

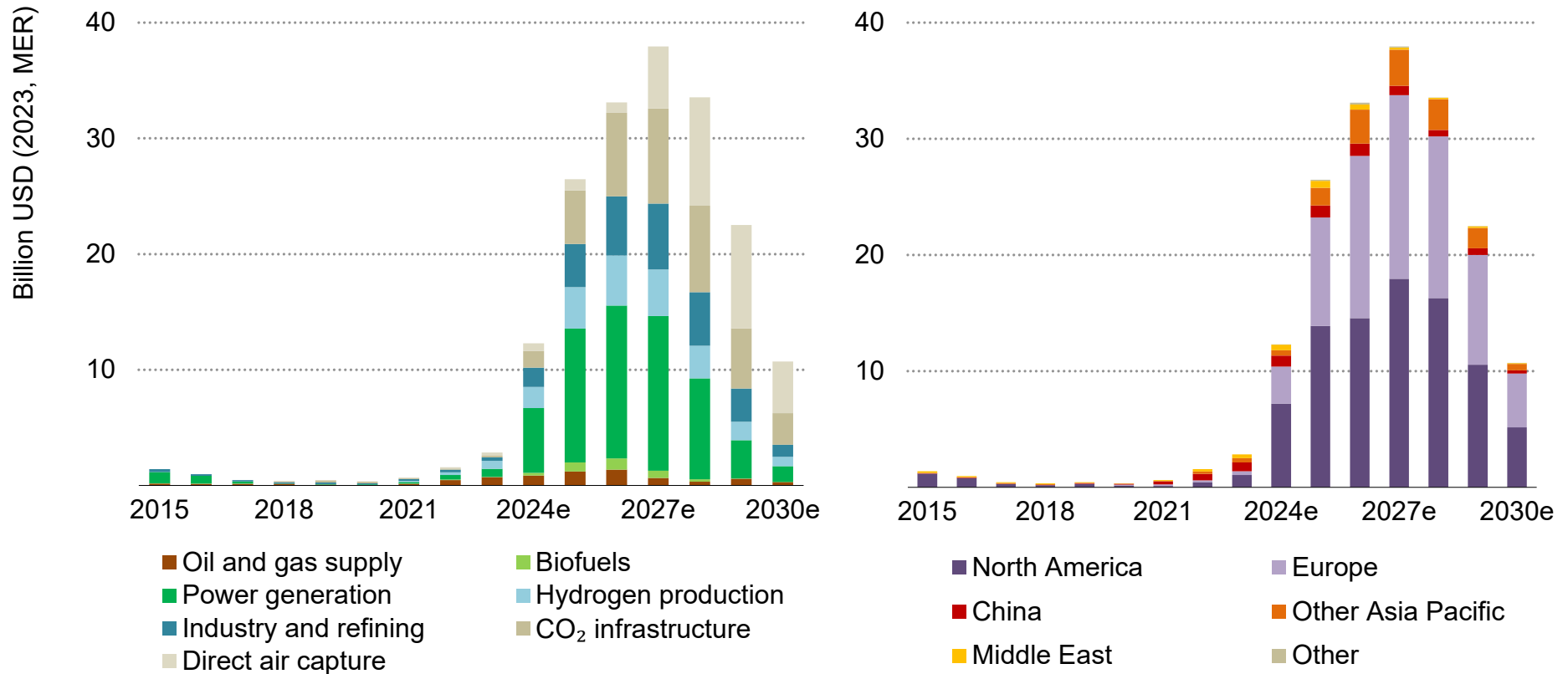
World Energy Investment 2024



CCUS

Successfully executing announced CO₂ 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



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Note: Includes commercial capture facilities with a capacity of over 0.1 Mt CO₂ 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 CO₂ capture capacity would increase to 430 Mt CO₂/year by 2030, and global CO₂ storage capacity would reach 620 Mt CO₂/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 CO₂/year project](#) in September 2023 to build one of the largest integrated CCUS projects

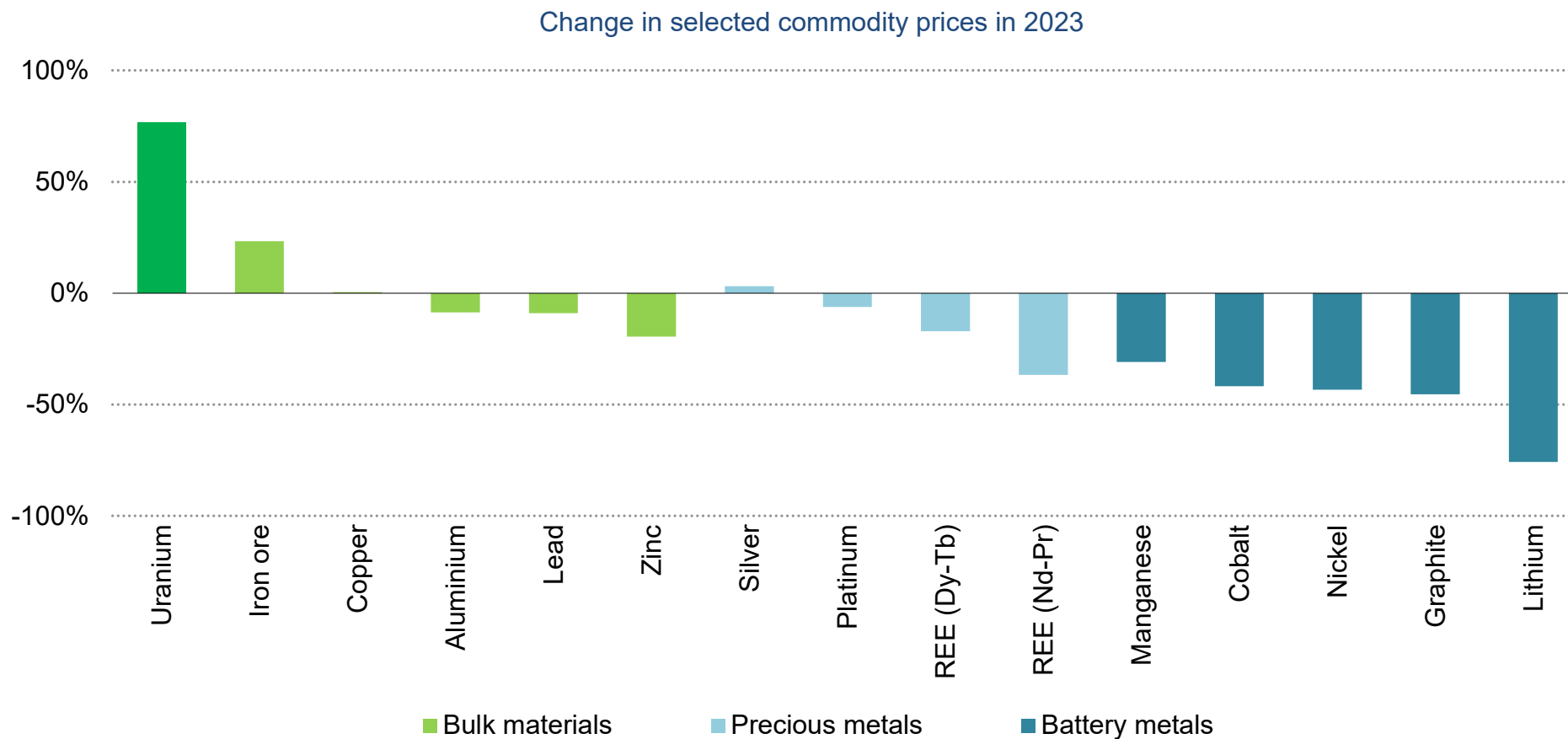
in the Middle East. Several CCUS M&A deals involving oil and gas companies were also announced in 2023 and 2024.

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 CO₂/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 CO₂/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 CO₂ (storage or use) have not yet been finalised.

Investment in CO₂ 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 CO₂/year). The [extension of the Alberta Carbon Trunk Line](#) by Wolf Midstream Canada will allow 7 Mt CO₂/year to be permanently stored. A [CO₂ transport and storage hub in Louisiana](#) by CapturePoint Solutions is set to store more than 10 Mt CO₂/year.

Critical minerals

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



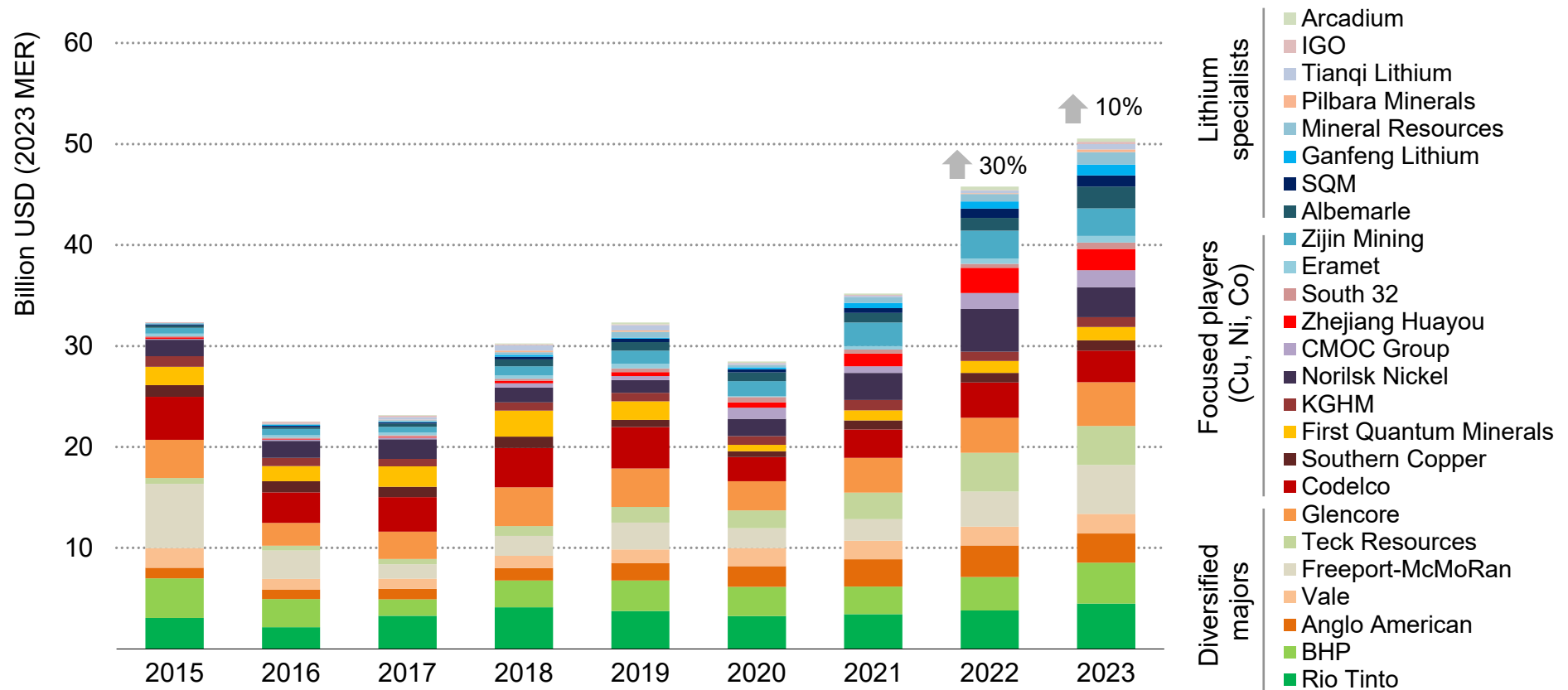
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Note: REE = rare earth elements. Dy-Tb = dysprosium and terbium. Nd-Pr = neodymium and praseodymium.

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



IEA. CC BY 4.0

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.

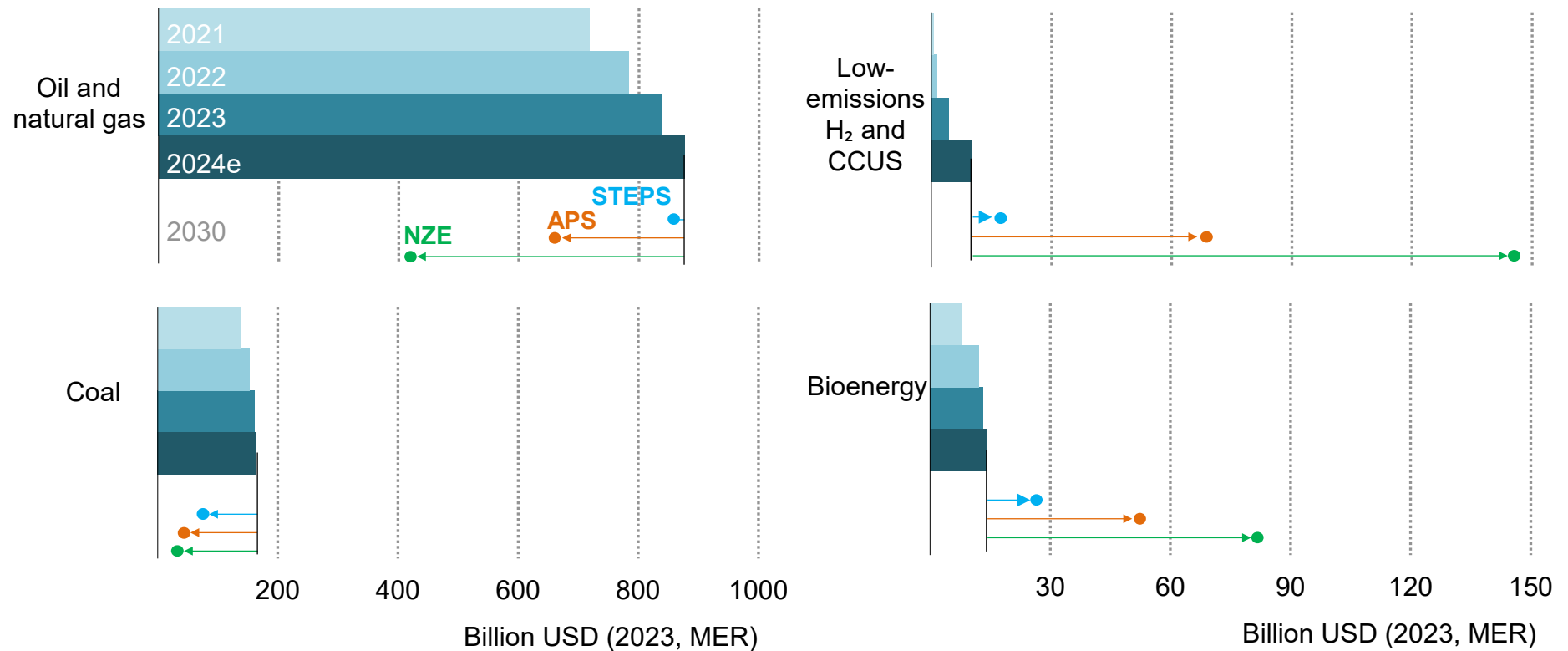
The geographic concentration of production has remained largely unchanged in recent years. One exception is nickel, where supplies have become more concentrated: between 2021 and 2023, Indonesia's share of mined nickel production increased from 34% to 52% and its share of refined nickel increased from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



IEA. CC BY 4.0

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

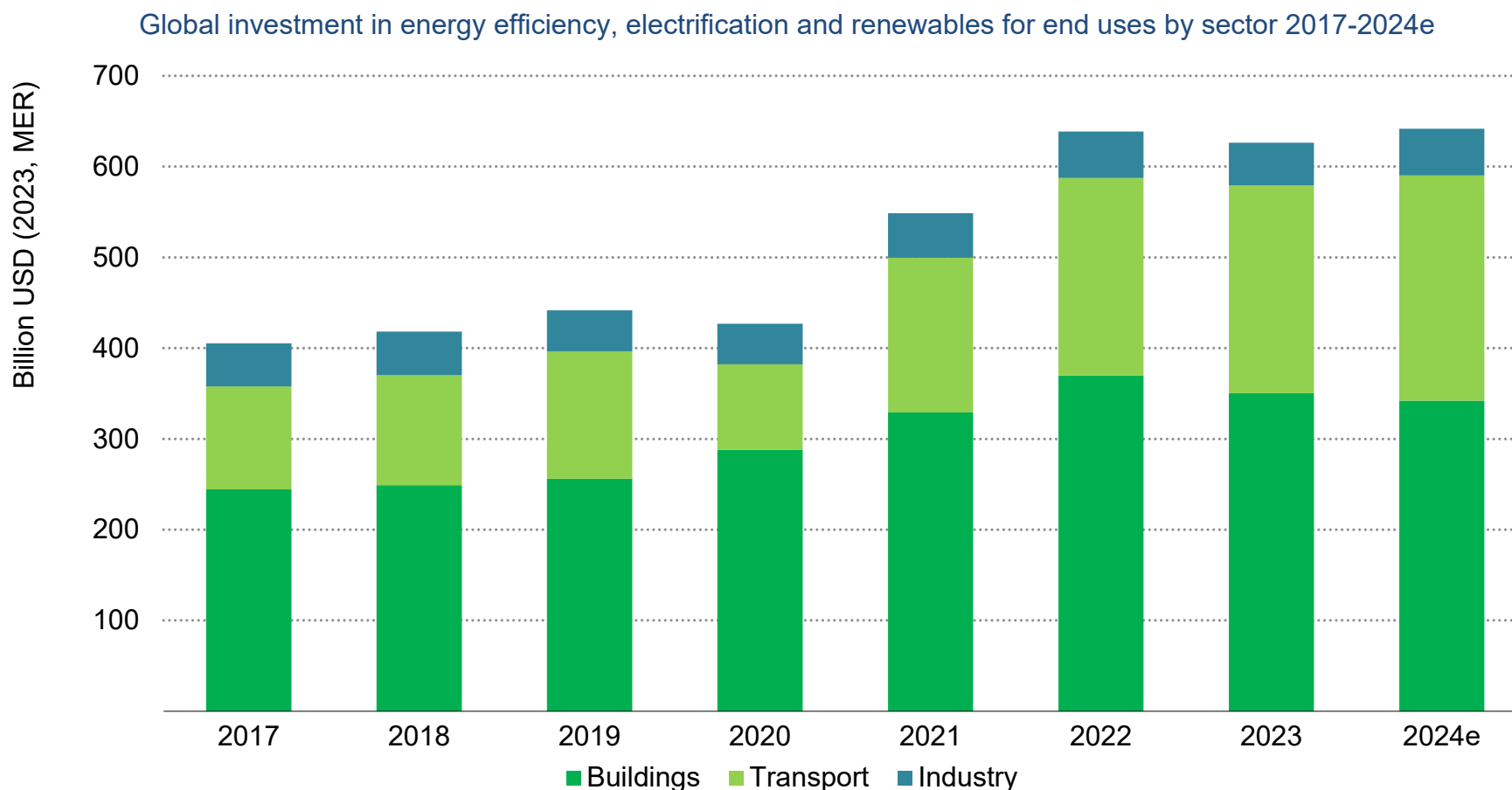
their spending in these areas, and less than 4% of the industry's total capital investment was invested into clean energy in 2023.

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

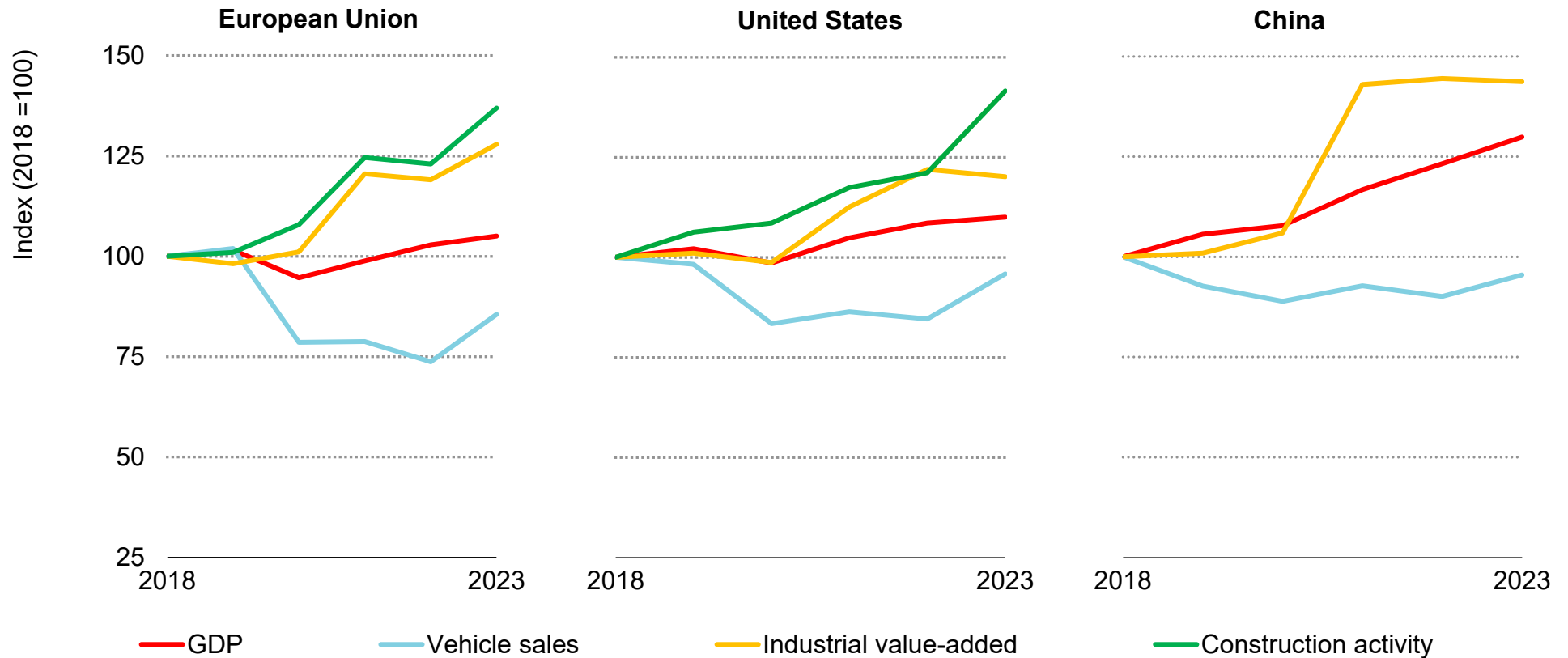


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Note: An energy efficiency investment is defined as the incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy use. The intention is to capture spending that leads to reduced energy consumption.

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



IEA. CC BY 4.0

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

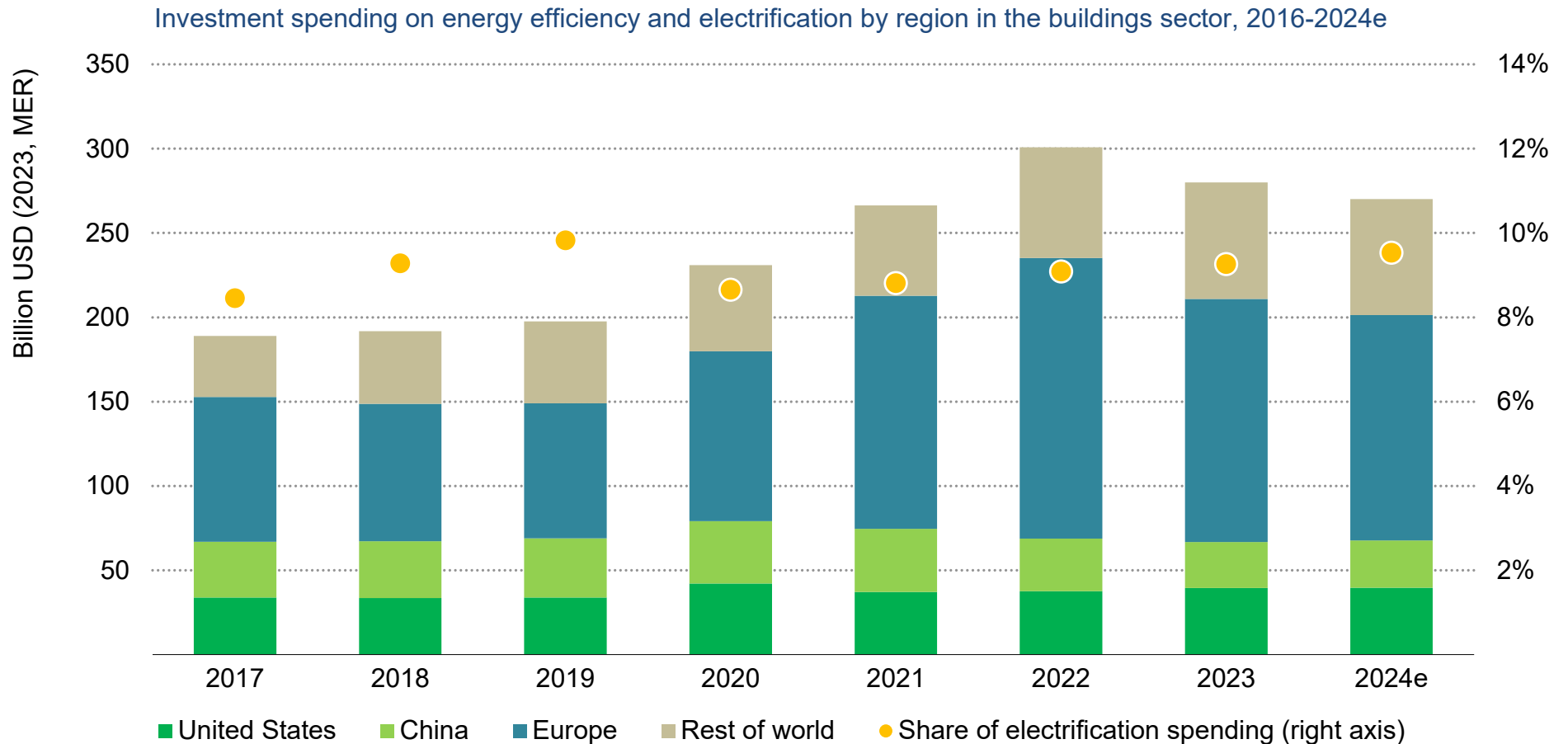
prospects for the next few years. In EMDE, weak building codes and poor enforcement continue to be a drag on investment.

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 ...



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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 GBP 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.

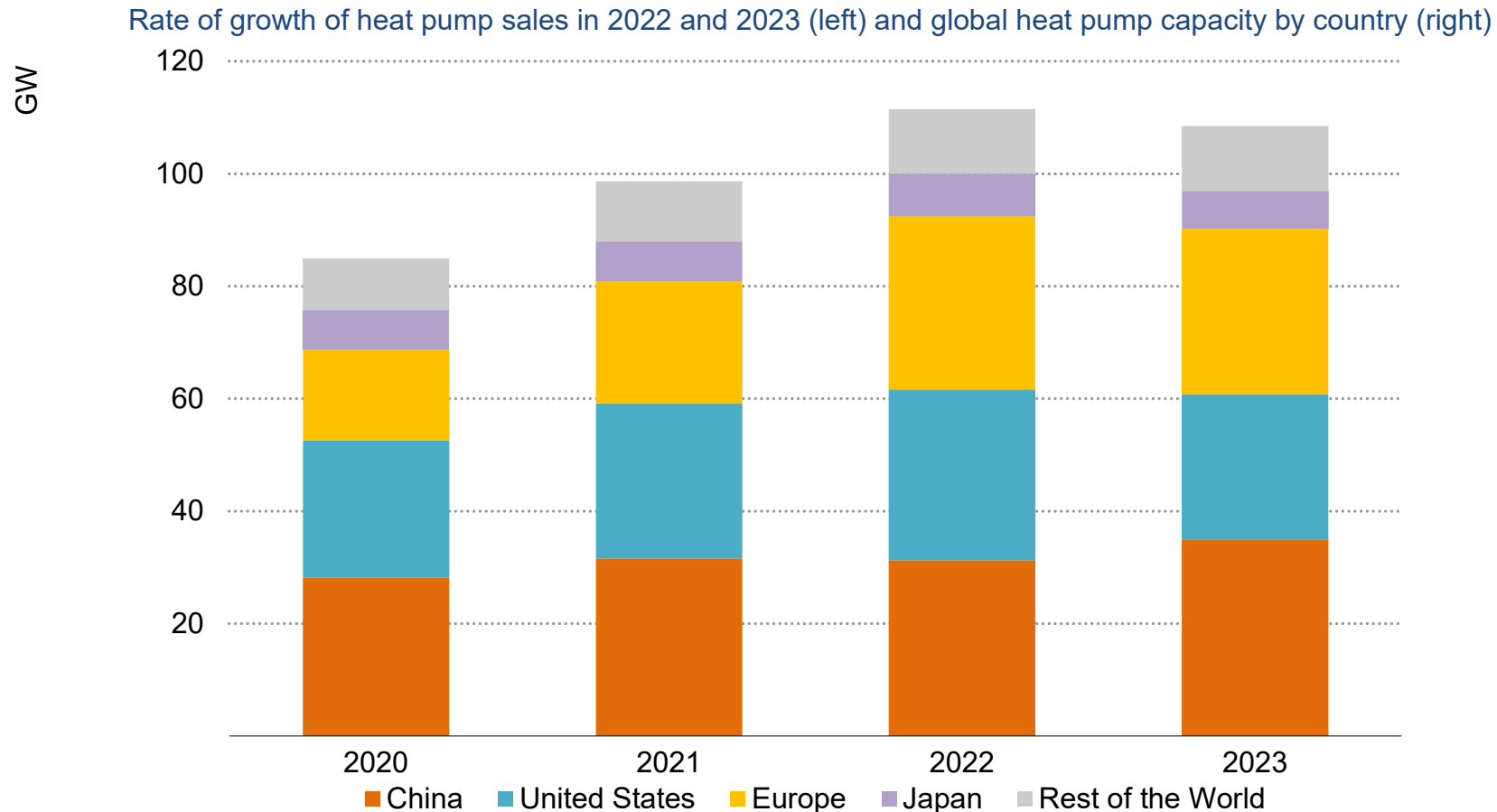
The United States has [continued to support investment in improving the energy efficiency of buildings](#) through the [Inflation Reduction Act of 2022](#). The Department of Energy is investing around [USD 705 million on building energy efficiency](#) and weatherization through the State and Community 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



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Note: heat pumps that deliver heat directly to households and residential or commercial buildings for space heating and/or domestic hot water provision. It includes natural source heat pumps, including reversible air conditioners used as primary heating equipment. It excludes reversible air conditioners used only for cooling, or used as a complement to other heating equipment, such as a boiler.

Source: IEA (2024), [Clean Energy Market Monitor](#).

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.

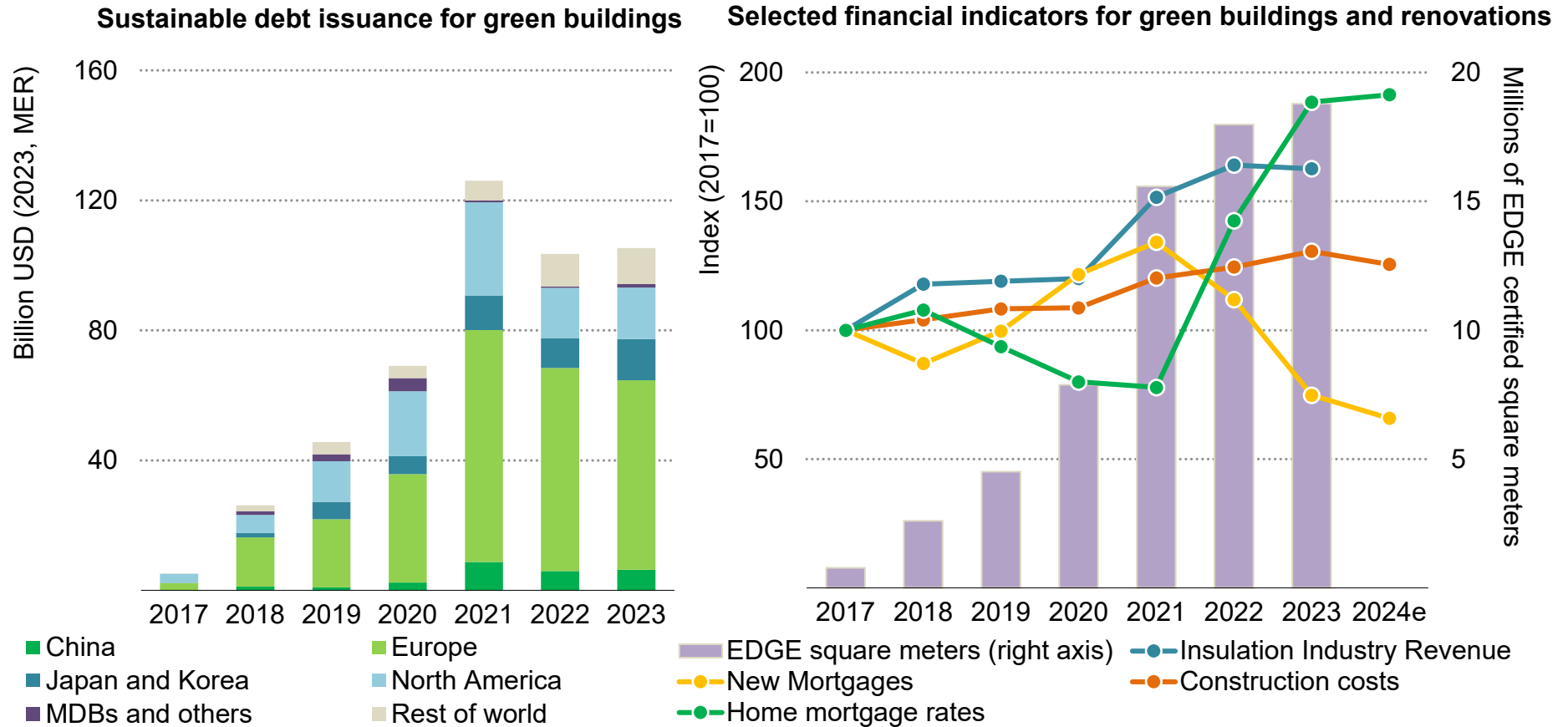
That said, this outcome was not entirely unforeseen, as several factors contributed to the reduced enthusiasm of consumers to invest in heat pumps in 2023. High interest rates deterred potential buyers, while the substantial upfront costs associated with heat pump installation posed financial challenges. 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



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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.

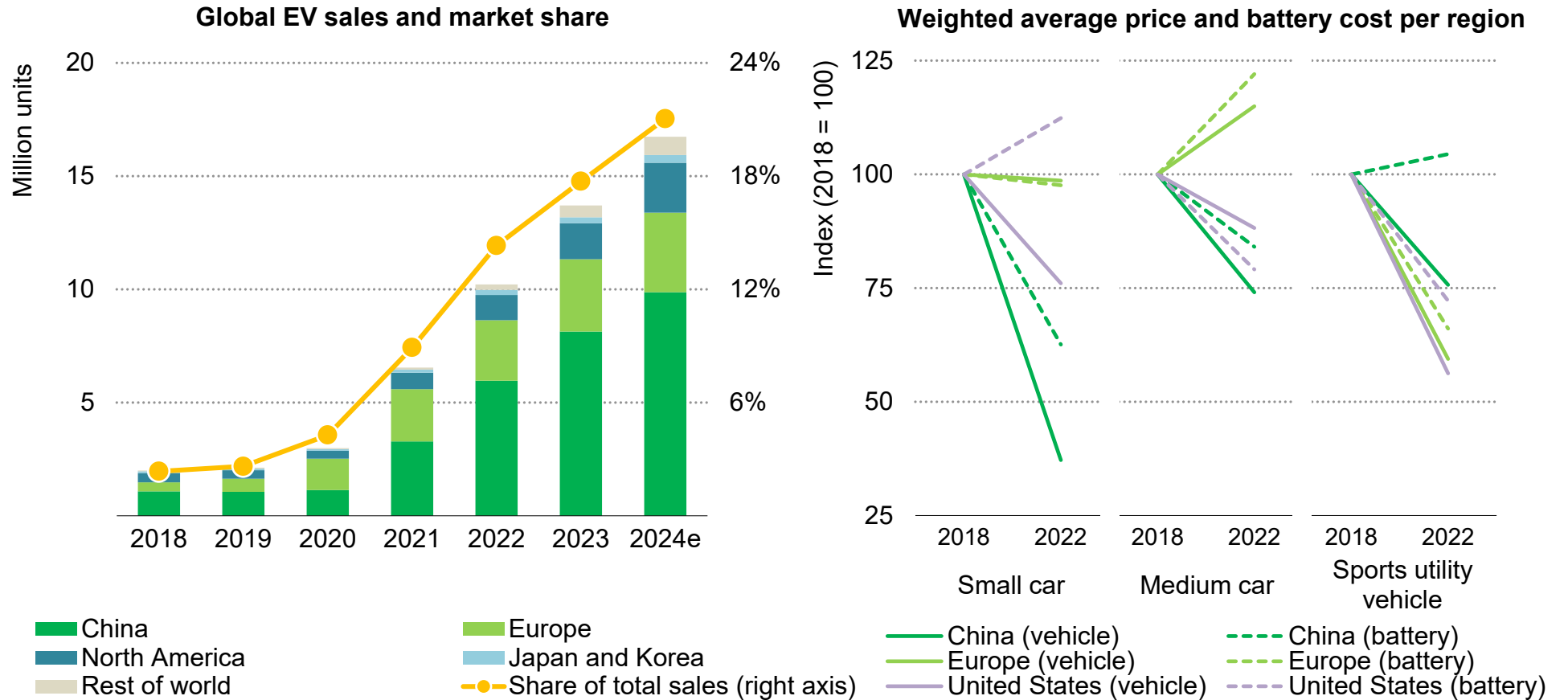
Innovative solutions exist to increase the amount of financing for green buildings, and they have been tested in various countries. In the United States, the [Property Assessed Clean Energy](#) Programs have shown a way to decouple the split incentives for owners – who must shoulder the cost of green 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



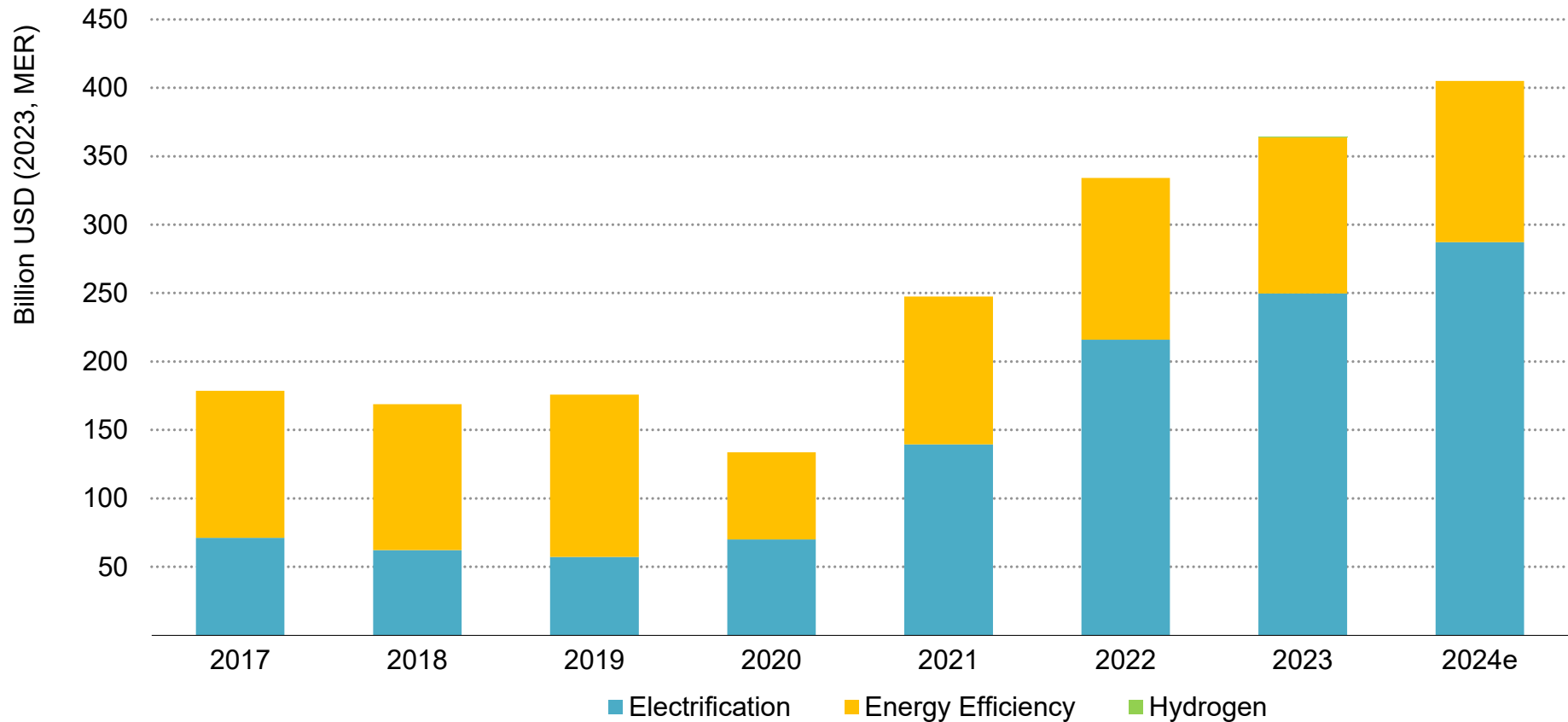
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Note: EV includes battery electric and plug-in hybrid passenger vehicles. 2024e = estimated values for 2024.

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

Investment in energy efficiency, electrification, and hydrogen in the road transport sector



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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.

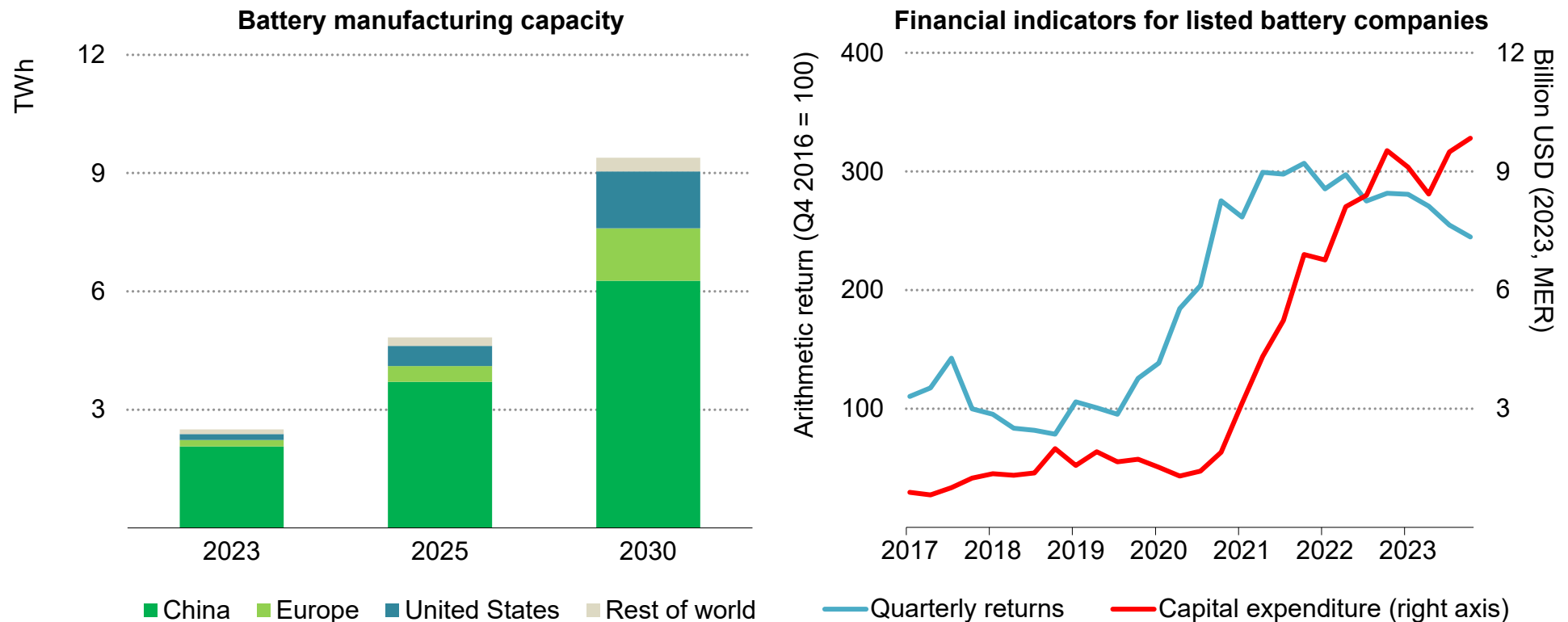
But as the market enters a new era of slightly slower growth, the car industry – which has seen many new entrants in recent years – is

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



IEA. CC BY 4.0

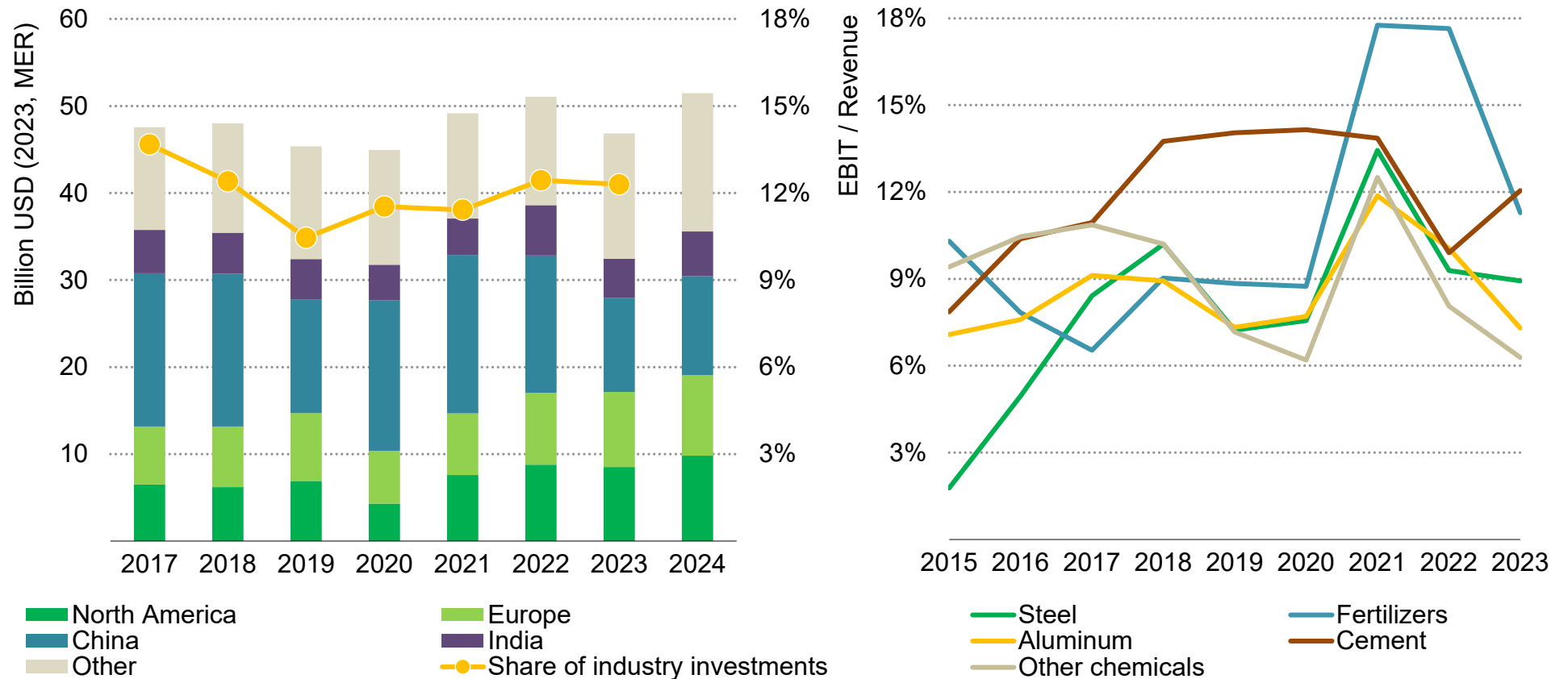
Note: Listed battery companies include LG Energy Solution, BYD, Contemporary Amperex Technology, Samsung SDI, Gotion High-tech, Eve Energy and Farasis Energy Gan Zhou. 2023 values are based on fully commissioned capacity. 2025 and 2030 capacity values are based on capacity that is either announced, under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



IEA. CC BY 4.0

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.

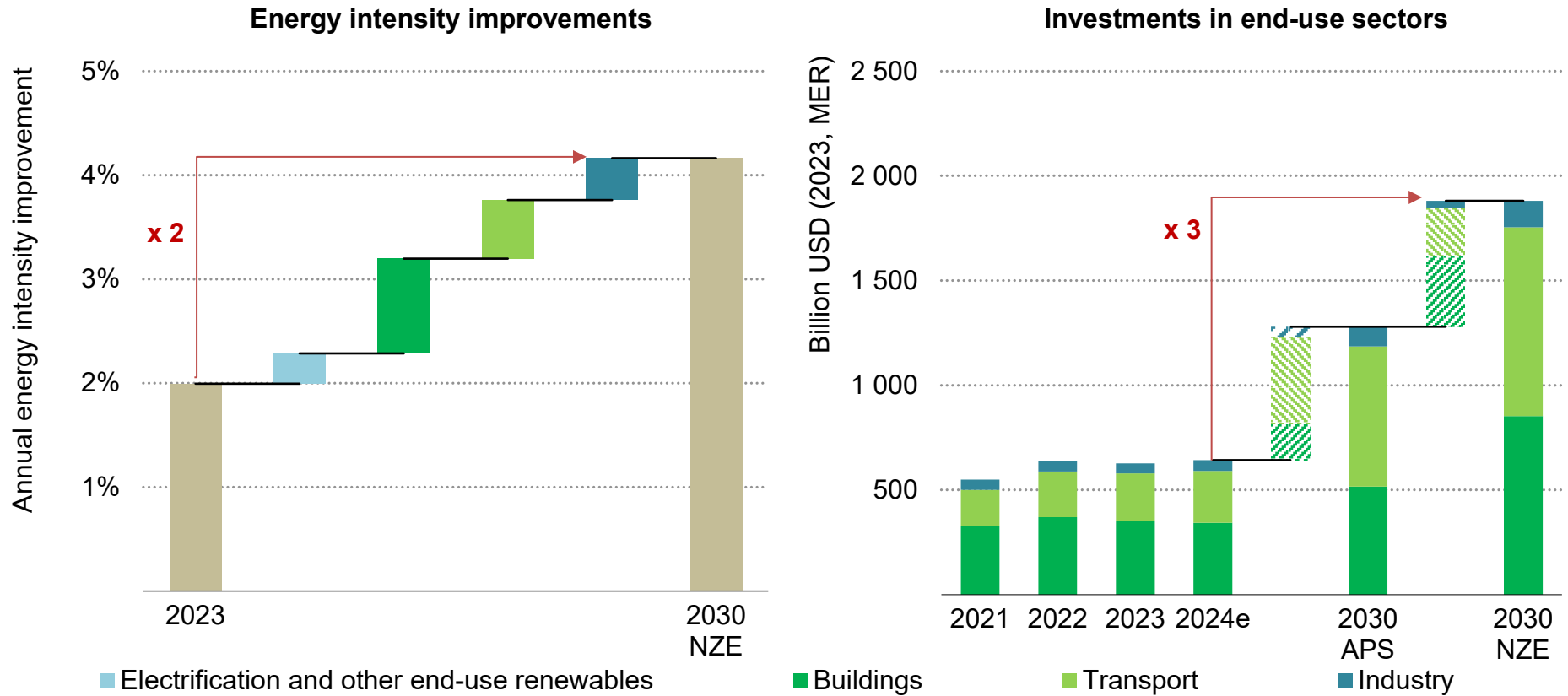
Compared with global capital expenditures across all industrial sectors (iron and steel, cement, aluminium, copper, and chemicals), energy efficiency and other end-use investments have stalled, representing 13% of total investment in 2023 compared to 14% in 2017. This suggests that even in a period of 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



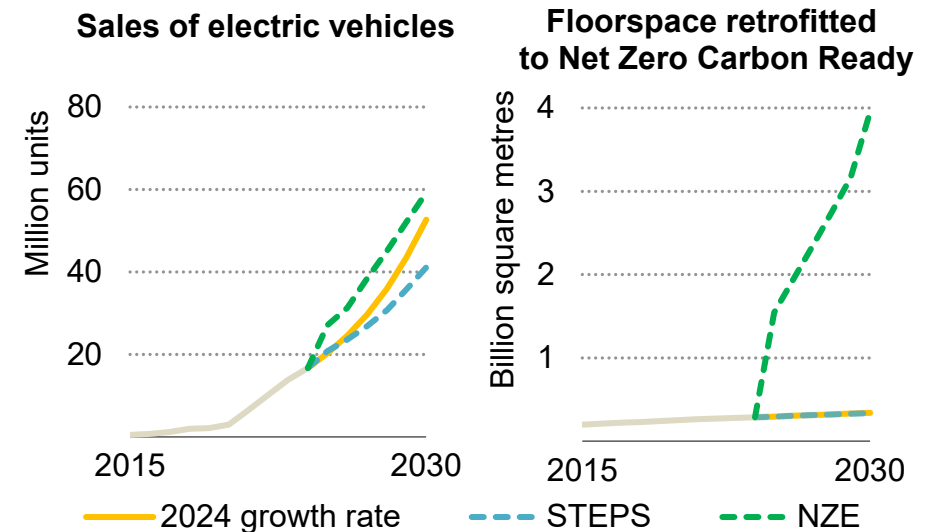
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Energy efficiency is one of the key pillars to keeping 1.5 °C within reach, but the world is not investing nearly enough

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

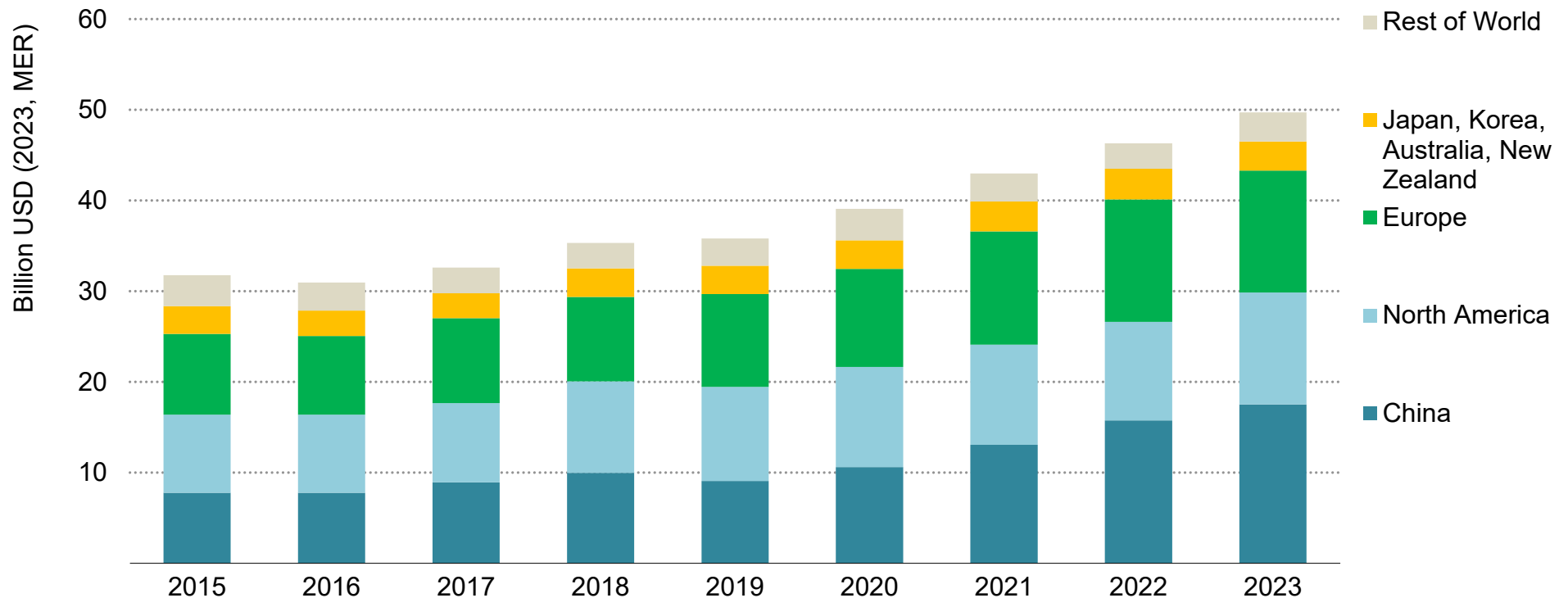
venture capital (VC) or venture loans – became significantly more expensive amid rising inflation and higher interest rates. Not only did higher interest rates make alternative investments relatively more attractive, but inflation and weaker outlooks for consumer spending lengthened the expected time 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

Government spending on energy R&D, 2015-2023



IEA. CC BY 4.0

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.

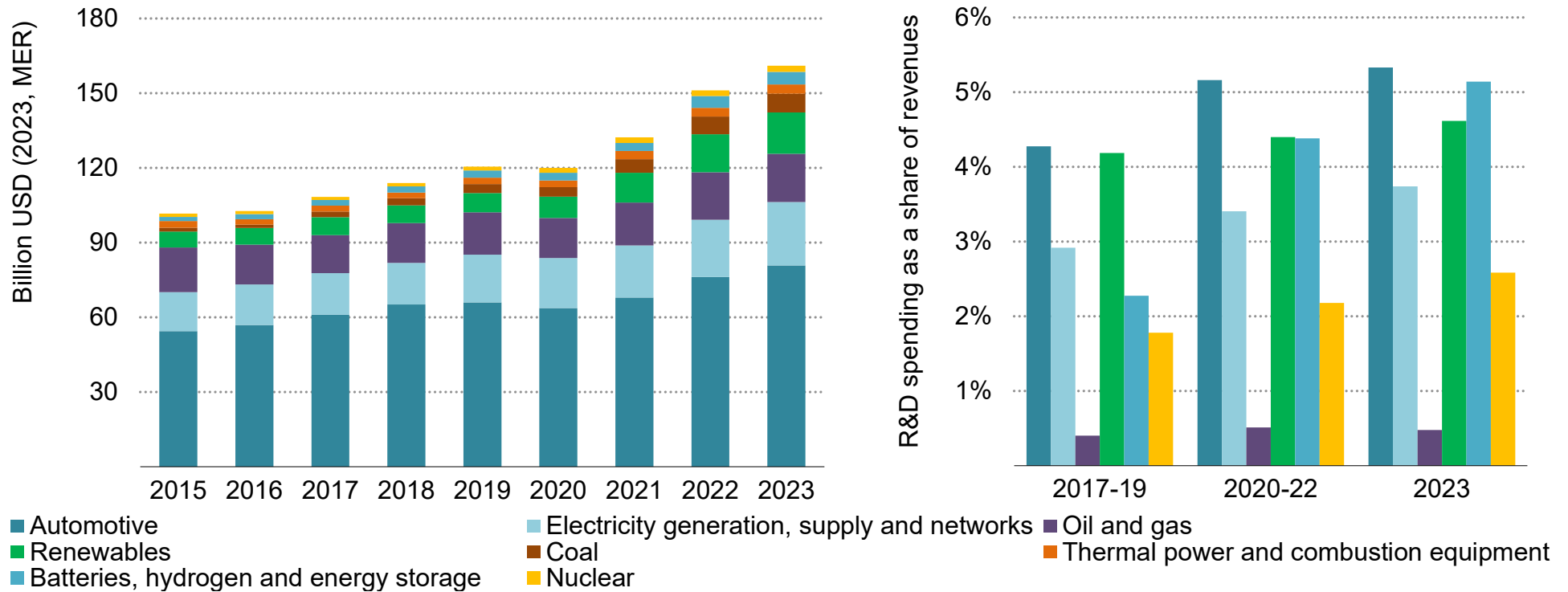
New government initiatives in this area include Korea's [List of Critical and Emerging Technologies](#) and a [Special Act](#) to create the support

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

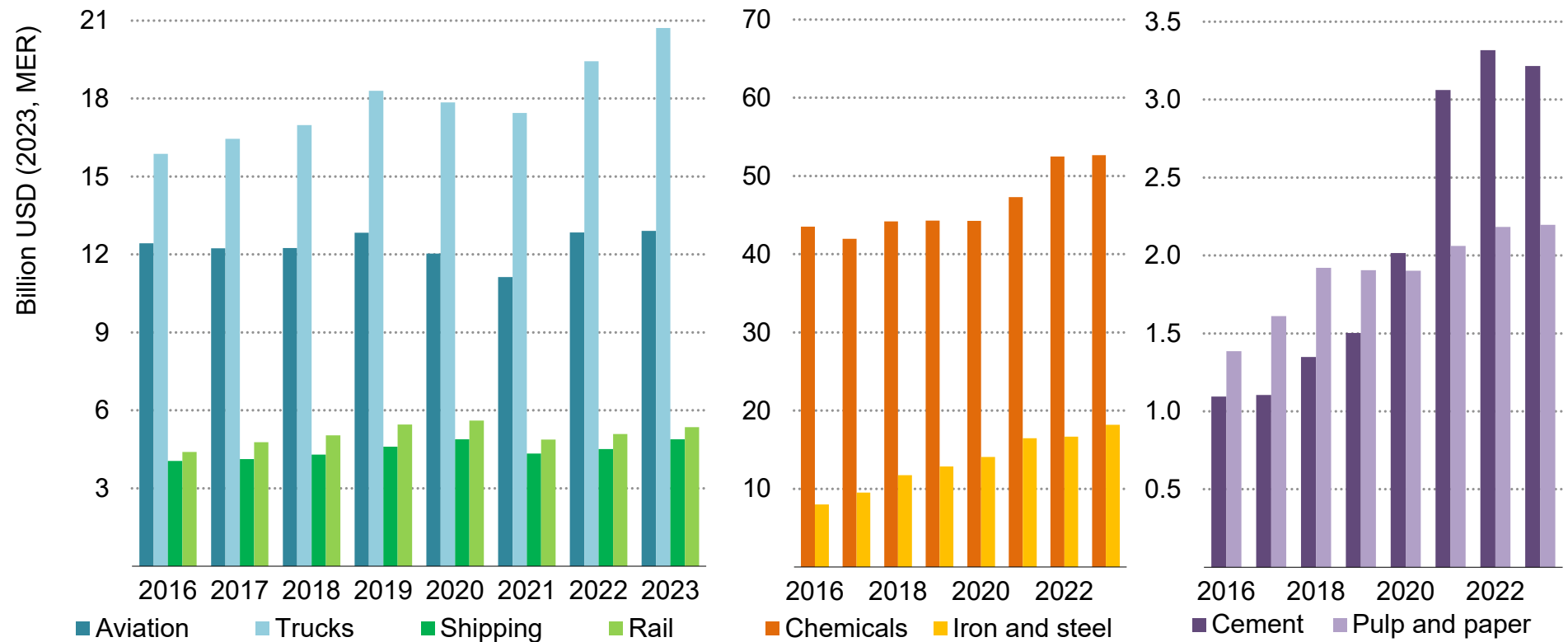


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Note: Includes only publicly reported R&D expenditure by companies active in sectors that are dependent on energy technologies, including energy efficiency technologies where possible, and based on the Bloomberg Industry Classification System. Automotive 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



IEA. CC BY 4.0

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.

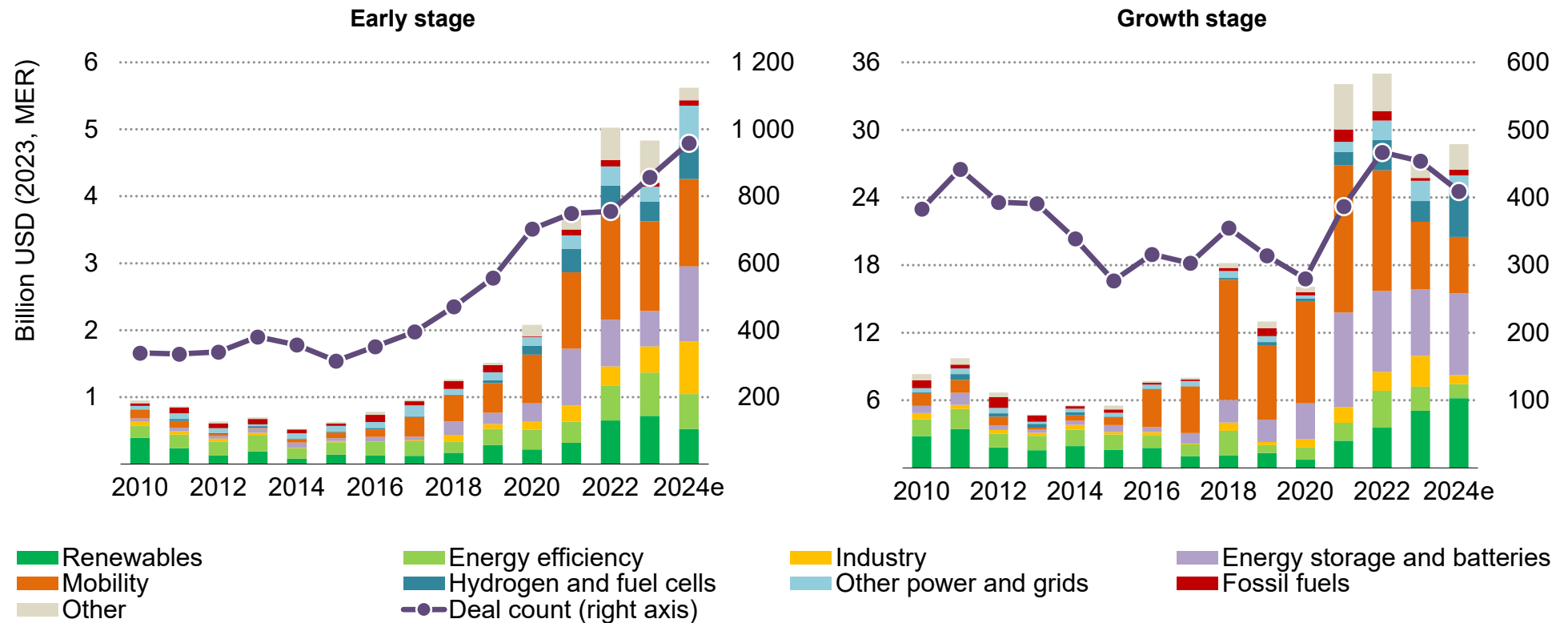
In the automotive sector, [Volkswagen](#) and [Mercedes Benz](#) increased R&D spending by a combined USD 5.5 billion, or 19%. This represents impressive growth at a time when sales of internal combustion engine vehicles are in decline and electric car sales, while growing, typically have thinner margins 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



IEA. CC BY 4.0

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).

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