energy storage – constituted more than 70% of hydropower FIDs. (Almost all approvals in China and Indonesia were for storage projects.)

In 2023, China and Egypt were the only countries starting the construction of new nuclear power plants (6 GW combined). The fact that nuclear continues to stagnate is cause for concern, even though additional capital is being spent on modernising and extending the lifetimes of existing plants, which is not captured by FIDs.

The strong growth in approvals of utility-scale renewables suggests that the construction delays and supply chain constraints of past years have been largely resolved. However, a range of issues is still hampering the scaling up of renewable capacity: Advanced economies face land acquisition, permitting and grid connection delays, for example, while China is keen to keep renewables curtailment rates at 10%. In EMDE outside China, FIDs are still lagging behind – with the exception of India and Brazil – and will require addressing in particular the high cost of capital for clean energy projects. Doing so will mean establishing clear and stable regulatory frameworks, reducing off-taker risk and deploying concessional finance where necessary. For 2024, we are therefore expecting overall growth to continue, but growth in FIDs for utility-scale renewables will slow in USD terms as costs continue to fall.

Grids and storage

Grid investment is starting to pick up and is expected to reach USD 400 billion in 2024, with Europe, the United Sates, China and parts of Latin America leading the way

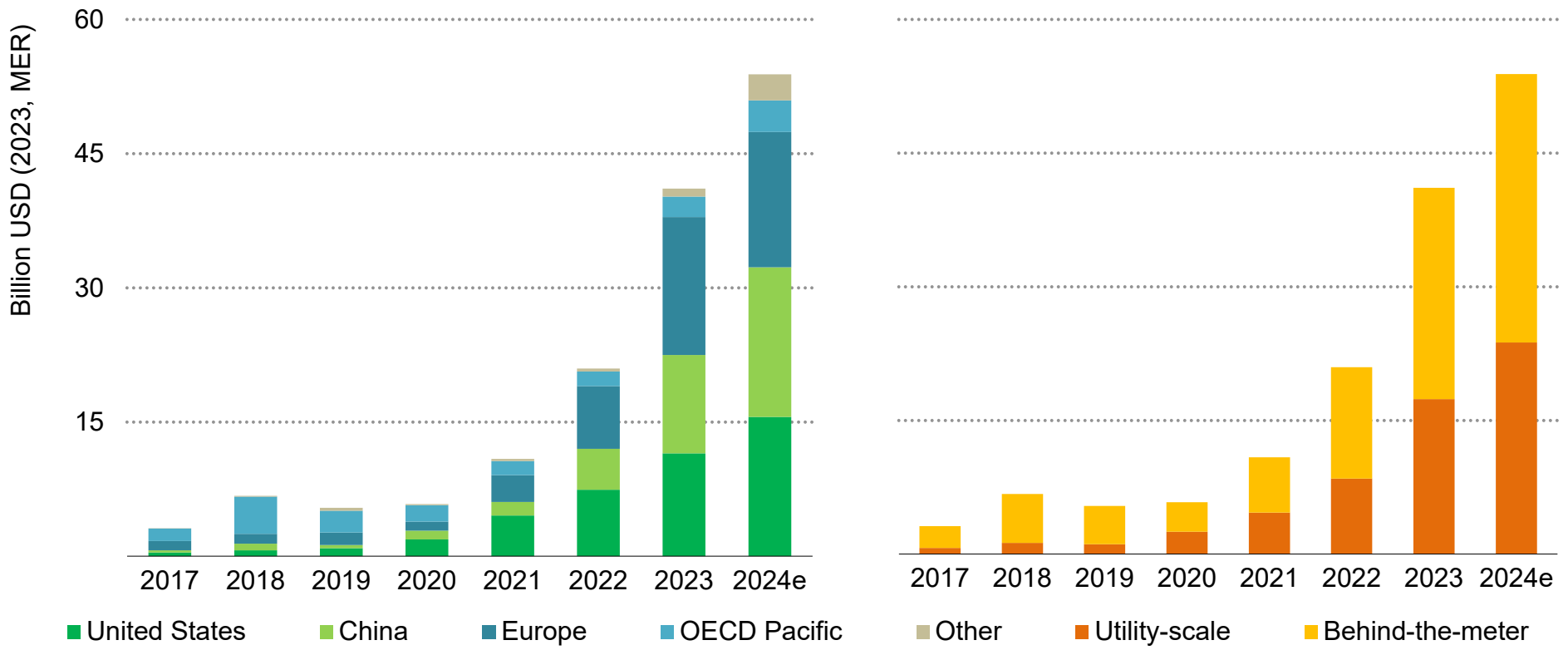


Note: 2024e = estimated values for 2024.

Source: IEA analysis based on transmission and distribution companies' financial statements, Global Transmission (2023).

Investment in battery storage continued its rapid growth to reach USD 40 billion in 2023, and further growth is expected in 2024 as costs continue to decline

Battery storage investment by geography (left) and segment (right), 2017-2024e



Note: OECD Pacific = Japan, Korea, Australia, and New Zealand. 2024e = estimated values for 2024. For this report, we improved our methodological approach to battery storage investment. This involved a more accurate association of capacity to utility-scale, commercial and residential battery storage projects as well as their corresponding capital costs.

Source: IEA calculations based on BNEF (2024), Wood Mackenzie (2024), China National Energy Agency (2024) and CNESA (2024).

Electrification efforts are accelerating in advanced economies and Latin America, yet progress is urgently needed in EMDE outside China

There were positive changes in the grid landscape in 2023. In some regions, efforts to deploy networks for electrification increased, though the gains still fell short of what is needed. Advanced economies and China continue to lead investment in power grids, accounting for about 80% of global spending. China held its level of investment at USD 80 billion, with the government-owned State Grid Corporation maintaining its appetite for new grids and networks.

Investment in advanced economies grew at a rate of 11% in 2023, led by the United States, which spent USD 100 billion – mostly on enhancing grid reliability and upgrading old infrastructure. Spending in the European Union rose strongly, reaching USD 60 billion, bolstered by the European Commission's Grid Action Plan which targets more than USD 600 billion in spending on grids in the next six years. Further investments in grid interconnection are very much required in the European Union to facilitate the flow of renewable power from southern to central European markets. Generally, in advanced economies, a key challenge lies in sustaining investment growth and ensuring its effective translation throughout the supply chain. Power transformers in particular encounter obstacles due to inflationary pressures and supply shortages.

Grid investment in EMDE outside China grew by an impressive 15%, reaching almost USD 80 billion in 2023. However, this increase masked very different patterns in the underlying regions. Investment in India, for example, remained flat despite the introduction of tenders for smart meters – of which only 10% of the government's original target number have been installed. Investment in Africa and Southeast Asia also remained mostly unchanged. However, this lack of new investment was partly offset by a doubling of spending in Latin America as countries like Colombia, Chile, Panama and Brazil made efforts to increase spending. Brazil made particular progress – more than doubling its grid investments in 2023 and auctioning a record 10 500 km of grid (where China State Grid won the biggest lot).

Many EMDE are highly dependent on concessional financing and public funding for grid investment, which represented 80% of total investment in 2023. Most of Southeast Asia lacks robust regulatory frameworks for private participation, for example. In Viet Nam there is no public-private partnership (PPP) infrastructure with a clear revenue model. In Africa, more than half of investment comes from public sources – and only every third utility can recover operational and debt costs, even after including subsidies from governments. One positive exception to this is South Africa, which plans to establish an independent transmission project office to procure new transmission capacity using a build-operate-transfer model. Grid connectivity in Africa generally remains a challenge, however.

Sharply declining costs helped battery storage investment to double again in 2023

As we point out in our recent Battery Special Report, battery storage is a critical component for the energy transition. In 2023, investments in battery storage reached more than USD 40 billion, 90% of which was concentrated in China, the United States and Europe. But for every 1 USD invested in battery storage in advanced economies and China, only one cent was invested in other EMDE countries. This lack of investment in EMDE is mainly due the absence of clear regulatory frameworks as well as high capital and financing costs.

Spending on battery storage in China increased by a factor of almost 2.5 in 2023 to USD 11 billion. This comes as provinces rolled out capacity payment schemes that subsidise both discharging and charging. In addition, many provinces require project developers to include a minimum of 10% to 20% of energy storage capacity in every new wind or solar project. After this record year of renewables and battery deployment (as well as continued declines in capital costs) we are expecting capital expenditure for battery storage in China to continue growing strongly in 2024, albeit at a slightly slower pace.

In the United States, investment also rose to USD 11 billion and we expect similar growth 2024. This is supported by the US Inflation Reduction Act and liberalised power markets that allow for favourable storage economics, as well as strong dynamism in the residential battery market. Even stronger growth has been held back by permitting issues and higher financing costs.

Europe saw battery storage investment more than double to USD 15 billion in 2023, with behind-the-meter applications – for example, battery storage combined with rooftop solar – performing particularly well in Germany and Italy and strong growth in utility-scale systems in the United Kingdom. Continued power price volatility, supportive energy storage auctions, and tax exemptions are expected to support a similar investment level in 2024 with progressively greater focus on utility-scale systems.

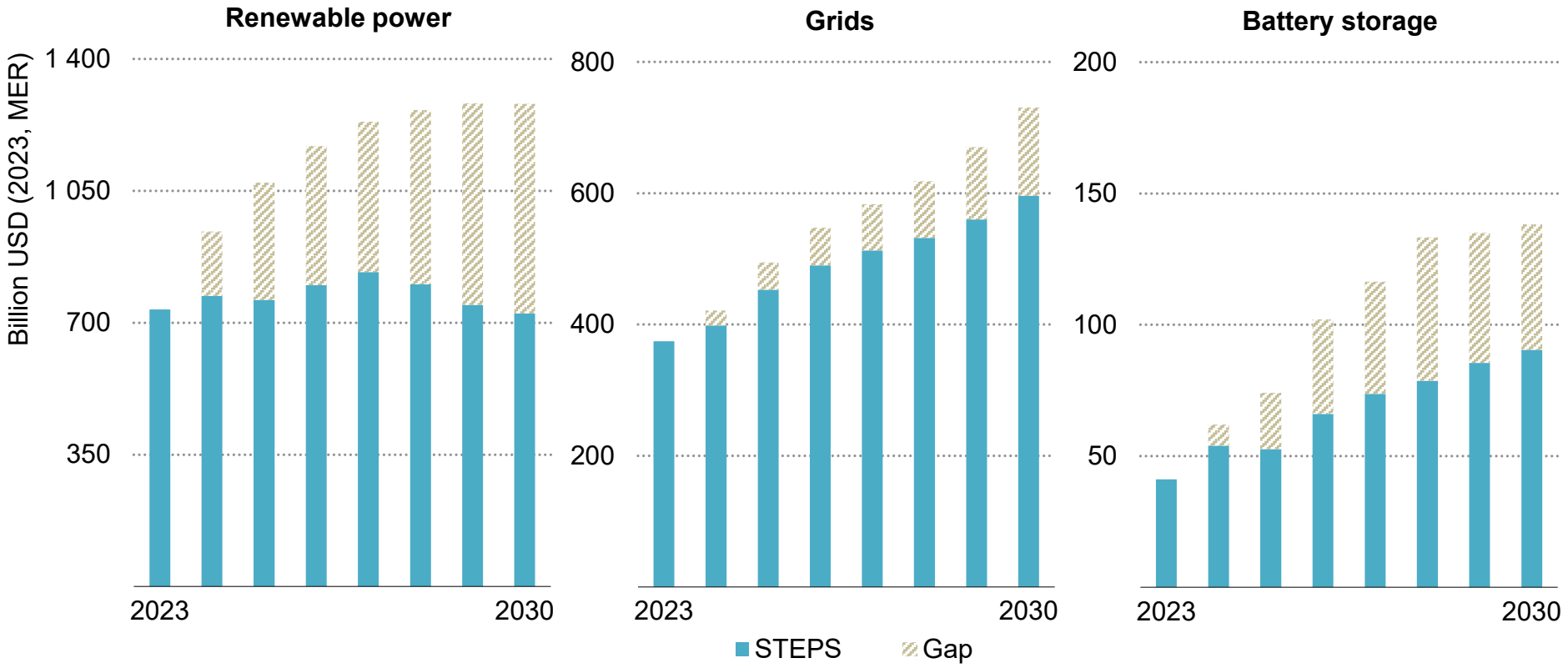
The Asia-Pacific region (outside China) increased its battery storage spending by 40% to almost USD 2.5 billion, led by Japan and Australia. India did not meet its growth expectations due to project construction delays. For select other markets, such as Chile, 2023 marked the take-off year for battery storage as it passed legislation to incentivise energy storage and announced that it would be seeking to procure 5.4 GWh in energy storage and non-variable renewables capacity by 2028 while setting aside USD 2 billion.

Despite high expectations for future capacity growth, investment spending will likely moderate over time as capital costs continue to come down. After increasing in the previous year for the first time, capital costs returned to their 2021 levels in 2023 due to falling prices for critical minerals and expanding battery manufacturing capacity. Capital costs also continued to be significantly lower in China than in Europe or the United States.

Implications

Tripling installed renewables capacity by 2030 will require annual investment in renewables and grids to increase by 12% and 11%, respectively, while battery investment needs to rise by 25%

Gap in investment spending to triple installed renewables capacity by 2030



Note: STEPS = Stated Policies Scenario. The annual growth rates mentioned above would ensure that the cumulative required investment to triple installed renewables capacity by 2030 for renewable power, grids and battery storage in 2024-2030 is met.

While investment in renewables, batteries and (most recently) grids is accelerating, more effort is required to achieve a tripling of renewables capacity – especially in EMDE

At the COP28 international climate conference in Dubai, countries famously signalled the “beginning of the end” of the fossil fuel era. As part of this pledge, they agreed to triple installed renewables capacity by 2030. While global spending on renewable power hit a record USD 735 billion in 2023, more efforts are required for the tripling goal.

Early signs of a potential slowdown in the growth of global spending on renewables, and persistently insufficient levels of investment in EMDE outside China, underline the need to double down if we are to achieve our climate and energy access goals. Ensuring further increases in renewables investment requires the following: clear and stable regulatory frameworks; policy support; simpler and faster permitting; grid expansion; energy storage and sources of flexibility; payment guarantees and more concessional finance.

Under current policies and market conditions, renewables investment over the next seven years could meet around two-thirds of the spending necessary to triple installed renewables capacity by 2030. This creates a gap of around USD 400 billion per year in required spending on renewables between 2024 and 2030. While advanced economies and China will need to increase their current annual investments by an average of 6% to meet the cumulative required, the spending gap is particularly pronounced in other EMDE regions, where annual investment will need to increase by 30% per year.

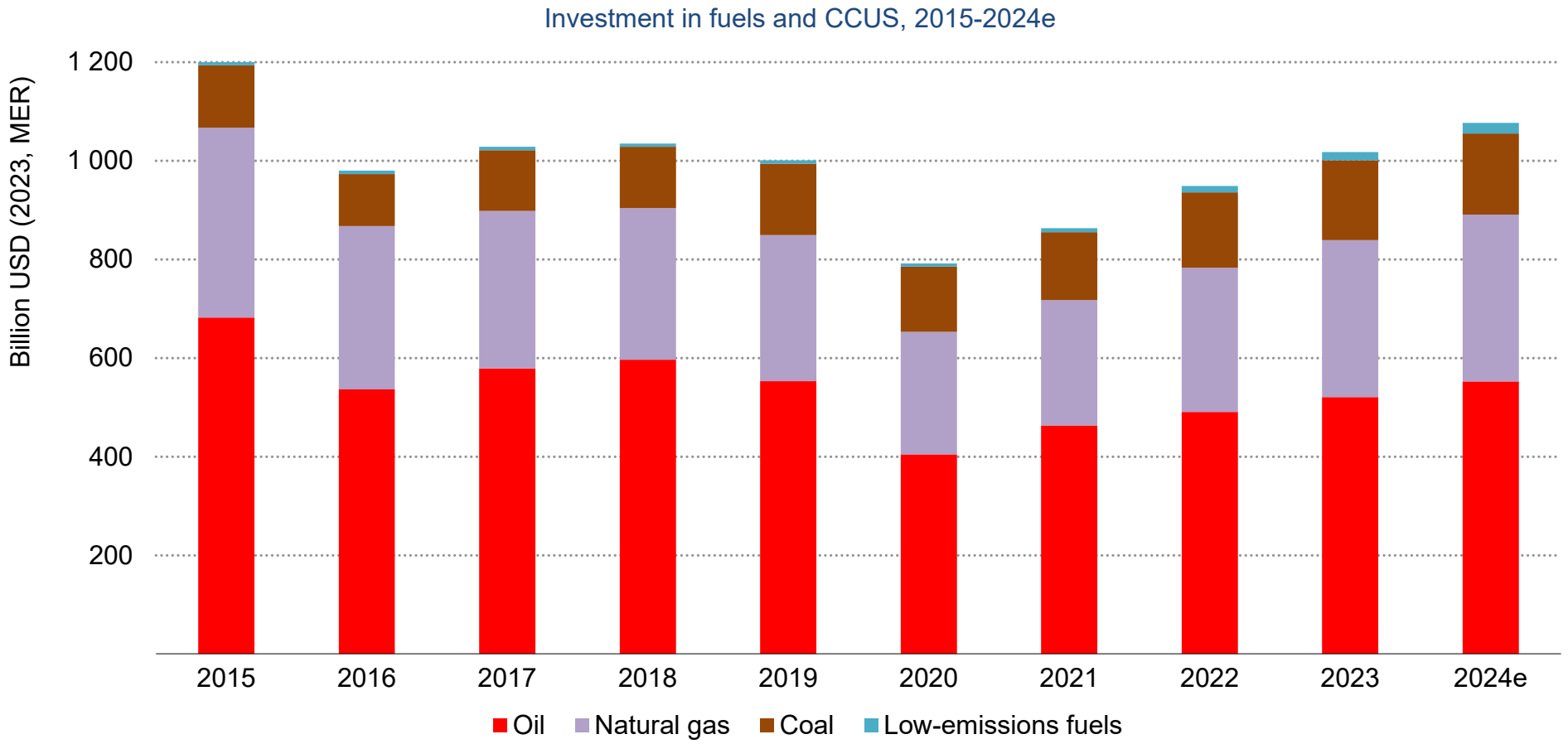
Key enablers for the tripling of installed renewables capacity are grids and battery storage. While spending on grids has been relatively flat in recent years, there was significant growth in 2023 and investment is projected to further accelerate. Despite this, in the IEA’s Stated Policies Scenario (STEPS), grid investment would still face a significant shortfall to the investment levels required for tripling renewables capacity. Current global spending on grids needs to grow by an average of 11% every year to meet the cumulative required investment. Tackling tariff risks, establishing forward-looking regulatory frameworks and financing models to mobilise private capital are essential to facilitate this increase in investment levels.

Through its ability to smooth the load curve by storing electricity when it is produced in abundance and discharging when additional electricity is required by the system, battery storage is primed to support the variability of renewables generation. Even though it experienced explosive growth in the past two years, in the STEPS battery storage investment could only meet around two-thirds of the cumulative investment need. Closing the gap will require current annual spending on battery storage to grow by 25% every year. In our recent Special Report on Batteries, the IEA highlights the importance of clear and stable regulatory environments, as well as addressing off-taker risk, to attract battery investment at scale.

Fuel supply

Overview

Fossil fuel investment is set to continue its rise in 2024; commitments to low-emissions fuels are growing rapidly but from a very low base



Notes: Low-emissions fuels = modern bioenergy, low-emissions hydrogen, hydrogen-based fuels and CCUS associated with fossil fuels. 2024e = estimated values for 2024.

Fuel supply investment remains overwhelmingly focused on fossil fuels with a major new wave of LNG approved for development

While power sector investment, discussed in the previous chapter, has shifted substantially in support of energy transitions, the same cannot yet be said for investment in fuel supply. Demand for fossil fuels remains robust as the world emerges from a period of vast turbulence caused first by the Covid-19 pandemic and then by Russia's invasion of Ukraine. But investors peering beyond the short term confront a range of possible energy futures, each with very different implications for fuel supply projects.

Upstream oil and gas spending is set to increase by around 7% in 2024 – reaching USD 570 billion – building on a larger increase seen in 2023. This is led by national oil companies (NOCs) in the Middle East and Asia.

The huge increase in revenues and profits during the price spikes of 2021-2022 has not translated into a similar-sized rise in new capital expenditures. More has gone towards dividends, share buybacks and net debt repayment than to new investments. Upstream investment is focusing on projects that are considered viable even under challenging assumptions about future price and regulatory developments, typically through a combination of low costs and low emissions intensities. Expenditure aimed at extracting value from existing fields is an important element of many strategies, hitting USD 200 billion in 2023 for the first time since 2019. Strong cash positions and a hunt for advantaged resources also explain the volume and types of mergers and acquisitions (M&A) activity.

Investment in LNG is set to rise with a major wave of new LNG export project approvals promising to increase LNG supply capacity by 250 bcm (a 50% increase) between 2023 to 2030, with 75% of the growth coming from the United States and Qatar. Unlike previous LNG supply surges, now there are fewer committed end-use off-takers for these additional volumes, implying a strong shift away from the sellers' market seen in recent years toward a buyers' market in the second half of the decade.

Investment in refineries remained broadly flat from 2022 to 2023 and is expected to drop in 2024 as long lead time projects and uncertainty about future demand stymie final investment decisions. Refinery capacity growth, driven by projects in China, Nigeria, and the Middle East, added 1.3 mb/d of net capacity in 2023. Future capacity will mainly come from China, India, and the Middle East.

Investment in coal supply increased in 2023, particularly in China, India, and Indonesia, with further growth expected in 2024. Coal

investments will be heavily dependent on the demand outlook in China, which may slow due to economic uncertainties and rapid growth in renewables.

Existing policies, plans, and commitments – like the Global Methane Pledge – could reduce methane emissions from fossil fuel operations by 50% by 2030. Achieving these reductions will require more than USD 80 billion in cumulative investments, led by fossil fuel companies. The investment will be offset by the value of the additional gas that will be brought to market. Financial support for low- and middle-income countries will be essential to reach this level of abatement, and even more so to achieve the 75% reduction in emissions by 2030 that is needed to limit global warming to 1.5 °C.

Commitments to low-emissions fuels are rising rapidly, but from a very low base. Overall clean energy investment by oil and gas companies grew to around USD 30 billion in 2023, but this remains less than 4% of overall capital spending. Around half of clean energy investment by the oil and gas industry in 2023 involved M&A of clean energy companies.

Low-emissions hydrogen is another nascent area for clean energy investment. Spending is growing but uncertainties, such as the future of demand and lack of reliable off-takers, constrain the development of large-scale supply projects.

There has also been some progress with new CCUS projects. Around 20 commercial-scale CCUS projects in seven countries reached final investment decision (FID) in 2023 and according to company announcements, more than 110 capture facilities and transport and storage infrastructure projects could reach FID in 2024.

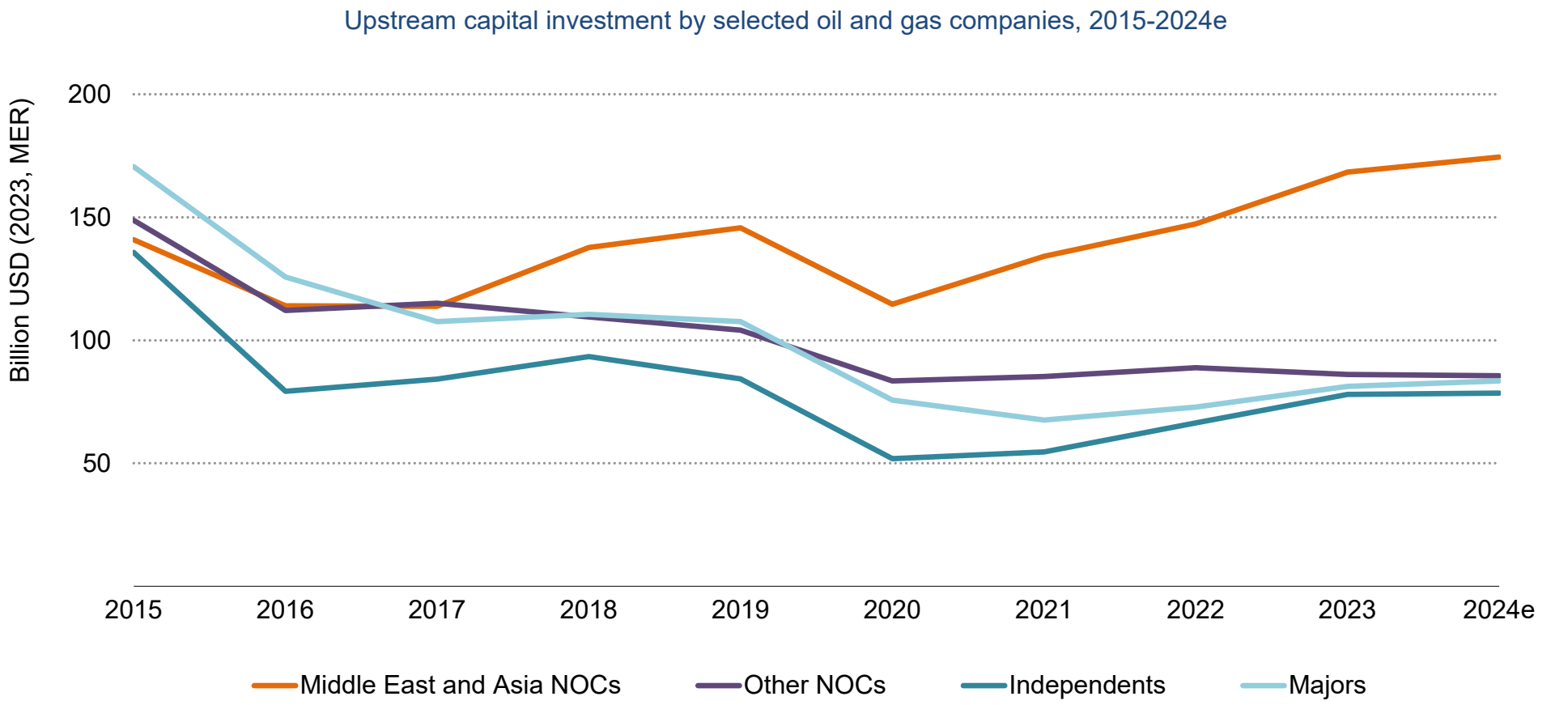
The size of the critical mineral market in 2023 was USD 325 billion, shrinking due to commodity price declines, especially for battery materials (lithium, graphite, cobalt, nickel, and manganese). Diversifying supply by activating additional investment in different geographies, as well as stepping up demand-side measures such as recycling, are crucial to ensure well-balanced and resilient markets as energy transitions propel demand.

Anticipated oil and gas investment in 2024 is broadly in line with the level of investment required in 2030 in the Stated Policies Scenario, a scenario which sees oil and natural gas demand levelling off before 2030. However, global spare oil production capacity is already close to 6 million barrels per day (excluding Iran and Russia) and there is a shift expected in the coming years towards a buyers' market for LNG. Against this backdrop, the risk of over-investment would be strong if the world moves swiftly to meet the net zero pledges and climate goals in the Announced Pledges Scenario (APS) and the NZE Scenario.

Coal investment in 2024 is set to be far higher than the 2030 level seen in any IEA scenario. By contrast, despite the positive momentum in developing low-emissions fuel projects, investment in these technologies remains far below the levels projected for 2030 in both the APS and the NZE Scenario.

Upstream oil and gas

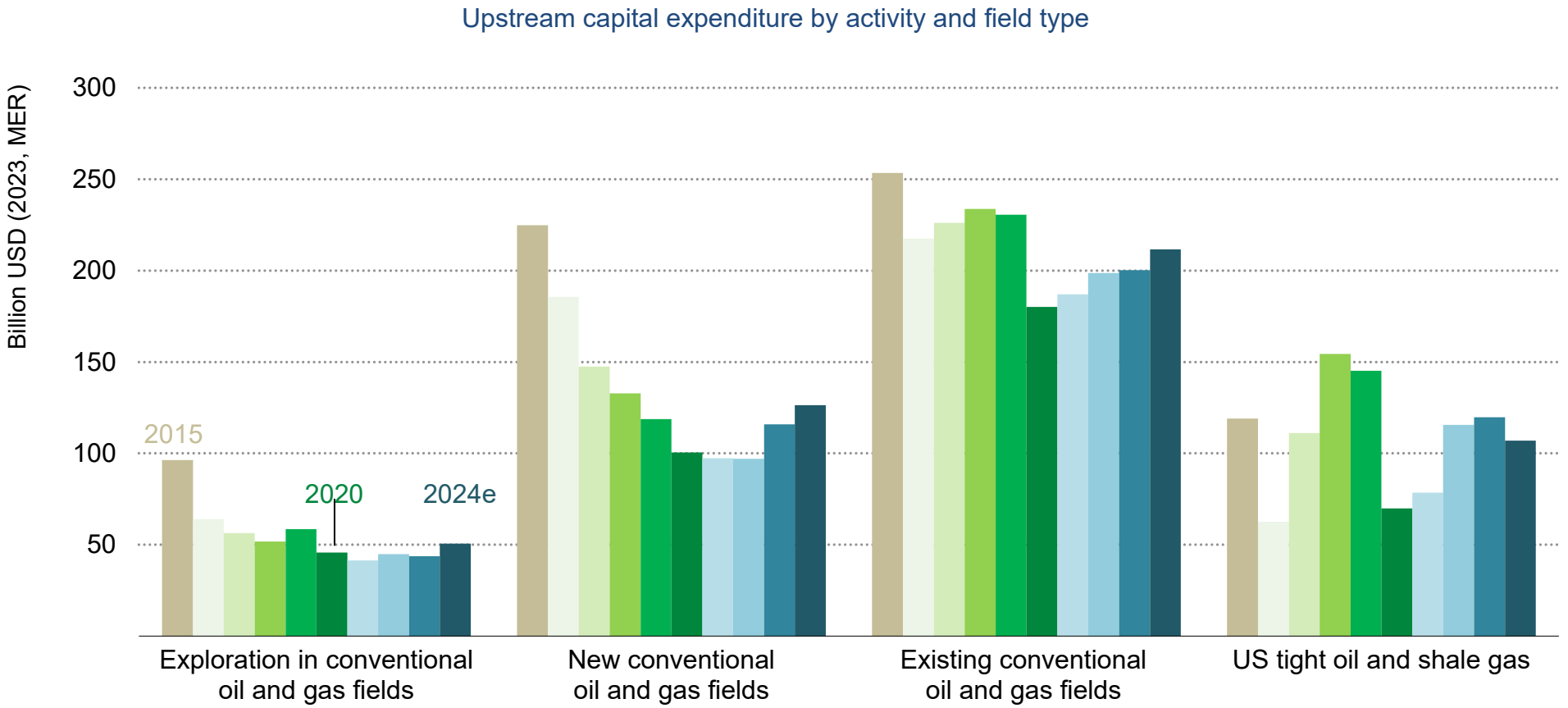
Upstream oil and gas investment increased globally by 9% in 2023 and looks set for a 7% rise in 2024, with most increases coming from Middle East and Asian NOCs



Note: 2024e = estimated values for 2024. Majors = bp, Chevron, ConocoPhillips, ENI, ExxonMobil, Shell, TotalEnergies. NOCs = national oil companies.

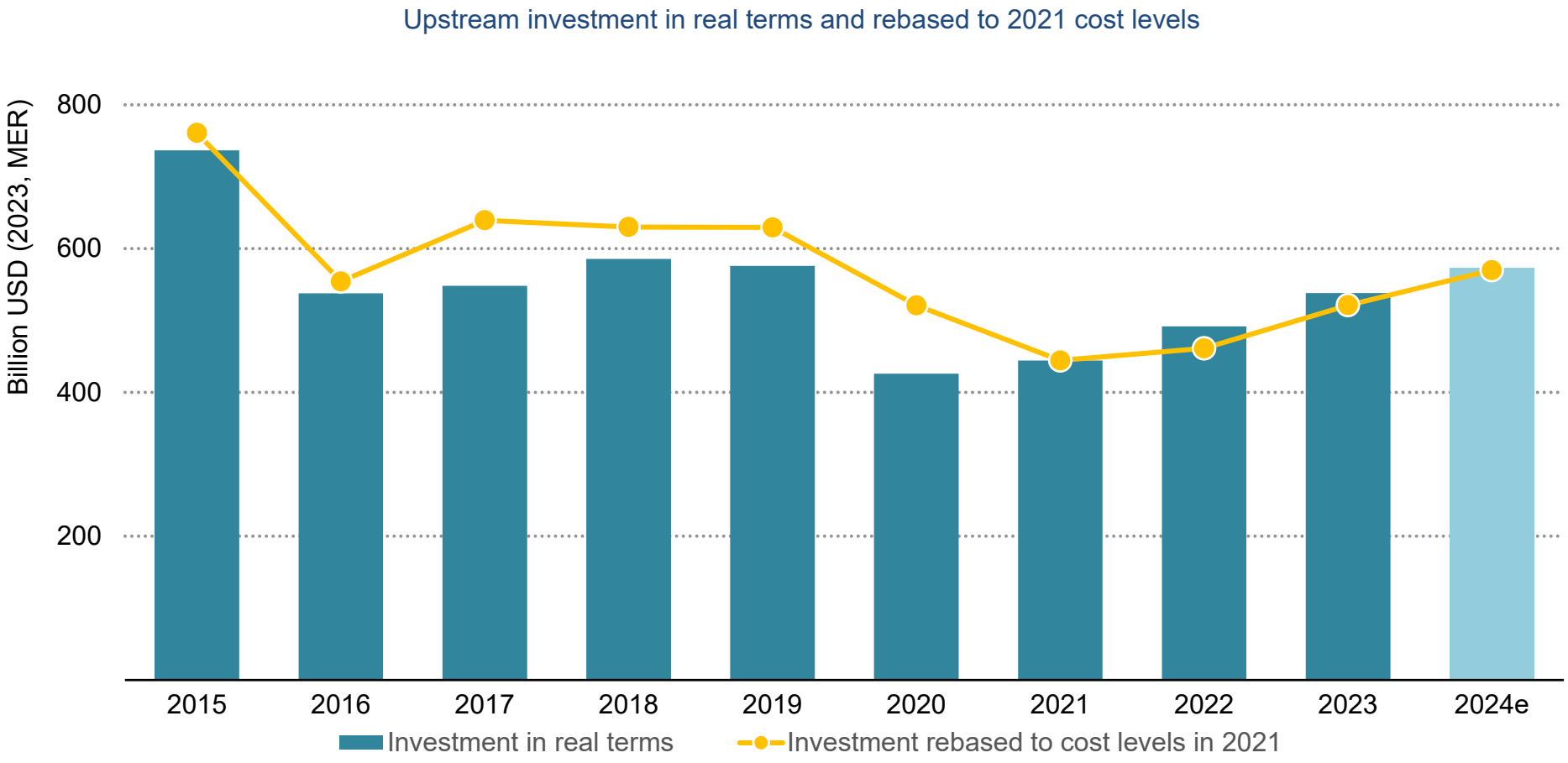
Sources: IEA analysis based on S&P, Bloomberg and Rystad and annual reports. Includes a sample of companies that are responsible for about 70% of global production.

Investment in exploration and development rose in recent years pushed by cost inflation while still remaining 30% below the peak in 2015 because of cost efficiency improvements



Note: 2024e = estimated values for 2024.
Source: IEA analysis based on Rystad (2024).

Upstream cost inflation cooled in 2023 and costs may fall marginally in 2024 which means recent investment trends translate into larger increases in activity



Note: 2024e = estimated values for 2024. Investment rebased to 2021 cost levels adjusts investment in real terms by the IEA's Upstream Capital Cost Index.
Source: IEA analysis based on Bloomberg Terminal, FRED, IEA, IMF, and Rystad data.

Upstream investment is realigning globally, with national oil companies taking the lead

Based on a review of the spending plans of companies representing about 70% of global production, we estimate that upstream oil and gas investment in 2024 will increase to around USD 570 billion, up 7% from 2023 levels, building on the 9% increase seen in 2023.

The period since 2015 has seen a major reorientation in upstream investment, with greater cost discipline across company types along with a major shift in the approach to spending. Between 2017 and 2024, investment by Middle East and Asian NOCs increased by more than 50% while investment by private companies fell by close to 20%. NOCs are set to provide over 40% of global upstream spending in 2024, compared with less than 25% in 2015, and NOCs in the Middle East and Asia have been responsible for nearly all the increase in investment in 2023 and 2024. This includes investment by PetroChina to explore for conventional resources and develop tight liquids and gas basins, Saudi Aramco's push to meet its expanded gas production target (even as it cuts back on plans to expand oil production capacity), and new sour gas field developments in the United Arab Emirates.

Capital investment in existing conventional oil and gas has accounted for around 40% of total upstream oil and gas investment over the last decade. A further one-third of overall investment has been devoted to new field development and exploration, and most of the rest has flowed to US tight oil and shale gas production.

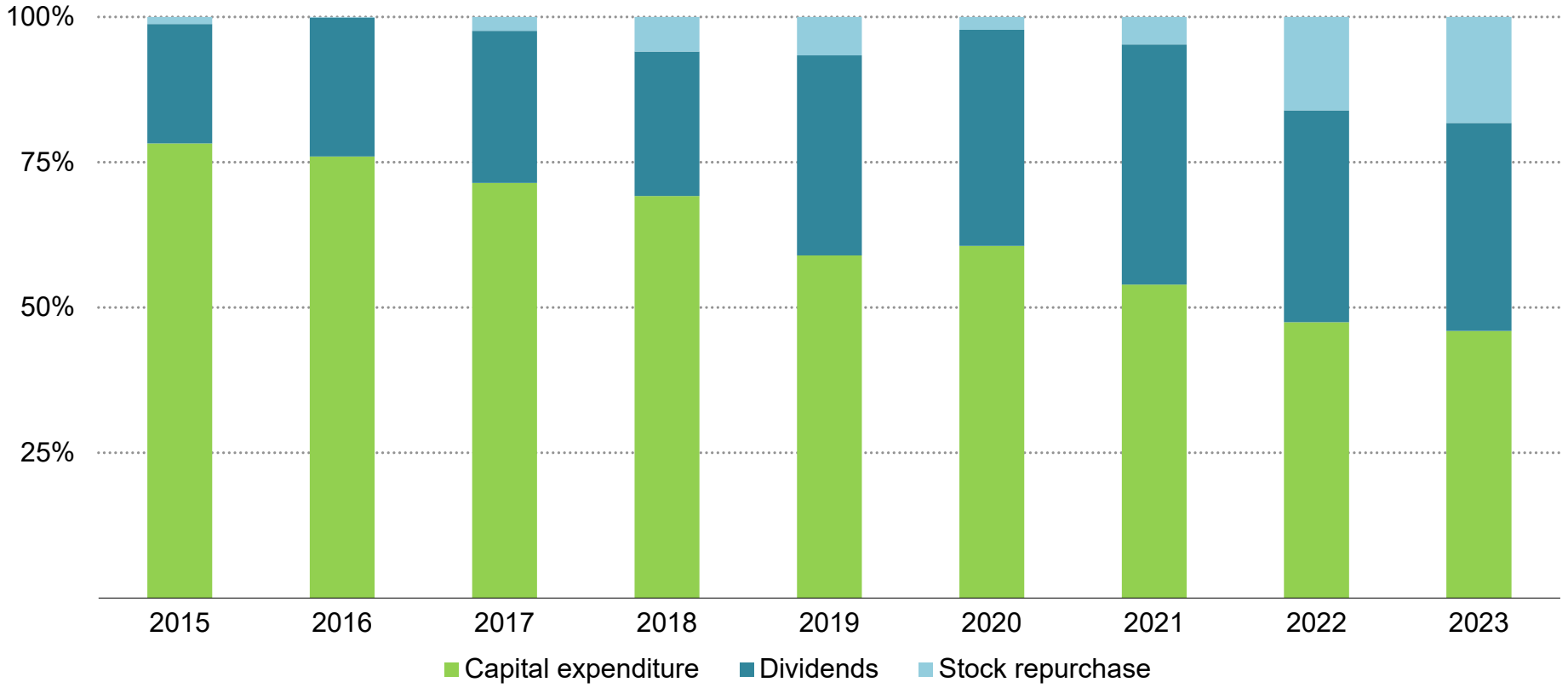
From 2021 to 2023, nearly USD 130 billion was spent on conventional oil and gas exploration. More than half of this investment took place in China, North America, Norway, and Russia – but the largest discoveries were seen in Guyana (in the Stabroek block) and Namibia. Exploration investment is set to increase by a further 15% in 2024, mainly because of increases in China and North America.

Investment in US tight oil and shale gas peaked in 2018-2019, at around USD 130 billion per year, and has since fallen back amid significant cost cutting. Activity is set to remain broadly flat in 2024 but investment will fall marginally, given cost reductions and M&A consolidation that should yield efficiency benefits.

The IEA's Upstream Capital Cost Index (UICI) increased by 6% in 2022 because of tight markets for services and labour as well as increased raw material costs. However, the UICI in 2022 was still nearly 15% below 2014 levels due to efforts by operators to downsize and simplify project designs to maintain competitiveness. Inflation cooled in 2023 and costs could even fall marginally in 2024. The increases in upstream investment in 2023 and 2024 thus translate into a near 20% increase in upstream activity since 2022, a rate of increase not seen since 2010-2012.

Dividend payments and stock repurchases exceeded capital expenditure again in 2023

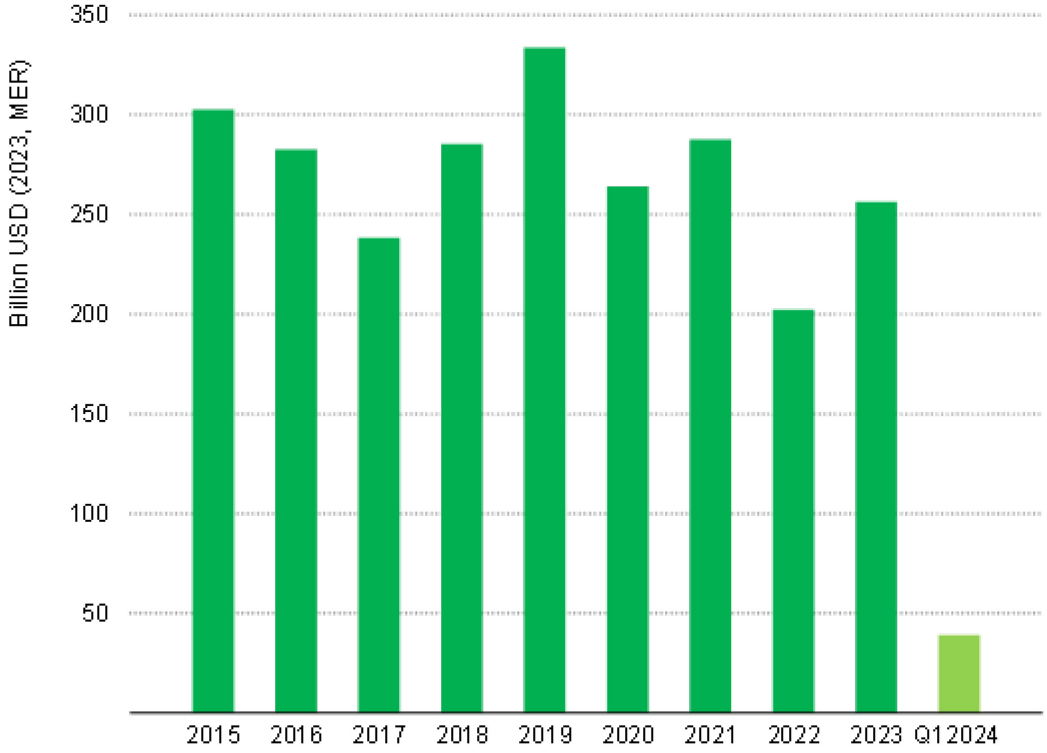
Capital expenditure, dividends, and buybacks by the 30 largest upstream oil and gas companies, 2015-2023



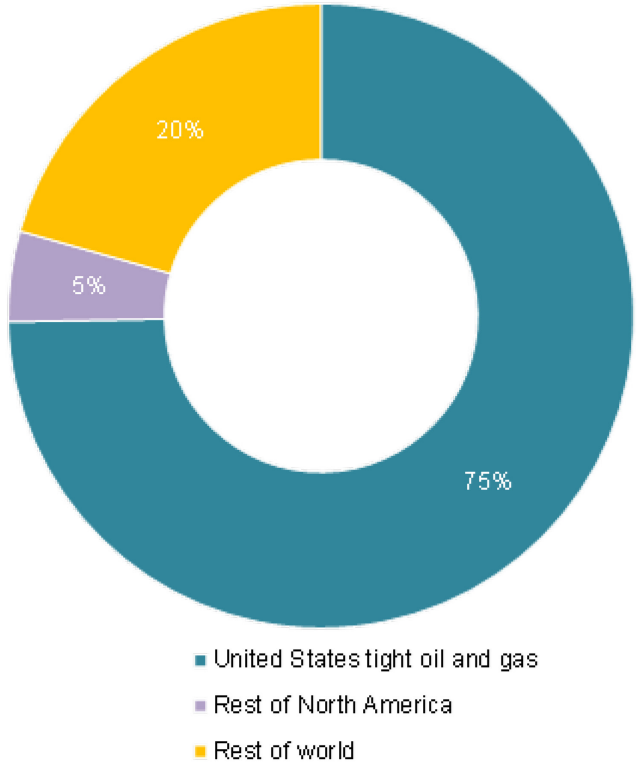
Source: IEA analysis based on Bloomberg (2024) for the largest 30 upstream companies by revenue.

Robust mergers and acquisitions activity focused on consolidating United States tight oil and shale gas assets

Upstream merger and acquisition deals by announcement year



Announced and completed deals by geography, 2023-Q1 2024



Note: Upstream deals include completed deals up to 2020 and completed and pending deals from 2021 to Q1 2024.
Source: IEA analysis based on Bloomberg and other market and company data.

High recent profits have been used mainly to benefit stockholders and to fund extensive mergers and acquisitions

Oil and gas exploration and production companies generated USD 2.4 trillion in net income in 2023, down USD 1.5 billion from 2022, but still well above the lows seen between 2015 and 2017 and again in 2020. Based on a review of the 30 largest upstream oil and gas companies, buybacks rose to historic highs in 2023, accounting for 20% of cash flow from operations and payouts from dividends rose to around 30%. For a second consecutive year, less than 50% of cash flow was allocated to capital expenditures.

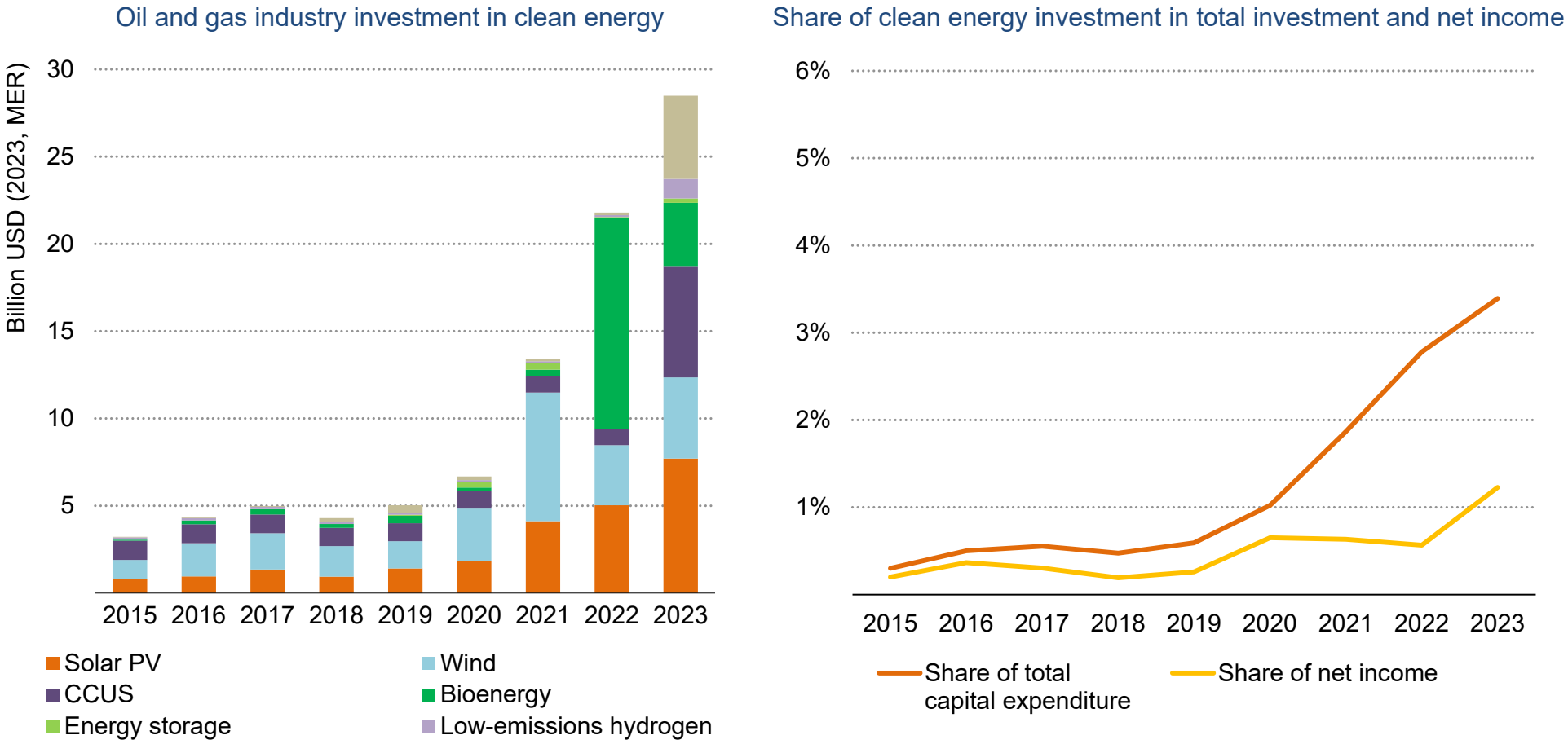
Many large M&A deals were completed and announced in 2023. Three quarters of these involved US shale companies, reflecting the trend towards consolidation of operational footprints in specific basins while also looking to increase overall production levels.

Some of the largest deals in 2023 included Chevron's purchase of PDC, with a total enterprise value of USD 7.6 billion and Occidental's announced acquisition of CrownRock for USD 12 billion. Significant deals were also announced that are likely to be completed in 2024. These include: ExxonMobil's USD 60 billion purchase of Pioneer; a USD 26 billion merger between Diamondback and Endeavour (the combined company will control close to 1 million acres in the Permian Basin); a USD 7.4 billion merger between Chesapeake and Southwestern, which will create the largest US gas producer; and SLB's acquisition of ChampionX, which will enhance its services to the Permian basin. Chevron also announced its intention to acquire Hess – which has significant assets in the US oil and tight shale sectors, notably the Bakken basin – for USD 60 billion, but the deal remains subject to several legal challenges related to some of Hess's non-US assets.

M&A activity beyond North America highlights a trend for oil majors and NOCs to focus portfolios on specific geographies. ENI purchased Neptune Energy's assets in Europe, Indonesia, and North Africa – locations where ENI already has a presence – for USD 2.6 billion, while Var Energi acquired Neptune Norge for USD 2.3 billion. TotalEnergies strengthened existing positions in Malaysia with a stake in SapuraOMV Upstream for USD 1 billion while Shell sold its Masela blocks in Indonesia to Pertamina and Petronas for USD 650 million. In 2024, a number of majors also announced a goal to scale down, or exit entirely, activities in Nigeria, partly driven by the need to comply with sustainability goals.

The acquisitions announced or completed in 2023 were funded either through cash, stock, reserve-based lending, or other investment vehicles, with financing coming from a variety of banks, private equity, and institutional lenders.

Clean energy investment by oil and gas companies grew to USD 28 billion in 2023 which is less than 4% of overall capital spending and less than 1% of net income



Note: Includes project finance and M&A. CCUS = Carbon Capture Utilisation and Storage. “Other” = EV infrastructure, geothermal, tidal, minerals and M&A of companies with a portfolio of clean technologies.

Source: IEA analysis based on Bloomberg, Clean Energy Pipeline and companies’ annual reports and presentations.

Nearly half of clean energy investment by the oil and gas industry in 2023 involved M&A of clean energy companies, with a particular focus on CCUS

In 2023, oil and gas companies invested USD 28 billion into clean energy, a 30% increase from 2022 levels. This was well below the 65% jump seen from 2021 to 2022, reflecting in part the inflationary environment and supply chain issues for some renewable projects in the wake of the energy crisis, as well as some recalibration of company strategies.

Mergers and acquisitions completed in 2023 comprised just under half of total clean energy investment by the oil and gas industry. The largest transactions included: ExxonMobil's acquisition of Denbury's CCUS network for USD 4.9 billion, which raises ExxonMobil's CCUS capacity to over 100 Mt CO_2 across its refining, chemicals, and enhanced oil recovery businesses; TotalEnergies' USD 1.6 billion takeover of Eren Re, a renewable energy company, and Occidental's USD 1.1 billion purchase of CarbonEngineering, a direct air capture (DAC) business. The ExxonMobil and Occidental deals together comprised the bulk of the industry's USD 6 billion worth of investments in CCUS in 2023.

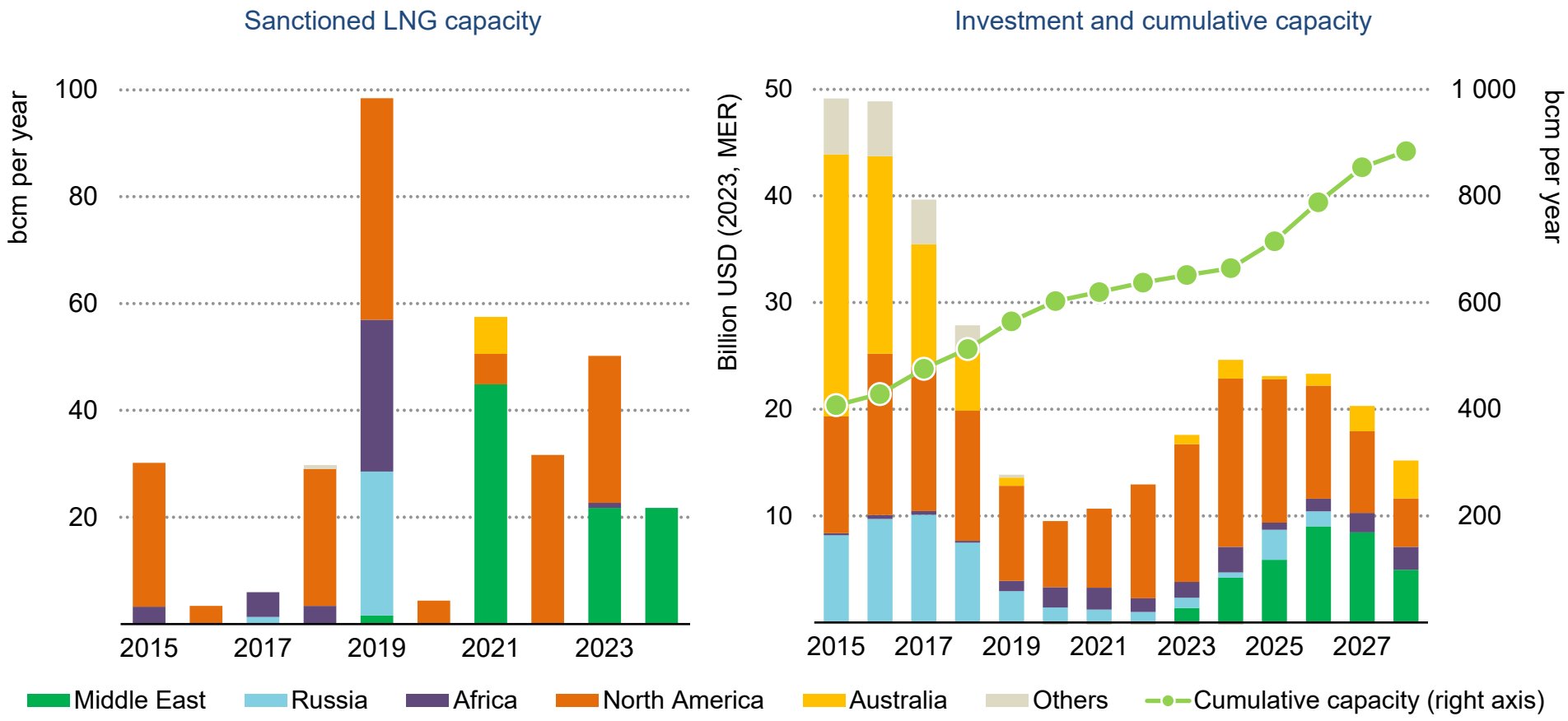
Investment in solar PV and wind projects comprised more than 40% of total clean energy spending by the oil and gas industry in 2023. This includes more than USD 2.7 billion in investment by Equinor, USD 2.2 billion by TotalEnergies and USD 1.8 billion by Repsol (these three companies accounted for around 45% of total investment in renewables by the oil and gas industry). Despite announced cancellations and divestments in offshore wind projects, investment remained substantial in 2023. Equinor invested nearly USD 1.6 billion in offshore wind in 2023. Two other recent projects – by bp in Korea and TotalEnergies in the United States – each involve around USD 2.5 billion worth of investment.

Capital expenditure in electrolysers reached a new high of almost USD 1 billion in 2023. Despite increasing policy support, the investment environment for low-emissions hydrogen remains fragile, mainly because of uncertainty about demand and the price that consumers will be willing to pay for low-emissions hydrogen. Other areas of increasing interest include EV charging infrastructure, enhanced geothermal systems and lithium extraction from brine.

Clean energy investment by NOCs rose to more than USD 1.5 billion in 2023, representing around 5% of total clean energy spending by the oil and gas industry. Petronas, Sinopec, and Saudi Aramco led the NOC investments, which were mostly focused on solar PV and low-emissions hydrogen. Overall, the share of clean energy in total capital investment rose only marginally from 2022 levels.

LNG and refining

The new wave of LNG export projects will add 50% to supply capacity by 2030, mostly from the United States and Qatar



Note: 2024 data is up until Q1 2024. Sanctioned means projects that have received a final investment decision (FID). Qatar's North Field West expansion is included in the figure for 2024, although it has not yet received formal FID.

Additional LNG capacity will come online at an uncertain time for demand with fewer committed off-takers for these additional volumes

Global LNG trade expanded by 2% (or 12 bcm) in 2023. This is the lowest growth rate since 2014, barring the exceptional contraction in 2020. Growth was driven primarily by the United States on the supply side, which accounted for 90% of incremental global LNG volumes. The Asia-Pacific region led LNG demand growth, accounting for virtually all incremental imports.

Since Russia's invasion of Ukraine tightened global LNG markets, around 140 bcm per year of new capacity has been announced, representing some USD 80 billion of cumulative investment. Despite the cyclical nature of the oil and gas industry investment, total LNG trade was one of the few parts of the oil and gas sector to see consistent growth through the Covid-19 pandemic, Russia's invasion of Ukraine and multiple other geopolitical headwinds.

Around two-thirds of the new capacity announced since early 2022 has been in the United States. The federal decision made in early 2024 to pause approvals of new LNG projects does not affect the existing ones but raises uncertainty for the 350 bcm worth of developments that are seeking to raise financing and secure a final investment decision.

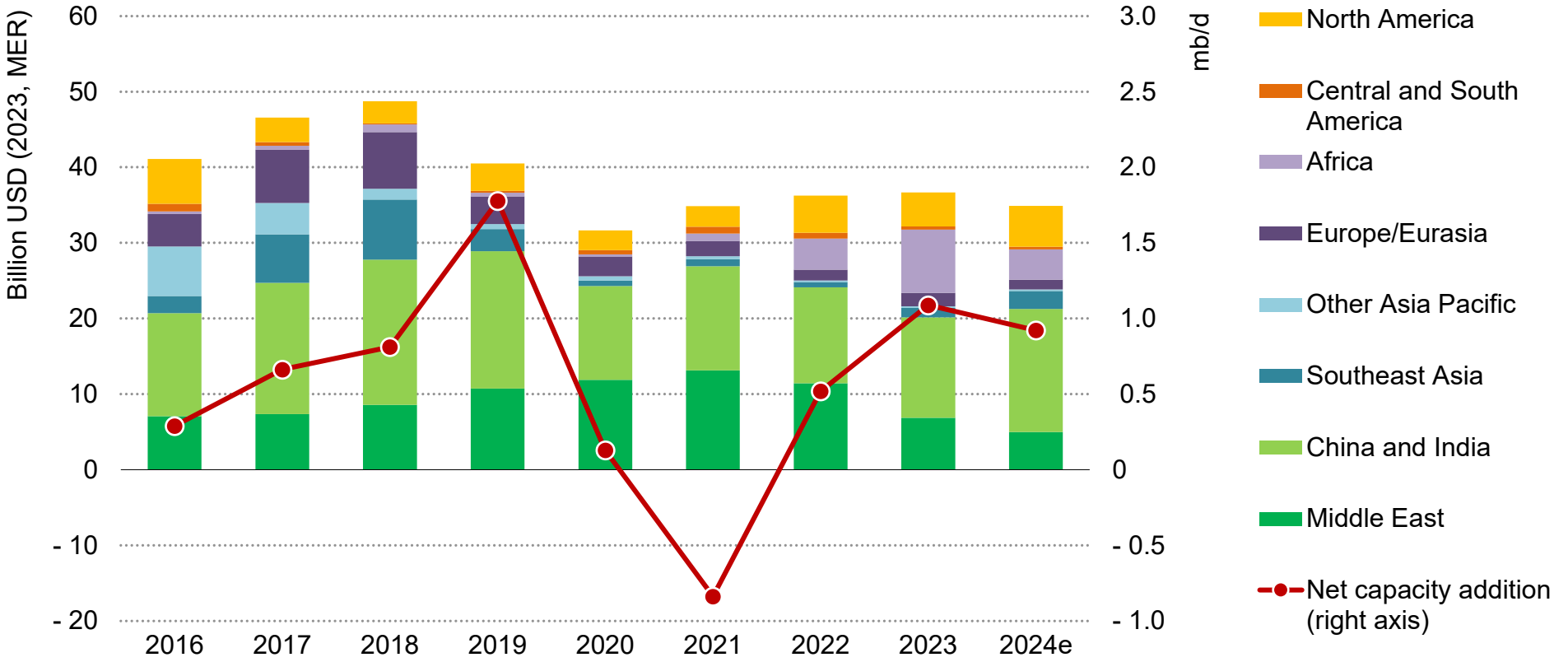
In February 2024, Qatar announced that it would develop the North Field West project, adding a further 20 bcm of new LNG capacity. The total announced and under-construction projects would see Qatar's LNG export capacity nearly double to almost 200 bcm/year. With low-cost reserves, established infrastructure and well-developed relationships with contractors and buyers, Qatar can expand its capacity without needing to attract project financing or secure long-term offtake contracts. Qatar is also looking to invest in CCUS to improve the environmental footprint of its LNG exports.

LNG markets look amply supplied in the second half of the decade, with the potential to soften global markets and attract price-sensitive buyers. Nearly 250 bcm will come online between 2024 and 2030, with about one-third from Qatar and close to one-half from the United States.

Unlike previous waves of LNG supply, there are fewer committed end use off-takers for these additional volumes. Of the new capacity coming online, 70 bcm is to be delivered to fixed destination terminals. Another 100 bcm has been contracted to portfolio players who sold the volume to end consumers using a mix of short, medium and long-term contracts. The remaining 80 bcm of new capacity does not yet have firm off-takers and would therefore currently be sold on the spot market. If future demand for LNG does not materialise, or if regional price benchmarks fall to low levels, the sellers of these uncontracted volumes would be the most exposed.

Investment in refining held steady around USD 37 billion in 2023, but is set to fall in 2024

Investment in oil refineries (greenfield and upgrades) by region and net refining capacity additions



Notes: Investment figures do not include maintenance capital expenditure. 2024e = estimated values for 2024.

Around 0.8 mb/d of new refining capacity is set to come online in 2024, but uncertainties around future demand growth weigh on new investment decisions

In 2023, investment in oil refineries (excluding maintenance spending) was just under USD 37 billion, similar to 2022. China saw the largest share of investment globally, followed by Africa, mainly related to spending in Nigeria's Dangote refinery. The industry witnessed the addition of 1.3 mb/d of net capacity in 2023, and refinery runs increased to 82.3 mb/d in 2023. Heightened activity in China largely drives the 1.5 mb/d increase from 2022 levels.

A further 0.8 mb/d of new refinery capacity is set to be added in 2024, but investment is expected to decline globally by 5%. China and India will likely account for almost half of the expected spending. Between 2020 and 2022, an average of around 1.3 mb/d of capacity was shut down annually, but the pace of capacity closures is slowing: an estimated 300 kb/d is expected to be taken offline in both 2023 and 2024. Global refinery runs are expected to rise by 1 mb/d in 2024, a slower pace compared to 2023, due to lower runs in Russia, unplanned outages in Europe and decelerating growth in China.

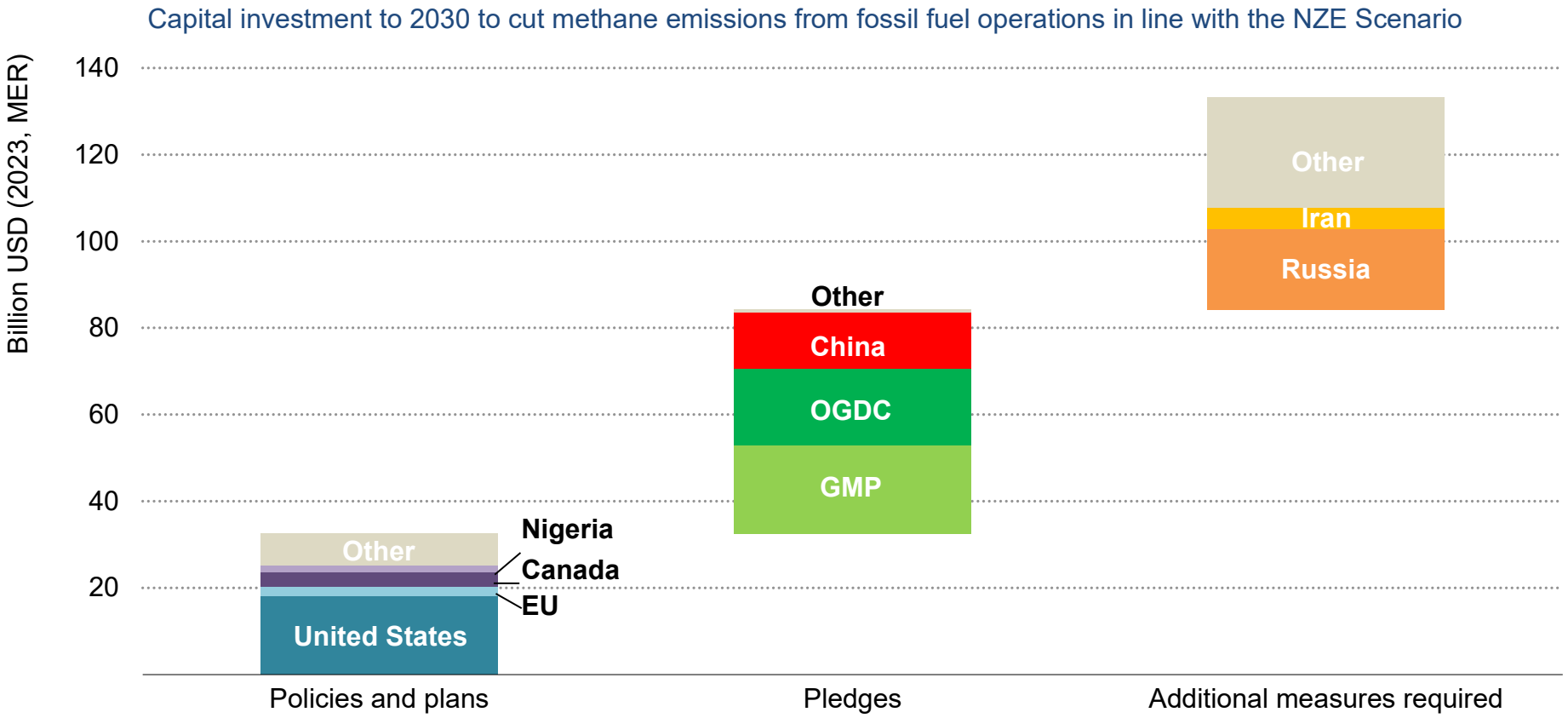
The sanctions and embargoes on Russian oil trade flows had limited effect on Russian oil export volumes, but their impact on export revenue was notable. The redirection of trade routes maintained Russian export volumes at 7.4 mb/d in 2023. However, this resulted in a 25% reduction in oil export revenue to USD 14.6 billion in 2023.

Following record margins and profits in 2022, refining margins began to trend downward in 2023 even though strong middle distillate cracks have kept margins well above historical averages. Despite the healthy margin environment, a new wave of investment in refining capacity is unlikely. Building new refineries entails significant capital commitment and long lead times (typically 5-10 years), and uncertainties surrounding long-term demand prospects present challenges for investment decisions. Unless the region experiences strong anticipated demand growth or expected operating costs are highly competitive, justifying investment decisions for large-scale greenfield refineries will be challenging. Future investment is therefore likely to be further concentrated in a few regions such as China, India, and the Middle East.

Amid a multitude of challenges, an increasing number of refiners are opting to rationalise capacity or shift to low-carbon feedstock processing. Following recent decisions by Petroineos and Shell to close capacity in 2025, bp recently announced a restructuring of operations, with crude processing at the 257 kb/d Gelsenkirchen site in Germany being reduced by around 80 kb/d in 2025.

Methane

Existing policies, plans and pledges to cut methane emissions would reduce emissions by around 50% by 2030 and will require more than USD 80 billion in capital investment



Note: GMP = Global Methane Pledge. OGDC = Oil and Gas Decarbonisation Charter. There is overlap between several of the plans and pledges shown: those with more detail provided are given preference in the reductions shown. Other policies, plans and pledges include those of Algeria, Australia, China, Colombia, Côte d'Ivoire, Ghana, Korea, Mexico, Norway, Qatar, United Kingdom, Uzbekistan, and Viet Nam.

Investment in methane abatement is increasing, but a step change is needed in both spending levels and emissions transparency

Methane emissions from the energy sector remained near a record high in 2023. However, with several major policies and regulations recently announced – and with 157 countries joining the Global Methane Pledge – the world could soon reach a turning point in efforts to reduce methane emissions. If all existing pledges on methane were to be achieved in full and on time, methane emissions from fossil fuels will decrease 50% by 2030. In many cases, however, pledges still need detailed plans.

Methane abatement in the oil and gas industry is one of the lowest cost options to reduce greenhouse gas (GHG) emissions anywhere in the economy. Achieving current pledges and plans will require around USD 80 billion of investment to 2030. Investment levels that are needed to cut emissions by 75% by 2030 – the reduction assumed in the IEA's Net Zero Emissions by 2050 (NZE) Scenario – would require an additional USD 90 billion. The total (USD 170 billion) includes USD 135 billion in capital investment and USD 35 billion in operating costs.

This total amount of spending required to 2030 is less than 5% of the income the industry generated in 2023. Fossil fuel companies carry primary responsibility for financing methane abatement at their operations and currently there is very limited public reporting on the amounts companies spend on reducing methane emissions. Additional transparency is needed to track progress and the efforts companies are making. Regulations and policies could also help.

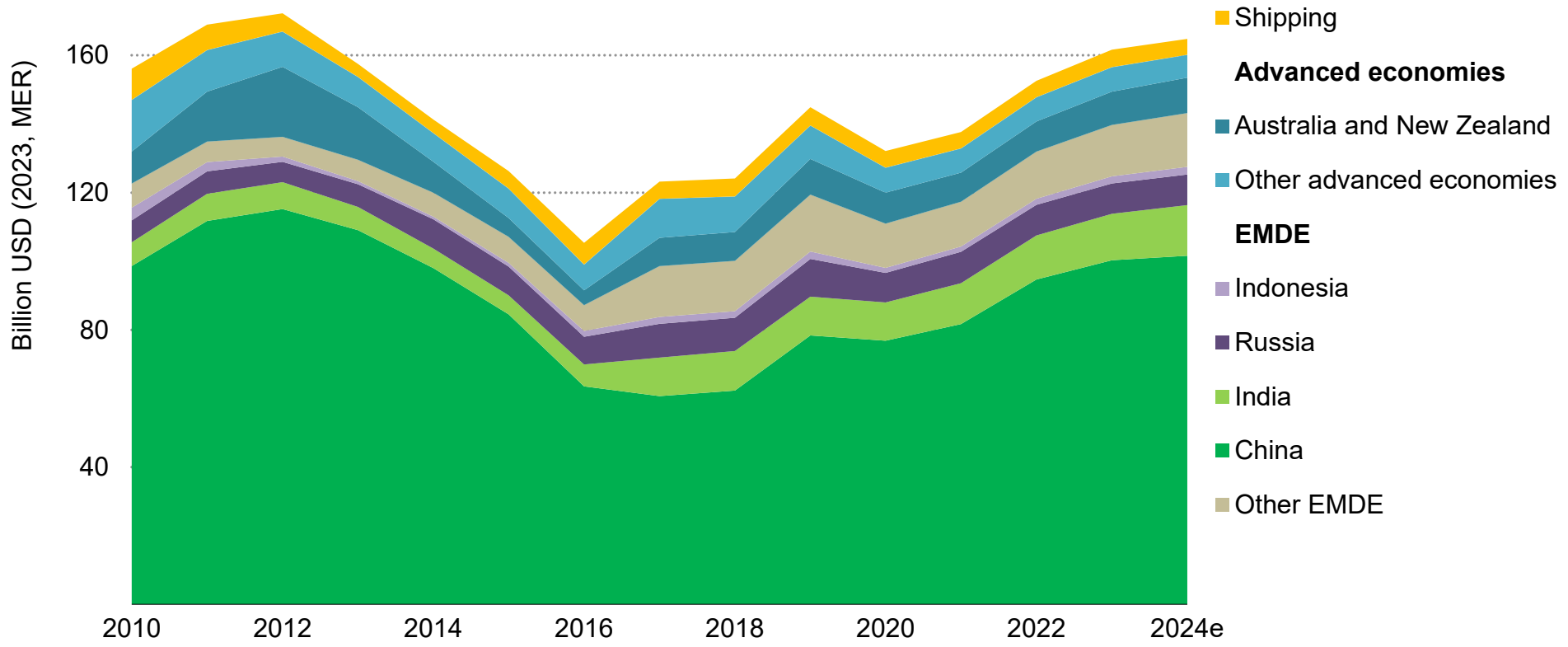
Some spending on methane abatement will require special attention, especially to reduce emissions in low- and middle-income countries and for measures that do not generate meaningful return over their lifetimes. Several efforts are underway to increase financing and investment for methane abatement. These include international emissions pricing schemes and regional emissions trading markets, as well as direct public funding, emissions standards for market access and price premiums for low-emissions fuels.

In terms of publicly announced funding for methane abatement, the Bipartisan Infrastructure Law and Inflation Reduction Act in the United States will provide USD 4.7 billion to plug old oil and gas wells and USD 1 billion in financial and technical assistance to cut methane emissions. The World Bank's more than USD 255 million Global Methane and Flaring Reduction Fund aims to help cut emissions in developing economies. Additional programs are also emerging: the Climate Bonds Initiative, for example, is developing guidance to incentivise capital markets to finance methane emissions abatement.

Coal

Global coal investment is set to grow by 2% in 2024 to more than USD 160 billion, close to the average level seen in the early 2010s, led by increases in India, Indonesia and Australia

Global investment in coal supply by region, 2010-2024e



Note: 2024e = estimated values for 2024. EMDE = Emerging market and developing economies.

Coal investment teeters between strong short-term demand and longer-term uncertainty

In 2023, coal demand growth in several countries, most notably China, India, and Southeast Asia, led to a 6% increase in investment in coal supply. A further 2% global increase is likely in 2024.

Coal companies saw income surge in 2021 and 2022, which increased their capacity and appetite for investment in new supply and ushered in a heightened period of merger and acquisition activity.

China is by far the largest coal producer and consumer globally, and it is also the main market for coal exports. Coal shortages in 2021, combined with very high prices in 2022, increased the focus on energy security and investment in domestic coal supply. Annual coal investment increased by nearly 10% on average between 2018 and 2023. This resulted in increased production which, combined with a high level of imports, led to a surge in coal stocks.

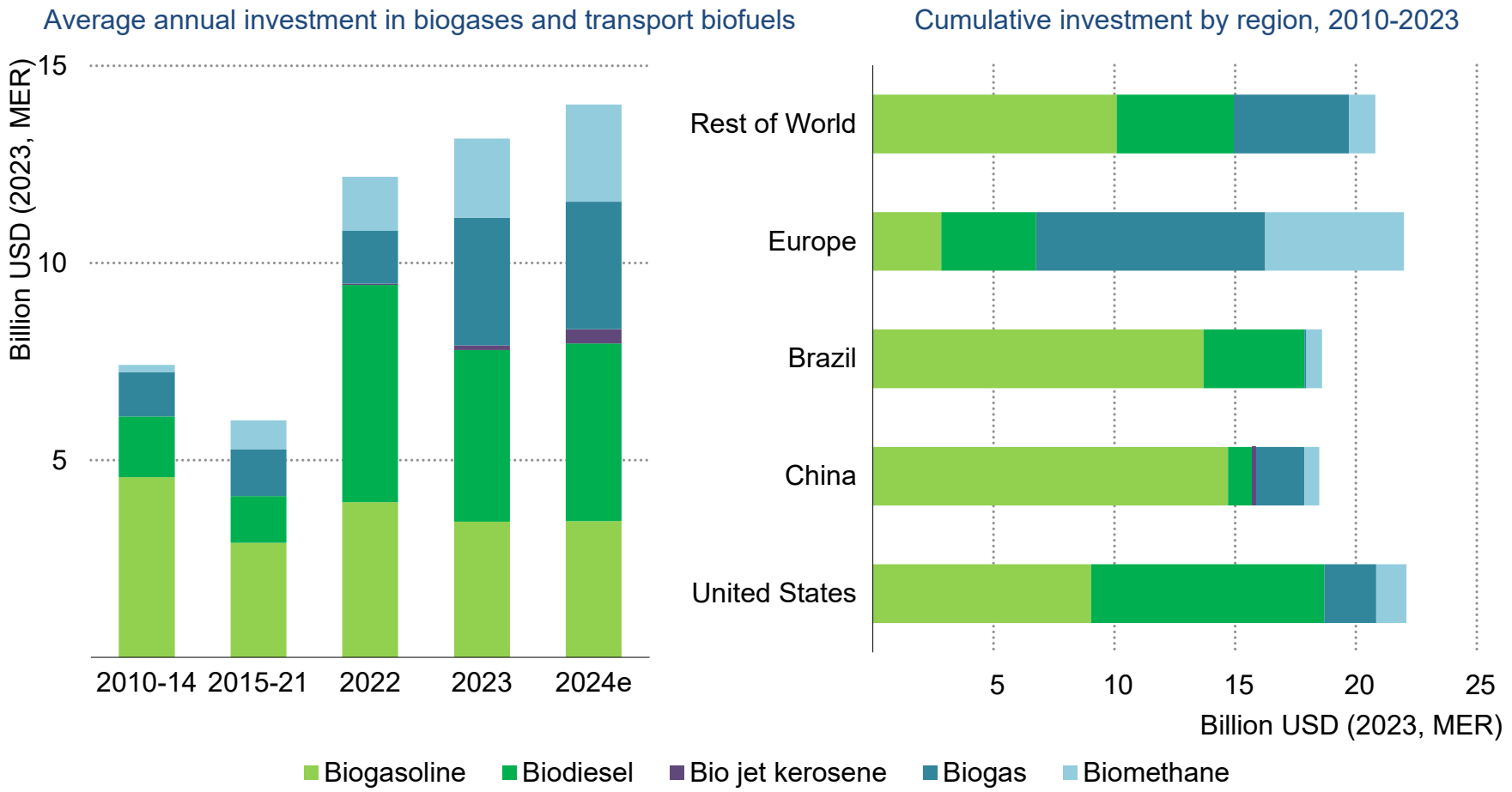
In 2024, the combination of high stocks, lower coal prices and an expected slowdown in economic activity is likely to reduce Chinese coal demand growth. We estimate that annual investment in coal supply will increase by around 1% in 2024 to roughly USD 100 billion (more than 60% of the global total). The use of coal in the power sector in China is coming under pressure from competition with renewables. Coal demand in aggregate is set to enter terminal decline, limiting the need for any future increases in coal investment in the country.

India is the world's second-largest coal producer and consumer. The government has announced plans to increase domestic production to meet rising demand and investment has been growing steadily since 2021. Investment increased by 5% in 2023 and is set to expand by nearly 10% in 2024 to around USD 15 billion. The Ministry of Coal is relying on a series of measures to boost coal supply, including commercial auctions with a revenue share mechanism, allowances for the sale of additional coal production and rolling auctions. Nonetheless, based on current trends, demand is set to rise faster than supply, which means India could soon overtake China to become the world's largest coal importer.

Elsewhere, Australia and Indonesia are the two largest coal exporters globally and investment in these two countries is set to expand by around 5% in 2024 (following a 12% increase in 2023). Poland has seen an increase in coal investment in recent years as the European Union weaned itself from Russian imports. This increase is likely to be short-lived given the European Union's climate targets and the increasing share of renewables in new capacity additions. The United States and other advanced economies are likely to see a continued downward trend in investment.

Bioenergy

Investment in bioenergy grew in 2023 and with a further rise in 2024, activity encompasses both liquid and, increasingly, gaseous fuels



Note: Biomethane investment includes the cost of producing biogas as an interim step before upgrading to biomethane. 2024e = estimated values for 2024

Source: IEA analysis based on S&P Global (2023).

Supported by commercial prospects for sustainable aviation fuels, liquid biofuels could see a wave of new investments in the coming years

Transport biofuel capacity additions in 2023 reached a decade-high of 270 kb/d, a 6% increase from 2022 that translates into an 8% increase in investment. The growth stems mainly from the expansion of renewable diesel refining capacity in the United States, increases in bio-ethanol capacity in Brazil and growth (from a low base) in bio-jet kerosene in China, Brazil, and Europe.

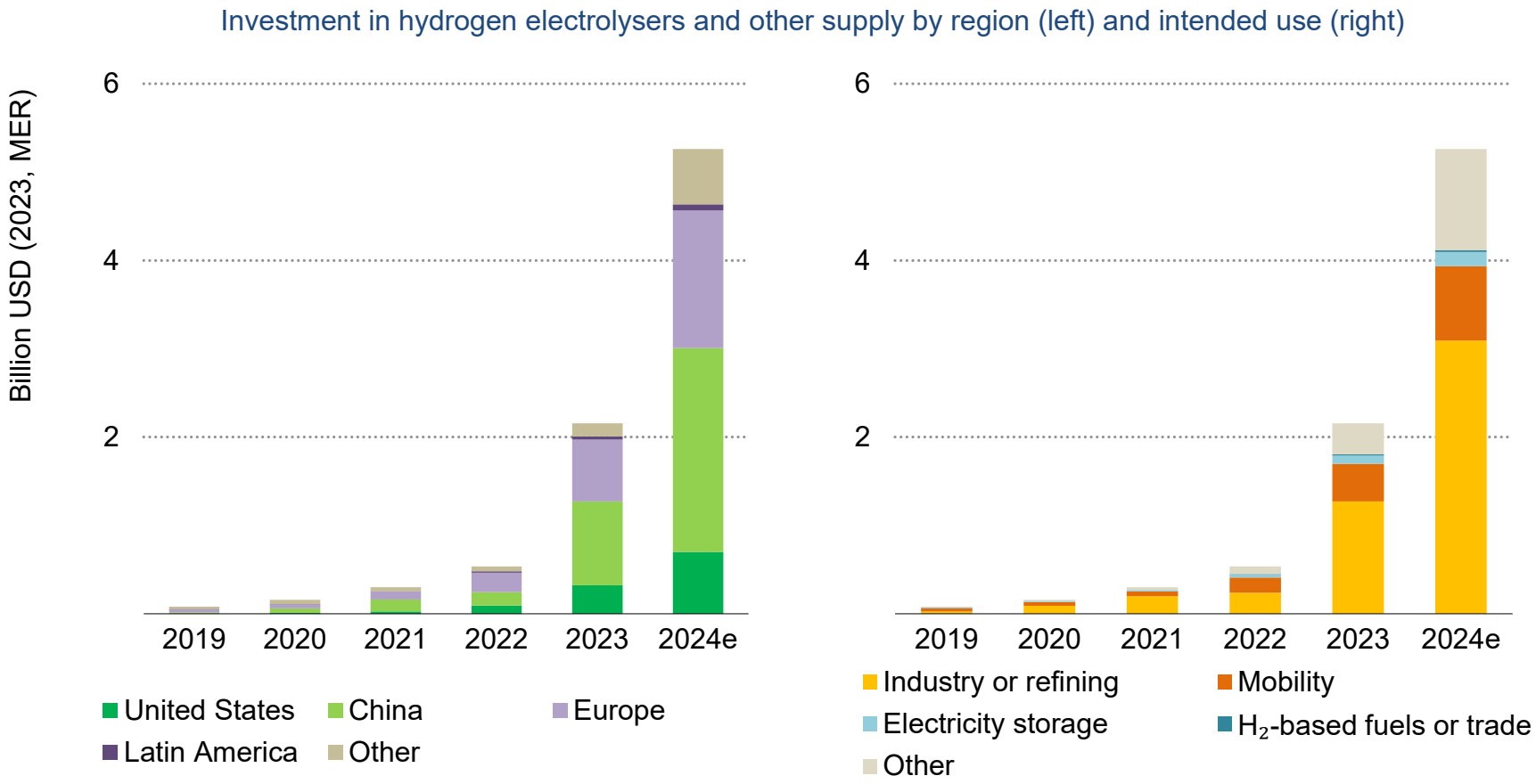
A number of traditional biofuel projects have been announced in recent years, including a doubling of capacity at OCI Global's green methanol facility in Texas (which will have a capacity of around 4 kb/d). However, most biofuels investment increases are set to come from new capacity for so-called "drop-in fuels" (substitutes for petroleum products that are not subject to any blending limits). For example, in Spain, Cepsa and Bio-Oils have begun construction of a USD 1.3 billion sustainable aviation fuel (SAF) and renewable diesel plant, with a capacity around 10 kb/d. Brazil's Acelen will invest USD 2.4 billion in a 20 kb/d green diesel plant which will come online in 2026. In China, American Honeywell, which teamed up in 2022 with Oriental Energy to build a 20 kb/d SAF plant, announced that its refining technologies will also be used by Sichuan Jinshang Environmental Protection Technology Co. in a new 6 kb/d SAF plant.

Major energy companies are also looking to invest in the expansion of biofuels. For example, Repsol announced plans to diversify into biofuels by retrofitting existing fossil diesel facilities and securing feedstock supply through new partnerships. TotalEnergies and Sinopec have formed an agreement to produce 5 kb/d of SAF in China. Engie announced the acquisition of Ixora Energy for USD 81 million and plans to spend about USD 3.2 billion to boost biomethane production in Europe. Neste is acquiring the cooking oil collection and aggregation business of Crimson Renewable. Goldman Sachs established Verdalia Bioenergy, with the view to invest USD 1.1 billion in the European biomethane sector.

The European Union, United States and India have adopted or extended policies supporting bioenergy. In March 2023, the European Union reached a provisional agreement that strengthens the sustainability criteria for the use of biomass for energy in the Renewable Energy Directive (RED III). A mandate to accelerate bioethanol in India has already allocated about USD 113 million from 2019 to 2024 to six commercial projects. Other governments have announced bioenergy support such as a USD 21 million grant from the UK Department for Transport's Advanced Fuels Fund for a new waste-to-fuels project, and USD 6 million from Canada's Clean Fuels Fund to help Azure Sustainable Fuels develop the front-end engineering and design for SAF production in Manitoba, with first production planned for 2027.

Hydrogen

Investment in hydrogen electrolysers is expected to jump by more than 140% in 2024



Note: 2024e = estimated value for 2024. Other intended uses include biofuels upgrading, grid injection, combined heat and power and domestic heating.
Source: IEA analysis based on the IEA Hydrogen Production Projects Database and recent announcements.

Investment in electrolysers is driven by higher deployment but also by higher financing costs

Investment in electrolysers is set to increase by close to 140% in 2024 to USD 5 billion. This is mainly because of new capacity additions as well as cost inflation in the sector and resulting increases in equipment prices and financing costs. Most of the electrolyser capacity coming online in the next few years aims to replace existing uses of hydrogen (refining and the chemical industry). These investments are generally perceived as lower risk than generating new potential sources of demand (e.g. mobility and conversion into low-emissions hydrogen-based fuels).

China is set to see a 140% increase in investment in electrolysers in 2024, accounting for 40% of global investment. A low-emissions hydrogen and ammonia production plant costing USD 900 million is expected to begin operations in 2024, producing around 32 kt of low-emissions hydrogen annually. By 2026, more than 20 projects above 100 MW, with combined capacities around 6.9 GW, could be operational in China.

Europe is expected to see a 120% increase in investment in 2024, accounting for less than one-third of global investment in electrolysers. Major projects include USD 270 million for a 100 MW electrolyser project being developed by GALP in the port of Sines, Portugal (capable of producing around 15 kt hydrogen per year) and just over USD 7 billion (USD 4.5 billion of debt, USD 2.3 billion of equity and USD 300 million of grants) for the construction of a low-emissions steel plant in Sweden by H_2 Green Steel. A number of projects have suffered from cost inflation and overruns: the Bad Lauchstädt Energy Park project in Germany, for example, which includes hydrogen production, storage and transport, has seen costs rise to USD 230 million when it received FID in 2023, an increase of 50% over initial estimates.

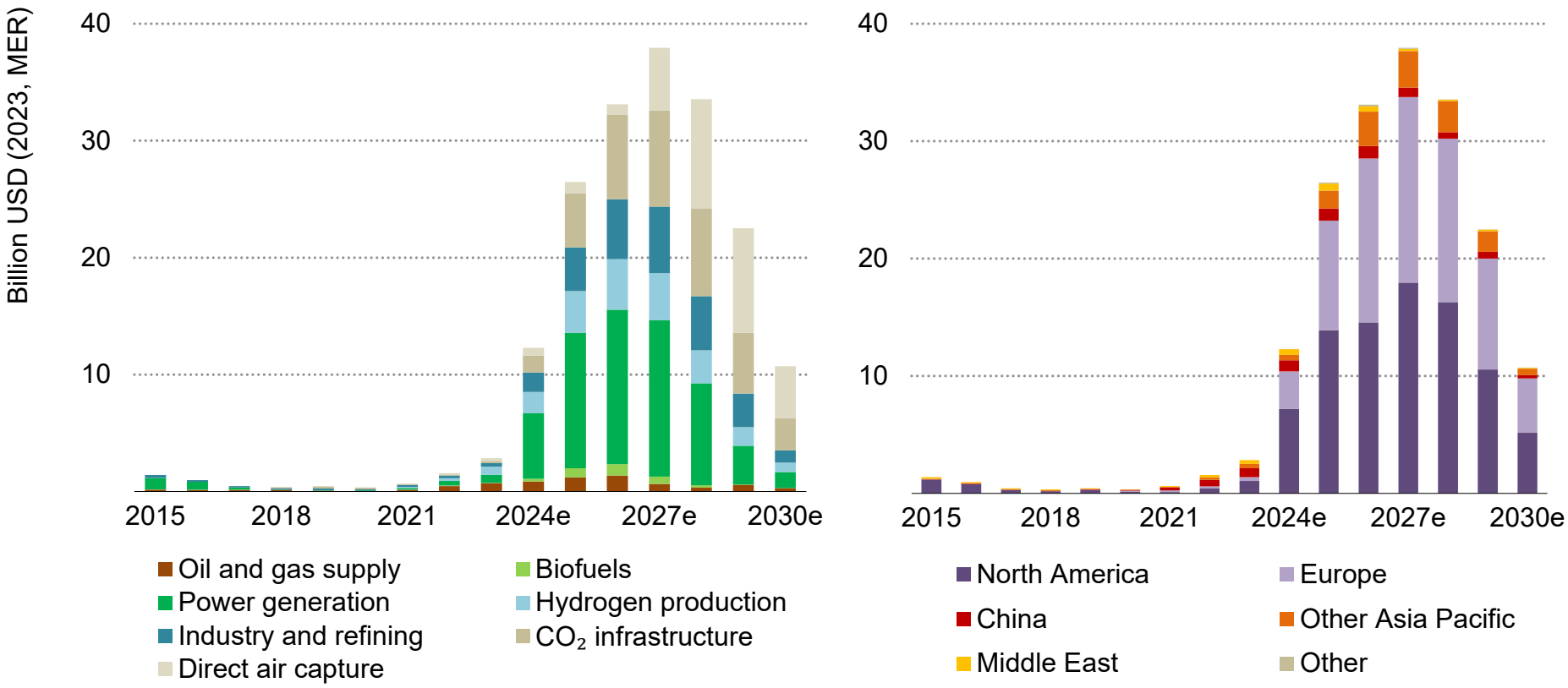
The United States, accounting for about 15% of global investment in hydrogen today, is expected to see a 120% rise in 2024, incentivised by programs such as the 10-year Clean Hydrogen Production Tax Credit which provides up to USD 3 per kilogram of low-emissions hydrogen. A number of large-scale projects are under development, including a USD 550 million liquid hydrogen production plant in Arizona under development by Fortescue that will be able to produce 11 kt of hydrogen per year from 2026.

Internationally, Fortescue is also set to spend USD 150 million on an electrolyser in Australia, scheduled to be commissioned in two phases, one in 2025 and the second in 2028. In Saudi Arabia, the world's largest low-emissions hydrogen plant is under development by NEOM Green Hydrogen – a USD 8.4 billion project due to start production in 2026. In Oman, ACME Group is poised to invest USD 480 million in a low-emissions hydrogen project, due to come online in 2025.

CCUS

Successfully executing announced CO_2 capture, utilisation and storage projects would boost investment by a factor of 10 by 2025

CCUS investment pipeline by type (left) and region (right) based on announced projects



Note: Includes commercial capture facilities with a capacity of over 0.1 Mt CO_2 per year. Projected spending represents the capital costs of projects with announced capacities based on their planned FID and operational dates. Spending is estimated where project-level cost data are unavailable. “Other” includes Africa, South and Central America and the Middle East.

Source: IEA analysis based on IEA CCUS projects database.

New policy momentum is supporting investment in CCUS worldwide, from direct capture projects to transport and permanent storage, but risks remain

Around 20 commercial-scale carbon capture, utilisation and storage (CCUS) projects in seven countries reached FID in 2023. More than 110 capture facilities, as well as transport and storage projects, could reach FID in 2024. If all projects are developed on time, there will be a near-tenfold increase in CCUS investment by 2025 (to USD 26 billion). Global CO_2 capture capacity would increase to 430 Mt CO_2/year by 2030, and global CO_2 storage capacity would reach 620 Mt CO_2/year. However, it remains an open question whether all of these projects will materialise.

Governments sought to significantly accelerate the deployment of CCUS in 2023, including initiatives such as the Carbon Management Challenge. Nearly USD 20 billion in public funding was allocated to CCUS projects in 2023 including: USD 1.7 billion announced by the United States as part of a Funding Opportunity for carbon capture demonstration projects; USD 1.2 billion announced by Denmark under its CCUS Fund; and more than USD 500 million to four CCUS projects under the European Union's Connecting Europe Facility. Risks include delays which may occur between the announcement, the securing of proposal funding and project mobilisation.

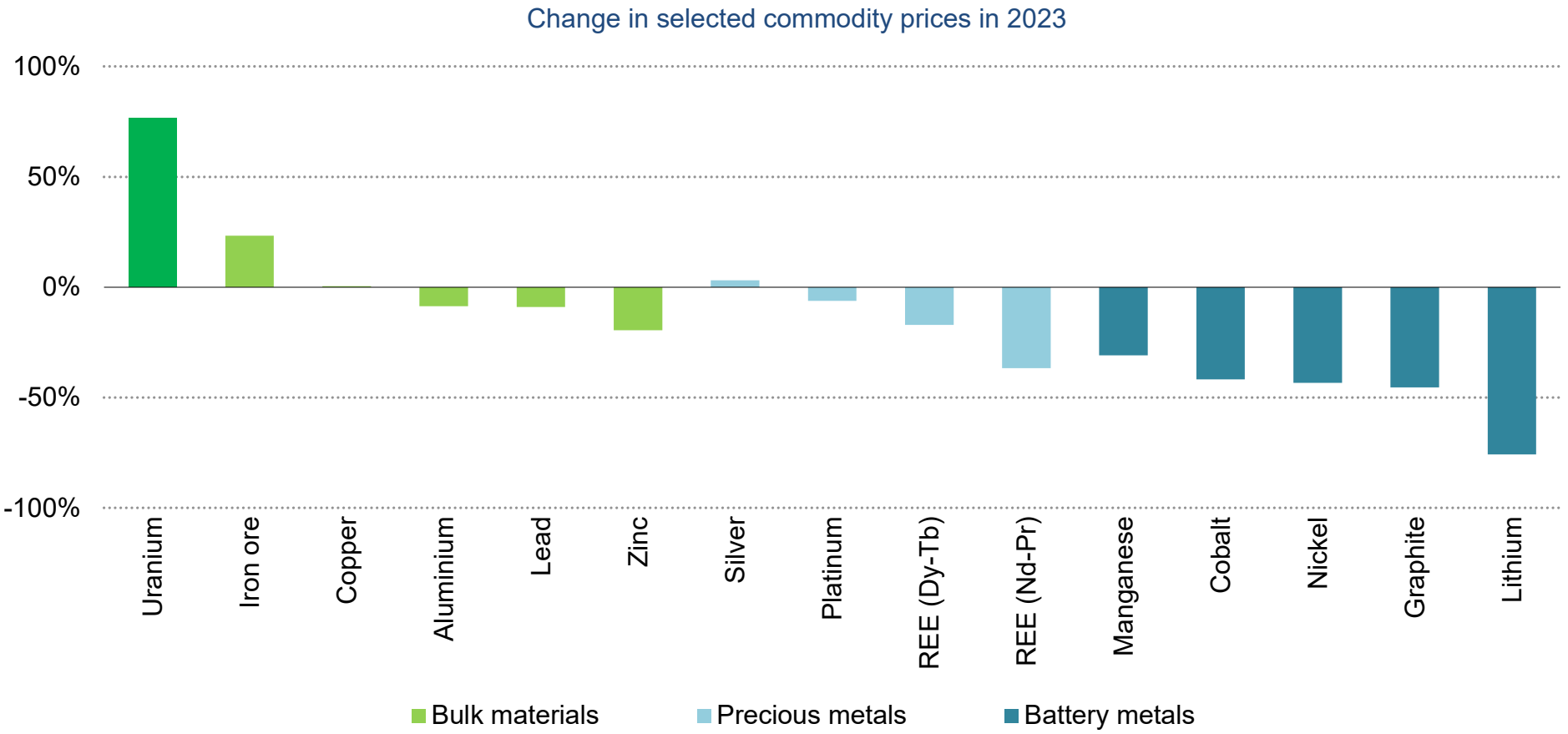
Oil and gas companies continue to develop new CCUS projects. For example, ADNOC took FID on a 1.5 Mt CO_2/year project in September 2023 to build one of the largest integrated CCUS projects in the Middle East. Several CCUS M&A deals involving oil and gas companies were also announced in 2023 and 2024.

Many direct air capture (DAC) projects are advancing, and investment is set to rise to USD 660 million in 2024 (a 140% increase from 2023). The 36 kt CO_2/year Mammoth DAC plant in Iceland started operation in May 2024, and the Stratos project in Texas – which will cost USD 1.3 billion and be the world's largest DAC facility with a capacity of 500 kt CO_2/year – aims for a mid-2025 start. Expansion plans have also been announced by 1PointFive and Carbon Engineering (now Occidental), with a target operation year of 2035, although locations and the fate of the captured CO_2 (storage or use) have not yet been finalised.

Investment in CO_2 transport and storage infrastructure is set to increase to USD 1.4 billion in 2024 (a tenfold increase from 2023) as new business models are developing to create CCUS hubs that more efficiently transport and store gases. Three FIDs taken in 2023 include the Porthos project to carry gas to depleted petroleum reservoirs in the North Sea (USD 1.4 billion, handling 2.5 Mt CO_2/year). The extension of the Alberta Carbon Trunk Line by Wolf Midstream Canada will allow 7 Mt CO_2/year to be permanently stored. A CO_2 transport and storage hub in Louisiana by CapturePoint Solutions is set to store more than 10 Mt CO_2/year.

Critical minerals

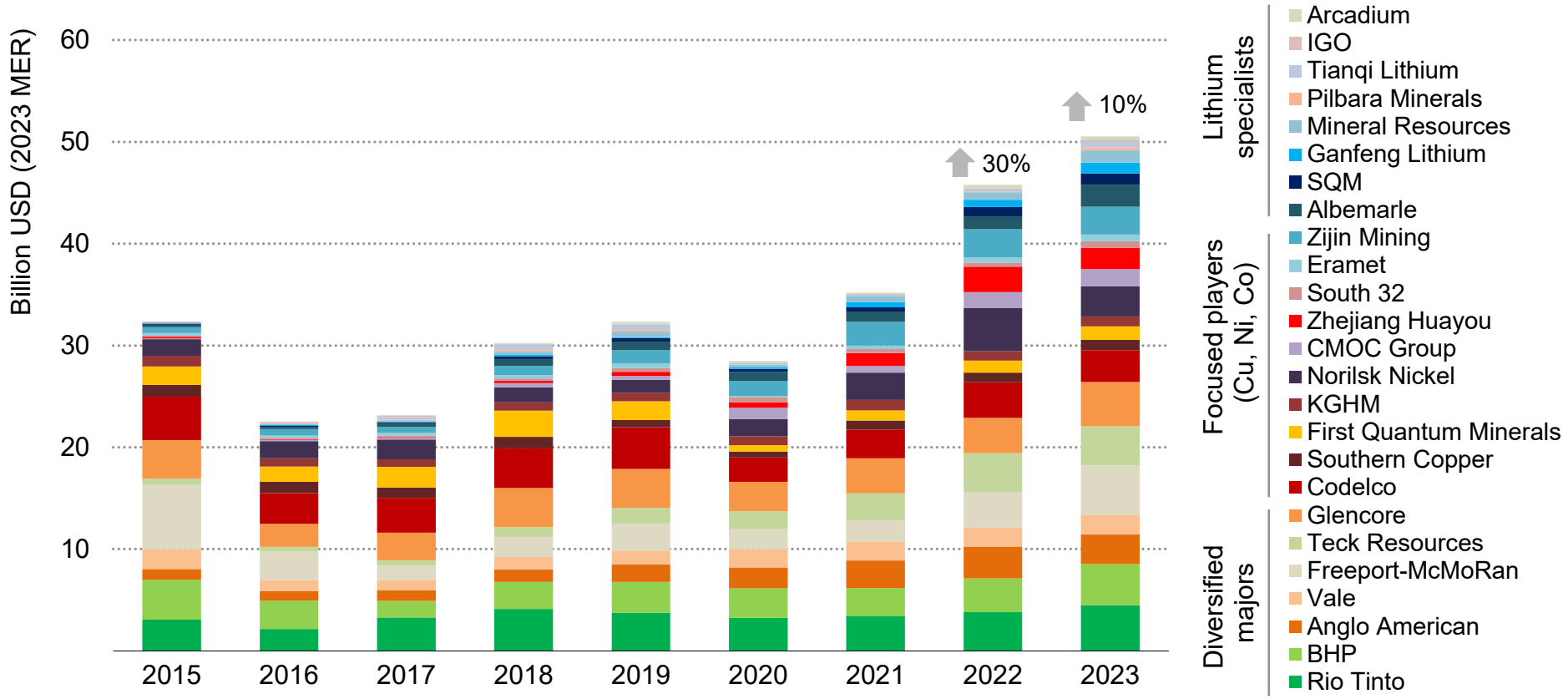
Prices for minerals and metals mostly fell across the board in 2023, with particularly sharp drops in metals required for batteries



Note: REE = rare earth elements. Dy-Tb = dysprosium and terbium. Nd-Pr = neodymium and praseodymium.
Source: IEA analysis based on Bloomberg and S&P Global.

Investment in critical mineral mining grew by 10% in 2023, a smaller increase than in 2022 as price declines weighed on the financial capacity of producers

Capital expenditure on non-ferrous metal production by major mining companies, 2015-2023



Notes: Co = cobalt. Cu = copper. Ni = nickel. For diversified majors, capex on the production of iron ore, gold, coal and other energy products was excluded. Nominal values. The results for arcadium start from 2016.

Source: IEA analysis based on company annual reports and S&P Global.

Recent critical mineral price declines challenge the diversity and reliability of future supply

Following a price surge that began in 2021, 2023 saw a significant decline in prices for most critical minerals and metals. Prices for battery minerals fell especially sharply, with lithium prices plunging 75%. Inventory overhang in the downstream sector (such as battery cells and cathodes), weaker-than-expected demand growth and an increase in overall supply all contributed to the decline. Uranium was a notable exception and saw a sharp price increase in 2023 due to renewed momentum for nuclear power and a lack of new supplies.

In early 2024, copper prices increased because mining outputs were lower than expected with the closure of the Cobre Panama mine and a reduction in production guidance by Anglo American, which shifted the market balance to a slight deficit. Nonetheless, battery mineral prices remain subdued, prompting some high-cost producers to curtail output and place facilities on care and maintenance. Industry revenue fell by 10% in 2023 and operating profit fell by 34%, which had a major impact on capital investment plans.

Our assessment of 25 large mining companies suggests that investment in critical minerals grew by 30% in 2022 and by 10% in 2023 (6% when adjusted for cost inflation). Exploration investment grew by 15% in 2023, with Canada and Australia registering the largest increases, followed closely by Africa. Lithium saw much larger gains with a 50% increase in investment, and an 80% jump in exploration spending.

Despite demand growth, the size of the market for critical minerals contracted by 10% to USD 325 billion in 2023. This figure would have been 20% higher if prices had remained at 2022 levels. While current supplies of most materials appear sufficient, the risks of market tightness and price volatility are constant as countries continue to pursue their energy and climate goals. Escalating geopolitical tensions, exemplified by trade restrictions on a number of elements in 2023 – including gallium, germanium, graphite, and rare earths – further compound these risks. Lower prices have contributed to cost reductions for many clean energy technologies, but they risk slowing efforts to diversify supply chains.

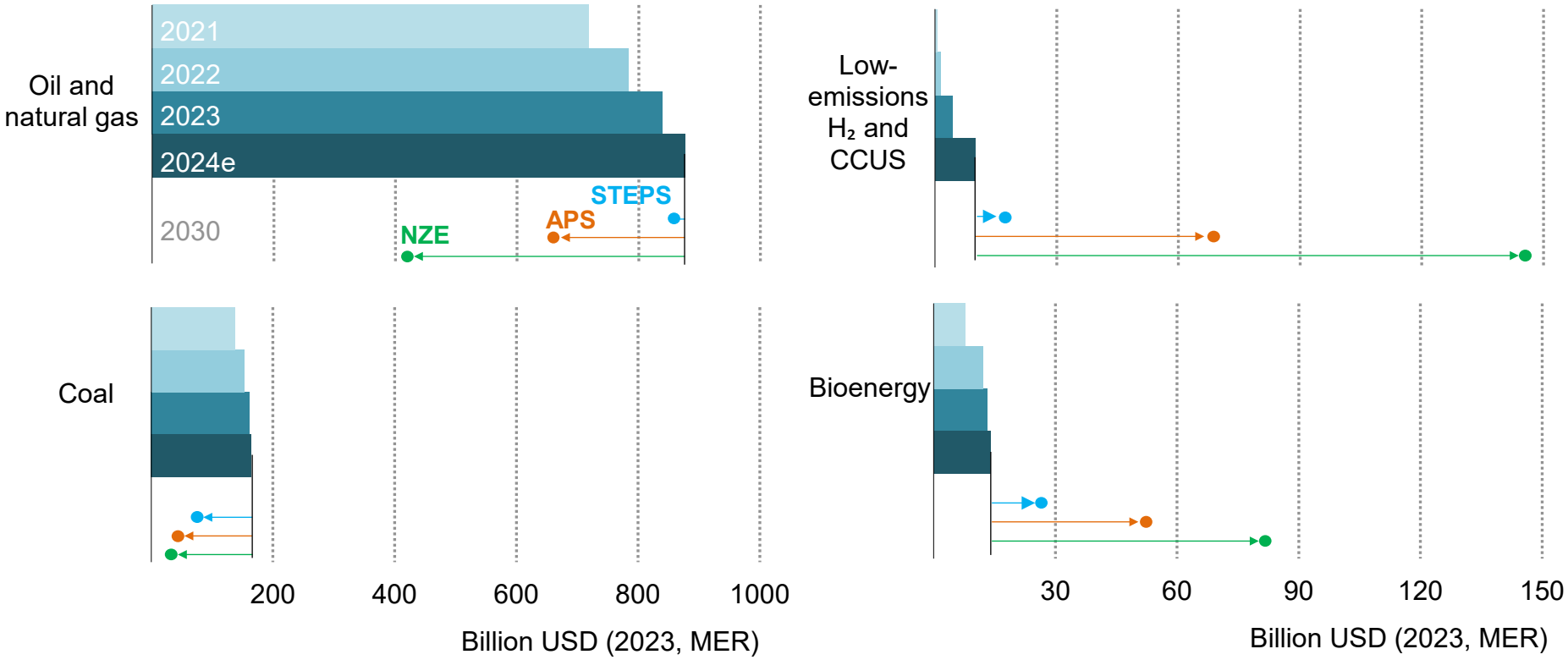
The geographic concentration of production has remained largely unchanged in recent years. One exception is nickel, where supplies have become more concentrated: between 2021 and 2023, Indonesia's share of mined nickel production increased from 34% to 52% and its share of refined nickel increased from 23% to 37%.

The current investment landscape could lead to further supply concentration for several critical minerals, especially in the processing and refining segments. Efforts to enhance the diversity and reliability of critical mineral supplies therefore remain vital. Mobilising investment in diversified projects, boosting innovation and recycling and promoting environmental and social considerations in policy and investment decisions must therefore remain priorities.

Implications

Oil and gas investment aligns with 2030 STEPS levels, but coal spending is twice as high as clean fuel investment is rising from a very low base

Global investment in fuels and CCUS historically and in 2030 in the STEPS, APS and NZE Scenarios



Note: STEPS = Stated Policies Scenario. APS = Announced Pledges Scenario. NZE = Net Zero Emissions by 2050 Scenario.

Risks of over-investment in traditional elements and under-investment in low-emissions alternatives

With the anticipated rise in 2024, overall investment in oil and gas supply is at the level projected in 2030 in STEPS, a scenario which shows coal, oil and natural gas demand levelling off or declining before 2030. The increase in 2024 investment is driven by national oil companies in the Middle East and Asia, although this does not necessarily coincide with expected growth in output. In the case of oil, increased near-term production is concentrated in the United States, Guyana, Canada, and Brazil.

Even though oil and gas investment is broadly aligned with the direction of travel in energy markets, as represented by the STEPS, this trajectory is associated with some significant commercial and environmental risks. Global spare oil production capacity is already close to 6 million barrels per day (excluding Iran and Russia) and there is a shift expected in the coming years towards a buyers' market for LNG. Against this backdrop, the risk of over-investment would be strong if the world moves swiftly to meet the net zero pledges and climate goals in the Announced Pledges Scenario (APS) and the NZE Scenario. Oil and gas investment in 2024 is set to be around 35% more than the level required in 2030 if governments achieved their climate targets in full and on time (as in the APS), and more than double the 2030 level needed if consumption falls in line with a 1.5 °C target (the NZE Scenario). Differences in coal industry are even more stark: investment in 2024 is more than double the 2030 level in the STEPS, almost four times more than in the APS, and five times more than in the NZE Scenario.

In the APS, the trajectory for oil and gas consumption is curbed by rapid growth in renewables, efficiency, and other clean energy sources. There is no need in this scenario for further oil and gas exploration, as already-discovered fields are sufficient to cover projected demand. Investment is needed in some new oil and gas projects, in maintaining production at existing fields and in safely decommissioning or repurposing existing operations. In the NZE Scenario, rapidly falling demand means that there is no need for long lead time conventional oil and gas projects. In both scenarios, investment in cutting greenhouse gas emissions from operations – most notably in reducing methane emissions – is essential.

The oil and gas industry generated very large profits in 2022 and 2023. The focus on companies has mainly been to return profits to shareholders through share buybacks and dividends. The oil and gas industry is well placed to scale up many crucial technologies for net zero transitions, especially those with strong overlap with existing strengths such as offshore wind, low-emissions hydrogen, bioenergy and CCUS. To date, only a few companies have markedly increased

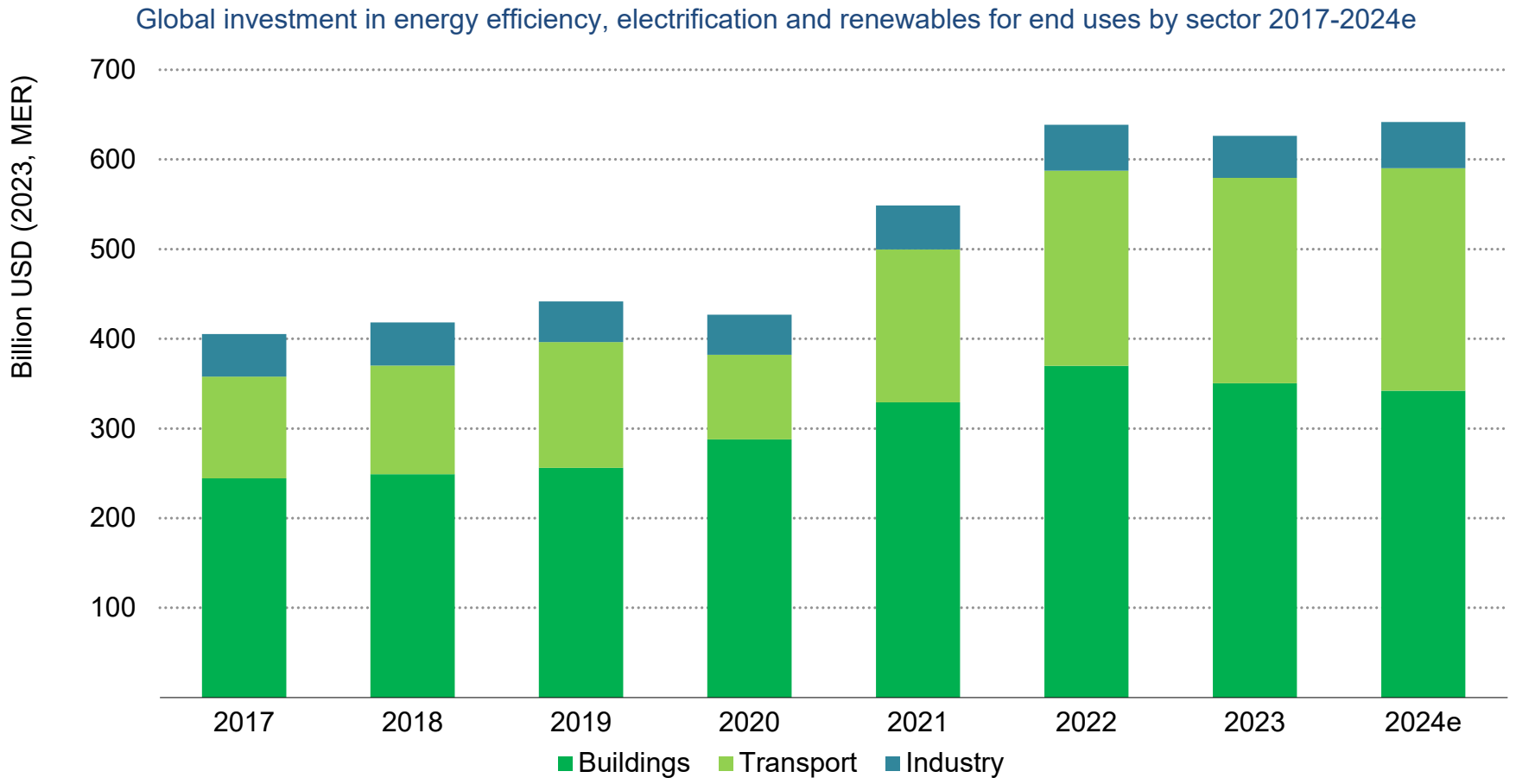
their spending in these areas, and less than 4% of the industry's total capital investment was invested into clean energy in 2023.

Scaling up clean energy investment rapidly is essential to mitigate future price risks while reducing emissions. Investment in hydrogen and CCUS has been growing rapidly in recent years, but from a very low base. Investment in bioenergy has risen modestly in recent years, but remains far below the levels needed by 2030 in the STEPS. To get on track with the APS and NZE Scenario, clarity over policy frameworks and incentives will be essential across all clean fuels and technologies to bring forward announced and new projects.

Energy end use and efficiency

Overview / Investment

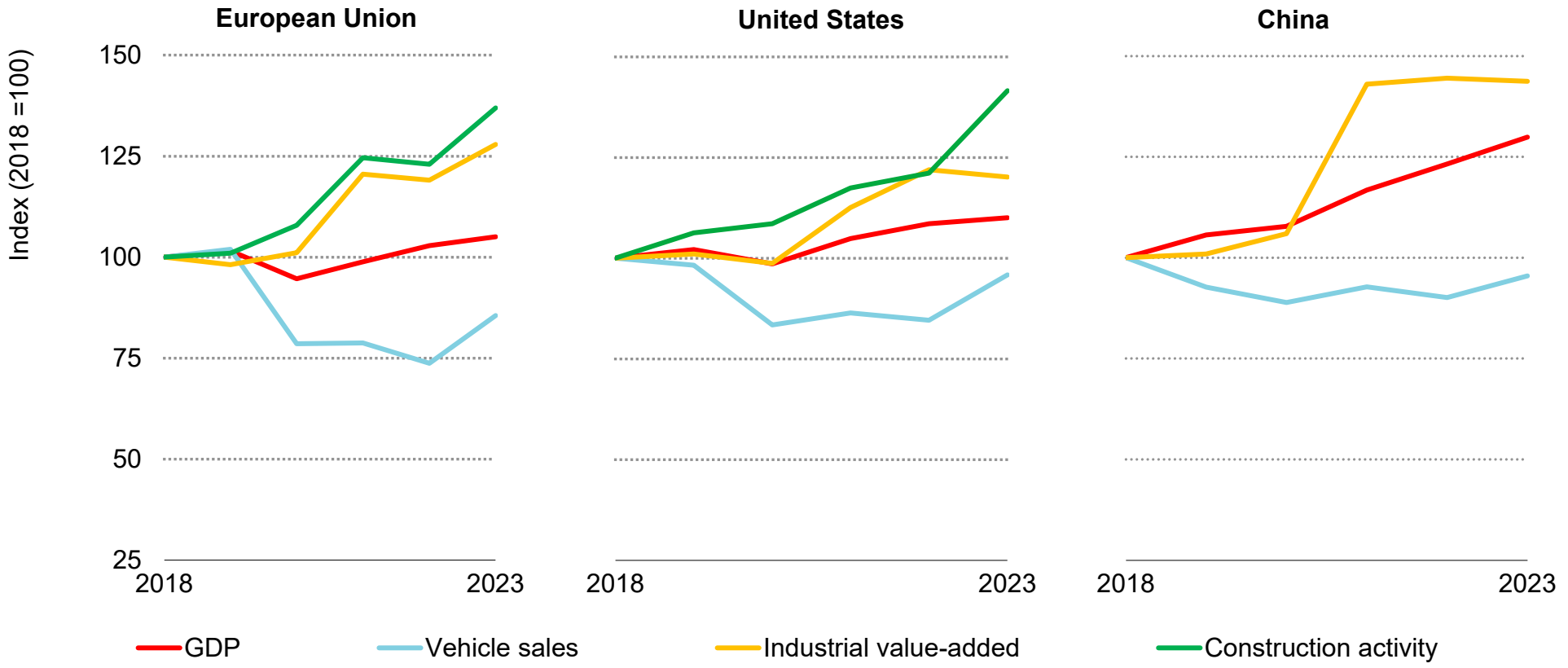
Supported by strong EV sales, investment on global energy efficiency and electrification remained resilient in 2023, despite strong headwinds for the building and industry sectors



Note: An energy efficiency investment is defined as the incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy use. The intention is to capture spending that leads to reduced energy consumption.

Indicators affecting investment in energy efficiency

Trends in sectoral indicators for three major economies that are relevant to key sectors for energy efficiency, 2018-2023



Note: Industry-value added for the United States is based on 2023 Q3 updates. The EU construction indicator is useful floor area for which building permits are issued (both residential and non-residential). The US construction indicator is new privately owned housing units authorised by building permits in permit-issuing places. The China construction indicator is newly started residential construction by floor meters, total construction area of houses constructed by real estate developers.

Source: IEA calculations based on Eurostat (2024); BEA (2024); NBS (2024).

End-use investments in 2023 show a mixed picture, with high inflation and interest rates affecting governments' ability to offer support

The year 2023 has been a challenging for investments in the energy efficiency and electrification of energy end-use sectors (Buildings, Transport, and Industry). Investment plateaued in 2023 at USD 646 billion: The buildings sector experienced one of its sharpest year-on-year declines (-5%), and industry investment fell by 8%, but this was partially offset by a 6% increase for transport, thanks to rapid growth in EV sales. The United States, Europe, and China account for about 75% of global end-use investment.

This slowdown comes at a time when the case for the affordability of both energy efficiency technologies and financing have been affected by the macroeconomic environment. Inflation not only made energy and technologies more expensive to buy, but high interest rates also meant that obtaining financing at reasonable terms became more difficult and more costly – especially as the housing market has been slow to cool down and disposable income has shrunk.

High interest rates are also eroding governments' fiscal room and their ability to provide incentives for energy efficiency and electrification measures. In recent months, several countries have announced plans to reduce – or scrap in some cases – incentives provided for EVs, heat pump purchases or building renovations. Despite lower gas prices, the level of industrial activity has also been slower to recover from the combined effects of the global energy and economic crises.

The question for the investment outlook in 2024 and beyond, is therefore whether spending can continue to be resilient in the face of waning government support as well as growing pressures on household budgets and company balance sheets.

In the transport sector, the recent drop in battery costs and the ongoing price wars between EV manufacturers (aimed at seizing market share) seem to provide hope for continued growth – albeit at a slower pace than before. In some large EMDE, EV sales are poised to take off, notably with the arrival of Chinese manufacturers in Latin America and the development of an EV industry in India. The effect of measures aimed at onshoring manufacturing capacity (e.g. the Inflation Reduction Act in the United States and the Carbon Border Adjustment Mechanism in Europe) should also increase spending on EV production outside China.

The outlook for investment in the building sector is very uncertain. On the one hand, the construction industry has been more resilient than anticipated, especially in China, with a focus on completing projects. But in advanced economies, uncertainty over the continued availability of public incentive packages dampens optimism about

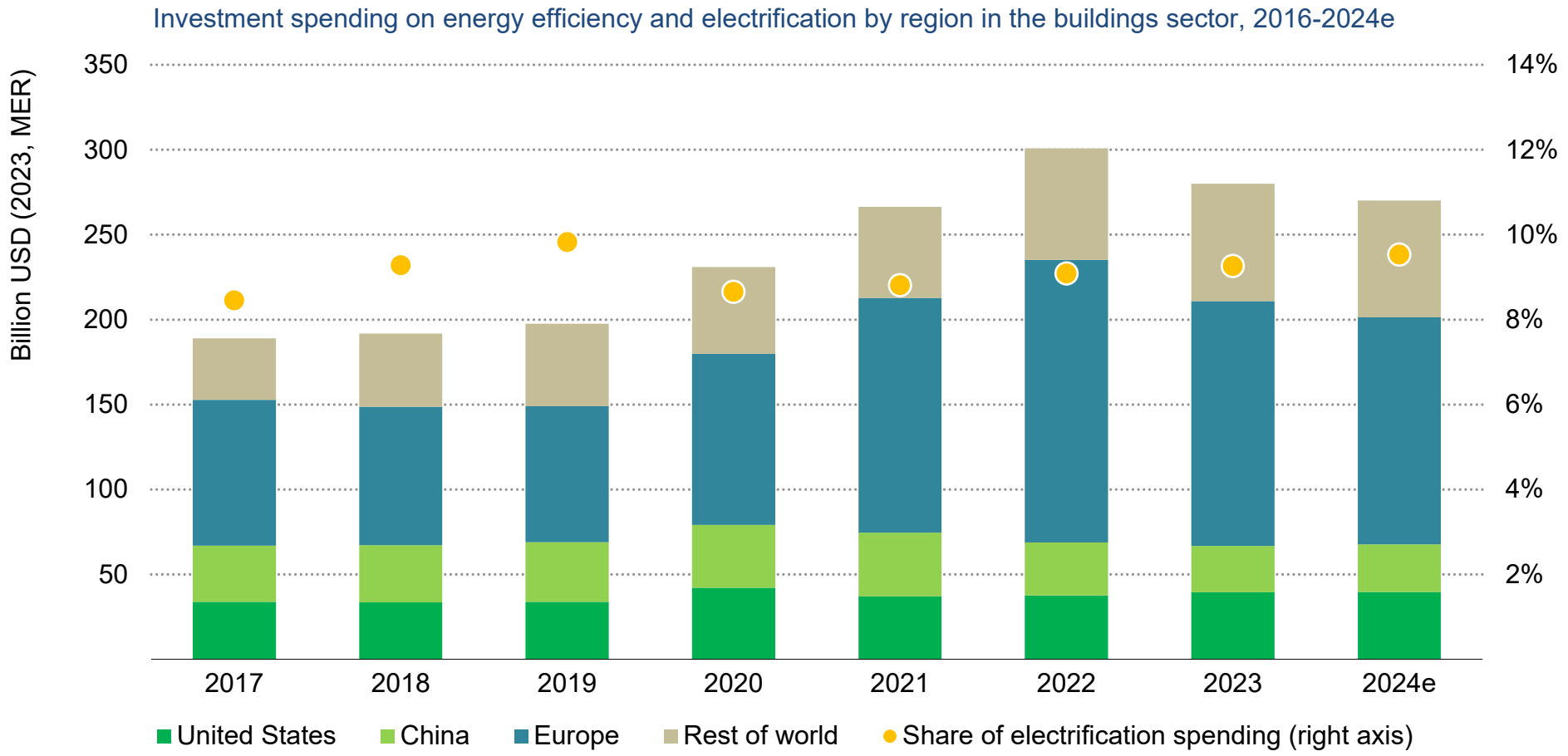
prospects for the next few years. In EMDE, weak building codes and poor enforcement continue to be a drag on investment.

Despite easing inflationary pressures and lower gas prices, the level of investment in energy efficiency in industry in 2024 remains dependant on the level of growth in industrial activity in Europe and China, for which the outlook remains quite uncertain.

For 2024, we project that aggregate spending in end-use sectors will be largely unchanged from the previous year. A continued, though slower, decline in building investment should be mostly offset by a recovery in the industrial sector and continued growth in transport.

Buildings

Energy efficiency spending on buildings slowed in 2023 …



Note: Spending on electrification (e.g. heat pumps) is included in the total spending and represented as a share of total spending on the right axis.
2024e = estimated values for 2024.

… while inflation, higher interest rates and a constrained fiscal space continue to challenge the outlook for 2024

In 2023, energy efficiency investments in the building sector stood at around USD 280 billion – a 7% drop from the 2022 peak – thanks to higher interest rates and the winding down of several large European government incentive programmes. This decline is projected to extend into 2024 due to continued pressures around construction financing costs and further phase-outs of government led support initiatives. From 2019 to 2022, stimulus spending and large structural government programmes in Europe, including public efficiency investment schemes in Germany and Italy, had supported average annual investment growth of 15%. But 2023 marked a turning point, where borrowing and construction cost pressures around the world slowed the delivery of finished buildings.

Several large economies saw a reduction in the construction of buildings in 2023. Construction in Brazil fell by around 2% from a year earlier, while China experienced a drop of 16%, significantly impacting global growth in construction spending and delivery of green buildings. Most of Europe has seen a drop in construction values, which translates into fewer efficient buildings being constructed. In 2023, the United Kingdom saw a 12% drop in housing deliveries, while they fell by 6% in France. Germany issued 27% fewer building permits in 2023 compared to the previous year.

Europe presented a mixed picture of energy efficient investment in 2023. Following a ruling in November 2023 by Germany's highest court that a EUR 6 billion climate budget was unconstitutional, the KfW development bank and BAFA export credit agency began to curtail support programmes such as the "Bundesförderung für Effiziente Gebäude" (Federal Funding Scheme for Efficient Buildings), which reducing funding by 34% in 2023. Together with cutbacks to other incentive schemes, Germany's investments in energy efficient buildings dropped by 27% compared to 2022.

The United Kingdom saw an increase in energy efficiency investment through the Energy Company Obligation, spending GPB 1.48 billion in 2023, a more than threefold increase from 2022. The Public Sector Decarbonisation Scheme reached around GBP 1.3 billion in 2023 with a focus on improving heating systems, and a further commitment to invest GBP 1.17 billion from 2024 onward.

In Italy, incentives in the building sector have led to more than EUR 80 billion of investments in 2023 – of which more than half, or EUR 44.4 billion was linked to the country's so-called Superbonus programme for homeowners. Since taking effect in July 2020, the Superbonus scheme – which reimbursed 110% of the cost of energy saving renovations – has led to EUR 102.7 billion in efficiency improvements. As of January 2024, however, the Superbonus is only

available for condominiums and the maximum tax credit has been cut to 70% for 2024 and will drop to 65% in 2025. A slowdown in investments is therefore anticipated. Italy's association of private construction contractors foresees that such changes will trigger a 27% drop in home renovation investments and a 4.7% decline in spending on new construction in 2024. The first two months of 2024 saw investment growth slowing to % from 4.8% a year earlier.

The EU has further strengthened the Energy Efficiency Directive (EED), setting a target of 4% improvement in energy efficiency per year and an 11.7% annual reduction in energy consumption by 2030. The EED is complemented by a strengthened Energy Performance of Buildings Directive (EPBD), which aims to boost the energy performance of buildings and requires new buildings to be solar-ready. The EPBD aims to reduce the primary energy use of residential buildings by 16% by 2030 and by 20% to 22% by 2035.

The United States has continued to support investment in improving the energy efficiency of buildings through the Inflation Reduction Act of 2022. The Department of Energy is investing around USD 705 million on building energy efficiency and weatherization through the State and Community Energy Program. Similarly, the Rural Energy for America Program (REAP) will focus on investments in rural communities through grants and guaranteed loans to rural communities and small and medium-sized companies (SMEs) for renewable energy and energy efficiency improvements.

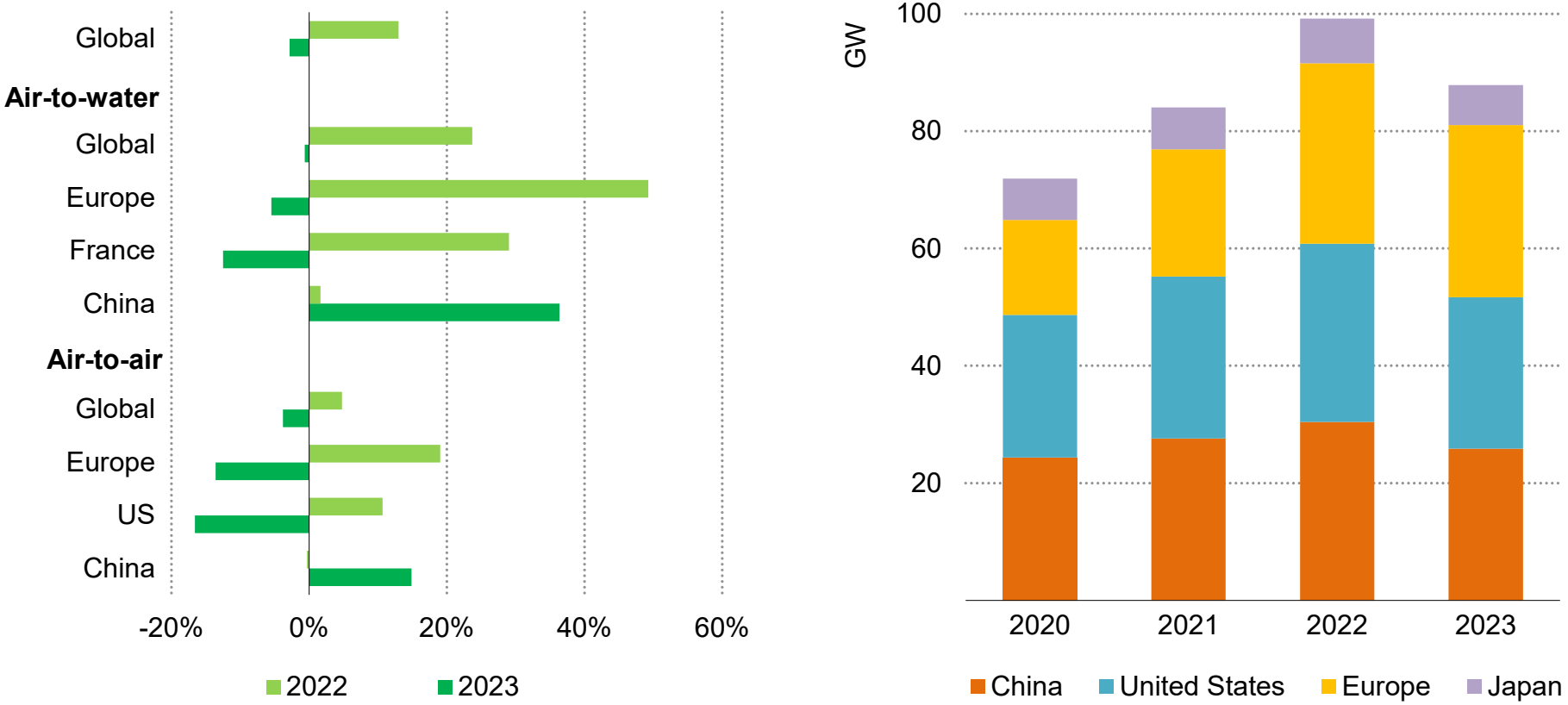
In February 2023, the African Development Bank introduced the Africa Super ESCO Acceleration Programme, which provides USD 5 million to support the establishment of public Super Energy Service Companies (Super ESCOs) in Rwanda, Senegal and South Africa. Standards that further promote energy efficient buildings across the African continent, such as the EDGE certification scheme from the International Finance Corporation, are also growing.

Alongside improvements to the National Construction Code, Australia recently launched several programmes to support building energy efficiency. The government established the Household Energy Upgrades Fund, which includes AUD 1 billion for the Clean Energy Finance Corporation to partner with lenders to offer low-cost finance for home energy upgrades, and AUD 300 million dedicated to social housing. The Small Business Energy Incentive supports SMEs with a 20% tax deduction for eligible upgrades, such as electric heating and cooling systems and efficient appliances.

Despite these initiatives, we estimate that global investments will fall by a further 3.5% in 2024 to USD 270 billion. Governments need to recommit to the doubling the rate of energy efficiency improvement through both a combination of direct support for homeowners and businesses to invest in efficiency and to help structure markets to incentivise private investment. For example, the explicit inclusion of building efficiency in green taxonomies and directives, such as in Europe and an emerging system in Canada, can start unlocking private financing at greater scale.

2023 saw heat pump sales fall for the first time as household budgets came under pressure

Rate of growth of heat pump sales in 2022 and 2023 (left) and global heat pump capacity by country (right)



Note: Air-to-water units include heat pump water heaters. Total also includes ground- and water-source heat pumps.

Source: Calculations based on data from AHRI, Assoclima, Assotermica, BDH, CHPA, ChinaIOL, EHPA, JRAIA, SPIUG and Uniclima; IEA (2024), The Future of Heat Pumps in China.

Sustained policy support is key to accelerate heat pump uptake

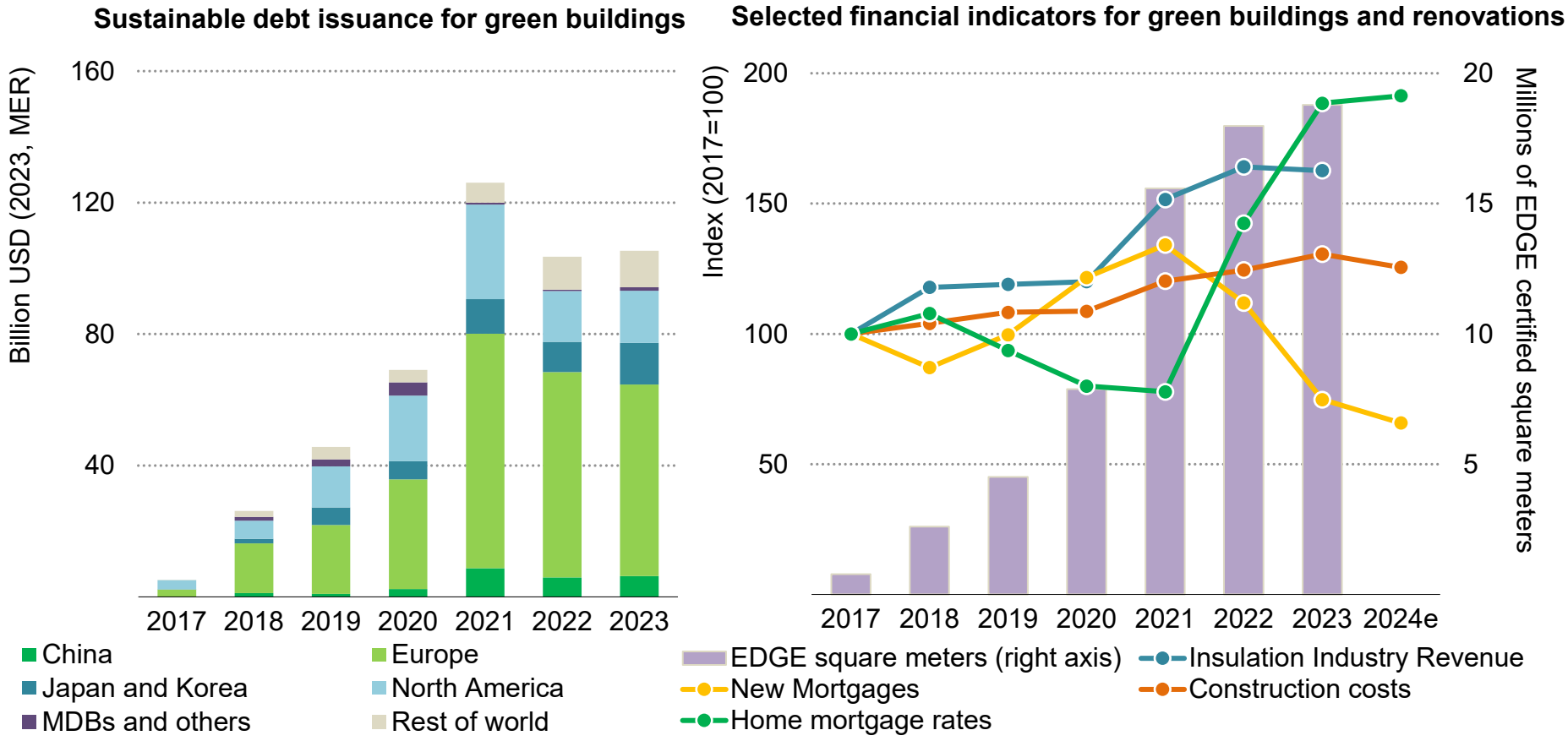
Throughout 2023, heat pump sales slowed, aligning with the broader investment trajectory seen in the building sector. This trend was particularly pronounced in Europe, where sales declined by 5% over the year. The United States also witnessed a near 17% decline during this period. These reversals in sales represent a departure from previously optimistic trajectories, despite the pressing global need for increased adoption of heat pumps to facilitate the transition to net zero emissions by 2050.

That said, this outcome was not entirely unforeseen, as several factors contributed to the reduced enthusiasm of consumers to invest in heat pumps in 2023. High interest rates deterred potential buyers, while the substantial upfront costs associated with heat pump installation posed financial challenges. Additionally, declining natural gas prices rendered electric heating options less economically appealing, further dampening demand. Uncertainties, including delays in the adoption of heat pump-related regulations in the European Union and the prolonged timeline for rebate distribution for heat pump installations in the US exacerbated the situation.

Nonetheless, there are still reasons to expect a brighter future for the industry. In the United States – where the overall market for HVAC equipment experienced a year-on-year decline – heat pumps still accounted for 55% of heating system sales as of December 2023, far outpacing a 20% drop in gas equipment sales. Meanwhile, nine US states – which together represent nearly a quarter of residential energy consumption – recently agreed to a collective target for new heating and cooling equipment sales to reach at least 65% by 2030. Additionally, there are tax credit schemes available through the Inflation Reduction Act that incentivise heat pump installations, further bolstering the outlook for the market. In Europe, while certain countries experienced declines in sales, others saw notable increases. Heat pump sales rose in Germany and the Netherlands for the first three quarters of 2023 – thanks to the carry-over effect of the previous year's sales spike – but eventually fell back amid market pressures and the weakening of government incentives. Such fluctuations illustrate the importance of effective regulations supporting the adoption of heat pumps and enhancing building efficiency.

China emerged as the market where heat pump sales thrived the most in 2023, with robust 12% growth from a year earlier. China currently leads the world in new heat pump installations, commanding more than a quarter of global sales. This trend has been bolstered by ongoing government initiatives aimed at promoting the adoption of clean energy equipment in various industries, such as agriculture. China's experience contrasts with Japan's relatively mature market, which saw a 10% decline in heat pump installations in 2023.

Sustainable finance for green buildings is holding up as construction costs level out



Source: Environmental Finance Data, EDGE, Bloomberg Terminal, European Central Bank, Federal Housing Administration, Fannie Mae, Freddie Mac.

Financing indicators for green building investment paint mixed picture for the years to come

Despite the decrease in investment in energy efficiency and electrification in the building sector, some financial indicators point to a brighter future. As with other energy sectors, rising prices and higher interest rates eroded the affordability of the entire construction value chain, pressing the pause button on the wave of the green buildings and renovation. But there are signs that construction costs have begun to stabilise and interest rates are expected to ease slightly over the next few quarters.

The number of sustainable bonds listing green building as a target for their proceeds had already begun to decline in 2022. But in 2023, the volume of issuances remained relatively stable, in contrast to the declining trend in the rest of the market for green, social and sustainability (GSS) bonds.

Historically, most green building bond sales have been driven by either by sovereign issuers (e.g. France, Belgium, Hong Kong) or public or quasi-public actors like Fannie Mae in the United States or KfW in Germany. But recently there has been a trend among private financial institutions and large utilities to issue debt to finance green buildings – though it remains unclear whether the proceeds of these bonds can be deployed fast enough to support the 2.5% annual deep retrofit rate required in the NZE Scenario.

Meanwhile, since the beginning of the inflationary period in 2021, the number and value of current long-term mortgages – typically good proxies for measuring renovation activity – have been declining both in the European Union and the United States. This is concerning, since all the IEA's scenarios assume a greater role for debt to fund renovations. Today, most retrofits are financed through owners' equity, which greatly limits their uptake.

Therefore, making sure the right consumer financing tools are in place will be crucial. Today, many options exist to finance the purchase of a vehicle or even a home, but few mechanisms provide readily available options to finance green buildings or renovations. Some governments and banks – mainly Australia, the United Kingdom, and United States – are experimenting with green mortgages, but uptake has so far been limited due to many factors, including low customer demand and complicated application processes, as well as a lack of lending capacity or willingness by banks to offer these products. In France, for instance, a recent initiative to provide zero-interest loans for small renovations was largely snubbed by banks and consumers alike until the rules were simplified and revamped in 2024. Financial institutions often point to a lack of available data and the difficulty of finding the right balance between the financial risk and return on smaller loans.

Banks have identified a need to better address financing for energy efficiency and electrification of the building sector, however: Today, 37 of the world's 100 largest commercial banks say they have implemented internal green building policies, although they still appear to struggle with communicating these policies across their branch networks. In June 2023, the International Sustainability Standards Board issued two new IFRS global sustainability disclosure standards that will require increased and more granular reporting from homebuilders and real estate companies on their building energy profiles.

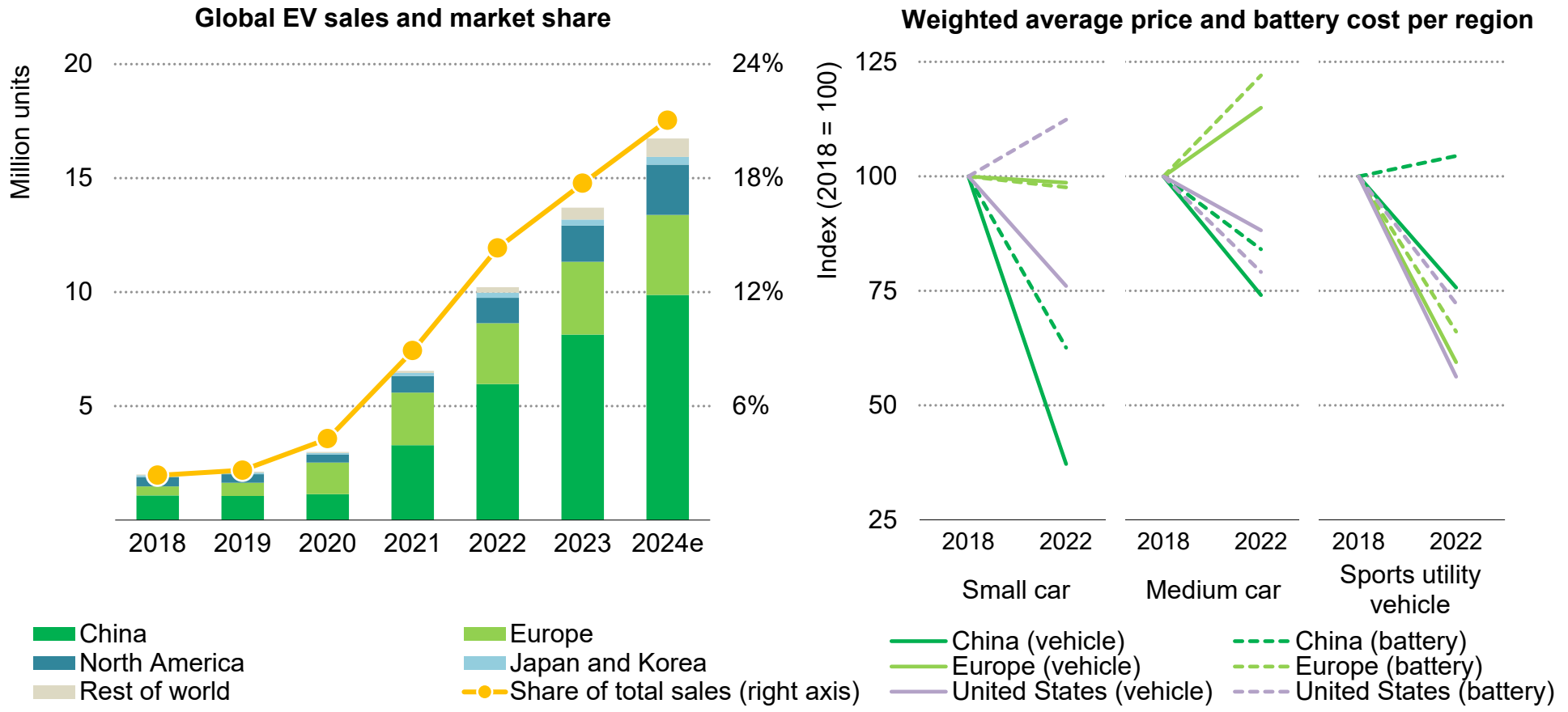
Innovative solutions exist to increase the amount of financing for green buildings, and they have been tested in various countries. In the United States, the Property Assessed Clean Energy Programs have shown a way to decouple the split incentives for owners – who must shoulder the cost of green investment but do not necessarily benefit from the resulting savings – by linking renovation costs to the value of the property itself. In Europe, some of the largest banks have already begun to implement voluntary Mortgage Portfolio Standards to incorporate climate targets into their lending practices.

About 80% of the world's population are homeowners and unlocking at least a portion of the trillions of dollars' worth of equity embedded in this housing pool could also be leveraged to help finance renovations. While many borrowers may not qualify for new mortgages – since homeowners tend to skew toward the top the age pyramid – public guarantees for home-equity loans could help to de-risk commercial financing for renovations.

Overall, these difficulties are compounded by a regulatory landscape which can be perceived as a moving signpost. As public budgets become tighter in many parts of the world, governments are tempted to cancel or scale back incentive mechanisms for renovations or green buildings, thereby reducing demand. One concrete example is from makers of insulation materials, who invested heavily in manufacturing capacity on the assumption that demand for renovation materials would rapidly materialise at scale. But recent hesitation by several European countries over whether to maintain incentive programmes have put these investments at risk and in 2023, revenues from the insulation industry started to decline.

Transport

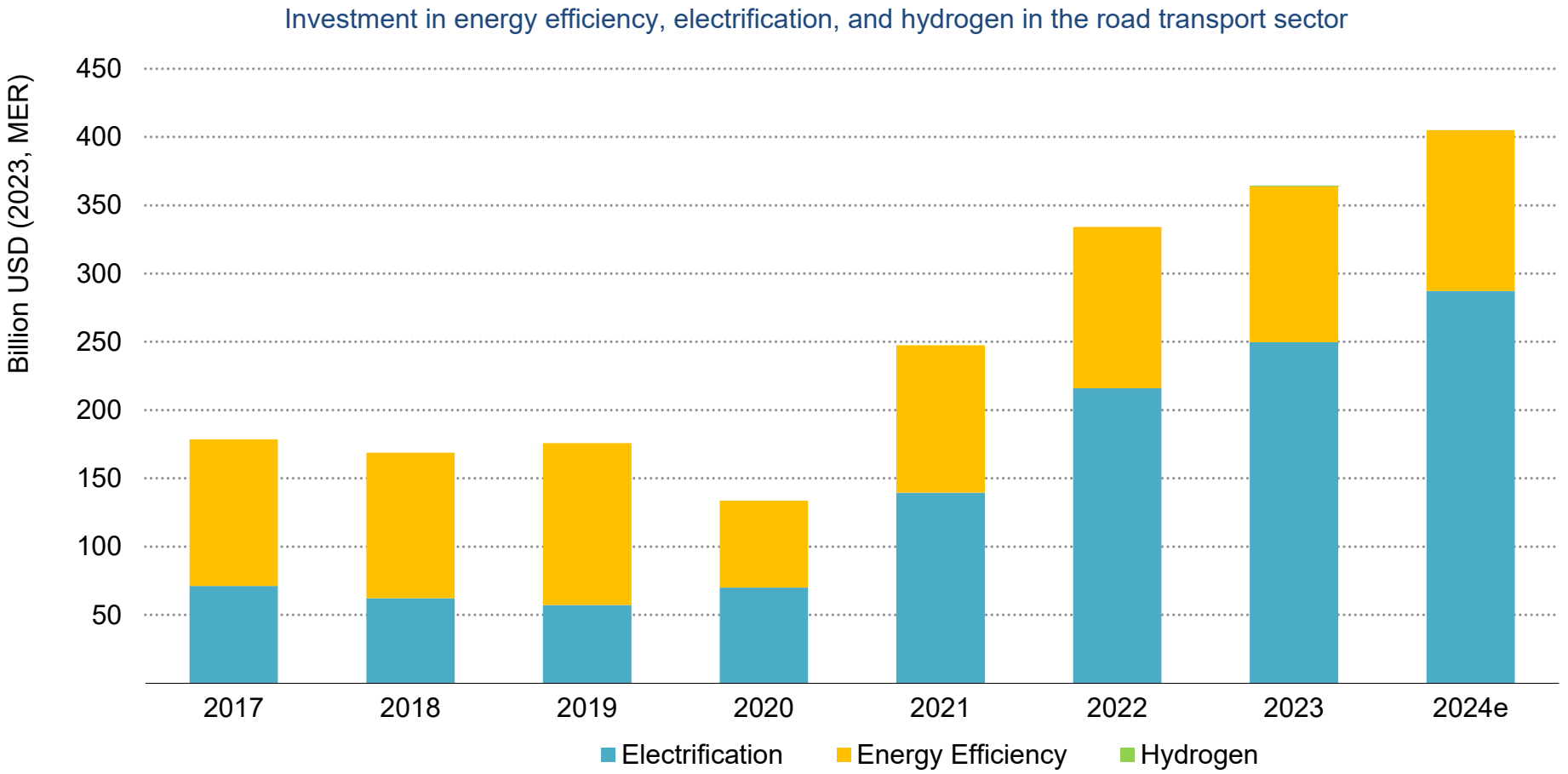
Sales of electric vehicles reached another milestone in 2023, driven by declining costs



Note: EV includes battery electric and plug-in hybrid passenger vehicles. 2024e = estimated values for 2024.

Source: IEA (2024), Global EV Outlook; Marklines.

Buoyed by lower battery costs, a price war in EVs and signs of life in the commercial markets, investment in the electrification of road transport is reaching new highs



Note: 2024e = estimated values for 2024. Hydrogen spending for transport is low and not visible on the figure, the category is included for completeness.

Nearly one in five new cars sold in 2023 was electric, although more than 90% of sales were in China, Europe, and the United States

In 2023, approximately 14 million electric cars were sold worldwide, constituting nearly one-fifth of total car sales. Sales of electric cars in 2023 were 35% higher than in 2022, a trajectory that – if maintained – would still be compatible with the targets set in the NZE Scenario.

Electric cars accounted for 18% of all cars sold in 2023, up from a 14% share in 2022 and just 2% in 2018. These trends indicate that growth in electric car markets remains robust as the technology matures. Battery electric cars accounted for 70% of the electric car stock in 2023. But sales continue to remain heavily concentrated in the traditional key markets. In 2023, almost 95% of all global electric car sales took place in China, Europe, and the United States. China led the way at almost 60% of sales, Europe at nearly 25%, and the United States at 10%. These regions also show significant adoption rates, with electric cars representing more than one-third of new car registrations in China, one quarter of registrations in Europe and 10% in the US market. In other developed car markets like Japan and India, EV sales remain limited.

China ended its national subsidies for EV purchases in 2022 after more than a decade – yet its EV industry and the level of EV sales remained resilient. While the growth rate for Chinese sales fell in 2023 to just over 35% it was from a high base, which speaks to the dynamism of the country's EV market.

Sales growth in the United States slowed somewhat but remained robust (up 42% year-on-year). The Inflation Reduction Act (IRA) and the revised qualifications for the Clean Vehicle Tax Credit, along with price cuts, seem to have helped in sustaining sales in 2023, despite initial worries that stricter domestic content requirements for EVs and batteries might trigger bottlenecks or delays.

In Europe, new electric car registrations reached nearly 3.2 million in 2023, marking a substantial increase of almost 20% compared to 2022. European governments have historically offered some of the world's most generous incentives for the purchase of new electric vehicles. However, these subsidies are beginning to wind down, notably in France, where a EUR 7000 (~USD 9000) per vehicle bonus is set to drop to EUR 4000 in 2024 (USD 5100). Germany has also ended its EUR 4500 (USD 5800) subsidy for the purchase of a new EV.

Sales increased significantly in EMDE regions, but still accounted for a small share of the global EV market. In Latin America, electric car sales reached almost 90 000 units in 2023. In Brazil, electric car registrations nearly tripled year-on-year to more than 50 000 units, supported by the entry of imported Chinese models, a trend we could expect to see more of as Chinese carmakers prioritise EMDE markets over the United States and Europe. EV registration in India

increased by 70% year-on-year thanks to purchase incentives under the Faster Adoption and Manufacturing of Electric Vehicles (FAME-II) scheme, supply-side incentives under the Production Linked Incentive scheme, tax benefits and the Go Electric campaign.

In 2024, global EV sales growth is expected to slow to around 20%. Contradicting forces are at play: A certain level of market maturity might have been reached in China, while the reduction or cancellation of some subsidies in China, Europe and India cloud the horizon for future sales. On the other hand, several factors should continue to support growth, including: recent price drops in many EV models; renewed activity in the commercial fleet segment and new emissions standards such as those proposed by the US Environmental Protection Agency. More targeted policy incentives, such as a French programme offering a EUR 100 per month EV lease to low-income households, could also be of help. (The French scheme was suspended in 2024 after more than 50 000 households signed up).

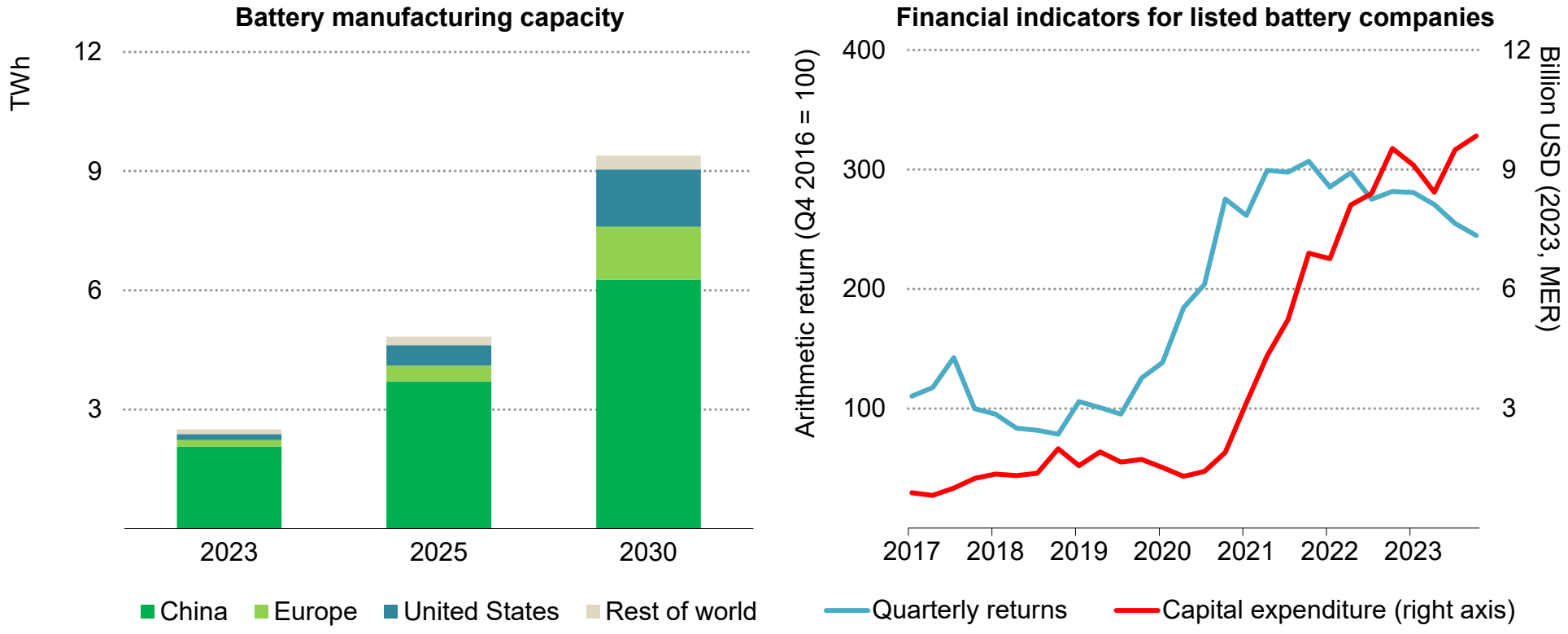
Despite drops in EV prices across the range of models, the largest EV manufacturers have been able to maintain their profit margins by delaying the pass-through of falling battery prices to their customers. Lower battery costs, supported by record levels of investment in manufacturing, should lead to further reductions in EV retail prices and increased sales.

But as the market enters a new era of slightly slower growth, the car industry – which has seen many new entrants in recent years – is likely to experience lower market capitalisations, increased consolidation, spending restraint and eroding margins amid price competition and slowing sales. The cancellation of two long-awaited IPOs of the battery and EV branches of Volkswagen and Renault points to a degree of investor scepticism about whether EV sales will be able to keep growing at the rates seen in recent years, especially in Europe. The story seems to be different in EMDEs, where in India for instance, companies like Exicom are starting to look to the capital markets for funding expansion into EVs. Announcements of new capital expenditures and additions of new battery manufacturing capacity continue to point to positive prospects for the sector globally.

Global sales of electric buses reached about 50 000 units in 2023, which represented 3% of total bus sales. Roughly 60% of those sales took place in China, thanks to early policy support and development of domestic production capacity. Battery electric buses reached a 43% share of new city bus sales in the European Union, and some progress was also made in Latin America and Kenya. In EMDE regions, mass transit public transportation investments have been supported by concessional finance, notably in India where multilateral development banks (MDBs) have worked with the government in its efforts to deploy a fleet of 50 000 electric buses and the corresponding charging infrastructure. In Dakar, Senegal, the all-electric Bus Rapid Transit system started operation in late 2023 and was co-financed by the World Bank, which provided USD 300 million. This push from MDBs can both establish strong order pipelines for electric buses and help develop local manufacturing capacity.

Capital expenditures by the major listed battery companies reached USD 10 billion for the first time in Q4 2023, and production capacity grew by 60% from a year earlier

Global trends in the battery manufacturing industry, 2017-2025



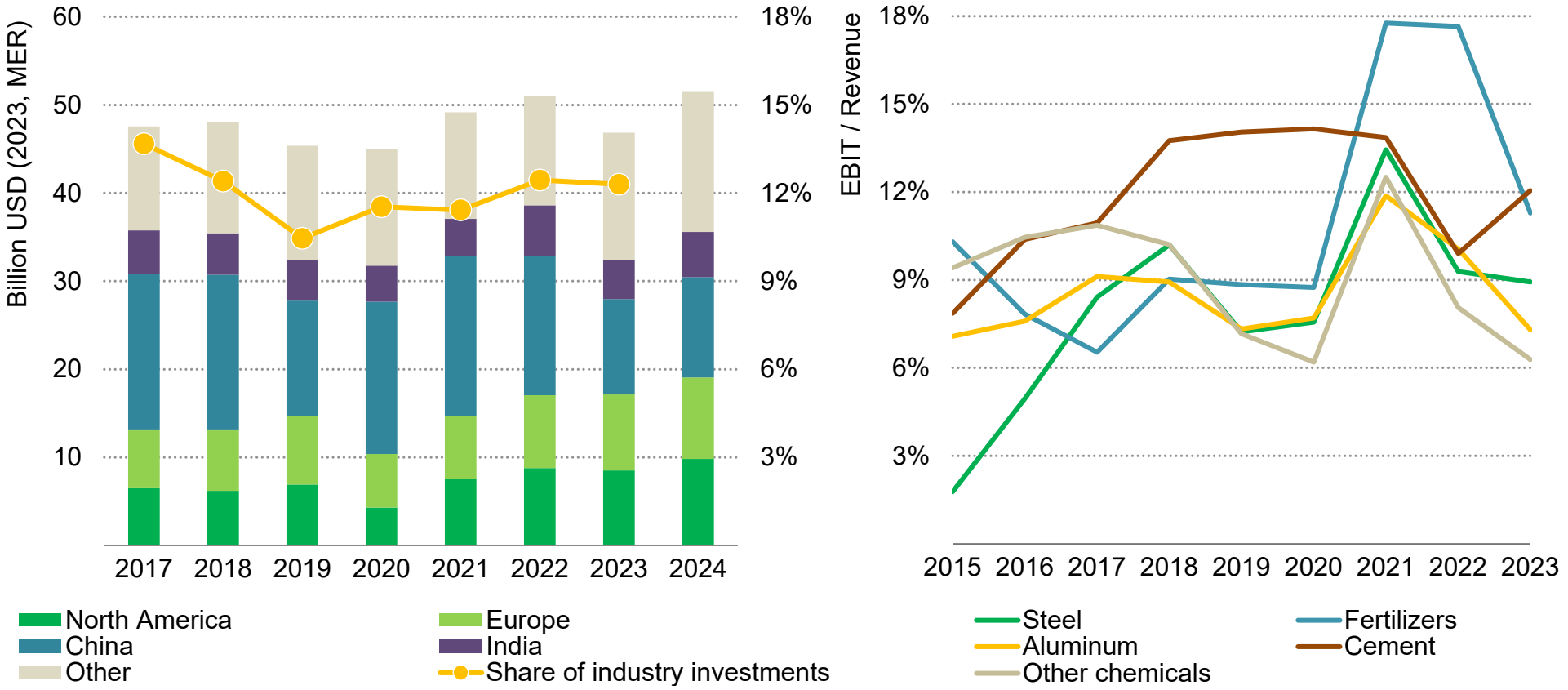
Note: Listed battery companies include LG Energy Solution, BYD, Contemporary Amperex Technology, Samsung SDI, Gotion High-tech, Eve Energy and Farasis Energy Gan Zhou. 2023 values are based on fully commissioned capacity. 2025 and 2030 capacity values are based on capacity that is either announced, under construction or fully commissioned.

Source: IEA calculations based on Benchmark Mineral Intelligence and Bloomberg Terminal (2024).

Industry

Energy efficiency investments declined in 2023 due to China's property sector downturn and the global slowdown, but remained stable relative to global industrial capital expenditures

Energy efficiency investment in the industrial sector, 2015-2022 (left) and EBIT margin of selected industries (right)



Note: The industrial sector includes iron and steel, cement, aluminium, copper, and chemicals. EBIT = earnings before interest and taxes.

Source: IEA calculations based on S&P Capital IQ.

This slowdown has taken place despite stubbornly high commodity prices across the board and rising margins, notably in the cement and fertiliser sectors

Investment in energy efficiency and electrification in the industrial sector shrank in 2023, cancelling out the gains seen in 2021 and 2022. This was driven mainly by a fall in investment in China, the largest materials producer in the world. The country is experiencing challenges from a declining property sector and lower growth and demand prospects. Depending on estimates, the property sector accounts for between 14% and 30% of China's GDP. Not only is the property sector itself very large, but it also drives many related industries such as steel and cement. The global economic slowdown and historically high inflation worldwide discouraged investment in other regions, which have remained flat.

Industrial energy efficiency investment was down by 30% between 2022 and 2023 in China, though it is expected to increase by 5% in 2024. Until 2021, roughly one-third of all energy efficiency and end-use investment in industry took place in China – but this share is expected to fall to 22% in 2024. As part of its 14th Five-Year Plan for National Economic and Social Government, China has set long-term objectives for 2025, emphasising the importance of low-emission and "green" development among heavy-polluting manufacturers such as steel companies. In practice, however, most subsidies to steel firms have gone to support investment in expanding capacity and capital equipment rather than targeting R&D expenses or investment in efficiency gains.

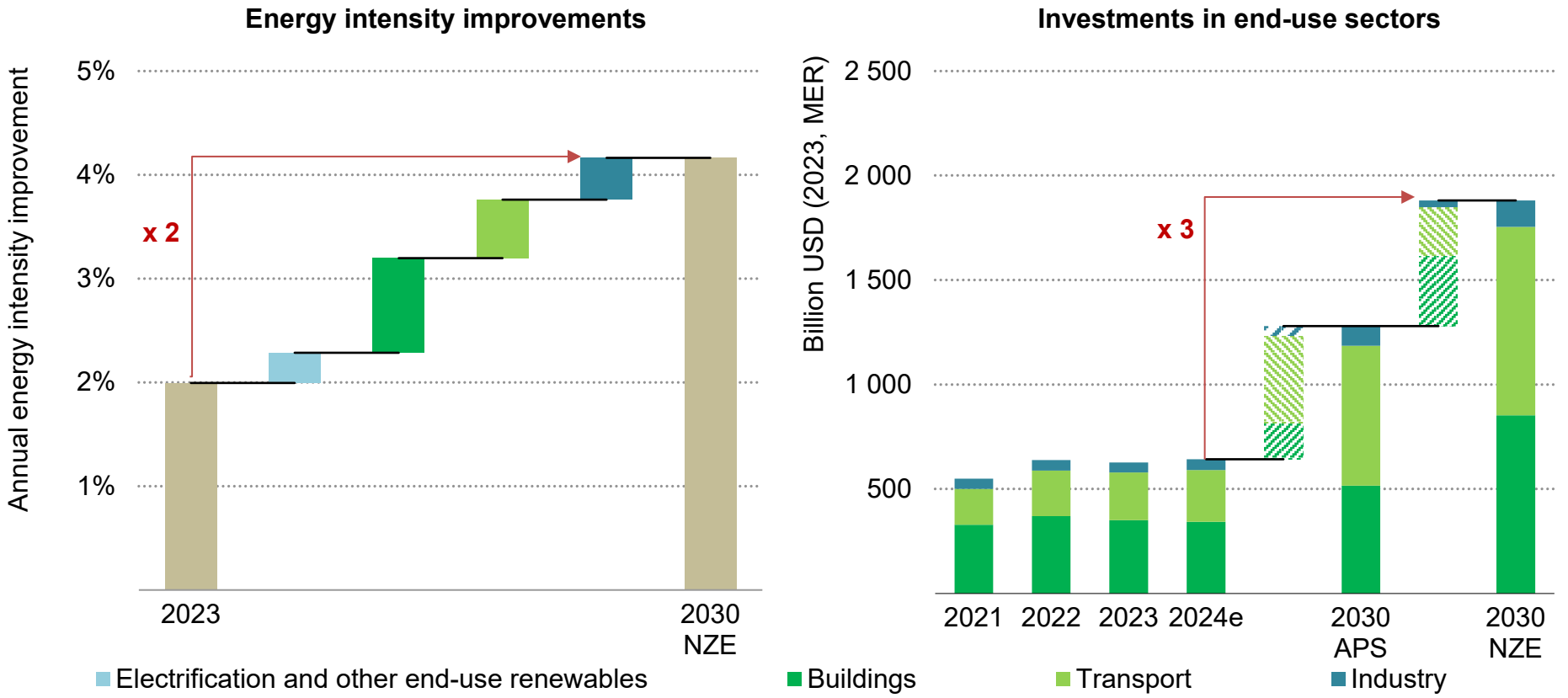
Compared with global capital expenditures across all industrial sectors (iron and steel, cement, aluminium, copper, and chemicals), energy efficiency and other end-use investments have stalled, representing 13% of total investment in 2023 compared to 14% in 2017. This suggests that even in a period of high energy costs such as 2021-2022, investments in energy efficiency and end-use have not been a priority.

The surge in commodity prices since 2021 has prompted industrial sectors to focus on higher-margin products and consolidation among smaller producers. Driven by the high price of natural gas – a key component of most fertilisers – fertiliser makers have enjoyed record profits in recent years. Nonetheless, this has not translated into bigger investments in energy efficiency.

In 2024, industrial sectors are expected to face growing turbulence. Global excess capacity is increasing, while demand shows signs of slowing, especially amid the potential for a downturn in Chinese demand if the real estate crisis drags on. Steel and cement production are declining in many countries, notably in Europe, while capacity is rising in Southeast Asia, the Middle East, and Africa.

Implications

Doubling annual energy intensity improvements by 2030 requires a tripling of investments

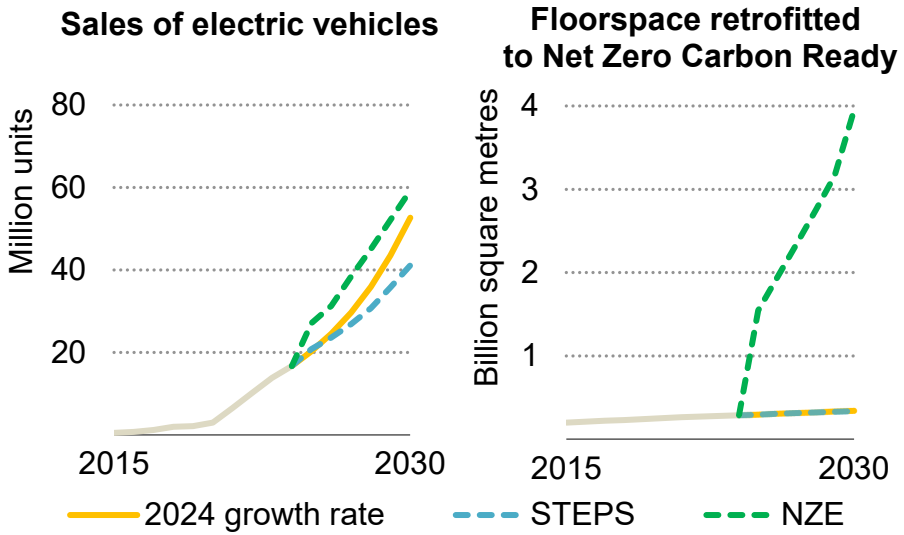


Energy efficiency is one of the key pillars to keeping 1.5 °C within reach, but the world is not investing nearly enough

During COP28, governments agreed on a set of key climate pillars for keeping the door open to net zero emissions by 2050 and holding global warming below 1.5 °C. One of these pillars is to double the rate at which the energy intensity of the global economy improves. Today the annual rate of improvement stands at about 2%. The NZE Scenario requires this rate to double by 2030. Decarbonizing the power and fuel sectors is crucial, but the largest emissions come from end uses and efficiency improvements are pivotal in curbing fossil fuel demand. To achieve a doubling of energy intensity improvement, annual investment needs to triple within a little more than five years.

By 2030, investment in buildings nearly triples in the NZE Scenario (as the share of deep retrofits reaches 2.5% per year), the number of heat pumps installed triples, and every new construction is net zero carbon ready. Clean investment in transport quadruples as 70% of new cars more than half of buses and trucks sold are electric, 17 million charging points become available and new internal combustion engine vehicles are at least 20% more efficient. While industry is one of the most difficult sectors to decarbonise, it is also the one where funding yields the best results. Only 6% of the total increased investment delivers 20% of the total intensity improvements by 2030.

Annual trajectory of EV sales and retrofits in the NZE Scenario



The upcoming years are pivotal for aligning the energy system with the NZE Scenario. Recent reductions in government support and slower growth in EV sales, heat pumps, and construction highlight the correlation between end-use efficiency investment and subsidies. However, public spending faces challenges due to inflation and higher interest rates. The key question will be whether the business case for electrifying transport, renovating buildings, and improving industrial efficiency becomes strong enough to attract significant private sector investment

R&D and technology innovation

Overview

Divergent trends for R&D funding and the scaling up of private capital, identified in last year's report, continued throughout 2023

The amount spent globally on clean energy R&D grew again in 2023, extending post-pandemic gains. A 13% rise in US government spending on energy R&D helped keep global public energy R&D spending on a steady upward trend, reaching USD 50 billion. Energy-related R&D spending in the corporate sector stood at USD 160 billion. Although the pace of growth was slower than the two previous years, the momentum of investment in clean energy technologies was maintained, led by the automotive sector.

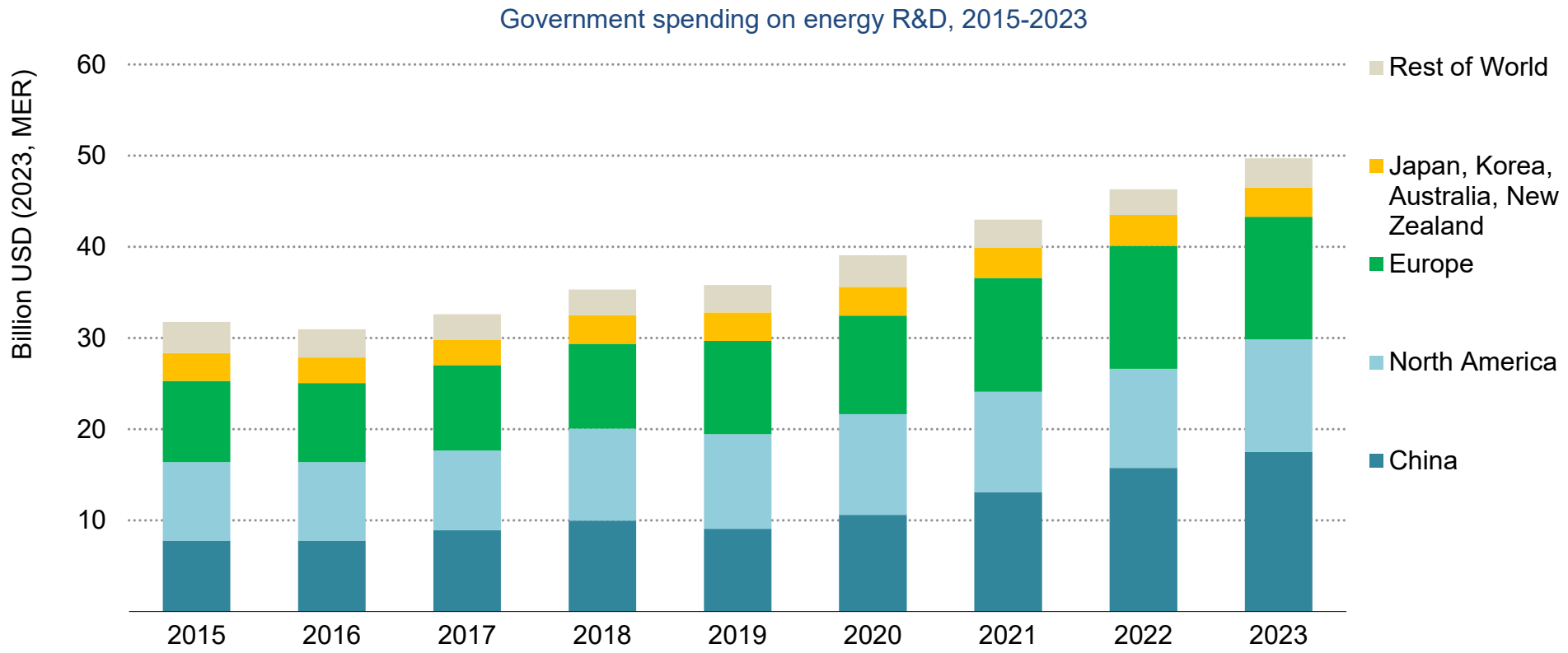
This growth trend is driven by three factors. On the public side, government commitments to reduce emissions are being taken seriously, and research funding is being strategically directed to areas that still show a gap between future deployment needs and technology readiness. Secondly, there is a fast-growing recognition at the highest levels of government that clean energy technologies can offer major opportunities for investment and growth and that benefits will accrue to those offering the most competitive products. Packages of government incentives aim to steer sectors towards low-emissions options and these are spurring corporate R&D to maintain firms' competitive advantages. These factors are evident in China, which further increased its share of energy R&D in 2023.

For smaller, innovative clean energy companies, however, 2023 was a difficult year. The types of capital on which start-ups rely – such as venture capital (VC) or venture loans – became significantly more expensive amid rising inflation and higher interest rates. Not only did higher interest rates make alternative investments relatively more attractive, but inflation and weaker outlooks for consumer spending lengthened the expected time that start-ups would need to reach profitability. As a result, many investors either moved their money out of VC funds, or the funds offered smaller amounts of equity or debt to start-ups – enough to keep them afloat until visibility improved. Based on data from the first quarter of 2024, we expect start-ups to find it difficult to raise capital through at least the end of 2024.

When it comes to energy innovation investment, emerging market and developing economies (EMDE) remain under-represented. Considering the active role these countries need to play in energy transitions, and the greater impact of higher interest rates on the cost of capital for innovators in these countries, their limited investment participation is a concern. In 2023, just 6% of public R&D spending and 3% of corporate R&D came from EMDE (outside China). For start-ups in some EMDE countries – where VC ecosystems are less developed than in advanced economies – borrowing rates have been reported to be as high as 25%. However, with an 85% increase in fundraising by Indian start-ups, the overall EMDE share of energy venture capital rose from 3% to 9% of the total in 2023.

Spending on energy R&D

Government spending on energy R&D continued to increase in 2023, rising 7% year-on-year. China and the United States led the way



Notes: Includes spending on demonstration projects (i.e. RD&D) wherever reported by governments as defined in IEA documentation. Figures for 2023 are a preliminary estimate based on data available by mid-May 2024. State-owned enterprise funds comprise a significant share of the Chinese total. China's 2022 estimate is based on reported company spending where available. The IEA Secretariat has estimated US data from public sources.

Source: IEA Energy Technology RD&D Budgets: Overview.

Clean energy R&D dominates the global total, and announced government initiatives point to continued future spending growth, but in 2023, R&D for unabated fossil fuels also increased

Globally, public spending on energy R&D rose by 7% in 2023, to almost USD 50 billion according to our estimates. This continues a trend that has buoyed innovation in recent years despite macroeconomic uncertainty. However, whereas the growth in 2022 was mostly driven by spending by the Chinese government and its major energy-related state-owned enterprises, in 2023 nearly half the growth came from North America, especially the United States. Collectively, budgets for US energy research at the national energy laboratories, Department of Defense and public grants given to energy R&D and demonstration projects rose by more than USD 1.3 billion in 2023.

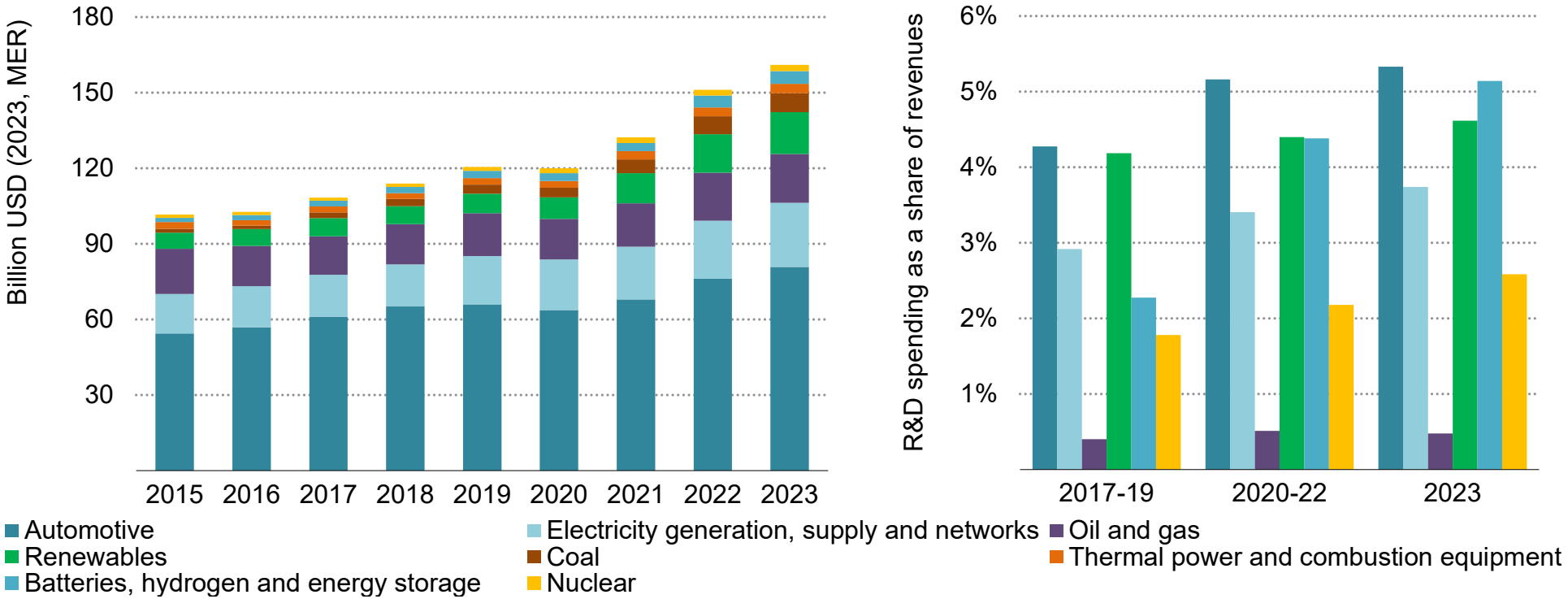
Despite slower growth in 2023, we estimate that China exceeded the 7% per year planned increase in energy R&D spending in its 14th Five-Year Plan (2021-2025). This maintains China's status as the largest public spender on energy R&D. However, compared to previous years, the share of growth in Chinese public energy R&D related to fossil fuel technologies was higher. As a result, the global share of public energy R&D devoted to clean energy topics dipped significantly for the first time in our dataset, after stagnating in 2022.

New government initiatives in this area include Korea's List of Critical and Emerging Technologies and a Special Act to create the support instruments for these technologies, which include rechargeable batteries, advanced mobility, advanced nuclear, biotechnology, aerospace and marine technology and hydrogen. Japan launched a programme to provide USD 300 million per year to support collaborative research on storage batteries, hydrogen and new bioproduction technologies. Austria's new Climate Neutral Industry initiative includes USD 260 million of R&D funding. The United Kingdom announced an USD 28 million fund for interdisciplinary, use-inspired research on clean energy and climate change through international partnerships.

Public energy R&D spending in EMDE rose in 2023 but, outside China, its share remained at 6% of the global total and was concentrated in a small number of G20 countries. Under Brazil's 2024 G20 Presidency the Group has begun work to help EMDEs develop effective long-term clean energy innovation systems so that they can participate more fully in emerging clean energy technology value chains. As an example of targeted action in 2023, Colombia established a Committee of Ministers for Sustainable Productive Development, which seeks to guide the government's support for development and commercialisation of technologies for climate neutrality, including lithium production.

Corporate energy R&D spending continued to ramp up, growing 7% to USD 160 billion, largely driven by the automotive sector but with growth across all technology areas

Spending on energy R&D by listed companies (left) and R&D budgets as a share of revenues (right), by sector of activity, 2015-2023

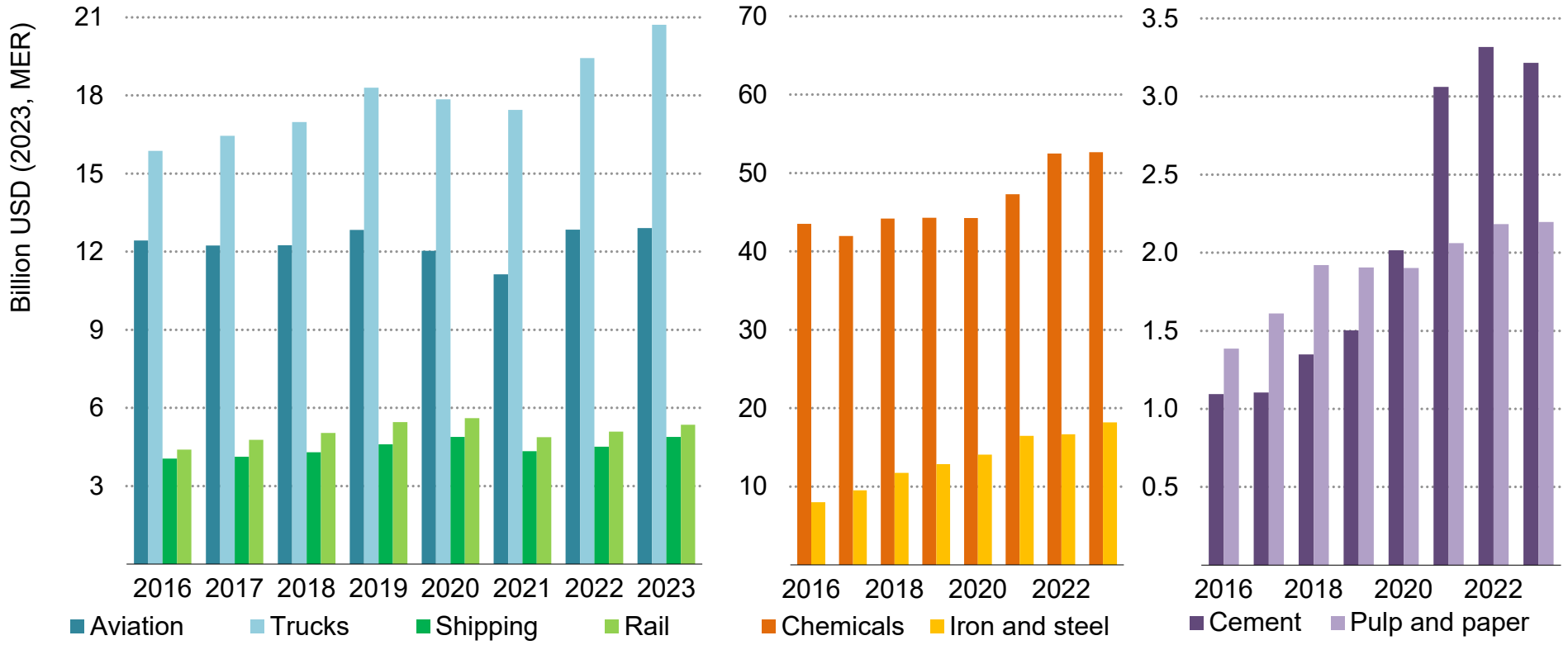


Note: Includes only publicly reported R&D expenditure by companies active in sectors that are dependent on energy technologies, including energy efficiency technologies where possible, and based on the Bloomberg Industry Classification System. Automotive includes technologies for fuel economy, alternative fuels and alternative drivetrains. To allocate R&D spending for companies active in multiple sectors, shares of revenue per sector are used in the absence of other information. Values may include both capitalised and non-capitalised costs, including for product development. Automotive spending is higher compared to that in WEI-2023 due to the inclusion of more component suppliers in the sample. Right-hand figure considers the top 20 companies earning more than half of their revenues in the sector.

Source: IEA analysis based on data from Bloomberg (2024).

R&D remained high in corporate sectors that are under pressure to develop low-emissions solutions, with notable growth for cement and trucks

R&D spending by globally listed companies in heavy and long-distance transport (left) and industry (middle, right) by activity, 2016-2023



Note: Values for 2023 are estimates based on reported data at the time of writing. Classifications are based on the Bloomberg Industry Classification System. Trucks include recreational vehicles, but not industrial vehicles. Year-on-year changes can result from new companies entering the dataset or companies ceasing operations, as well as changes in R&D spending.

Source: IEA analysis based on data from Bloomberg (2024).

Globally, energy-related companies are investing more in R&D to stay competitive and much of this is tied to rising revenue at Chinese firms or more competition among car companies

Since 2019, corporate spending on energy R&D has grown by an average of 7% per year – more than three times faster than the global GDP. This reflects the ability of large firms to continue to invest to develop their competitive advantage in a rapidly evolving technology landscape. In some cases it is also a product of counter-cyclical government support that has been earmarked for low-emissions technologies in these companies. Major automotive manufacturers and their suppliers are an example of this situation and their receipt of sizeable public loans for electrification R&D since 2020 was explored in WEI-2023. Another factor boosting global growth is the allocation of higher sums to energy R&D by Chinese firms. Not only are the revenues of Chinese energy-related firms rising faster than many of their international counterparts, but they also increasingly need to innovate to stay competitive domestically and internationally.

Of the top twenty energy-related corporate R&D spenders in our dataset, thirteen are automotive companies based in the United States, Germany, Japan or the Netherlands. The three non-automotive companies in the top ten are Chinese: PowerChina (a state-owned power plant engineering firm), PetroChina (a state-owned oil company) and State Grid Corporation (a state-owned electricity network operator). The French energy equipment manufacturer Schneider Electric also features among a “Top 20” group dominated by vehicle makers and auto parts suppliers, but the oil majors do not feature. Despite record revenues in 2022 and 2023, the oil major with the highest R&D spending, Shell, is below PetroChina, Sinopec and Saudi Aramco. In past years, the oil majors have been higher up the list.

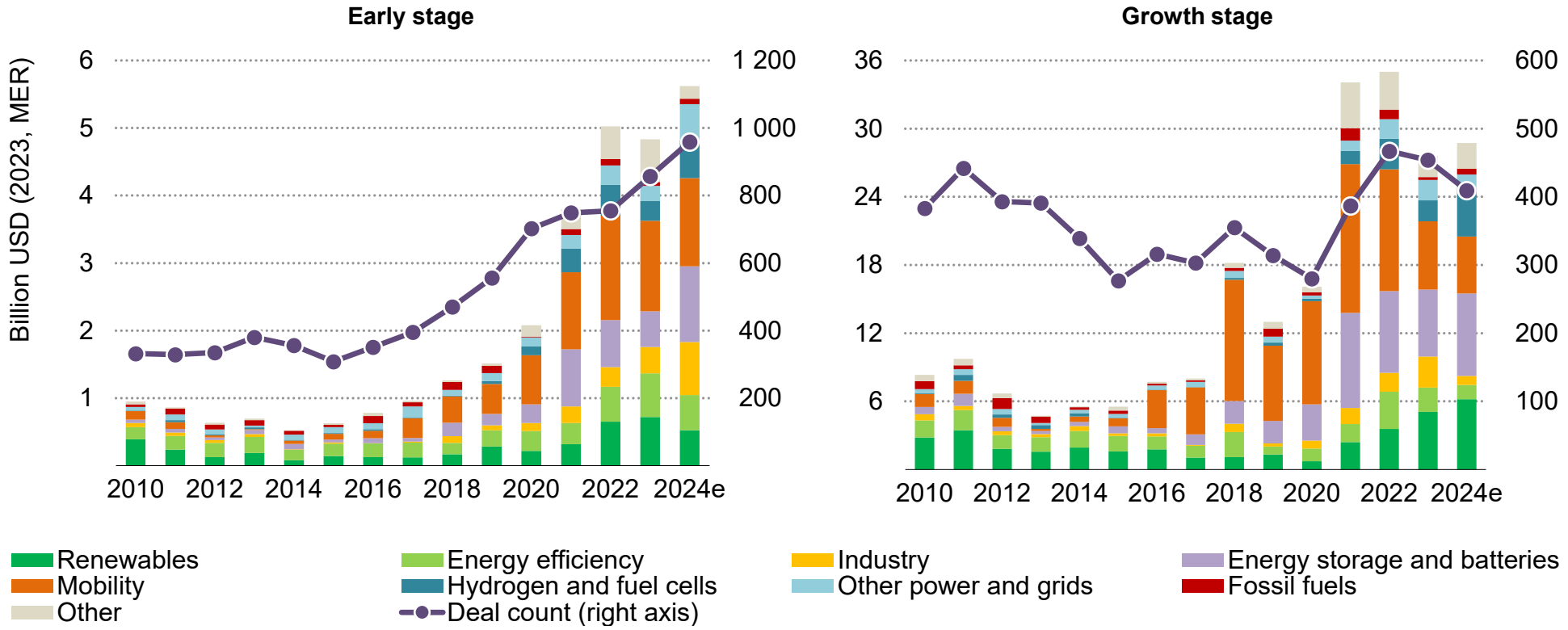
In the automotive sector, Volkswagen and Mercedes Benz increased R&D spending by a combined USD 5.5 billion, or 19%. This represents impressive growth at a time when sales of internal combustion engine vehicles are in decline and electric car sales, while growing, typically have thinner margins for the supply chain. Two companies focusing on electric vehicles, BYD and Tesla, rank thirteenth and fourteenth, respectively.

Outside the typical scope of the energy sector, corporate R&D has been rising in so-called hard-to-decarbonise sectors such as long-distance transport and heavy industry. This is a positive sign that companies, especially in the areas of trucks and cement, are embracing the challenge of rapidly changing their long-standing technological practices. Yet for chemicals, the recent upward trend stalled in 2023. There was no noticeable growth in annual R&D spending by companies engaged in the aviation, rail and shipping sectors.

VC funding of early-stage energy technology companies

Equity investors in energy start-ups took a “wait-and-see” approach in 2023, delaying deals or reducing deal sizes amid market uncertainty – growth-stage deals have not yet bounced back

VC investment in energy start-ups, by technology area, for early-stage and growth-stage deals, 2010-2024e

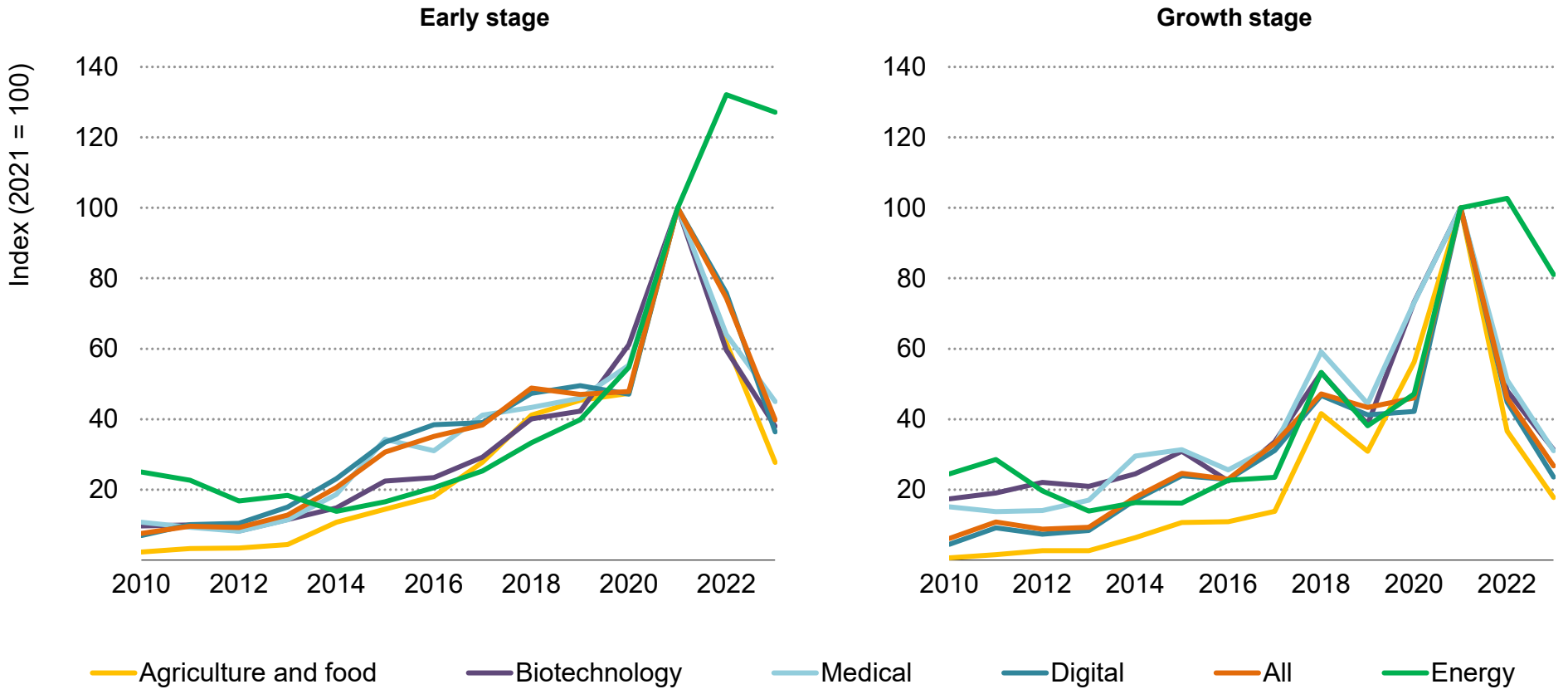


Note: Number of deals includes deals for which no value has been reported, meaning that the average deal value cannot be accurately derived from the chart. Industry includes start-ups developing alternative pathways to materials. Mobility includes technologies specific to alternative powertrains, their infrastructure and vehicles, but not generic shared mobility, logistics or autonomous vehicles. “Other” includes carbon capture utilisation and storage (CCUS), nuclear, critical minerals and heat generation. Fossil fuels covers start-ups whose businesses aim to make fossil fuel production and use more efficient or less polluting.

Source: IEA analysis based on Cleantech Group (2024) and Crunchbase (2024).

Energy has outperformed other VC segments since 2021, particularly for early-stage equity funding for start-ups, which held up well in 2023 thanks to policy backing for clean energy

Growth in global VC investment by sector of start-ups, 2010-2023



Notes: Indexed values are in constant USD.

Source: IEA analysis based on Cleantech Group (2024) and Crunchbase (2024).

Early-stage VC investment in energy start-ups fell in 2023 for the first time since 2014, largely because of macroeconomic conditions, but is set to get back on track in 2024

From the perspective of financial flows, 2023 was a disappointing year for venture capital (VC) investment in energy. Whereas 2022 achieved unprecedented levels of deals and funding, both early- and growth-stage equity investment declined in 2023. Early-stage funding, which supports entrepreneurs with technology testing and design – and plays a critical role in honing good ideas and adapting them to market opportunities – fell by 4%. Growth-stage funding, which needs more capital but funds less risky innovation, slid 21%.

This outcome can largely be attributed to macroeconomic conditions rather than a loss of confidence in clean energy technologies. With higher interest rates, fund managers found VC investments less attractive than other investment classes. For hardware developers, this was coupled with a more challenging path to market as their input costs rose and potential customers tightened their belts. These trends were already apparent in 2022 and are still expected to reverse as the macroeconomic environment improves. Encouragingly, there are also reasons for optimism about VC for energy technology innovation. Energy VC investment did not fall as far as other VC segments, such as digital, which saw funding drop by more than 70% compared with 2021.

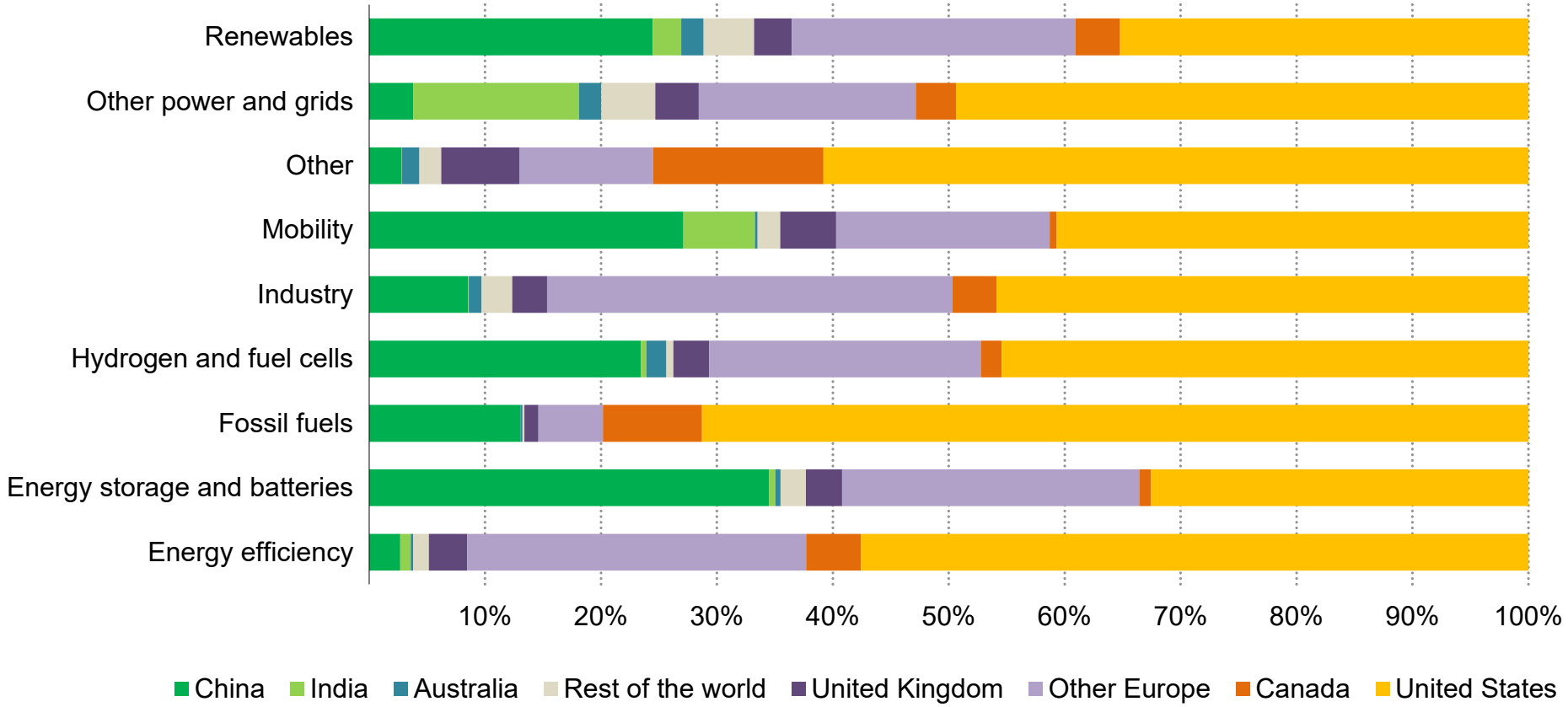
The number of specialist VC funds targeting clean energy and other climate segments continues to grow. These funds are often backed by investors that impose criteria – such as potential for deep reductions in greenhouse gas emissions – on the use of the money, and in some cases allow returns to accrue over longer timeframes.

This additional investor focus on energy technology innovators is one reason behind the rise in the number of early-stage deals for energy start-ups in 2023. The overall investment trend appears therefore to stem from a reduction in the amount invested per deal and a possible postponement of very large deals, especially growth equity deals. Such an approach may be expressed as “wait-and-see” via the provision of “bridge finance” – which suggests there could be an upward correction if macroeconomic conditions improve.

Data from the first quarter of 2024 indicate that the investment environment has improved somewhat and delayed early-stage deals are getting done. We estimate that early-stage VC funding for energy will return to growth in 2024, but the growth-stage capital shortage will continue. This is despite some big deals already being completed. Several start-ups have already raised USD 250 million or more in 2024, including Deep Green (waste heat), Electra Charging (vehicle charging), Fervo Energy (geothermal), H2 Green Steel (hydrogen and steel projects), Koloma (hydrogen), NexAmp (solar projects) and Sunfire (electrolysis). These deals are similar in magnitude to the biggest energy VC transactions in early 2023.

US-based start-ups attract the most energy-related VC, but there are variations among sectors including European dominance in energy efficiency and Chinese leadership in batteries

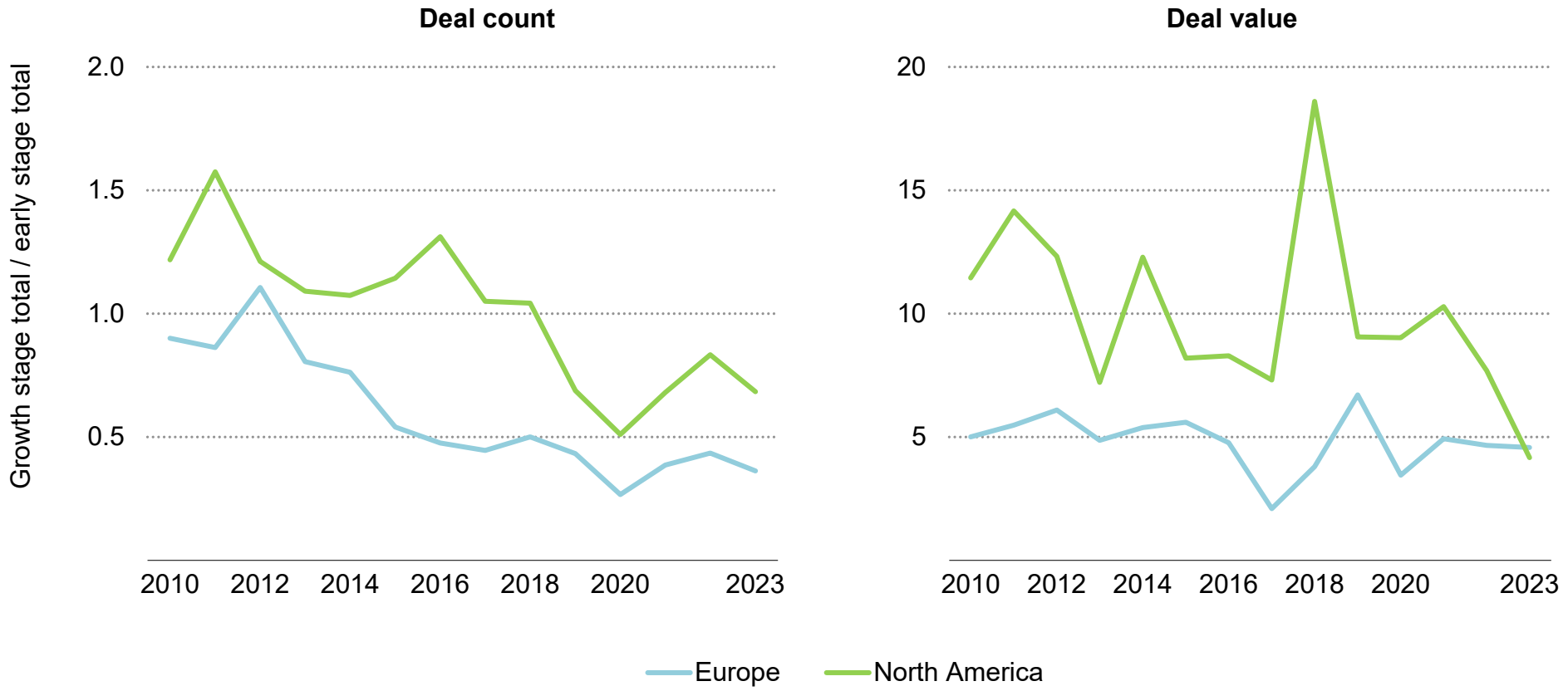
Early- and growth-stage equity investment in energy start-ups by region and technology area, 2020-2023



Source: IEA analysis based on Cleantech Group (2024) and Crunchbase (2024).

The number of US growth-stage energy VC deals relative to early-stage deals is still higher than in Europe, but Europe's ratio of growth-to-early-stage VC deal value was higher in 2023

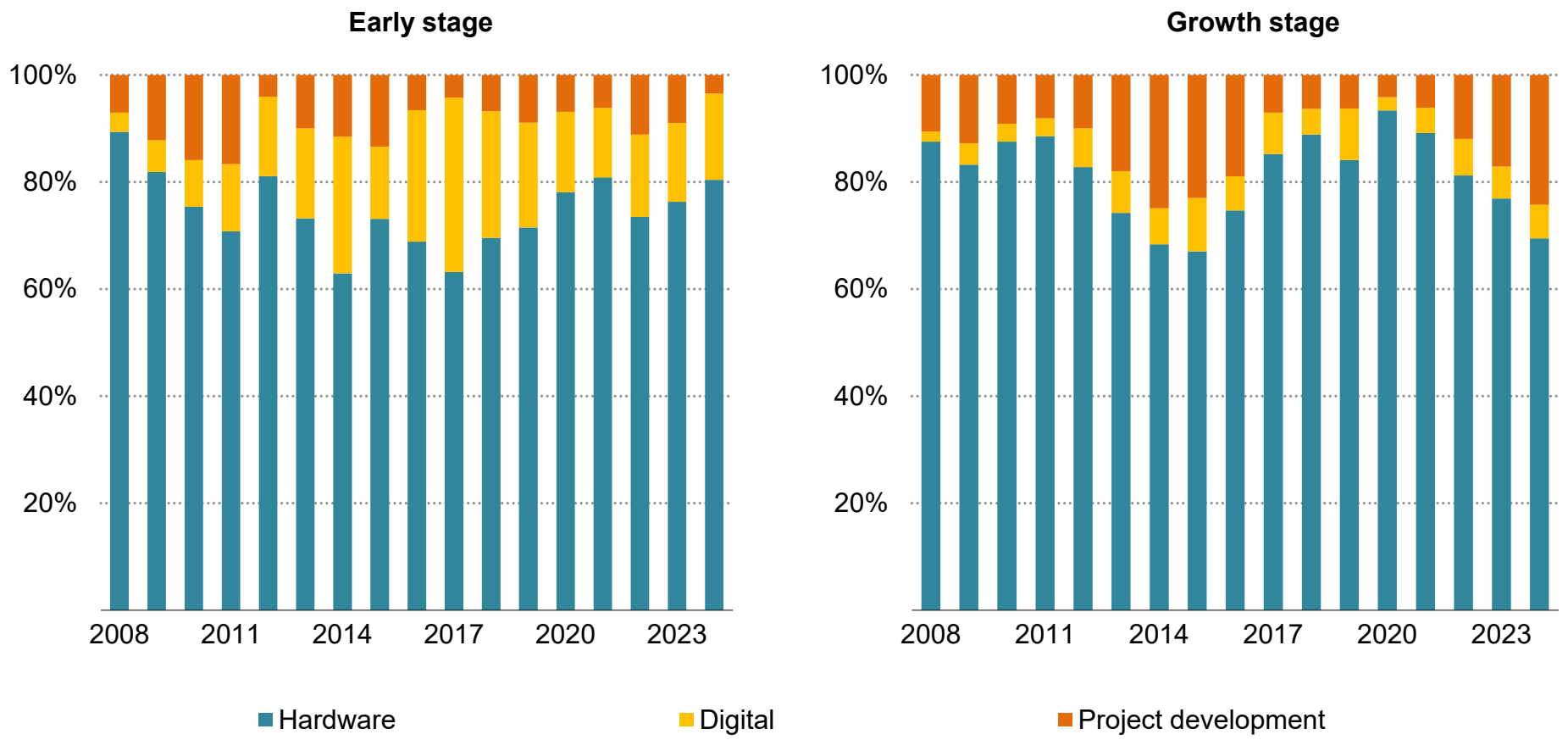
Ratio of growth- to -early-stage VC deal counts and deal values for Europe and the United States, 2010-2023



Source: IEA analysis based on Cleantech Group (2024).

VC software vs hardware

Share of early and growth-stage VC investment in energy start-ups, by type of start-up, 2008-2023



Note: 2024 represents Q1 only.
Source: IEA analysis based on Cleantech Group (2024) and Crunchbase (2024)

In 2023, energy-related VC deals were more likely to be for early-stage companies and those developing projects rather than hardware

In the three years to 2023, start-ups based in the United States raised more than those in other regions. Most investors in these deals were US-based. While China, Europe and India have consistently represented growing shares of the total as investment has increased in recent years, this is not evenly distributed between the different funding stages or among technologies. The share of Chinese start-ups is highest in energy storage and batteries, where it now stands at 35%, while Indian start-ups have been most successful in the mobility sector – including electric urban vehicles and charging infrastructure – where they represent a 6% share.

European start-ups have significantly increased their share of global energy efficiency VC funding. In absolute terms, the amount of money raised in 2021-2023 was nearly three times more than in 2018-2020, reaching USD 1.5 billion in 2023. The share of growth equity in this total has also increased, indicating greater success for European energy efficiency start-ups as they scale up. However, across energy sectors, there has been a decline in the number of growth-stage deals – when a defined product or service is in development – relative to the number of deals for early-stage start-ups, when the business is still being defined. This trend has been most visible in the North American data: Between 2016-2018, the average growth-to-early stage VC deal ratio was more than one growth-stage deal and USD 11 of growth equity for every early-stage deal and USD 1 of early-stage equity. In the 2021-2023 period, this ratio was 0.7 growth-stage deals and USD 7 of growth equity per early-stage deal. In absolute terms, nearly three times as much funding went to early-stage deals in 2023 compared to 2018, while growth-stage deal value fell by 35%. For the first time in our dataset, European energy start-ups in aggregate raised more growth equity for every early-stage deal than their North American counterparts. The relative attractiveness of the two regions for scaling up a new energy technology, which has traditionally favoured US start-ups in terms of the availability of growth equity, may be converging.

Much of the need for clean energy technology innovation relates to the development of hardware solutions, and energy start-ups developing hardware continued to attract most of the VC funding. However, growth-stage funding for energy start-ups dropped further in 2023 after a drop in 2022 and now stands at around 75% of total funding. Based on data for the first quarter of 2024, this level is dropping further: just 69% of growth-stage VC funding was for hardware developers.

Hardware products can take many years of VC funding to be developed to meet customers' needs, but these start-ups can achieve

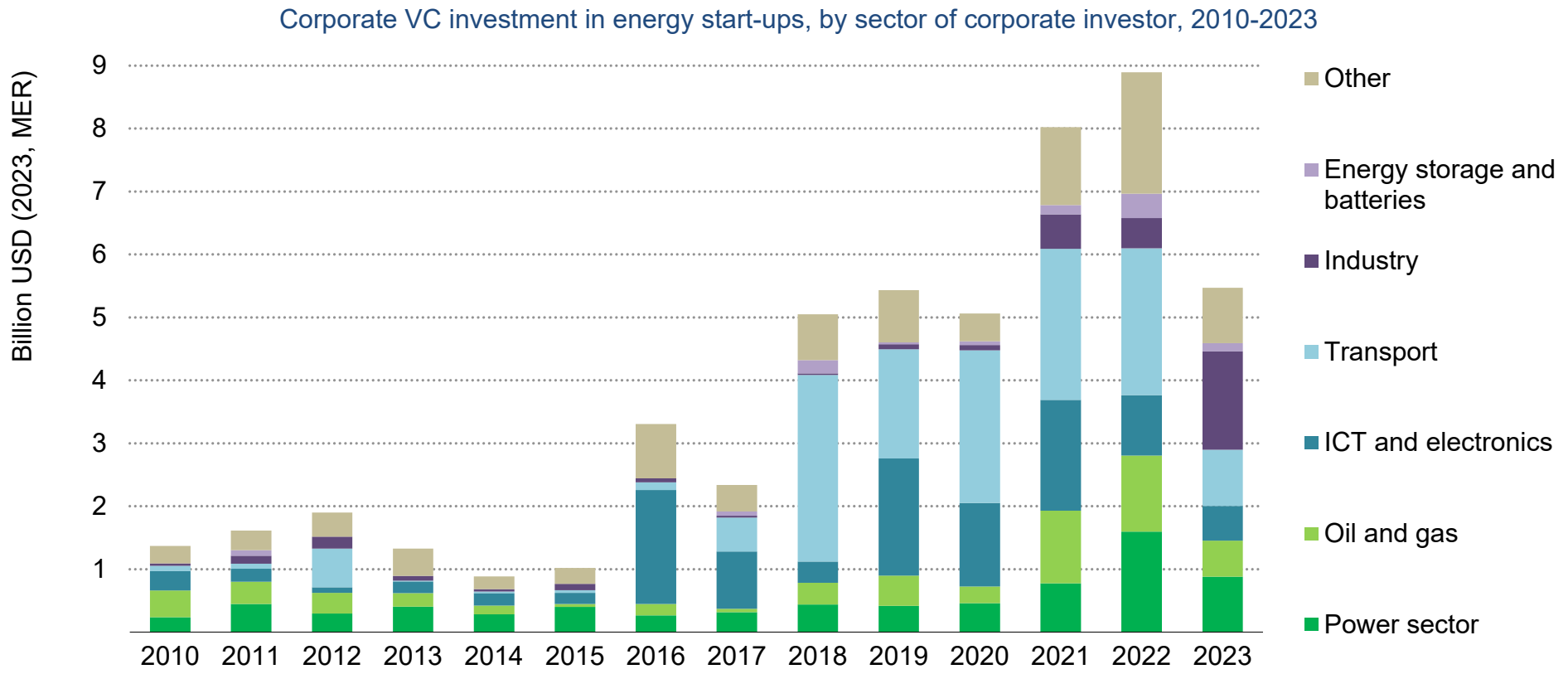
high valuations and pay-offs for investors. By contrast, energy software and project development companies can have a quicker path to market but offer lower returns. The decline in 2022-2023 likely reflects lower willingness among VC funds to make large, long-term bets in the current macroeconomic environment. Thus, the share of hardware developers in early- and growth-stage deals tends to shift with changing risk perceptions. This indicates that governments could preferentially offer counter-cyclical support to hardware developers during periods when capital is temporarily more costly.

In a given technology area, the share of VC deals represented by project developers can indicate technology and policy maturity. One of the biggest deals in 2023 saw 14 different investors take USD 1.6 billion equity in H2 Green Steel, a Swedish project developer for hydrogen-based steel production. The same company raised a further USD 300 million from three different investors in January 2024. The ability of H2 Green Steel to attract these levels of growth equity signals that its backers are increasingly comfortable with the level of technology risk and market outlook for hydrogen production and low-emissions steel.

In contrast, renewables project developers in 2023 attracted the smallest proportion of renewables VC investments in more than a decade (excluding 2020, an outlier year due to the global pandemic). After 2011, when many VC investors made losses on solar companies that did not successfully scale up, there was a shift toward investment in solar project developers or companies that help building owners to install proven technologies: Between 2014 and 2018, project developers attracted more than 60% of VC investment in solar, peaking at 70% in 2018. This increase accompanied an industry shakeout triggered by cheaper, Chinese-made crystalline photovoltaic panels. This was partly a reaction to how risks and innovation incentives evolve in a maturing sector. However, VC investors and start-ups have once again shifted its focus: In 2023, owners of new solar hardware technologies received 70% of solar VC investment.

This recent shift back to hardware shows that, even in sectors like solar, which many people consider to be a mature and stable technology, government policies can have a significant impact on innovation. While the trend may relate, in part, to consolidation in the market for renewable energy project developers, another factor is likely to be the renewed interest of many governments in hosting solar manufacturing facilities. Knowing that government support is available for setting up a production facility that can compete with imports incentivises researchers to push forward the technology frontier to compete for the domestic market. Start-ups developing new approaches to solar photovoltaics – such as thin film, flexible designs and products that integrate solar cells – raised more VC money in 2023 than in the previous eight years combined.

Corporate VC investment in clean energy start-ups dropped by almost two-fifths in 2023, with automotive companies reducing their investment activity more than other sectors



Notes: Includes early- and growth-stage deals. Includes only investment by private-sector investors. Where there are several investors, deal value is evenly split among them. ICT = information and communications technology. Industry includes chemicals, cement, commodities, construction (excluding real estate), iron and steel and other equipment suppliers. Power sector includes independent power producers as well as electricity and renewables equipment and services. “Other” includes food, health, research and mining.

Source: IEA analysis based on Cleantech Group (2024) and Crunchbase (2024).

Big corporations cut back equity investment in energy start-ups more sharply than other types of VC investors, with the exception of industrial companies

In 2023, large companies spent USD 5.5 billion buying equity stakes in smaller energy-related start-ups with potential strategic value for the investing firm. This injection of corporate venture capital (CVC) has risen dramatically in recent years, as a way for big corporations to acquire knowledge, new technologies and business models quickly and at low cost. The nimbleness of start-ups and the "optionality" for investors can be particularly valuable under conditions of uncertainty, competition and budget pressures. While CVC remains lower than corporate R&D budgets (which usually target the development products that fit well with existing business lines) it has notable strategic value when disruption from mass-produced, modular and quick-to-scale technologies is anticipated.

For start-ups, CVC complements other sources of funding and can accelerate scaling up by providing access to corporate experience and resources, especially for manufacturing, as well as access to consumers around the world.

Apart from 2020, when the global pandemic triggered a market contraction, 2023 was the first year since 2017 that energy-related CVC declined. This follows a broader dip in energy-related VC activity in 2023, but the drop in CVC was more pronounced than the overall VC trend. As a result, CVC fell from 22% of total energy-related VC in 2022 to 17% in 2023. The change was largest for early-stage VC, for which CVC fell from 17% to 11% of the total. This raises important questions about the availability of this strategic source of capital during periods of macroeconomic uncertainty.

Two sectors that have underpinned much of the recent growth in energy-related CVC – oil and gas and automotive – made cuts to their investment activities. For some firms, this was accompanied by messages about refocusing CVC on technologies closer to their core business and integrating start-up activities with corporate strategy. Saudi Aramco said in January 2024 that it would increase the capital of its CVC fund and prioritise clean energy technology. Volvo announced it would follow some other automotive companies, such as BMW, in deepening its start-up incubation and collaboration efforts, as a complement to CVC. In 2023, Porsche moved the headquarters of its VC fund and restructured it for efficiency.

Increased investment by companies in industrial sectors helped to offset some of the CVC decline. Some of these deals were large: The Chinese aluminium firm Shandong Weiqiao Pioneering Group invested USD 1 billion in the EV maker Rox Motor; the Chinese chemicals company Yibin Tianyuan Group participated in a USD 375 million round of funding for Libode New Material, a battery cathode start-up; and ArcelorMittal took part in a USD 120 million capital round for Boston Metal, a US iron electrolysis start-up.

Implications

Clean energy policies are fuelling innovation spending, but with high capital costs slowing progress for some technologies, maintaining momentum may require targeted measures

Several conclusions can be drawn from the 2023 trends presented in this chapter. First, governments are continuing to increase spending on R&D and demonstration projects in keeping with their pledges to cut emissions while maintaining economic growth. Second, policies that push the private sector to adopt low-emissions technologies are inducing more corporate R&D in the automotive and heavy industrial sectors. Third, the cost of capital matters most for early-stage and smaller companies, for whom the pool of available finance has shrunk since 2022.

It is encouraging for the prospects of addressing climate change that many governments are successfully expanding their budgets for clean energy R&D, despite competing shorter-term priorities for government funds. Grants for applied research and demonstration projects are essential for shepherding the next generation of energy technologies to market at lower cost. However, governments should also be concerned by the apparent loss of momentum in equity funding for clean energy start-ups, given the urgency of the challenge. While recent years have demonstrated that higher government ambitions and expectations for tackling climate change translate quickly into the founding of more innovative energy companies and a corresponding flow of VC capital, it has also revealed the volatility of this funding in a changing interest rate environment.

Compared with other segments, clean energy start-ups developing new hardware ideas require more capital and are often more reliant on large equity deals to pay for testing and manufacturing facilities. When access to this type of finance tightens, high-potential technologies risk being abandoned or delayed. However, governments can use tools such as non-dilutive project debt, equity or guarantees to accelerate the sector's transition to cheaper forms of capital for scale-up.

The VC data also shows some changes in the technology focus areas for investors, as revealed by their selectiveness in a more capital constrained environment. Funding for electric vehicle start-ups, for example, has noticeably declined. Despite continued growth in electric vehicle sales, these are capital-intensive firms and riskier bets when the world's largest car companies concentrate their resources on this sector. In comparison, VC investment continues to flow to newer areas with less dominant industrial players, including critical minerals, battery components, direct air capture of CO_2, ammonia production and renewable heat. These areas benefit strongly from the entry of new VC investors that have exclusive mandates to support climate mitigation technologies, including hardware for challenging areas like industrial heat.

Regionally, China is estimated to be the biggest spender on energy innovation. China drove the year-on-year growth in corporate R&D and, along with the United States, led the growth in public energy R&D. While the link between spending and innovation outcomes is unpredictable and not always direct, it is clear that China's increased spending on energy R&D over the past decade has borne fruit. China's presence is growing in the global market segments for high quality electric vehicles, batteries, heavy equipment for power plants and solar PV manufacturing. Each of these areas incorporates a higher share of Chinese domestic innovation than ten years ago.

The resulting competition within global markets for clean energy technologies is positive for consumers and for accelerating energy transitions. However, this good news is contingent on the free flow of knowledge to stimulate further innovation, and access to markets to encourage innovators to compete. Governments around the world face a challenge to balance the goal of raising the global pace of energy innovation with securing a return on their R&D investments in terms of domestic economic prosperity. The policy toolbox for addressing this challenge includes the prioritisation of technologies that are a good fit with existing local industries, measures to support effective innovation ecosystems and innovation related to maintaining the competitiveness of manufacturing processes and high added value products.

Except for VC fundraising, especially in India, clean energy innovation investment in EMDE did not noticeably grow in 2023 as a share of the global total. There is much that governments, multilateral institutions and philanthropists can do to support these countries to contribute actively to clean energy technology development. Domestic expertise and private-sector advocates can be instrumental in helping EMDE countries to advance their energy transitions and make technology choices that fit the local context. As an example of how more attention to this issue has led to creative solutions, in May 2023, the International Finance Corporation took a USD 20 million equity stake in Boston Metal – a start-up developing an early-stage technology for low-emissions steel production – which is contingent on construction of the company's first facility in Brazil.

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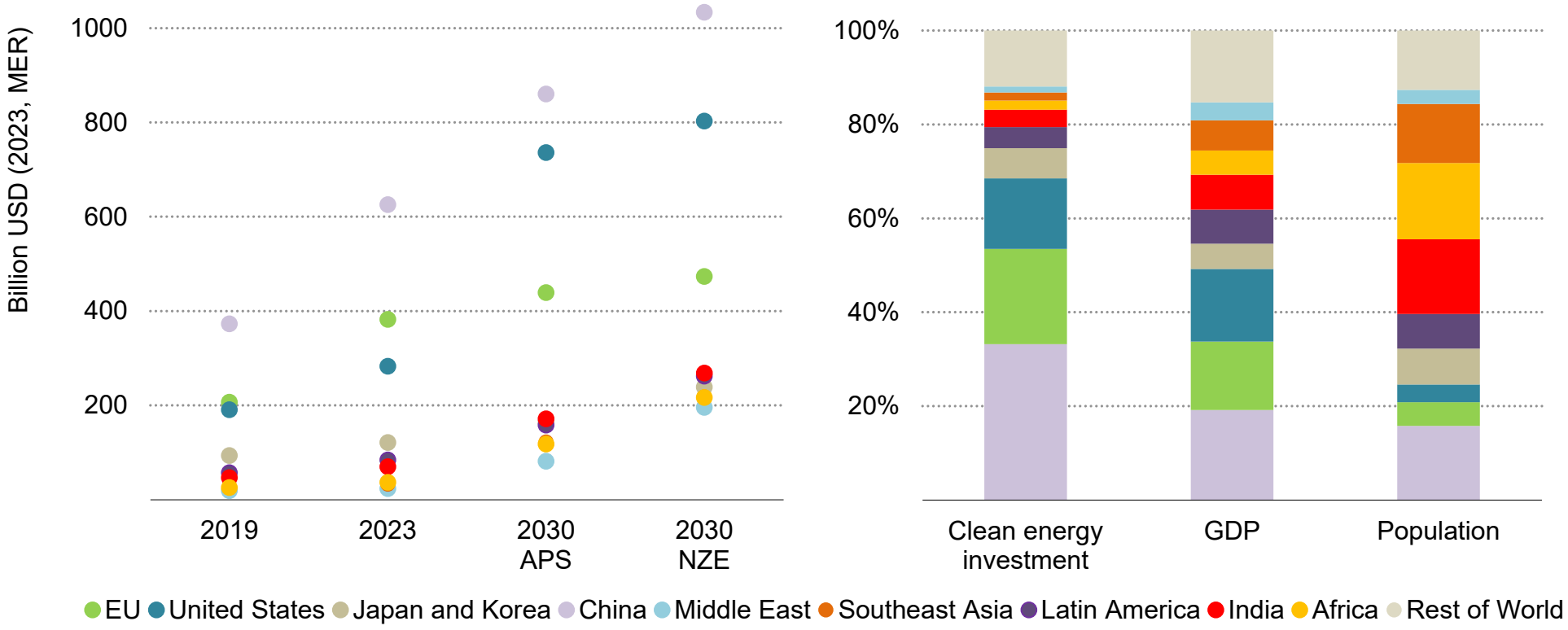
Regional deep dive

China, the European Union and the United States have taken the lead on clean energy investment, accounting for almost 60% of the current global spending on clean energy

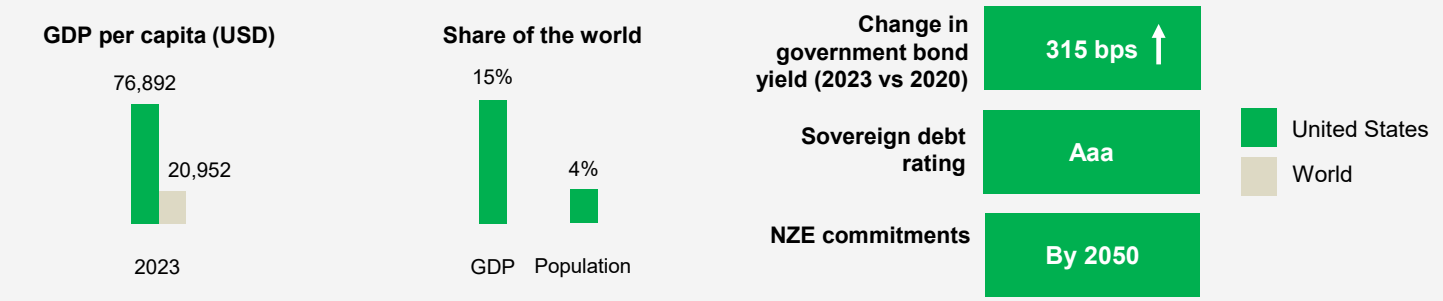
Shares of clean energy investment (left), GDP and population (right) by selected countries and regions



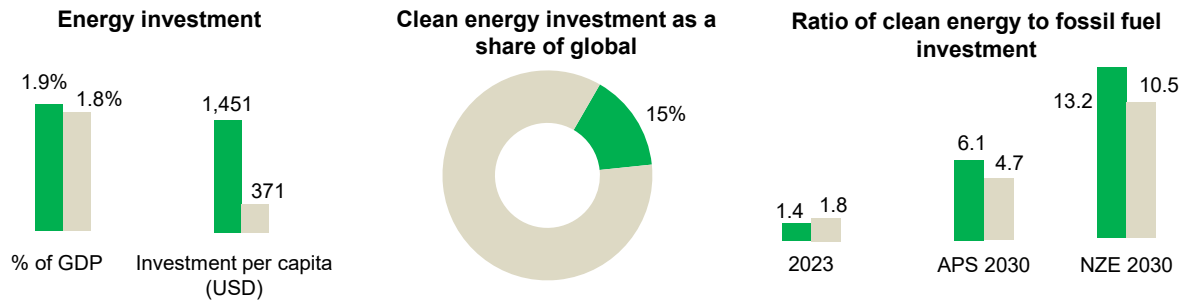
Note: RoW = rest of the world. EU = European Union. APS = Announced Pledges Scenario. NZE = Net Zero Emissions by 2050 Scenario.

United States

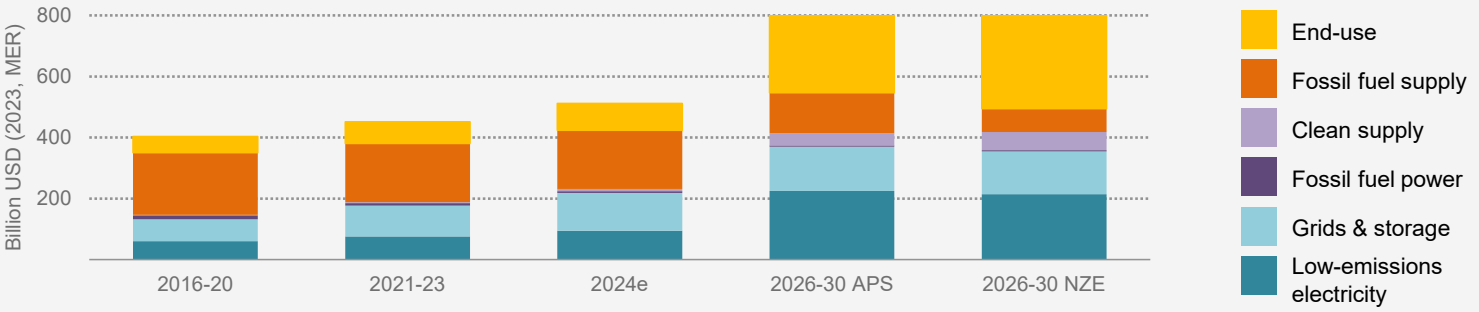
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Note: Sovereign yields of bonds in local currency. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods. For other definitions see the WEI Methodology Annex.

Source: Moody's credit ratings (Aaa is the highest rating), Refinitiv Eikon, World Development Indicators and IEA analysis.

The United States, the second largest economy in the world, accounts for 15% of global clean energy investment, and remains a major investor in oil and gas

The United States has taken important steps to scale up investments in clean energy. These investments overtook the spending that went to fossil fuels in 2020 – when oil and gas investments fell sharply – and increased to USD 280 billion in 2023 from USD 200 billion in 2020. The country also invests a significant amount in oil and gas: for every USD 1.4 spent on clean energy in 2023, US investors directed 1 USD to fossil fuels. (That is slightly below the global average of USD 1.8.)

New legislative vehicles supporting clean energy investment in the United States are the Bipartisan Infrastructure Investment and Jobs Act of 2021, which allocated around USD 550 billion for clean energy and infrastructure, and the US Inflation Reduction Act (IRA) of 2022, which provides an estimated USD 370 billion in funding to promote energy security and combat climate change.

These incentives are prompting faster deployment and the development of new clean energy manufacturing capacities. By the end of 2023, the Infrastructure Investment and Jobs Act allocated nearly USD 75 billion to clean energy, including projects related to grid improvement and expansion (USD 21.3 billion), clean energy demonstrations (USD 21.5 billion), energy efficiency (USD 6.5 billion) and clean energy manufacturing and workforce development (USD 8.6 billion). Meanwhile, tax credits from the IRA make clean energy projects in the United States more competitive and incentivise investment in vulnerable energy communities.

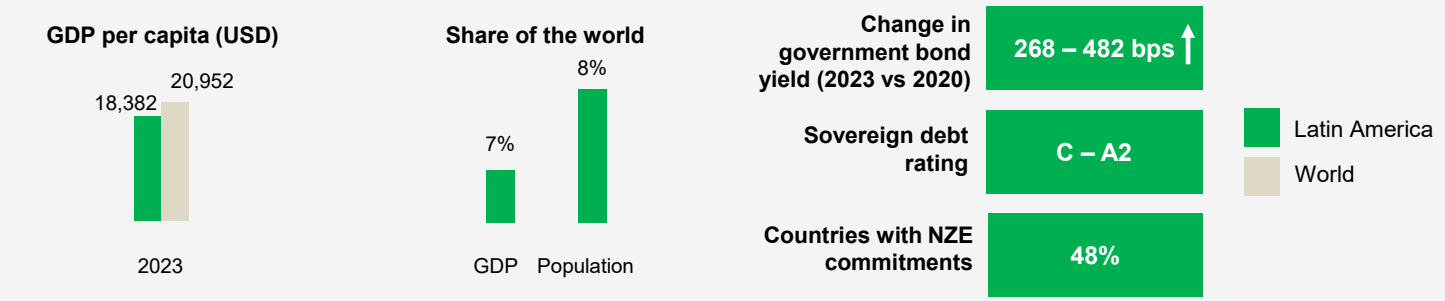
The increase in clean energy investment moves capital flows towards alignment with the long-term goal, announced in 2021, to achieve economy-wide net zero emissions by 2050. However, clean energy investors have faced some headwinds, including high financing costs due to higher benchmark interest rates (that reached over 5.0% since the summer of 2023). Permitting issues and the finalisation of tax credit guidance under the IRA have also meant delays in some cases.

The United States is the world's largest oil and gas producer, and its spending on fossil fuel supply – more than USD 200 billion – accounts for around 19% of the global total. The United States is home to around 40% of the wave of new LNG export capacity that is set to come to market in the second half of the decade. US spending on clean fuels is also on the rise, amid a surge of interest in opportunities for low-emissions hydrogen and CCUS.

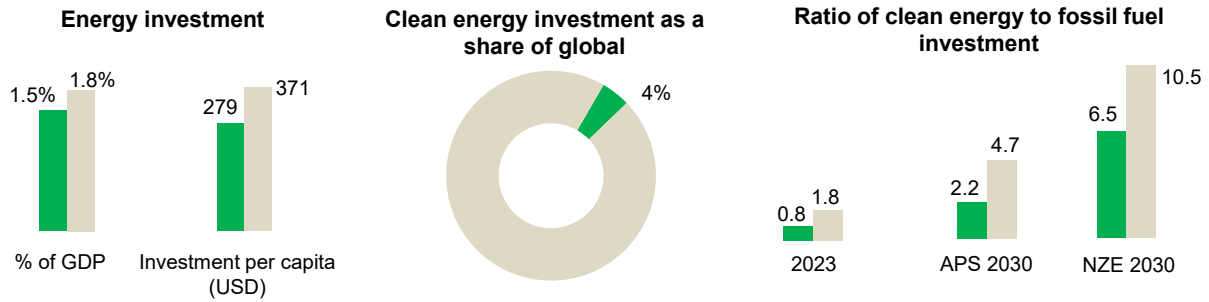
In the IEA's Announced Pledges Scenario (APS), lower demand for fossil fuels brings a significant reduction in upstream and midstream spending, while investments in low-emissions power double and in energy efficiency nearly triple by 2030.

Latin America and the Caribbean

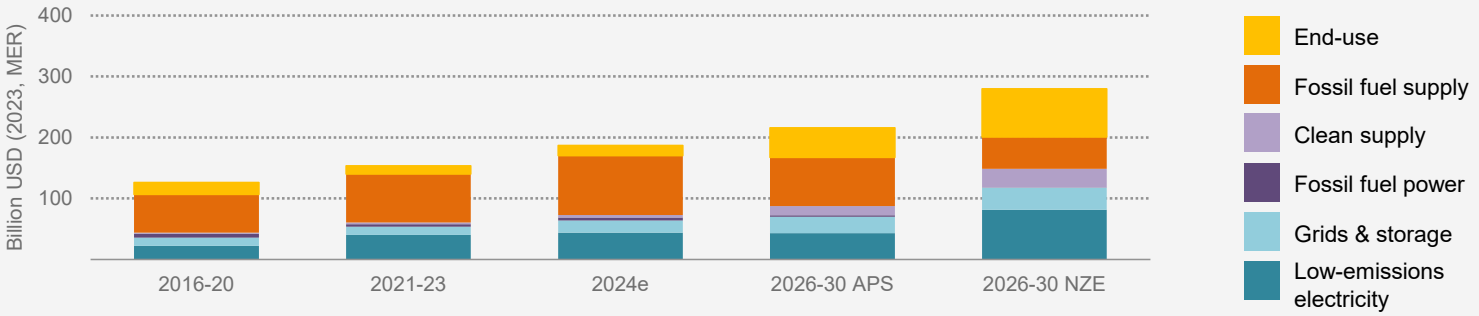
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Notes: Sovereign yields of bonds in local currency (range of Brazil and Mexico). bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods. Debt rating reflects the credit rating range for various countries in the region.

Source: Moody's credit ratings (only Aaa, Aa, A and Baa are considered investment grade), Refinitiv Eikon, World Development Indicators and IEA analysis.

Latin America has been a leader in clean energy but needs to step up investment to stay ahead

Latin America and the Caribbean (LAC), a diverse region of more than 30 countries, accounted for 7% of the world's GDP in 2023, while income per capita is slightly below the world average. LAC countries have generally been prone to high inflation, high debt and fiscal issues, although sovereign credit ratings vary from debt in default (Venezuela) to upper-medium grade (Chile). LAC had a period of slow growth the past decade, where the region's GDP expanded at about one-third of the average global pace. This partially explains why energy investment has been relatively low.

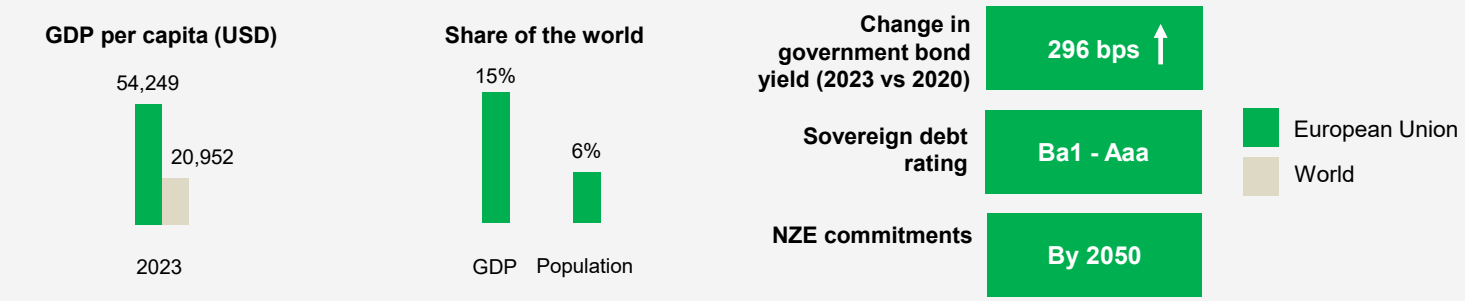
Fossil fuels represent two-thirds of the energy mix, well below the world average of 80%. The use of coal is quite low, but oil use – mainly for transport but also for industry – is relatively high, despite a share of biofuels in road transport that is twice the global average. The use of renewable energy has been central to LAC, where renewables represent a 60% share of the power mix (double the world average). LAC has a legacy of strong use of hydropower for electricity production, with many large dams built long ago. While its growth prospects are limited, hydro remains important for flexibility. There has been strong momentum for clean investments in parts of the region, and spending in fossil fuels has also risen in recent years. LAC's overall ratio of clean energy to fossil fuels investment just under half the 2023 global average.

Energy investment is set to reach USD 185 billion in 2024, a record high. The power sector accounts for over 35%, while fossil fuels supply represents almost 55% and end-use less than 10%. Renewables and storage continue their strong growth, with solar leading on deployment (including small-scale projects), investment in storage accelerating in Chile (to reduce transmission bottlenecks) and even offshore wind picking up in Brazil and Colombia. Many countries are also developing long-term hydrogen strategies and implementing pilot projects, especially in Brazil (where a 1.2GW plant obtained environmental permits in late 2023) and Chile. Investment in the end-use sectors is low: Less than a third of LAC countries have minimum energy performance standards for industrial motors or household appliances, for example, and few have implemented mandatory building codes.

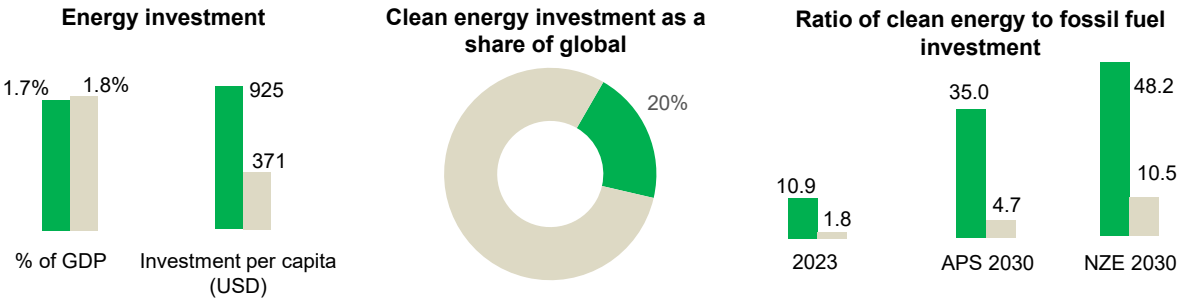
Almost half of the 33 LAC countries pledged to reach net zero emissions by 2050, including Brazil, Chile, Costa Rica and Colombia. Average annual clean energy investment over the 2026-2030 period needs to increase four-fold compared to the preceding decade in order to get on track for these goals, which would result in fossil fuel consumption peaking this decade. Efforts to reduce the cost of capital will be critical, and will require improving the economic proposition for clean investments while also reducing macroeconomic risks.

European Union

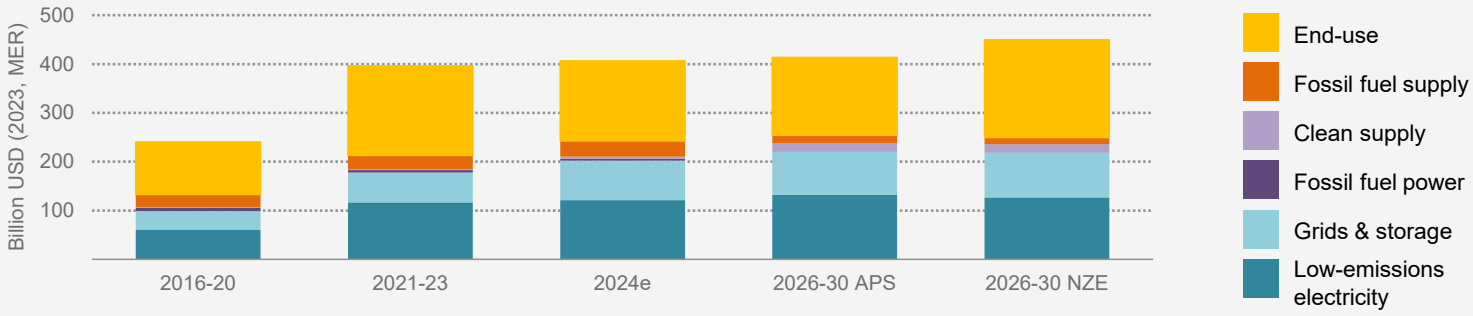
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Note: Sovereign yields of bonds in local currency, for Eurozone. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods. Debt rating reflects the credit rating range for various countries in the region.

Source: Moody's credit ratings (Aaa is the highest rating, and only Aaa, Aa, A and Baa are considered investment grade), Refinitiv Eikon, World Development Indicators and IEA analysis.

Clean energy investment in the European Union has risen as governments respond to the global energy crisis and the cut in Russian gas supplies

The European Union (EU) is one of the leading regions for clean energy deployment and policy momentum has intensified in many countries, and at EU level, due to the global energy crisis that followed Russia's invasion of Ukraine and its subsequent cut in gas deliveries. In large part because of its reliance on imported fuels, the European Union stands out as one of the regions that has the highest clean energy to fossil fuels investment ratios: it spends more than USD 10 on clean energy for every USD 1 invested in fossil fuels.

In 2023, investment in renewables generation totalled almost USD 110 billion, an increase of more than 6% from the previous year. Although the cost of capital for renewables has seen a slight rise due to supply chain and inflation pressures, renewable investments remain very cost-competitive. Denmark and Germany remain at the forefront of the wind power sector in Europe, despite ongoing profitability challenges. Spain has led the surge in solar adoption and has seen wholesale electricity prices fall to record lows during periods of high solar output – bringing some benefits for consumers but also a warning sign for some investor revenue streams and the prospects for future investment.

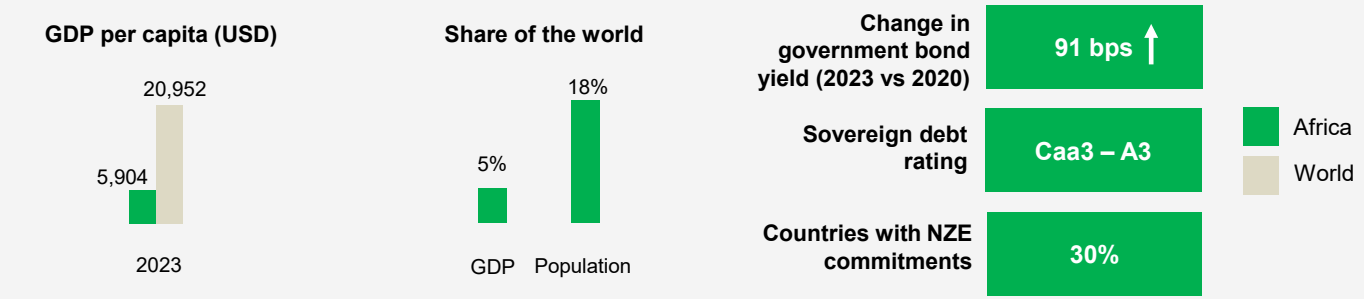
A good balance of investment across generation, grids, storage and demand-side flexibility is key. Investment in power grids rose by more than 20% in 2023, nearly reaching USD 65 billion, a very positive development that reflects the need for more grid interconnection, especially to facilitate power flows to central European markets.

Meanwhile, there was also ongoing growth in oil and gas investments, which reached over USD 30 billion in 2023. Investment in liquified natural gas (LNG) reached nearly 7 billion, while Europe added more than 50 bcm/year of extra LNG import capacity to switch away from Russian gas, mainly via Floating Storage Regasification Units (FSRUs). The Netherlands, Italy, Finland, Greece and Germany have all acquired or leased FSRUs.

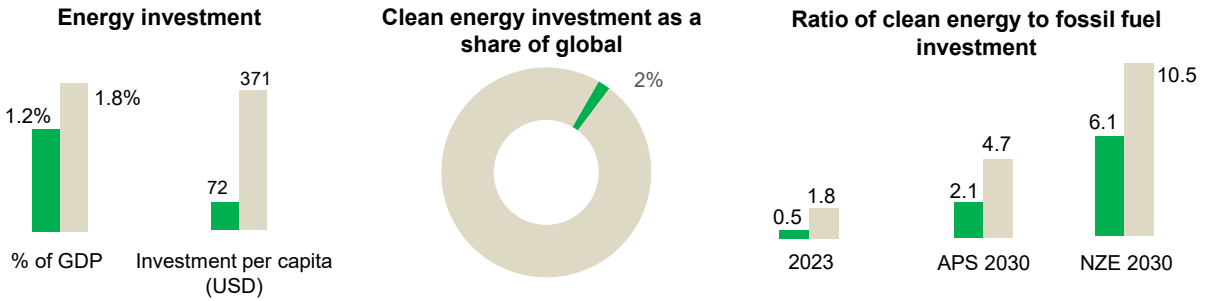
The European Union has set a target to reduce net greenhouse gas emissions by at least 55% by 2030, relative to 1990 levels, and to reach climate neutrality by mid-century. Alongside a range of policies and targets focused on increased deployment of renewables and energy efficiency, there is also a focus on the diversity and resilience of clean energy supply chains, both for manufacturing and for critical minerals. The European Commission adopted the Net Zero Industry Act in June 2024, to bolster the manufacturing of clean technologies, with the objective of meeting 40% of the EU's deployment needs by 2030 and reducing today's reliance on imports. Overall clean energy investment trends are broadly aligned with the EU's energy and climate goals.

Africa

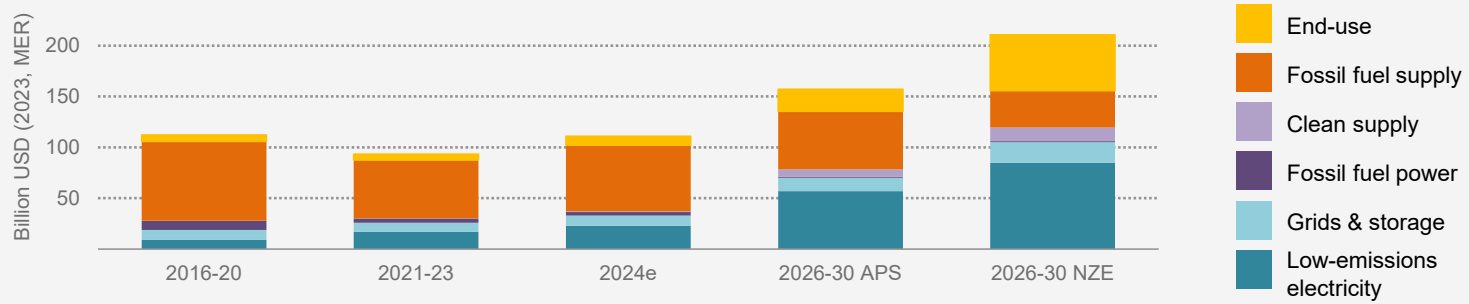
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Notes: Africa includes North Africa and sub-Saharan Africa. Sovereign yields of bonds in local currency show the change for South Africa. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods. Debt ratings reflect the credit rating range for various countries in the region.

Source: Moody's credit ratings (only Aaa, Aa, A and Baa are considered investment grade), Refinitiv Eikon, World Development Indicators and IEA analysis.

Burdened by significant debt repayments, financing for clean energy projects is scarce as the need for concessional support becomes increasingly evident

Achieving Africa's energy- and climate-related goals by 2030 will require annual investments of over USD 200 billion through the end of this decade. This will be vital to meet the growing energy needs of a continent where the median age of the population is 20 years and average GDP per capita is just over one-fourth of the global average.

Our tracking of energy spending suggests that around USD 110 billion is set to be invested in energy across Africa in 2024, of which nearly USD 70 billion to fossil fuel supply and power, with the remainder going to a range of clean energy technologies. Spending trends vary widely across Africa, but neither the total amount nor the proportion spent on clean energy are enough to put the continent on track to reach its sustainable development goals. As they stand, energy investments are equivalent to only 1.2% of the region's GDP and clean energy investments, while rising, account for just 2% of the global total.

Debt repayments, which have increased sharply in recent years, mean that many African governments have difficulty accessing the funds required for capital-intensive clean energy projects. Moreover, low sovereign debt ratings further limit access to outside investment – in 2023, only two countries, Botswana and Mauritius, held investment-grade ratings.

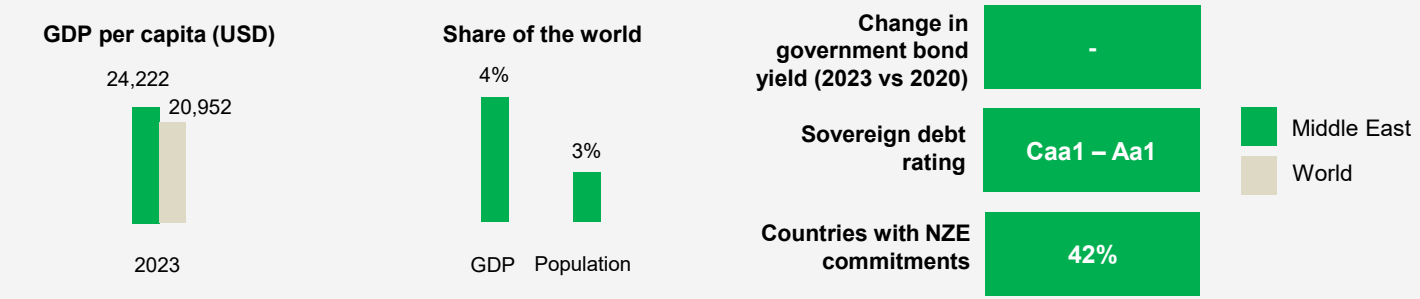
Of the clean energy investments that have recently been made, the majority are in renewable power generation. While these projects are vital to meet Africa's rising electricity needs in a sustainable way, the prospects for further growth will be limited as long as the grid itself is not upgraded and expanded. With average line losses of 15%, inefficient grids and insufficient interconnections are already creating bottlenecks for new renewable energy projects in the region.

Energy access is among the top priorities in Africa, where 600 million people live without electricity and roughly 1 billion people lack access to clean cooking. Financing needs for energy access initiatives fall well short of the annual USD 25 billion that is required to achieve the 2030 objectives of full access to modern energy. Progress in this area will require concessional finance providers to mobilise grants for the most vulnerable households and support the creation of bankable projects. The provision of other de-risking capital will also be critical to allow the private sector to take a more active role.

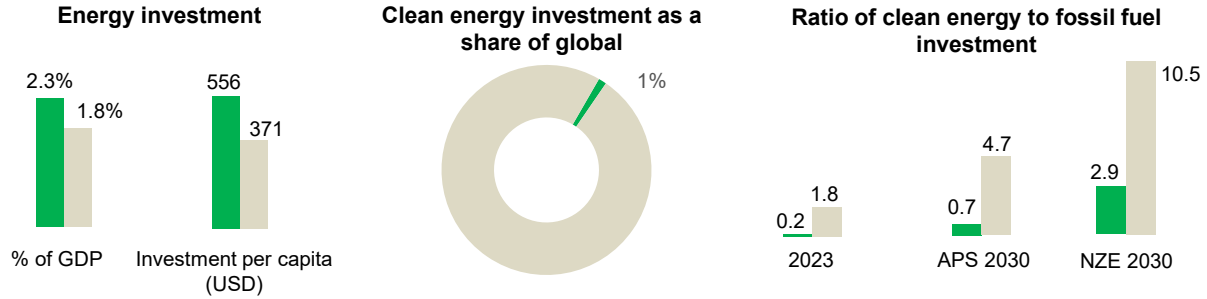
A high cost of capital is a major impediment to scaling up clean energy investments in Africa. Reducing country-wide and project-specific risks will require a major effort from national policymakers, based on clear strategies and ambitious NDCs, alongside significantly more international financial and technical support.

Middle East

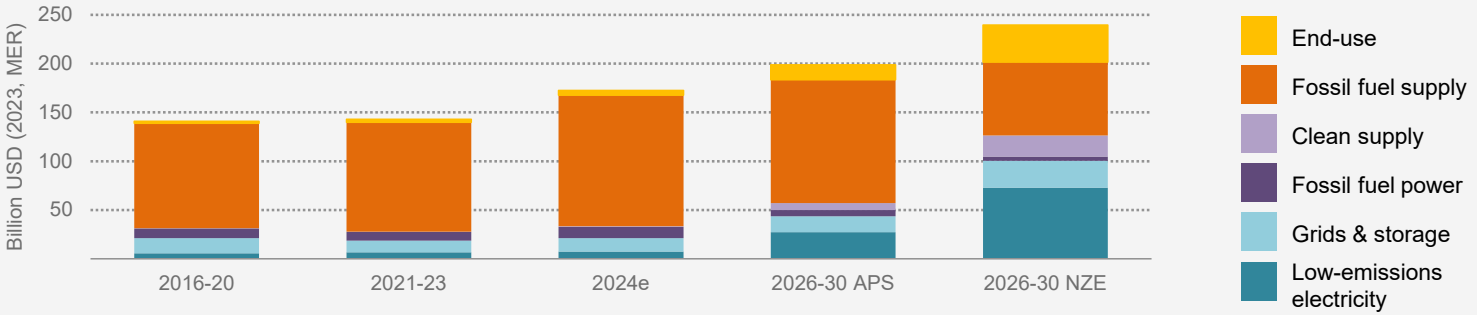
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Notes: Sovereign yields of bonds not available. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods. Debt ratings reflect the credit rating range for various countries in the region.

Source: Moody's credit ratings (only Aaa, Aa, A and Baa are considered investment grade), Refinitiv Eikon, World Development Indicators and IEA analysis.

Clean energy investment in the Middle East is rising, but it remains dominated by the region's traditional role as a supplier of oil and gas

The Middle East is home to five of the world's top oil producers: Saudi Arabia, Iraq, the United Arab Emirates (UAE), Iran, and Kuwait. Moreover, it plays a significant role as a producer of natural gas, with three of the world's top ten producers being Iran, Qatar, and the UAE. For the moment, spending on fossil fuel supply predominates: for every 1 USD invested in fossil fuels, only 20 cents are allocated to clean energy investment, which represents approximately one-tenth of the average global ratio of clean energy to fossil fuel investment.

There are wide disparities in per capita income and energy consumption levels across the region. For example, countries like Saudi Arabia, the UAE and Kuwait are situated at the higher end of income and energy consumption, while Yemen and Syria are positioned at the lower end. Sovereign credit ratings also vary significantly. Saudi Arabia, Kuwait, Qatar, and the UAE hold high ratings, while Jordan, Oman, and Bahrain fall into the medium-grade category. Conversely, Iraq and Lebanon have very low ratings.

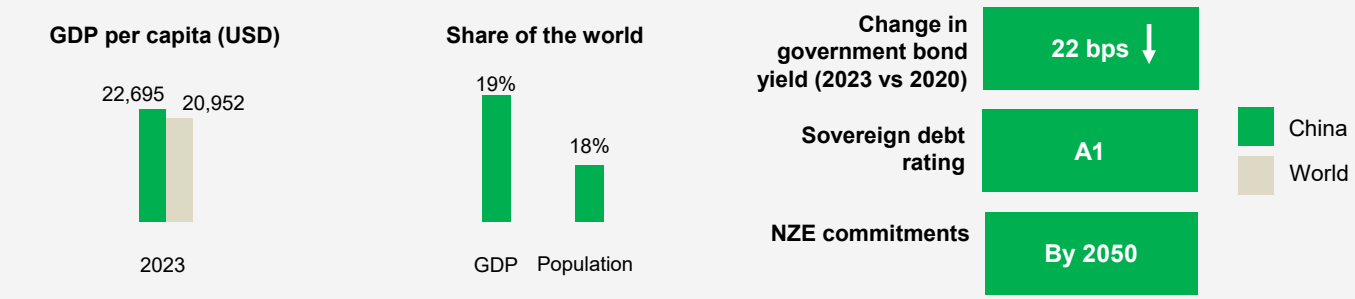
Energy investment in the Middle East is expected to reach approximately USD 175 billion in 2024, with clean energy accounting for around 15% of the total investment. In the APS by 2030, clean energy investment more than triples compared with 2024. As a result, by the end of the decade, every 1 USD invested in fossil fuels in this scenario would be matched by 70 cents going to clean energy.

Five of the twelve countries in the region have set net zero emission targets. The UAE and Oman have set targets to achieve net zero emissions by 2050, while Saudi Arabia, Bahrain, and Kuwait have announced a target for 2060. Additionally, the UAE has committed to reducing emissions by 19% by 2030 from 2019 levels, and it also pledged USD 30 billion in catalytic capital to launch a climate-focused investment initiative at COP28.

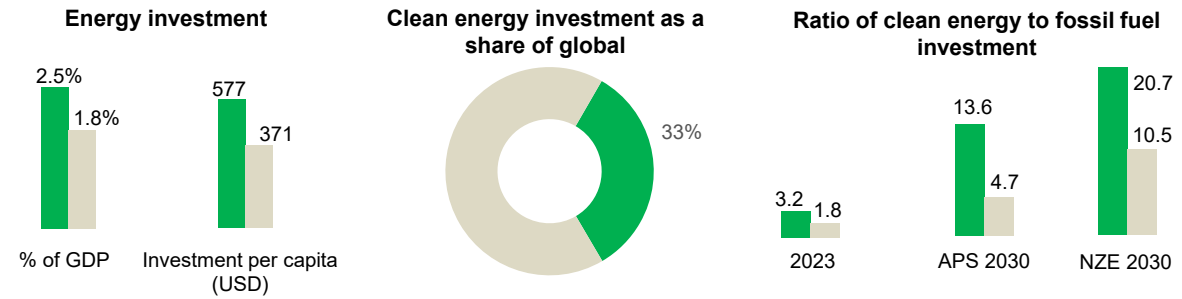
The region's power sector holds a distinct opportunity for increasing investment in clean energy technologies, notably for solar PV. Harnessing these resources could substantially decrease reliance on both oil and gas in the power sector. Saudi Arabia, for example, is targeting 130 GW of renewable capacity by 2030, up from less than 5 GW today. Projects including the large Al Shuaibah solar plant in Saudi Arabia and the Mohammed bin Rashid Al Maktoum solar park in UAE are underway. Various countries have also announced blue and green hydrogen investments, as well as intensifying investments in critical minerals. Saudi Arabia, for instance, has established a USD 182 million mineral exploration incentive program. Similarly, the UAE is expanding its efforts to establish a presence in the sector, including through a USD 1.9 billion mining partnership in the Democratic Republic of the Congo and securing new agreements in copper-rich Zambia.

China

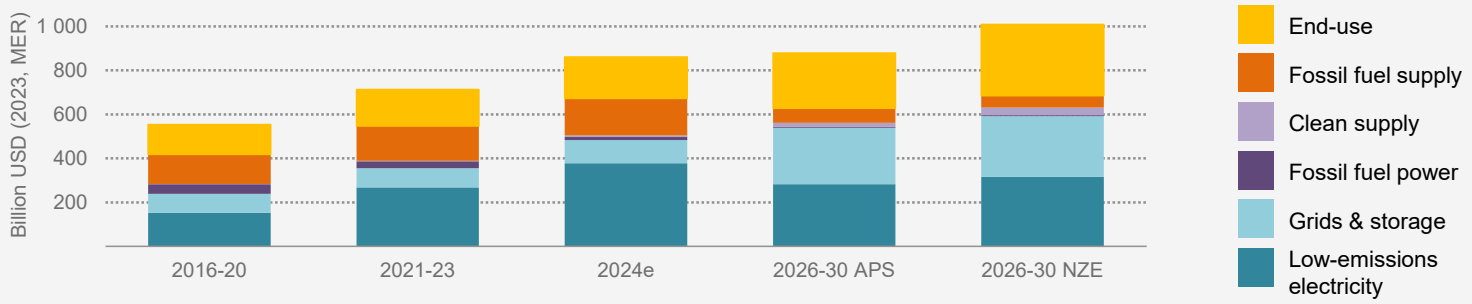
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Note: Sovereign bond yields in local currency. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods.

Source: Moody's credit ratings (A1 is investment grade), Refinitiv Eikon, World Development Indicators and IEA analysis.

China is a clean energy powerhouse, although energy security concerns continue to fuel approvals of new coal-fired power plants

China accounted for 19% of global GDP in 2023 and its annual economic growth rate of 5.2% narrowly exceeded the government's annual target. Despite initial signs that the recovery would be swift, China's economy continues to face some challenges, notably with a troubled property market. Yields on Chinese sovereign bonds have been declining steadily since 2021 and reached a record low in March 2024.The People's Bank of China, as well as other state-owned commercial banks, have continued to lower their interest rates, in contrast to the upward trend in most other major economies.

Chinese investments in energy remained extremely strong, accounting for one-third of clean energy investments worldwide and an important share of China's overall GDP growth. China has announced dual carbon goals – to peak carbon emissions before 2030 and achieve carbon neutrality before 2060 – and has shown remarkable progress in adding renewable capacity. In 2023, China commissioned as much solar PV as the entire world did in 2022 while its wind additions also grew by 66% year-on-year. Over the past five years, China also added 11 GW of nuclear power, by far the largest of any country in the world.

The year 2023 saw robust growth for the so-called "new three" (*xin-sanyang*) industries – solar cells, lithium batteries and electric vehicles (EV) – which saw a 30% jump in exports in 2023 from a year earlier, making them a major factor in Chinese trade. These trends are expected to continue into 2024, with the largest portion of China's investments heading towards low-emission power.

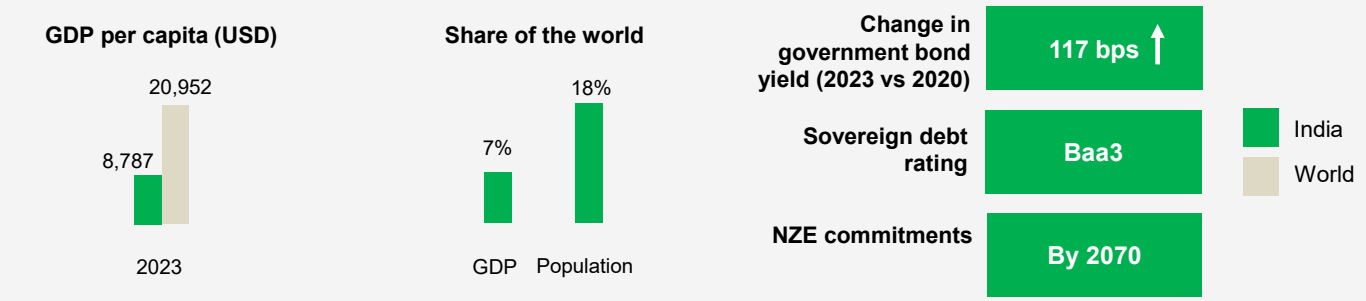
Ample domestic manufacturing capacity and continued government support for clean technologies provides a foundation for strong clean energy investment within China. However, pressures are increasing on China's ability to export these technologies to other large international markets, including Europe and the United States.

Another issue that requires close attention is China's continued investment in fossil fuels, especially coal with nearly all the new global coal-fired capacity. In tandem with its growing renewable capacity, coal still remains the most prominent fuel source in China's energy mix, with coal production reaching a record high in 2023. While China aims to ensure that coal and coal-fired power will play a supporting role in its energy system, these developments reflect a strong emphasis on energy security in China's energy strategy.

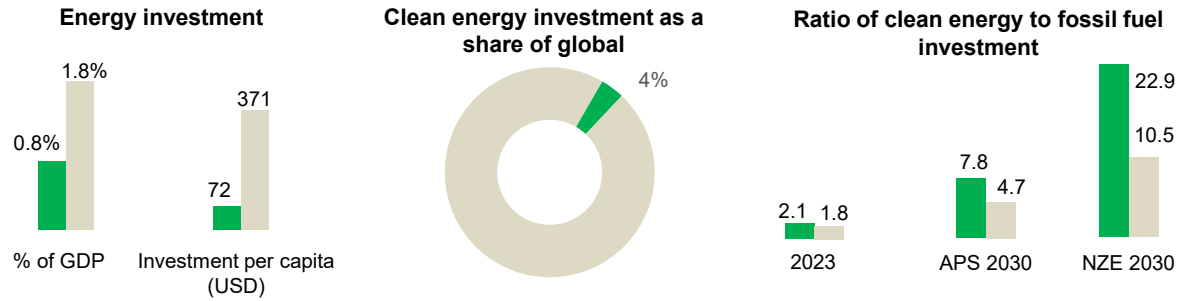
Overall energy investment levels in China are comparable to the amounts required to meet national energy and climate goals, although full alignment with the targets implies a rebalancing away from investments in fossil fuel supply, towards grids and the end-use sectors.

India

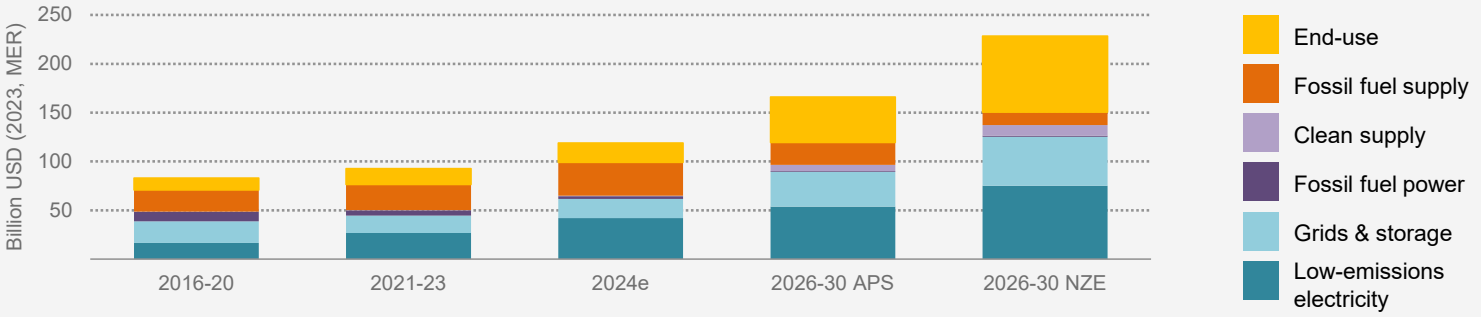
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Note: Sovereign bond yields in local currency. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods.

Source: Moody's credit ratings (only Aaa, Aa, A and Baa are considered investment grade), Refinitiv Eikon, World Development Indicators and IEA analysis.

India's clean energy investments have grown fast in the past three years in response to ambitious clean energy targets

With a GDP growth rate of 7.8%, India was the world's fastest growing major economy in 2023. Its economy is now the world's fifth largest, and is on track to become the third largest by 2030 behind the United States and China. However, per capita income is less than half of the world average, and India's development priorities remain focused on poverty alleviation, job growth and infrastructure creation.

As a result of its GDP growth potential, urbanisation, growth in built spaces, and the increased demand for electricity as well as materials such as cement and steel, energy demand growth in India is on track to outpace all other regions of the world by 2050. This could put strains on its energy system, which for the moment relies heavily on imported fossil fuels, especially crude oil and natural gas. In tandem with this sharp rise in energy demand, carbon emissions in India could increase significantly over this period due to a growth in fossil fuel use for transport, power generation and industry.

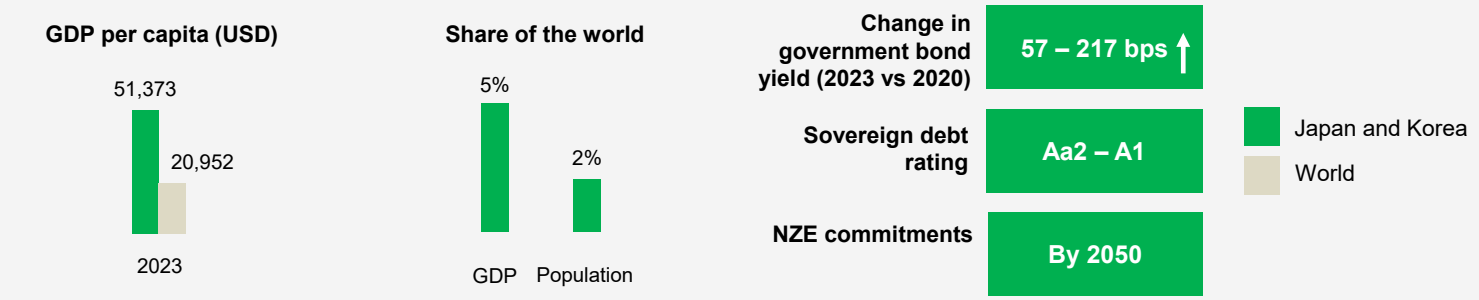
To address these challenges, India has been pursuing a range of decarbonisation and diversification strategies. Most notably, India has a set a target for reaching net zero emissions by 2070. In recent years, India has scaled up solar and wind power investments and also announced measures to promote domestic clean energy supply chains. In 2020, India announced the Production Linked Incentives scheme to set up domestic manufacturing of solar modules, batteries and other clean energy equipment. India also has a long-standing energy efficiency programme in place, as well as a new hydrogen policy that envisions domestic manufacturing of electrolysers and the production of low-carbon hydrogen.

India made its debut in the sovereign green bond market in January 2023. Two tranches of bonds valued at USD 1 billion (INR 80 billion) were marketed primarily to local investors. The issue of bonds – whose proceeds were destined to support renewables, metro rail lines, and low-carbon hydrogen production – was more than four times oversubscribed.

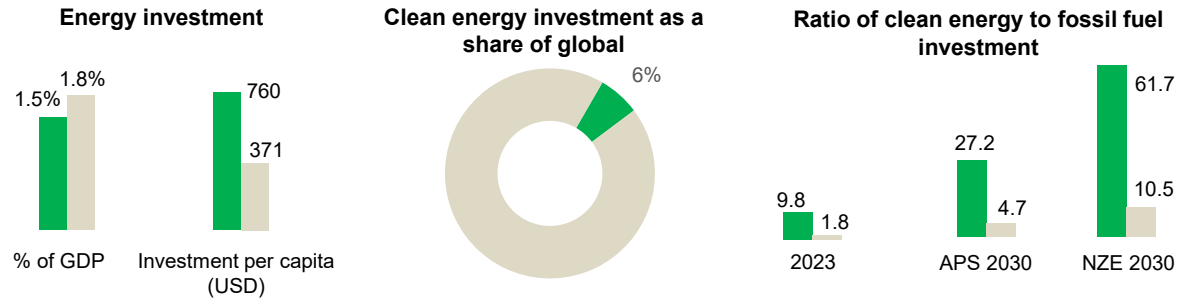
Such initiatives have led to a surge in Indian clean energy investment in recent years. Spending reached USD 68 billion in 2023, up by nearly 40% from the 2016-2020 average. Almost half of this was devoted to low-emissions power generation, which includes solar PV. Fossil fuel investment grew by 6% over the same period to reach USD 33 billion in 2023, in response to rising demand for fuel and coal-fired power generation. Clean energy investment is on track to double by 2030 under today's policy settings, but would need to rise by a further 20% to get fully on track for the country's energy and climate goals. Addressing risks that push up the cost of capital will be critical in this endeavour.

Japan and Korea

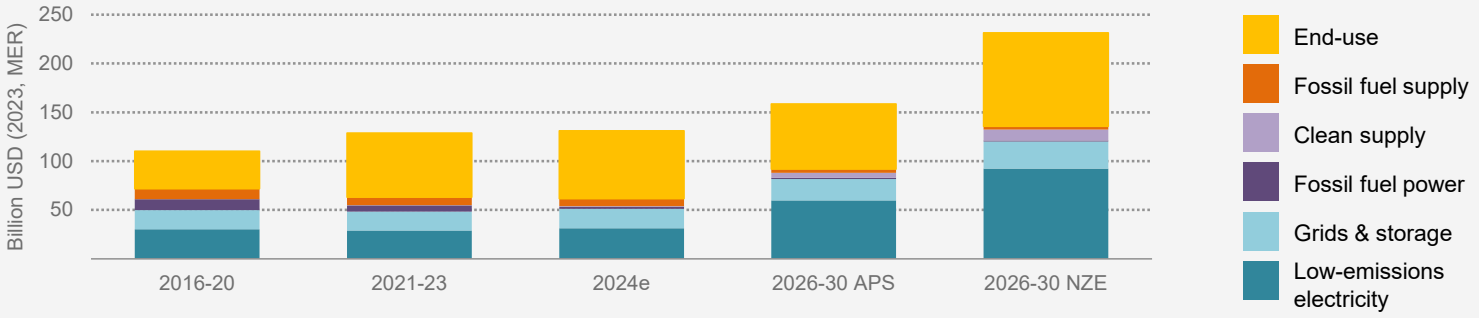
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Note: Sovereign bond yields in local currency show the change for Korea. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods.

Source: Moody's credit ratings (A and Aa are investment grade ratings), Refinitiv Eikon, World Development Indicators and IEA analysis.

Japan and Korea have made important steps to expand clean energy investments

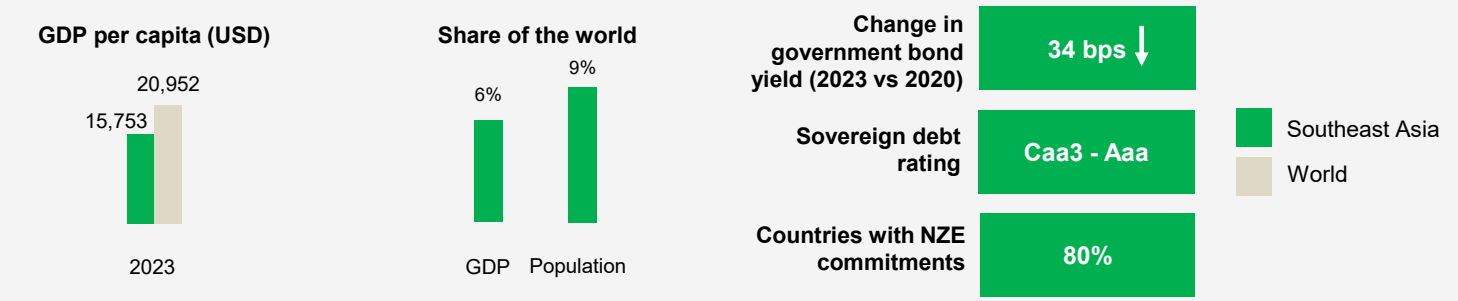
Japan and Korea are two of the most developed economies in the Asian region, accounting for 5% of global GDP, with a per capita GDP of approximately 2.5 times the global average. Energy investment represents 1.5% of GDP, and clean energy investment per dollar of fossil fuel investment is 9.8 – over five times the global average. This reflects recent growth in clean energy investment as well as the fact that both Japan and Korea import almost all of their fossil fuels. From 2021 to 2023, average annual clean energy investment in Japan and Korea increased by around 40% and 10%, respectively, compared with the 2016-2020 average. Both countries have announced targets to reach carbon neutrality in 2050 and in our Announced Pledges Scenario (APS), the countries increase their clean energy investment by a further 27% by the end of the decade to align with these goals. This expands investment in low-emission power sources, as well as in the decarbonisation of heavy industry and transport.

Both countries are pursuing policies to promote investments in energy transitions. Japan has clarified investment policies and industry-specific roadmaps for its energy transition under the Basic Policy for the Realization of GX. Multiple plans (such as the Basic Hydrogen Strategy and the CCS Long Term Roadmap) have been developed to support innovation and increase investment in the deployment of a range of decarbonisation technologies. Japan is introducing carbon pricing and setting incentives for companies to accelerate investments in decarbonisation by announcing plans to increase carbon prices in the future.

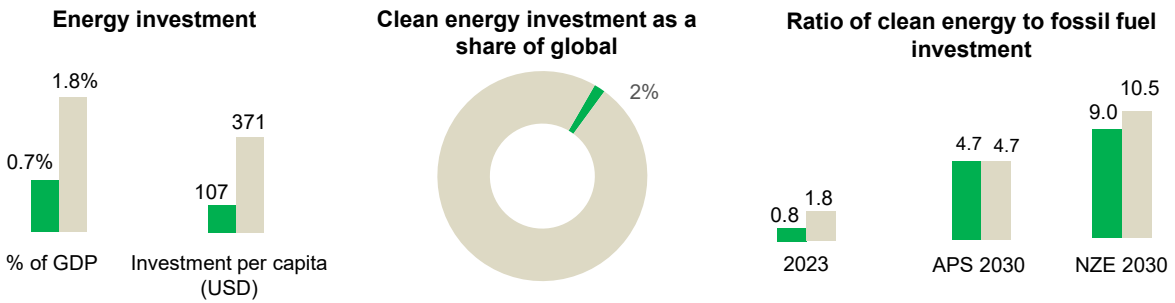
Korea's drive for energy security and its transition to clean energy sources have spurred substantial investments in recent years. With its first National Basic Plan for Carbon Neutrality and Green Growth announced in 2023 (in line with its pledge to achieve carbon neutrality by 2050) Korea plans to significantly increase power generation from renewable energy sources as well as nuclear power, develop core green technologies and nurture new green industries through policy and private financing support, alongside improvements to relevant systems. Commitments to boost carbon neutrality policies are backed by enhanced financial support, such as climate response funds to mobilise private investment. Korea also aims to refine its emission trading systems (ETS) and introduce emissions permit trading. International export and co-operation are also seen as key pillars of Korea's plan to help finance the energy transition, targeting the industrialisation of nuclear exports, as well as the EV, renewable energy, hydrogen and CCUS industries. Additionally, Korea has pledged to raise the amount of its development assistance devoted to climate and global energy transitions to OECD average levels by 2025.

Southeast Asia

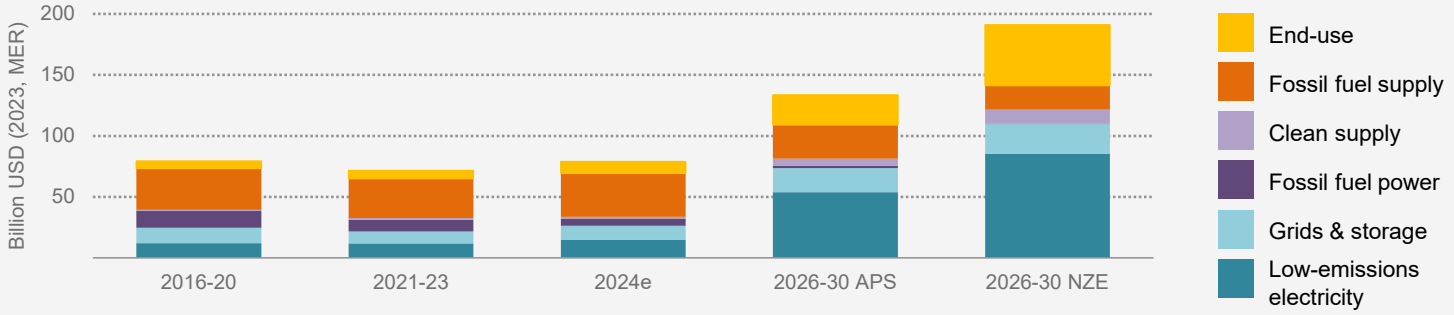
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Note: Sovereign bond yields in local currency reflect the range of change of Indonesia. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods. Debt rating reflects the credit rating range for various countries in the region.

Source: Moody's credit ratings, Refinitiv Eikon, World Development Indicators and IEA analysis.

Most countries in Southeast Asia now have ambitious long-term clean energy goals, but investments are not yet on track

Southeast Asia accounts for 9% of the world's population, 6% of the world's GDP and 4% of world energy consumption. The region's population is expected to grow to nearly 800 million by 2050; together with continued economic growth this will have strong implications for energy demand. Investment will determine how this rising demand is met, with implications for security, affordability and alignment with sustainability goals. Eight out of 10 countries in the region have announced target dates of carbon neutrality: Singapore, Malaysia and four others in 2050; Indonesia in 2060; and Thailand in 2065.

For the moment, there are significant gaps between investment trends and the region's long-term goals. Southeast Asia's spending on clean energy represents only about 2% of the global total. Annual average energy investment over the last three years was USD 72 billion, but would need to increase to over USD 130 billion to align with the APS by the end of the decade. There would also need to be a shift in the allocation of investment towards cleaner technologies: clean power would be the largest share of investment – nearly 40%.

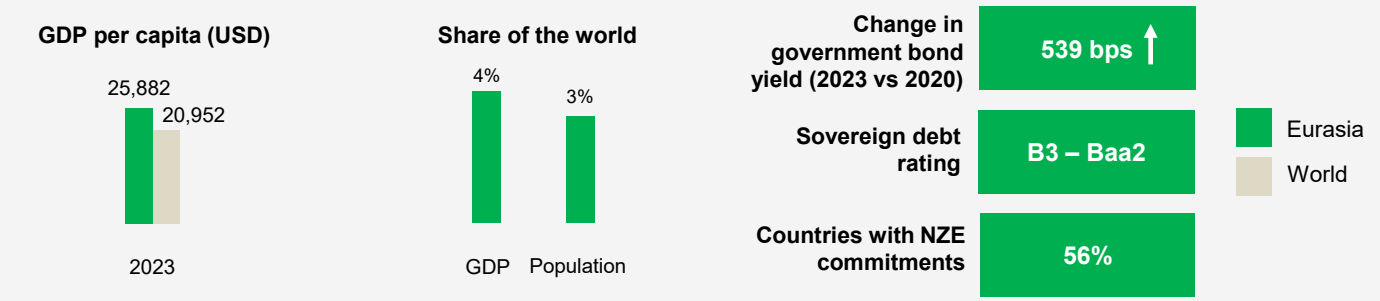
Some countries are signalling a shift in priorities. Viet Nam, for instance, approved its 8th Power Development Plan in 2024, which seeks to reshape its energy system, including extensive development of renewable technologies as well as the use of low-emissions hydrogen and ammonia and a reduction in reliance on unabated coal. However, the implementation plan is not yet fully clear and over 10 GW of new coal-fired capacity remains in the pipeline.

Updated expansion plans for low-emissions power and infrastructure, and changes in power purchasing agreements, are an important signal to investors. However, uncertainties remain in many countries over remuneration mechanisms for renewable output, which continue to affect risk perceptions and the cost of capital.

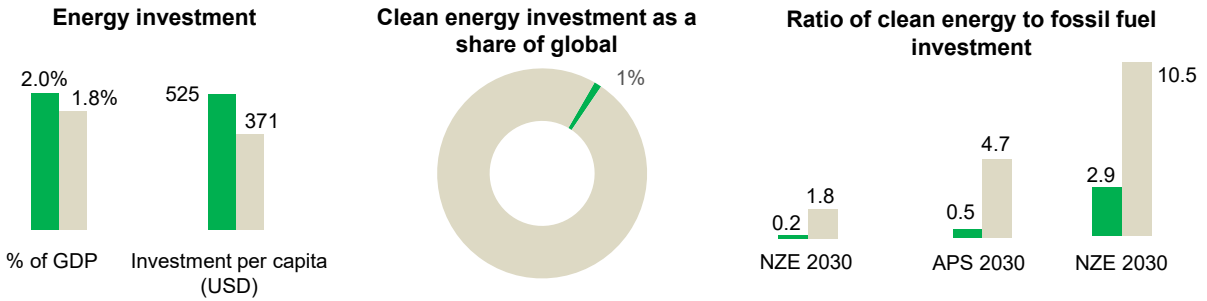
International development finance and support is crucial to Southeast Asia's energy transitions. The Just Energy Transition Partnerships (JETPs) launched in 2021 in Indonesia and Viet Nam provide a framework to mobilise capital for investments in clean energy and support the phasing out of coal-fired power generation. The release of the Indonesia Comprehensive Investment and Policy Plan in November 2023 was an important milestone for the JETP and is expected to mobilise USD 97 billion in power sector investments in Indonesia. The Asia Zero Emission Community initiative by Japan provides financial support of up to USD 8 billion to 2030 for energy projects in participating countries: Indonesia, Philippines, Thailand and Viet Nam. The ASEAN Taxonomy and ASEAN Transition Finance Guidance provide a valuable framework for the financial industry to improve credibility and transparency to capital providers.

Eurasia

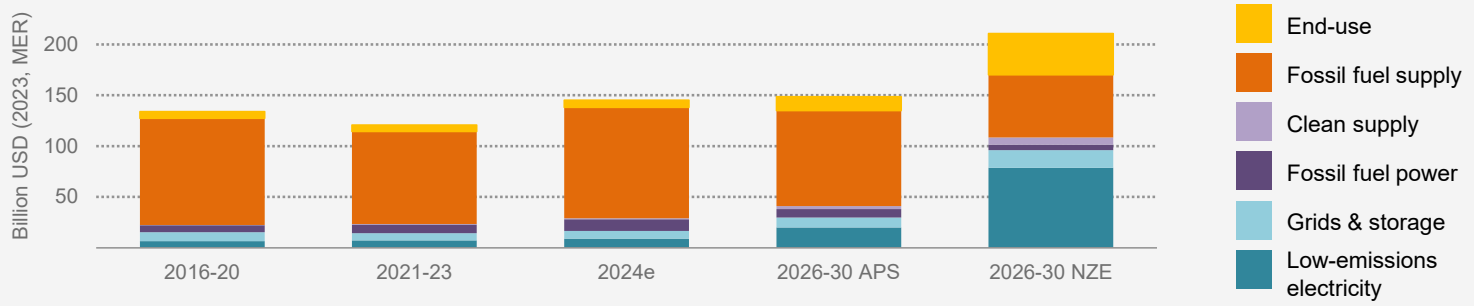
Economic and financial indicators



Energy investment indicators



Energy investment trends and amounts required to align with energy & climate goals



Note: Sovereign bond yields in local currency, reflecting the range of Russia. bps = basis points. 2016-20 investment reflects annual averages over the five years between 2026 and 2020, similar with other periods.

Source: Moody's credit ratings (only Aaa, Aa, A and Baa are considered investment grade), Refinitiv Eikon, World Development Indicators and IEA analysis.

Eurasia navigates a complex energy landscape, characterised by heavy reliance on fossil fuels, and an urgent need to ramp up investments in clean energy

Eurasia is a heterogeneous region in energy terms, containing major fossil fuel producers and exporters, as well as countries like Georgia, Tajikistan, and Kyrgyzstan that obtain around 85% of their electricity from hydro sources. The overall share of natural gas in the energy mix is one of the highest in the world, but gas infrastructure is ageing and often poorly maintained.

The region has been hit hard by energy instability in recent years. Ukraine's energy infrastructure has been targeted by Russian forces following the 2022 invasion. High prices have had widespread impacts on energy-importing countries and traditional energy relationships between countries have been shaken.

Levels of energy investment in Eurasia have stalled in recent years at around USD 110 and USD 120 billion per year, with around 80% of this going to fossil fuels. At around USD 20 billion, annual clean energy spending in the region is far below its potential, the result of significant obstacles that include pervasive fossil fuel subsidies and policy frameworks that are generally weak and unclear.

The global energy crisis has prompted rising interest in the potential for clean energy. Azerbaijan's hosting of the COP29 summit in 2024 presents an opportunity to give new momentum to energy transitions through efforts to scale up clean power and to reduce emissions from fossil fuels. Five countries in the region have set net zero targets: Armenia ,Georgia and the Kyrgyz Republic aim to achieve net zero emissions by 2050. Russia and Kazakhstan have set a target of 2060. Except for Russia, all countries in the region have signed the Global Methane Pledge.

Getting on track to achieve these commitments requires a steady increase in energy investment. In the APS, energy investment is projected to reach around USD 145 billion by 2030, with the share of clean energy investment reaching more than one third.

The oil and gas investment picture is subject to a high degree of uncertainty. Russia is looking to compensate for the loss of European markets by seeking out new markets in China and South Asia. This has largely succeeded for oil but putting in place new export infrastructure for gas has proved to be much more difficult. Russia has stepped up its bilateral agreements with Eurasian countries, however, including plans for fossil fuel and nuclear plant projects. In 2023, Russia signed an agreement with Kyrgyzstan for the construction of a new coal-fired plant (660 MW). As part of its push to open up new markets, Russia has also been seeking oil and gas supply and transit arrangements with Central Asia.

Annex

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Abbreviations and acronyms

ADNOC	Abu Dhabi National Oil Company
APS	Announced Pledges Scenario
CCGT	Combined-Cycle Gas Turbine
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization and Storage
CO2	Carbon Dioxide
CVC	Corporate Venture Capital
DAC	Direct Air Capture
EMDE	Emerging Markets and Developing Economies
ESG	Environmental, Social, and Governance
ETS	Emissions Trading Scheme
EUR	Euro
EV	Electric Vehicle
FID	Final Investment Decision
FSRU	Floating Storage Regasification Unit
GBP	British Pound Sterling
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ICE	International Combustion Engine
ICT	Information and Communications Technology
IRR	Internal Rate of Return
IT	Information Technology
JPY	Japanese Yen
km	Kilometre
LCOE	Levelized Cost of Electricity
LNG	Liquified Natural Gas
LNG	Liquefied Natural Gas
M&A	Mergers & Acquisition
MDB	Multilateral Development Banks
MENA	Middle East and North Africa
MI	Mission Innovation
NOC	National Oil Company
NZE	Net Zero By 2050 Scenario
OCGT	Open-Cycle Gas Turbine
OECD	Organisation For Economic Co-Operation and Development
OPEC	Organization of The Petroleum Exporting Countries
PACE	Property-Assessed Clean Energy
PV	Photovoltaic
R&D	Research and Development
RD&D	Research, Design, and Development
REE	Rare Earth Elements
ROIC	Return On Invested Capital
S&P	Standard & Poors
SAF	Sustainable Aviation Fuel
SES	Solid Energy Systems
SOE	State-Owned Entity
STEPS	Stated Policies Scenario
UICI	Upstream Investment Cost Index
USD	United States Dollar
VC	Venture Capital
WACC	Weighted Average Cost of Capital
WEI	World Energy Investment

Units of measure

g	Gram
GW	Gigawatt
GWh	Gigawatt Hour
kg	Kilogram
mb/d	Million Barrels of Oil per Day
kb/d	Thousand Barrels of Oil per Day
MBtu	Million British Thermal Units
Mt	Million Tonnes
MW	Megawatt
MWh	Megawatt Hour
TWh	Terawatt Hour

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