

# Energy Supply Investment for Net Zero: Regional Ratios

Implied energy supply investment ratios of net fossil-fuel  
importers and exporters diverge

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# Executive summary

Commonly referenced climate scenarios that are aligned with the goals of the Paris Agreement lay out the range of investment needed in energy supply at the global level. But there is still very little clarity on the regional composition of this capital expenditure to enable individual markets to understand what global scenarios say about them.

BloombergNEF analyzed historical energy investment data from the International Energy Agency and reconciled it to a forward-looking regional dataset from the Network for Greening the Financial System. The “energy supply investment ratio” was used to benchmark the current state of investment and progress implied to keep on track in the short term for 1.5C of global warming and net-zero emissions by 2050.

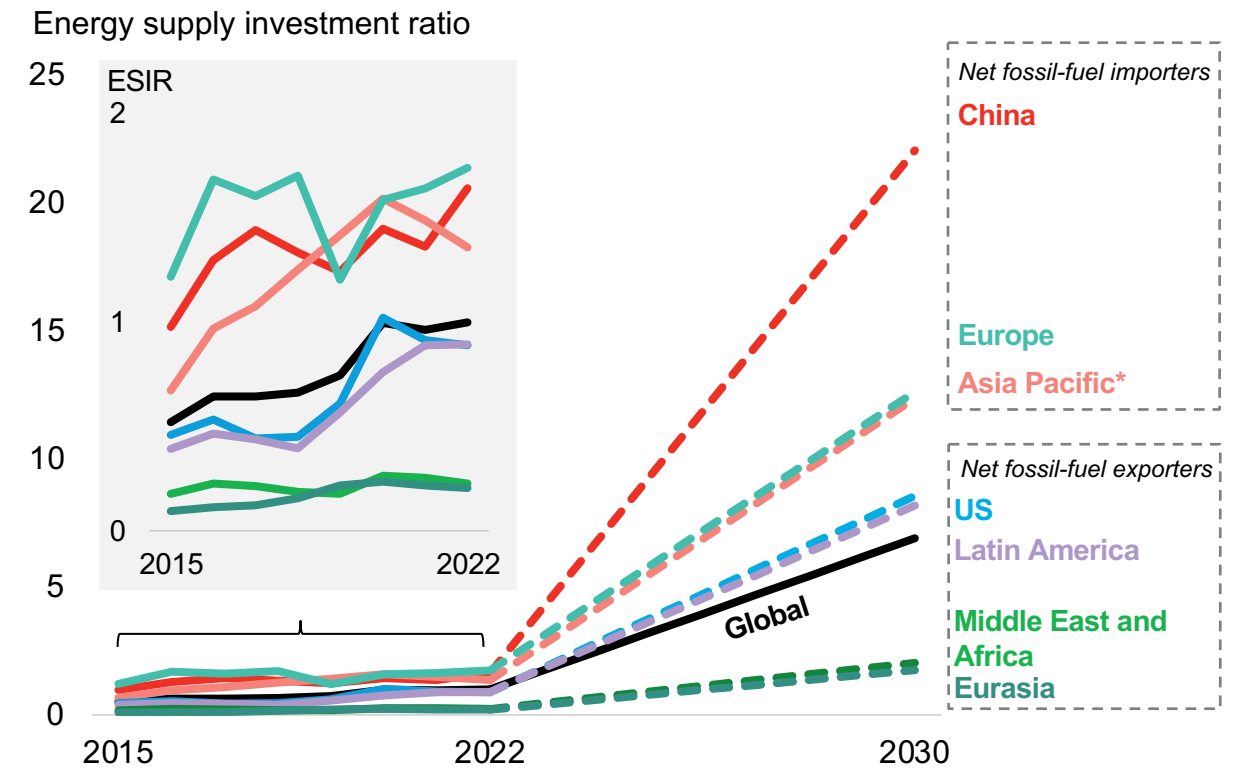
- **Globally, the energy transition is moving in the right direction, albeit slowly.** The ratio of investment in low-carbon and fossil-fuel energy supply hit parity in 2022, up from 0.5:1 in 2015, the year the Paris Agreement was signed. This is not, however, aligned to a 1.5C and net-zero trajectory. For that, the global ratio needs to average 4:1 across 2021 to 2030.
- **The availability of energy supply resources and policy environments underpin regional differences in investment.** Fossil-fuel importing regions such as China and Europe have led the shift to low-carbon investment. Conversely, major oil and gas exporters like the Middle East and Eurasia have invested significantly more in fossil fuels.
- **The forward-looking energy supply investment ratio acknowledges these different starting points.** China is modeled to require a low-carbon to fossil-fuel supply investment decadal ratio of more than 10:1. Meanwhile, Europe’s is over 6.5:1 and the US needs to aim for a ratio of 4:1 – in line with the global average. The Middle East and Africa and Eurasia have the lowest ratios, reflecting their continued role in fossil-fuel production and export.
- **The variation in energy supply investment ratios reflects the different roles markets play in global and regional energy supply.** These are a function of the underlying resources and policy frameworks they have in place. Financial institutions active in different regions of the world may wish to consider this and Nationally Determined Contributions – countries’ plans to help meet the goals of the Paris Agreement – when formulating their investment and financing policies.

**~ \$4** Implied investment in low-carbon energy supply for every \$1 spent on fossil-fuel energy supply from 2021 to 2030

**10.5:1** Energy supply investment ratio implied in China across 2021 to 2030 – the highest of all markets

**0.9:1** Energy supply investment ratio implied in the Middle East and Africa across 2021 to 2030 – the lowest of all markets

## Regional energy supply investment ratio, historical and modeled to 2030



Source: BloombergNEF, IEA, NGFS. Note: Latin America consist of Central and South America. ESIR = Energy Supply Investment Ratio. The ratio growth outlook to 2030 is based on the investment numbers aggregated by BNEF using the NGFS Net Zero by 2050 scenario. \*Asia Pacific excludes China.

# About the analysis

## Scope of work

- This note aims to shed light on the magnitude of capital investment required in global energy supply to remain aligned to the goals of the Paris climate agreement. It also aims to provide a forward-looking view of the potential investment environment for policymakers, corporations and financial institutions.
- Scenarios used for this work reach net-zero emissions by 2050 (or shortly after), limit the global temperature rise to 1.5C by the end of the century with no or limited overshoot of the carbon budget, and are evaluated by major intergovernmental bodies with significant authority delegated to them by national governments. These include pathways published by the International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC), and Network for Greening the Financial System (NGFS).

## Regional

- This note is a continuation of previous work on global energy supply investment ratios. Past papers include:
  - *Energy Supply Investment Ratios in a Low-Carbon World* ([web](#) | [terminal](#))
  - *Investment Needs of a 1.5C World* ([web](#) | [terminal](#))

## Energy supply investment and banking ratio




- The ratio of investment in low-carbon versus fossil-fuel energy supply normalizes for the varying assumptions and narratives of different climate scenarios, and offers a new lense on how corporations, state and non-state organizations, and financial institutions can examine their financing activity.
- This concept can also support the banking community in understanding the alignment of their financing with the real economy. BNEF addresses this through the following works on the “energy supply banking ratio”, a measure of banks’ financing of low-carbon versus fossil-fuel energy supply:
  1. *Financing the Transition: Energy Supply Investment and Bank Financing Activity* ([web](#) | [terminal](#))
  2. *Energy Supply Banking Ratio Tool* ([web](#) | [terminal](#))

## Acknowledgements

- This report was written by BNEF at the request of the Glasgow Financial Alliance for Net Zero (GFANZ) Secretariat. BNEF would like to thank all those who have contributed to the work and development of this report.
- This note has benefited from past correspondence with the IEA, IPCC and NGFS. BNEF thanks them for their support but notes this report is not endorsed by these organizations.

# Scenario and source overview

## Investment data granularity and availability

|                                   |   |  |  |
|-----------------------------------|--|--|---|
| <b>Historical – global</b>        | Available from the <a href="#">World Energy Investment</a> reports   | Historical energy supply investment is modeled and does not represent actuals      | Historical energy supply investment is modeled and do not represent actuals         |
| <b>Historical – regional</b>      |  | Incomplete or do not have historical investment data on a regional basis           | Incomplete or do not have historical investment data on a regional basis            |
| <b>Forward-looking – global</b>   | Available through the <a href="#">World Energy Outlook</a>   | Available through the <a href="#">AR6 data explorer</a>                            | Available through the <a href="#">Phase 3 data explorer</a>                         |
| <b>Forward-looking – regional</b> | Incomplete or not publicly available   | Incomplete or not publicly available   |   |
| <b>Comments</b>                   | The IEA provides the data for historical energy supply investment at both a global and regional level. The NGFS net-zero scenarios were used to infer forward-looking investment values to 2050, based on both the Net Zero by 2050 and Divergent scenarios. |  |   |

Source: NGFS Climate Scenarios Vintage 3, BloombergNEF. Note: *Red shading* indicates incomplete or not publicly available data. *Green shading* indicates availability for data.

## NGFS scenarios used for the regional outlook

### Net Zero by 2050

- Limits warming to below 1.5C by 2100, with no or limited overshoot. Net-zero CO2 emissions reached shortly after 2050.
- An **ambitious, orderly scenario** that seeks to minimize physical risks through **immediate and firm uptake of climate and energy policies**. Energy transition risks are minimized as policies become stringent over time, although technology change is fast through rapid uptake of innovations.
- **CO2 removal is used** to accelerate decarbonization but reliance on this technology is limited.
- Final energy demand by 2050 drops more than 14% compared with 2020 levels, as energy efficiency and intensity scale up.

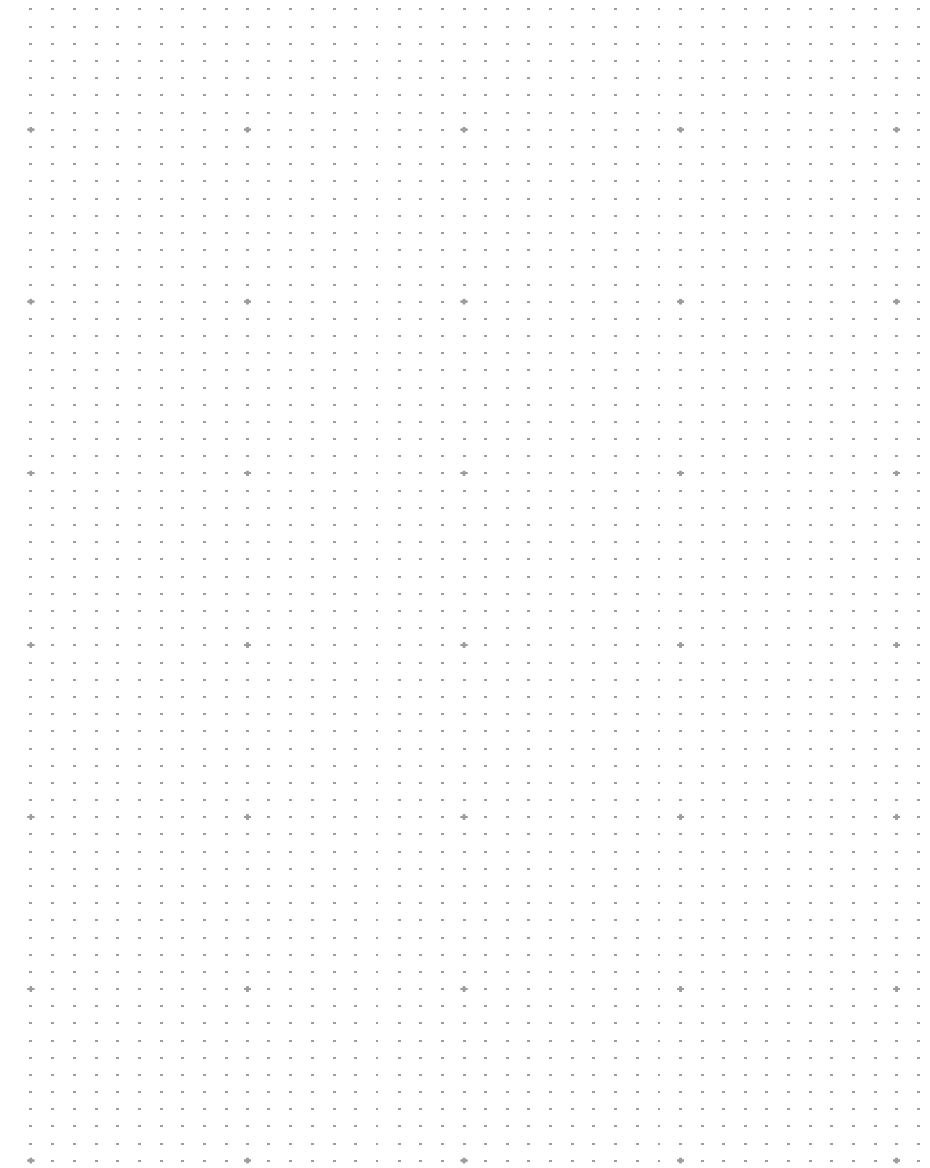
### Divergent Net Zero

- A similar temperature and net-zero trajectory to the NGFS Net Zero by 2050 scenario.
- A **disorderly scenario** with more rigid policies in the transport and building sectors. Less emphasis is placed on decarbonizing energy supply and industrial sectors.
- Energy transition risks are high as **policies diverge or are delayed**. Physical risks are minimized through instant changes in technologies used, leading to rapid fossil-fuel phase-out.
- The **use of CO2 removal is minimized** and lower than the NGFS Net Zero by 2050 scenario.
- Final energy demand by 2050 drops by more than 16% compared with 2020 levels.

For more information on the modeling framework used within the NGFS scenarios, please see [Appendix 1](#).

# Energy supply investment ratio – historical

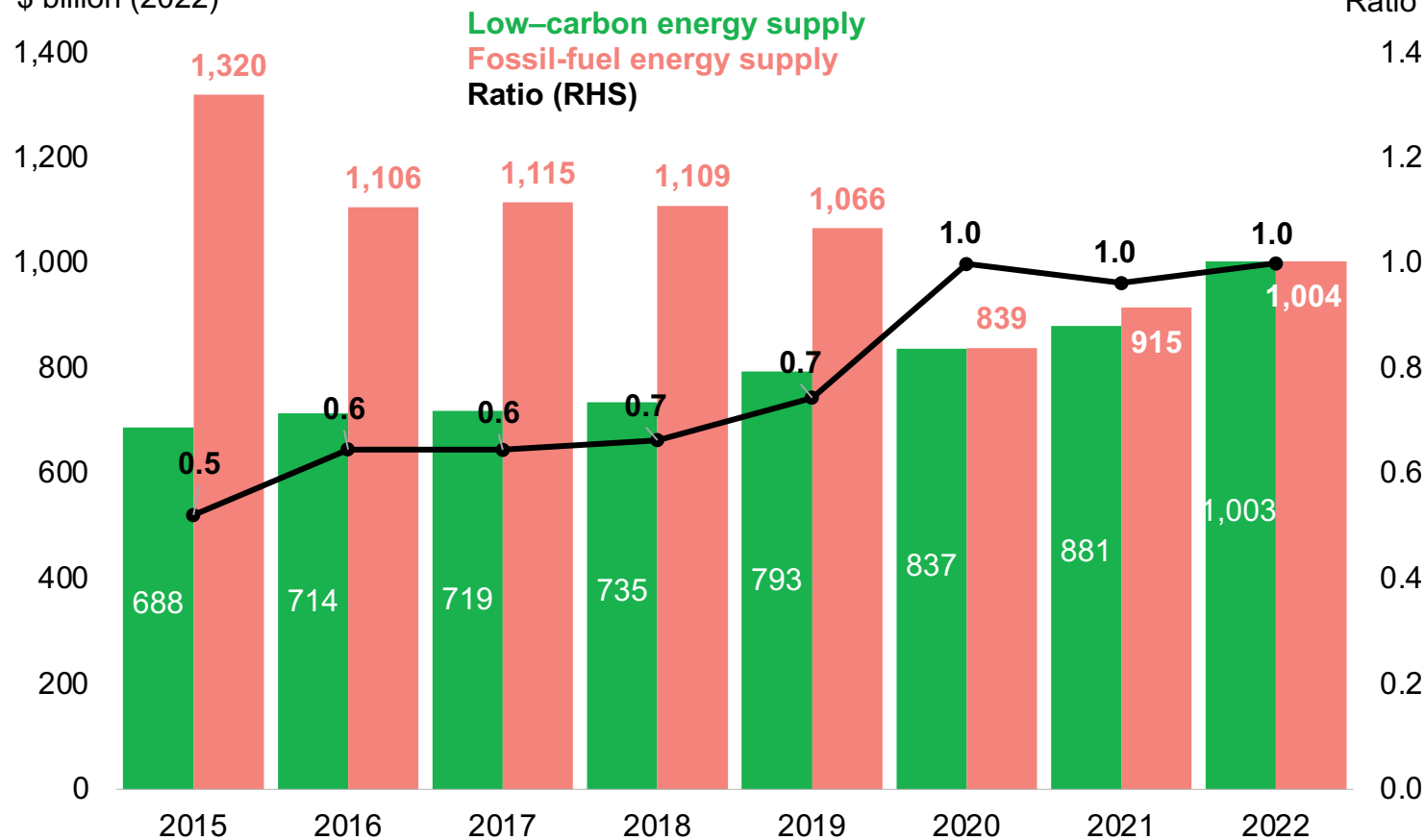
Global and regional



# Global investment in low-carbon and fossil-fuel supply swings to parity

## Energy supply investment and ratios by type

\$ billion (2022)



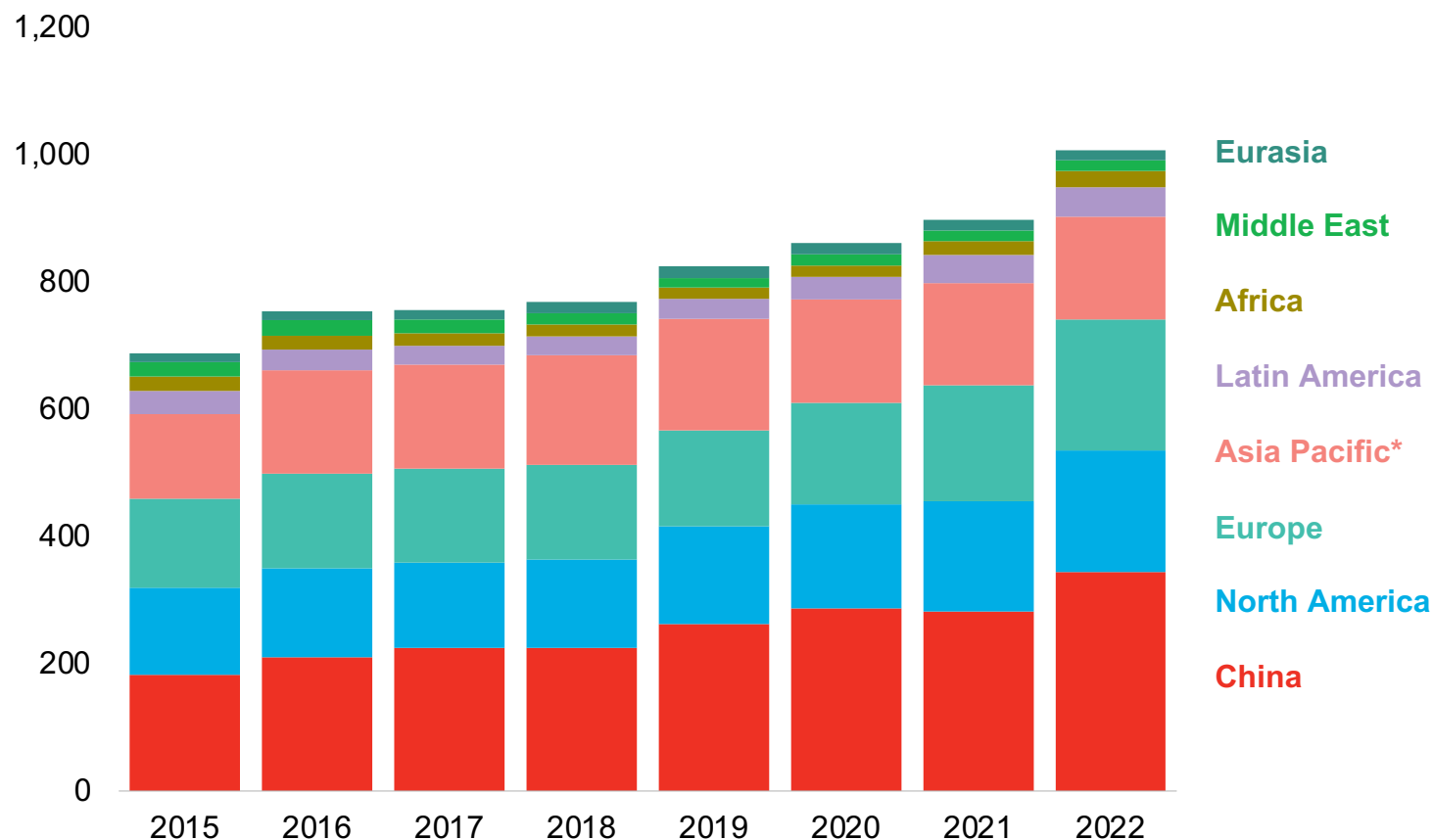
- Global investment flowing into energy supply surpassed \$2 trillion in 2022, according to BNEF’s aggregation of the IEA’s World Energy Investment dataset. Low-carbon and fossil-fuel energy supply investment hit parity for the second time ever – the first year being 2020, when capital outlay in fossil fuels tumbled due to Covid-19.
- Faster deployment of renewable power generation, implementation of supportive policies (such as the Inflation Reduction Act in the US and REPowerEU in the European Union) and a rising focus on decarbonization have supported the upward momentum of low-carbon supply investment. Between 2015 and 2022, the compound annual growth rate for low-carbon energy supply investment stood at 5.5%.
- The global energy crisis following Russia’s invasion of Ukraine significantly shifted the focus to shoring up energy security. This saw both emerging markets and developed economies increase their spending on fossil fuels.
- Despite the recent uptick in fossil-fuel supply investment, spending remains below pre-pandemic levels. This is indicative of a shift in the investment allocation and strategy of oil and gas producers, with many seeking to diversify and take a more conservative approach to spending.

Source: International Energy Agency, BloombergNEF. Note: Data are based off BNEF’s aggregation of IEA’s World Energy Investment 2023 data. The energy supply investment ratio shows the proportion of capital outlay going into low-carbon supply components as a share going into fossil-fuel supply areas. The methodology is further elaborated in [Appendix 6](#).

# Low-carbon energy supply investment has been increasing, driven by China

## Low-carbon energy supply investment by region

\$ billion (2022)



- All regions apart from Eurasia saw an annual uptick in low-carbon energy supply investment in 2022. This growth was largely driven by China, which saw a \$61 billion year-on-year increase, followed by Europe and North America with expansions of \$24 billion and \$19 billion, respectively. Other regions' momentum was more sedate.
- Local incentives and policies played a key role in pushing low-carbon investment higher in China, North America and Europe. The **Inflation Reduction Act in the US** is set to drive more investment into technologies that accelerate the energy transition. Similarly, **REPowerEU in Europe** has the potential to increase capital into alternative energy systems in a bid to reduce reliance on Russian oil and gas. **China's top position** reflects its importance as an industrial leader in the low-carbon space, capitalizing on efficient technology supply chains.
- An upcoming research note will focus on the state of policies influencing low-carbon energy investment in various regions, and their effects on matching the investment gap required for net zero.
- There are some factors that may hinder investment in low-carbon energy supply, including high inflationary pressures, interest rate hikes, the rising cost of living, and higher renewable and financing costs.

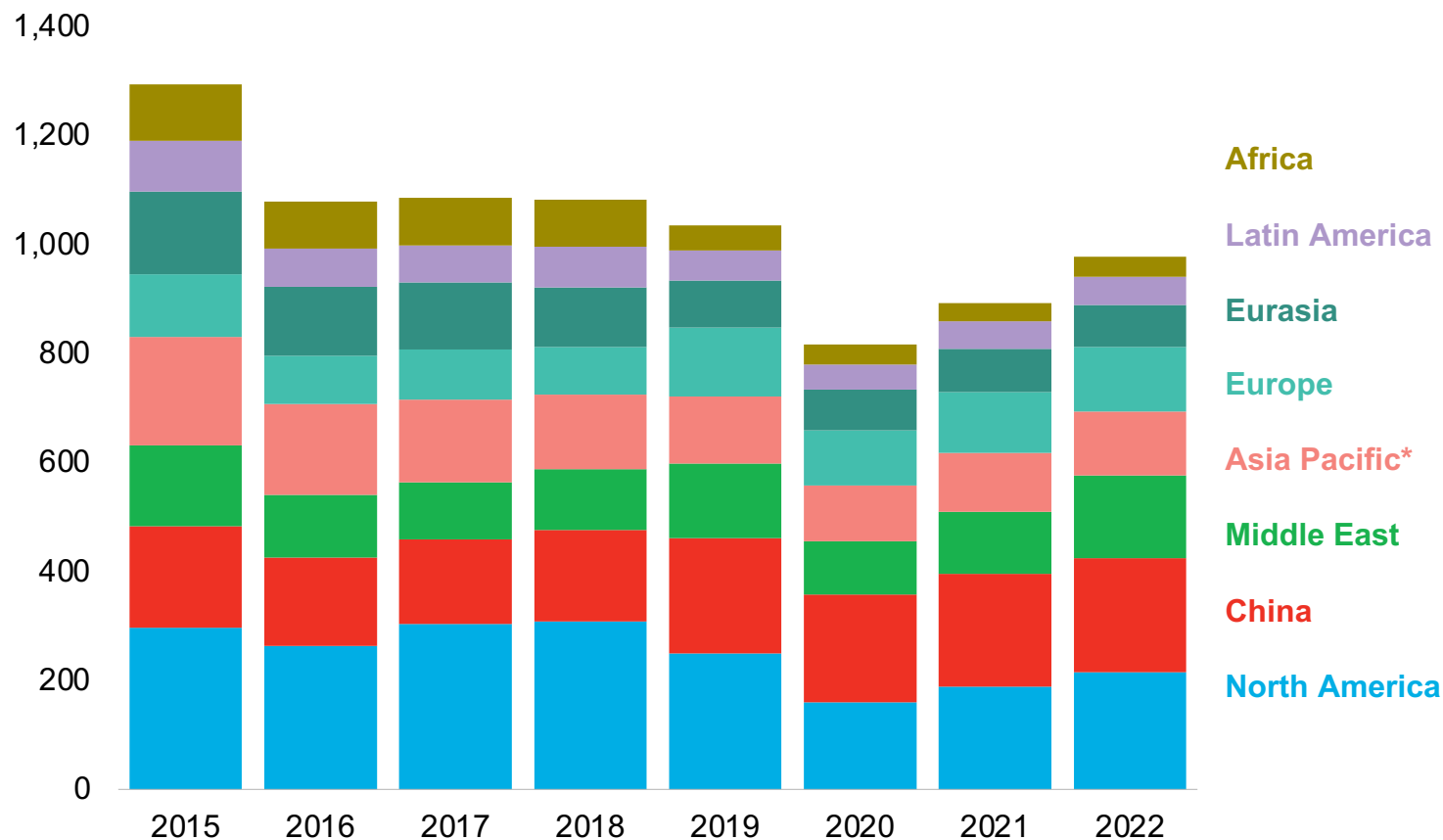
Source: International Energy Agency World Energy Investment 2023 Report, BloombergNEF. Note: Latin America comprises both Central and South America. The total of the regional energy supply investment numbers may slightly deviate from the global standalone value as reported by the IEA due to aggregation of the data given. Asia Pacific excludes China.



# Fossil-fuel supply capex grew post-2020 but has yet to match pre-pandemic levels

## Fossil-fuel energy supply investment by region

\$ billion (2022)

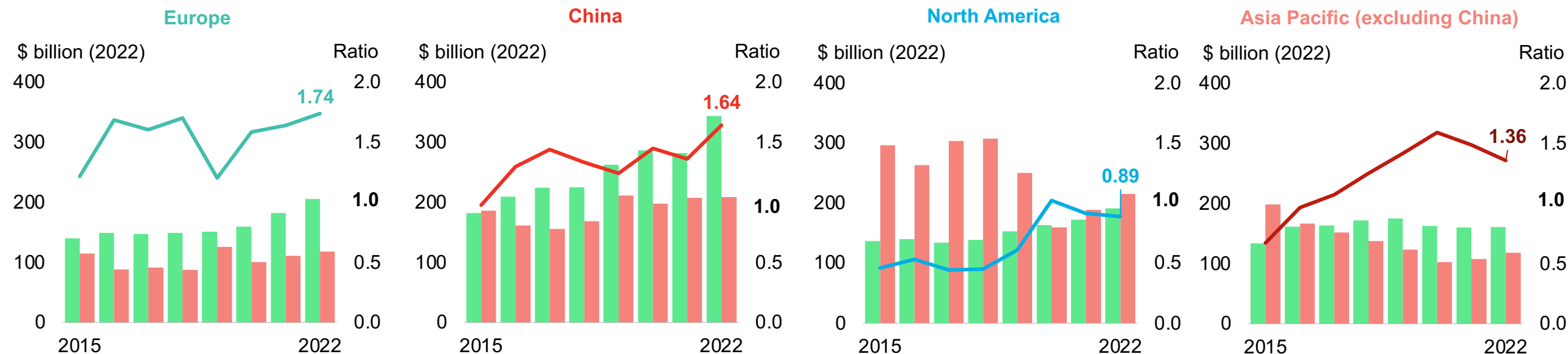


Source: International Energy Agency World Energy Investment 2023 Report, BloombergNEF. Note: Latin America comprises both Central and South America. The total of the regional energy supply investment numbers may slightly deviate from the global standalone value as reported by the IEA due to aggregation of the data given. Asia Pacific excludes China.

- Annual investment in fossil-fuel energy supply grew by \$88 billion in 2022, some 14% higher than the previous year. This comes as fossil-fuel demand rebounded.
- Regionally, everywhere but Eurasia saw annual growth in fossil-fuel energy supply investment last year. The Middle East saw the most growth, driving up oil and gas capital spending by \$27 billion and \$10 billion, respectively. National champions like Adnoc, QatarEnergy and Saudi Aramco ramped up investment to capitalize on the demand rebound and meet capacity expansion targets. North America followed with an investment rise of \$27 billion, largely driven by a \$19 billion hike for oil.
- Fossil-fuel investment has yet to rebound to pre-pandemic levels, despite the high oil and gas price environment in both 2021 and 2022 emanating from tight markets and upended trade flows. The Middle East is the only region where investment in 2022 surpassed that of 2019.
- A driver of this is a shift in the investment strategies of many energy majors. Pressured by environmental and societal concerns, along with an uncertain demand outlook for oil and other fossil fuels, companies have shifted to exercising capital discipline – prioritizing shareholder returns through buybacks and dividends, and debt repayments, despite windfall profits in 2022.

# Europe and China lead the investment shift towards low-carbon supply

## Investment in low-carbon and fossil-fuel energy supply investment by region

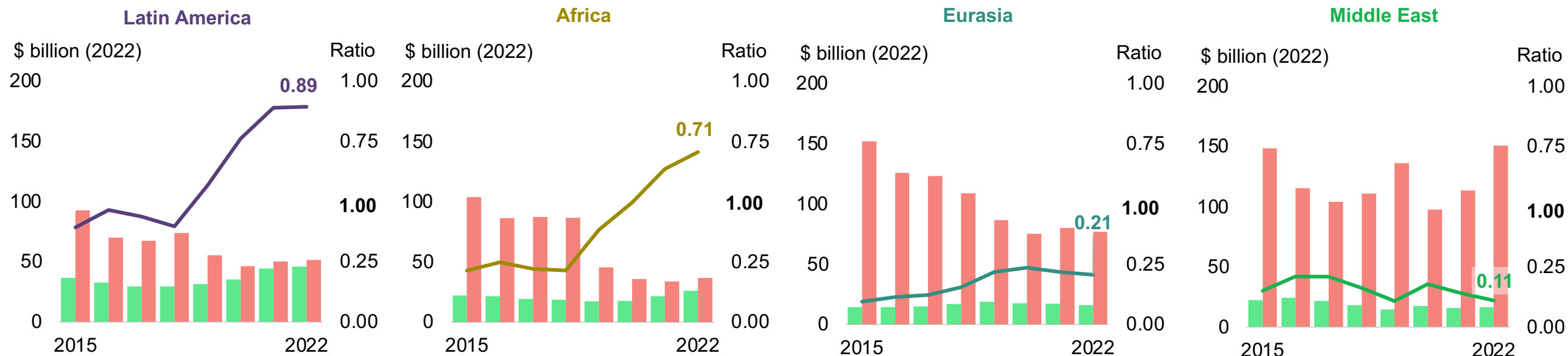


Source: International Energy Agency World Energy Investment 2023 Report, BloombergNEF. Note: The classification of both “low-carbon” and “energy supply investment” are categorized by BNEF classification. The methodology is further elaborated in [Appendix 6](#).

- **Europe and China** are spearheading the investment shift towards low-carbon energy supply. They had the highest energy supply investment ratios in 2022, at 1.7 and 1.6, respectively. Europe was able to grow its ratio by 0.1 in the face of various headwinds – such as the energy crisis, which saw developed nations like Germany return to coal, and permitting bottlenecks and grid interconnection delays. For China, the 0.3 increase in its ratio last year was largely due to the \$55 billion jump in investment in renewable energy and electricity grids. However, the region still saw high investment in fossil fuels, especially coal, which saw a \$19 billion increase in 2022.
- The energy supply investment mix in **North America** still skews towards fossil fuels, mainly due to the region’s strong oil and gas footprint. Its ratio briefly reached parity in 2020 when drilling operations were halted, but dropped in the following years as the rebound in fossil-fuel investment outpaced spending on low-carbon supply. This came despite more independent oil and gas companies opting to increase capital discipline, favoring dividends and share buybacks for shareholders in lieu of investing in expanding production. Similar ratio trends can be observed in **Asia Pacific**, where low-carbon spending has stayed relatively stagnant at around \$160 billion post-pandemic. Barriers such as a lack of an enabling environment and high financing costs have reduced the flow of capital into low-carbon energy systems in the region.

# Latin America and Africa increase their ratio; Eurasia and Middle East focus on fossil fuels

## Investment in low-carbon and fossil-fuel energy supply investment by region

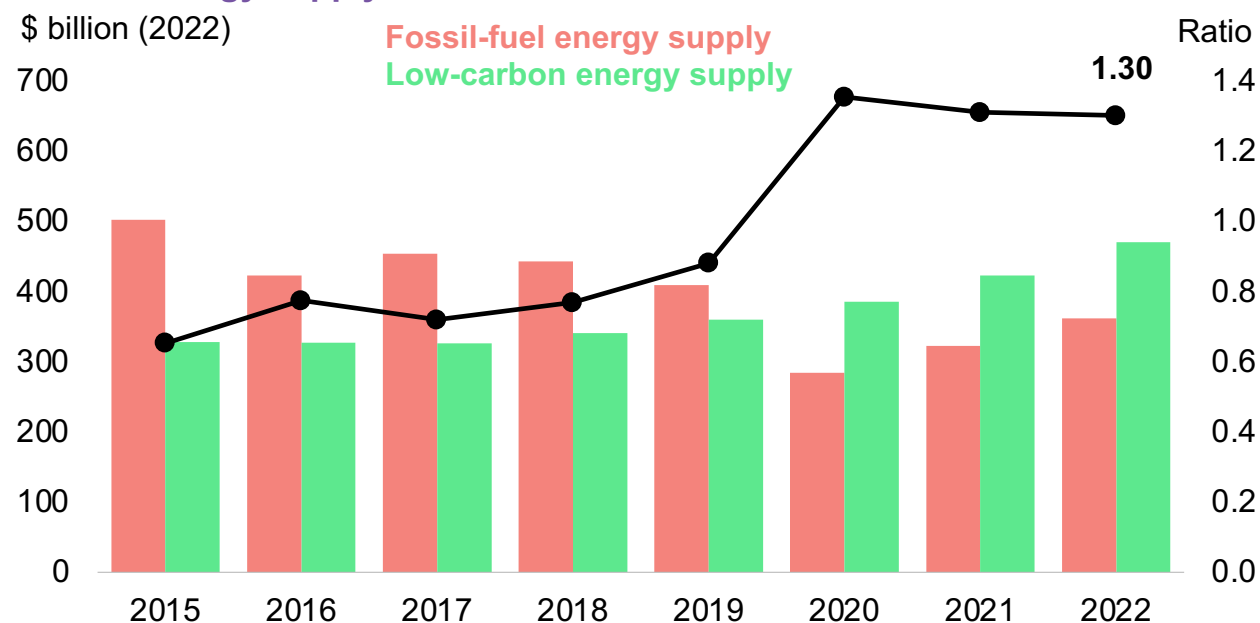


Source: International Energy Agency World Energy Investment 2023 Report, BloombergNEF. Note: Latin America comprises both Central and South America. The classification of both “low-carbon” and “energy supply investment” are categorized by BNEF classification. The methodology is further elaborated in [Appendix 6](#).

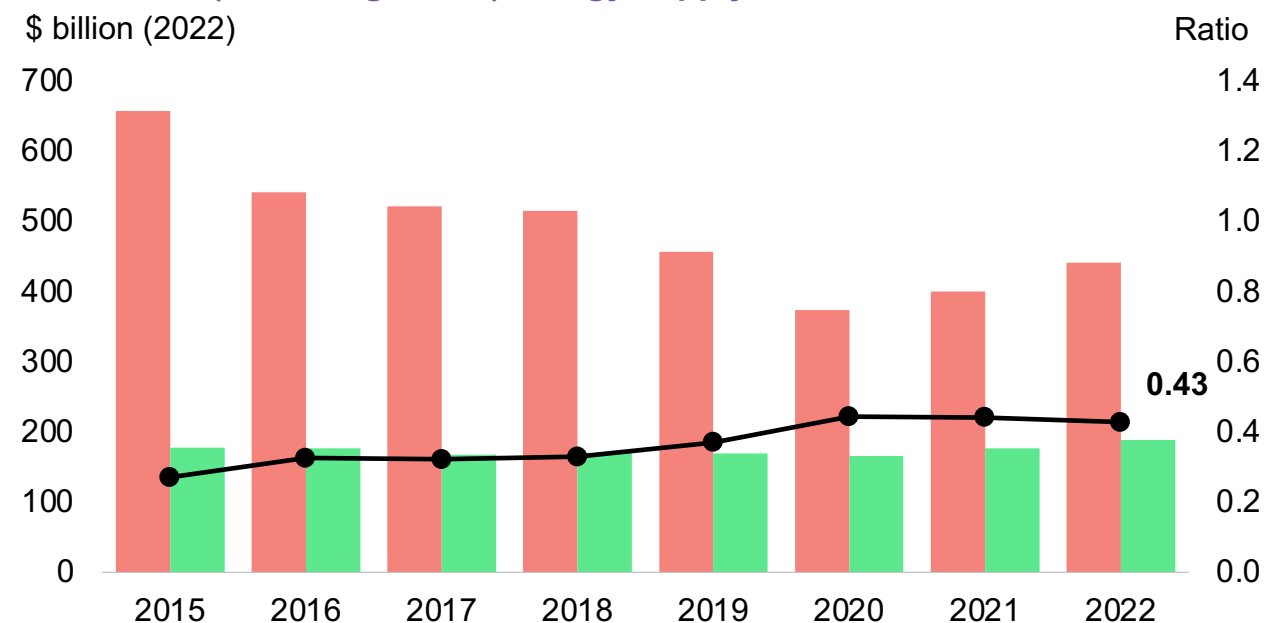
- Of all the net fossil-fuel exporting regions (barring the US), the Middle East invested the highest amount into energy supply investment in 2022, at \$167 billion. Some \$151 billion of this was channeled into oil and gas. Africa, meanwhile, had the lowest investment volume at just \$63 billion, less than a fifth of the capital outlay for just low-carbon supply in China.
- None of these net exporting regions have yet reached parity line for their energy supply investment ratio. For **Latin America and Africa**, the ratio has trended upwards since 2018, reaching 0.9 and 0.7 in 2022, respectively.
- The narrative differs for **Eurasia and the Middle East**, whose macroeconomic stability is closely tied to oil and gas production. These two regions had the lowest ratios of 0.2 and 0.1 in 2022, with most of the energy supply investment heading exclusively to oil and gas. The spike in commodity prices last year was a boon for the profitability and cash flows of Middle Eastern oil and gas companies, supporting the \$36 billion gain in annual investment in these sectors. There is little incentive so far for these regions to decarbonize, as demonstrated by their stagnant spending on low-carbon energy supply, which still has not rebounded to pre-pandemic levels.

# OECD and non-OECD regions have distinctly different investment profiles

## OECD+ energy supply investment



## Non-OECD (excluding China) energy supply investment

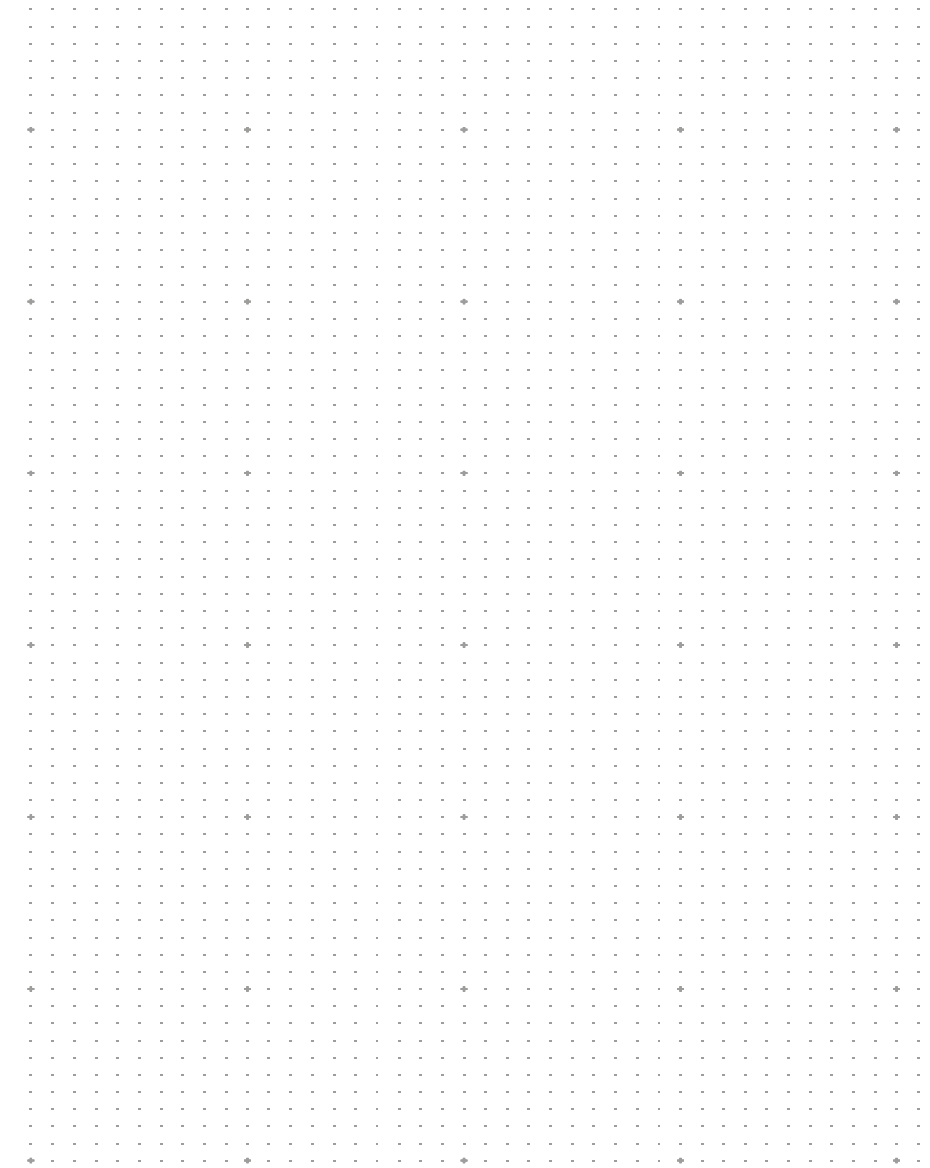


Source: International Energy Agency, BloombergNEF. Note: Aggregated by BNEF using IEA's World Energy Investment 2023 dataset. The methodology is further elaborated in [Appendix 6](#). "OECD" stands for Organization for Economic Cooperation and Development. For more on regional conventions, please see [Appendix 7.1](#). Data above excludes China.

- The energy supply investment allocation for fossil-fuel and low-carbon assets differs between **OECD+** and **non-OECD** regions. In the former, investment in low-carbon energy supply has surpassed that for fossil fuels since 2020 due to the increasingly favorable policy environment and strong push for greener economies. The high investment into renewable power and grids (amounting to over 50% of overall supply capex in 2022) is driven mainly by the push to decarbonize and fully electrify power systems.
- Conversely, non-OECD regions have lagged when it comes to decarbonization. As of 2022, only \$0.43 was invested in low-carbon supply for every dollar invested in fossil fuels. The rise in the ratio has also been tepid, climbing from just 0.27:1 in 2015.
- With the continued shift away from fossil fuels and the added policy boost of the Inflation Reduction Act, REPowerEU, and the EU's Fit for 55 package in OECD+ markets, their energy supply investment ratios may increase in 2023. It is unclear how the ratios for non-OECD regions will change.

# Energy supply investment ratio – 2030 outlook

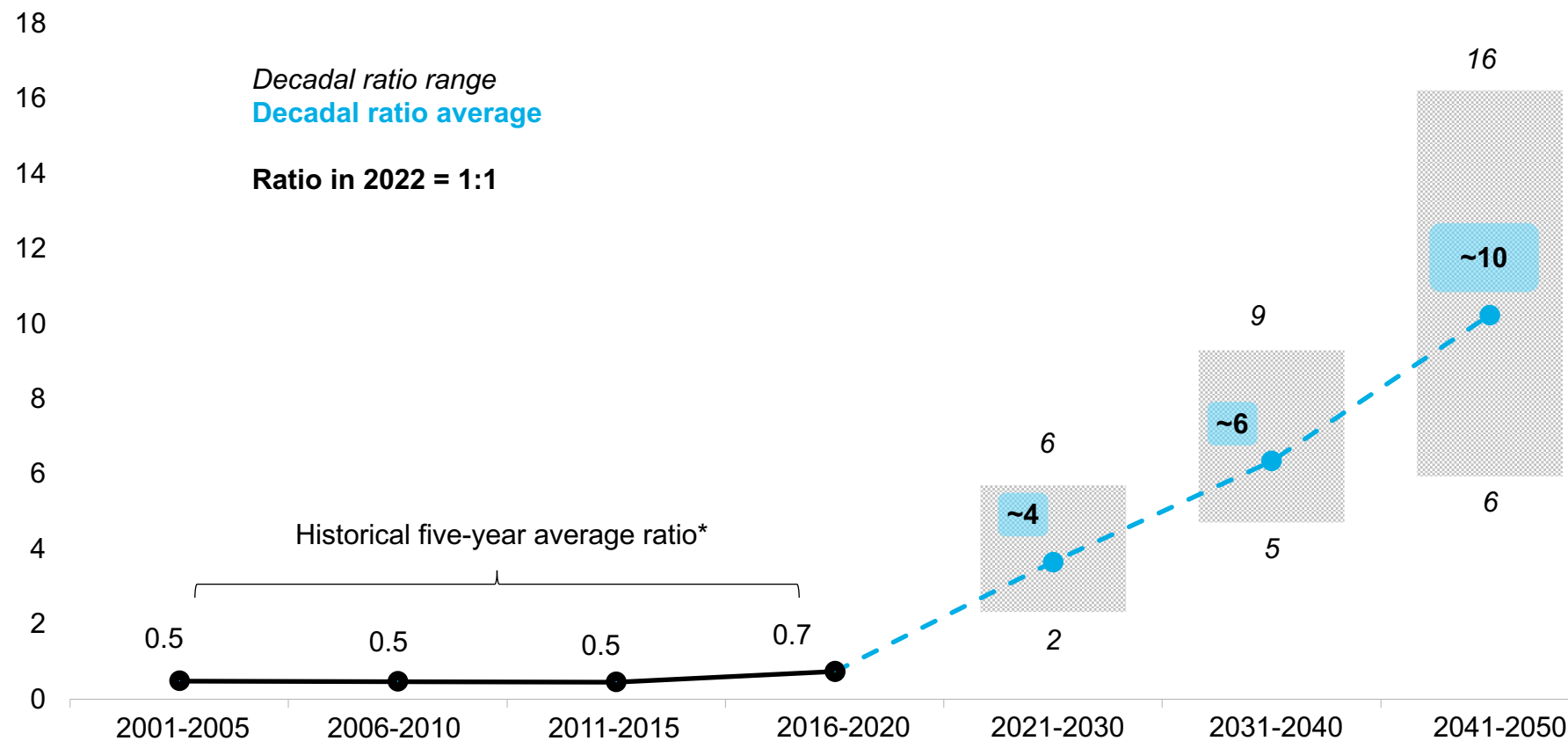
Global and regional



# Aligning the world to net zero and 1.5C requires a minimum ratio of 4:1 by 2030

## Energy supply investment ratio by decade

Energy supply investment ratio



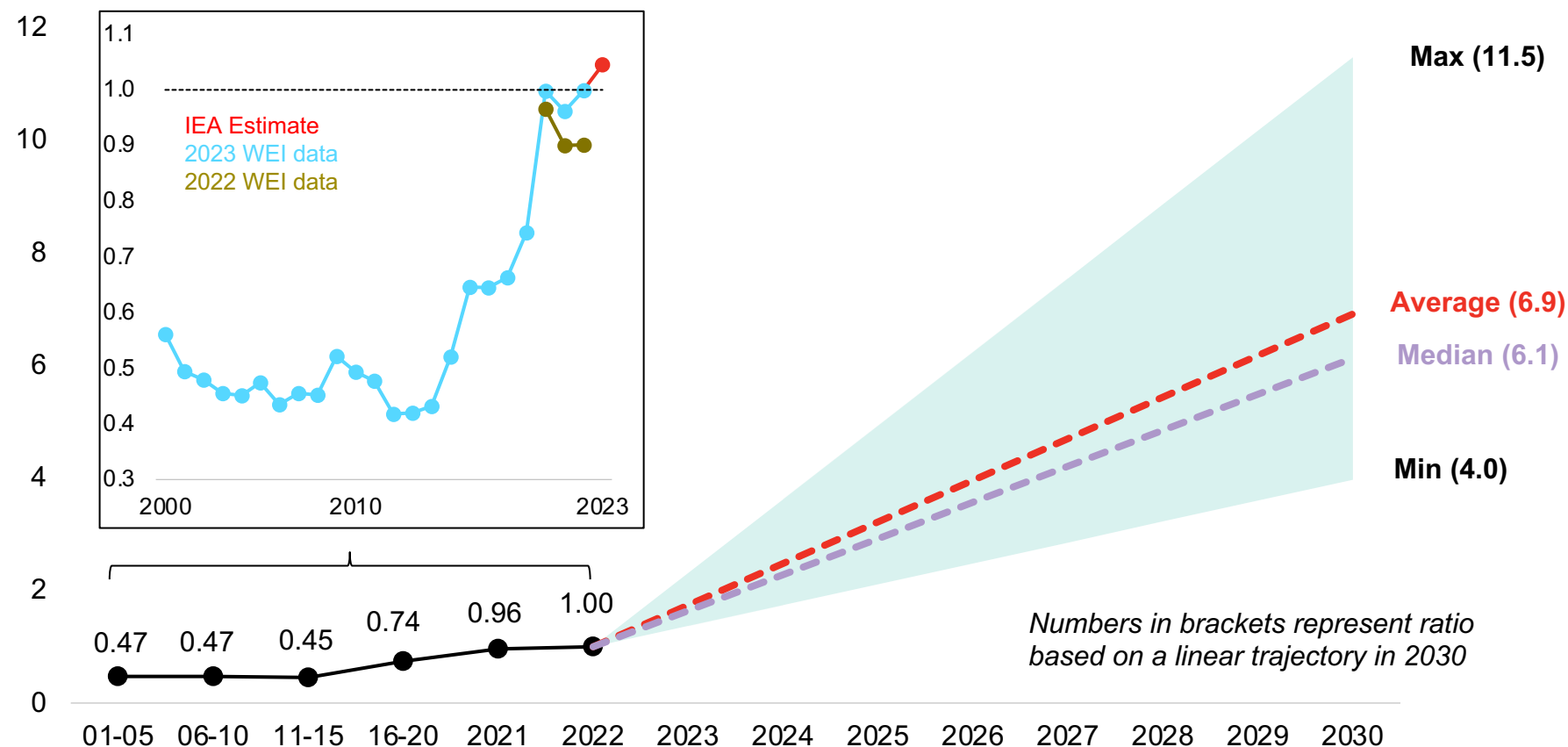
Source: BloombergNEF, IEA, IPCC, NGFS. Note: The decadal values and ranges have been rounded to the nearest whole number. \*Denotes BNEF aggregation of previous IEA World Energy Investment reports and datasets.

- BNEF aggregated the decadal low-carbon and fossil-fuel energy supply investment totals and accompanying ratios across various climate scenarios from the IEA, IPCC and NGFS. This serves as a usable metric for financial institutions to track alignment to climate targets. For more on the energy supply investment ratio, please see [Appendix 2](#).
- The average decadal energy supply investment ratio stands at roughly at **4:1, 6:1 and 10:1** across the coming three decades, respectively. In other words, in the 2020s, for example, for every dollar invested in fossil-fuel supply globally, at least four needs to be invested in low-carbon energy supply to remain on track for net-zero emissions and 1.5C of warming.
- The average decadal ratios across all these scenarios jumps by roughly 60-75% per decade across the 2020s to 2040s, as fossil-fuel investment drifts lower in each consecutive decade, while capital into low-carbon supply stays elevated.

# This calls for a significant increase in the ratio over the remainder of this decade

## Energy supply investment ratio by decade

Energy supply investment ratio



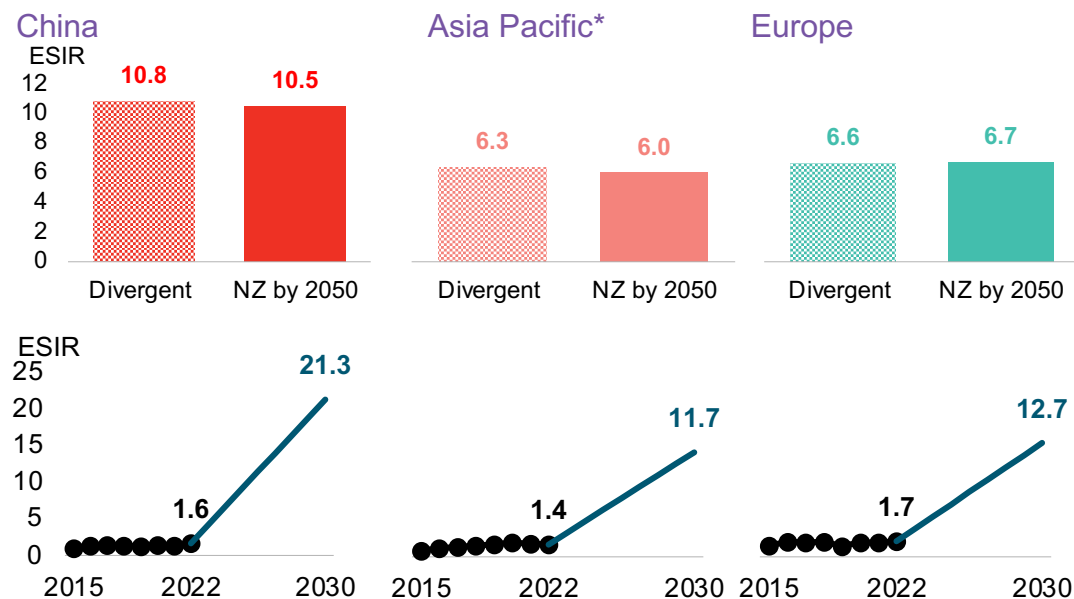
- The estimated energy supply investment ratio **needs to ramp up significantly** to match the average ratio required for the current decade.
- To determine the implied pace of that jump, a simple linear increase signals the need for a ratio rise of 0.74 annually to average roughly 4:1 across the decade, ending at 6.9:1 in 2030. Growth of at least 0.37 per year is required to reach the lower end of the range in 2030 of 4:1.
- An extrapolation of historical growth rates would mean **missing climate targets**. Based on the 8% compound annual ratio growth rate seen across 2015 to 2022, the ratio would only rise to approximately 2:1 by 2030, far from the minimum of 4:1 required, let alone 7:1.
- The short term (up to 2030) is a pivotal time to kickstart the higher investment volumes necessary for the energy transition and prevent a backlog of emissions that need to be reduced more rapidly later.

Source: BloombergNEF, IEA, IPCC, NGFS. Note: Historical ratios are based on BNEF's aggregation of previous IEA World Energy Investment reports and datasets. Estimates are based of IEA data.

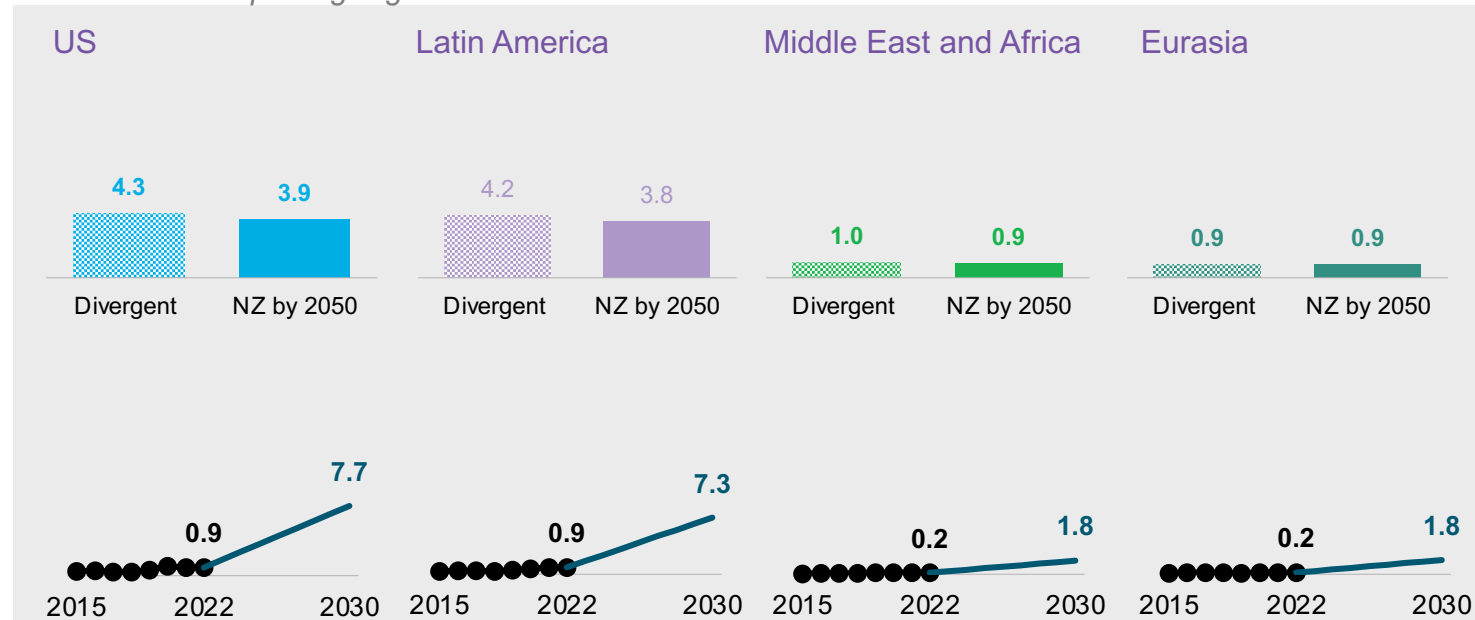
# Fossil-fuel exporting regions have lower ratios than importing regions

## Average decadal ratio (top) and linear growth required to meet average decadal ratio (bottom)

Net fossil-fuel importing regions



Net fossil-fuel exporting regions



Source: BloombergNEF, NGFS Climate Scenarios Vintage 3. Note: “ESIR” refers to energy supply investment ratio. Regional investment levels are aggregated by BNEF based on NGFS data. For more information on the methodologies, please see [Appendix 6](#). For more on the designation given towards net fossil-fuel importing and exporting regions, please see [Appendix 5](#). \*Asia Pacific excludes China.

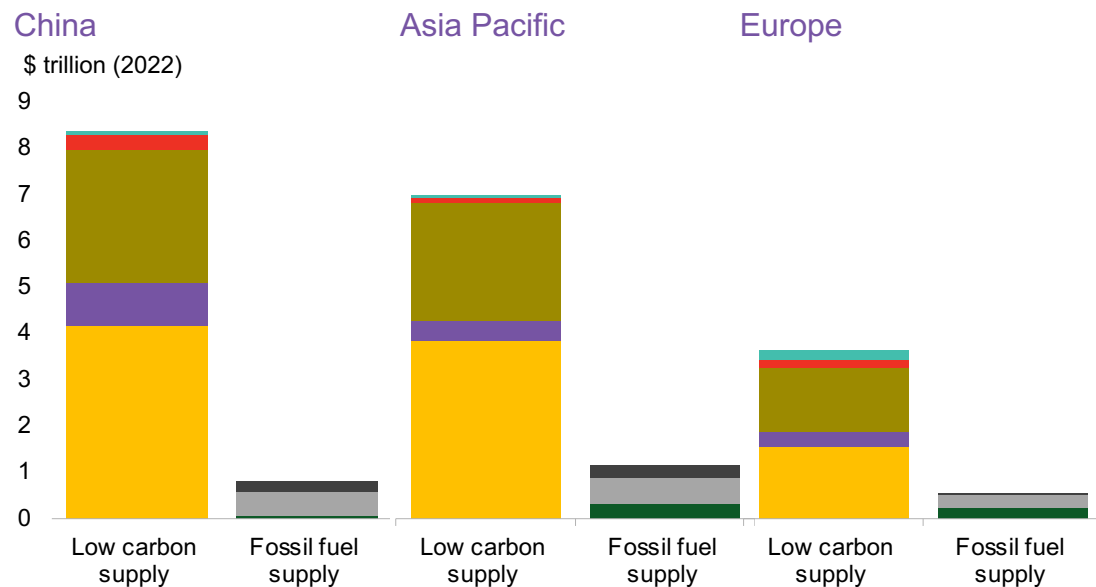
- Geography matters as each region will have varying investment opportunities and ratios. In the current decade, China requires the highest ratio, with levels of above 10:1 for both the net-zero NGFS scenarios. Europe and Asia Pacific follow. However, these ratios decline dramatically in net fossil-fuel exporting regions, such as the Middle East and Africa and Eurasia, where the energy sectors and economies continue to source energy from domestic fossil-fuel industries in the scenarios.
- Two key findings emerge when reconciling the aggregated IEA historical ratios with the outlook for the different regions using the NGFS scenarios: 1) **the pace of ratio scale-up will vary** among the different regions, and 2) **none are on track** to align with the required ratios.
- Despite strong historical ratios, China, Europe and Asia Pacific possess the largest opportunity implied to scale their ratio, in large as they are net importers of fossil fuels. Meanwhile, the scale-up is much less aggressive in the net fossil-fuel producing regions, with Middle East and Africa and Eurasia.
- Financial institutions can take note of these regional differences to better understand their regional lending and investment footprint relevant to an appropriate ratio – for example, banks operating in China and Europe might have a different trajectory than those with Middle Eastern energy exposure.



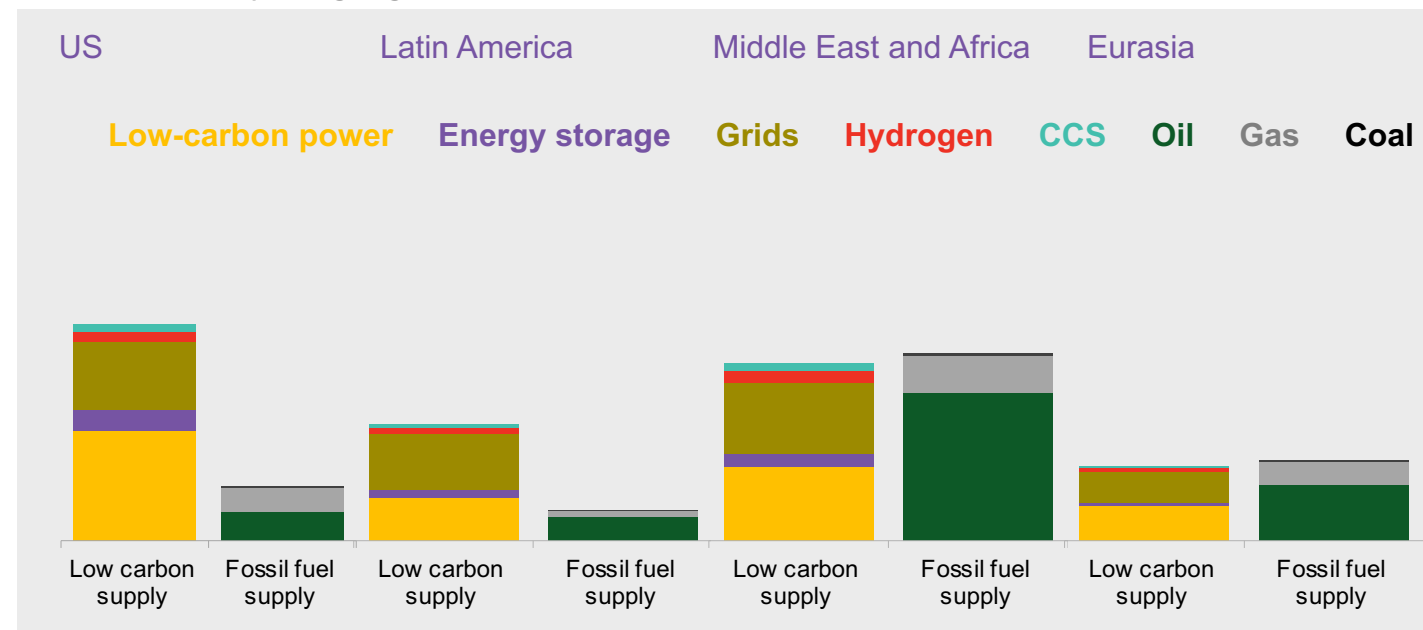
# Low-carbon supply plays a more significant role in fossil-fuel importing regions

## Energy supply investment across 2021 to 2030 by region

Net fossil-fuel importing regions



Net fossil-fuel exporting regions

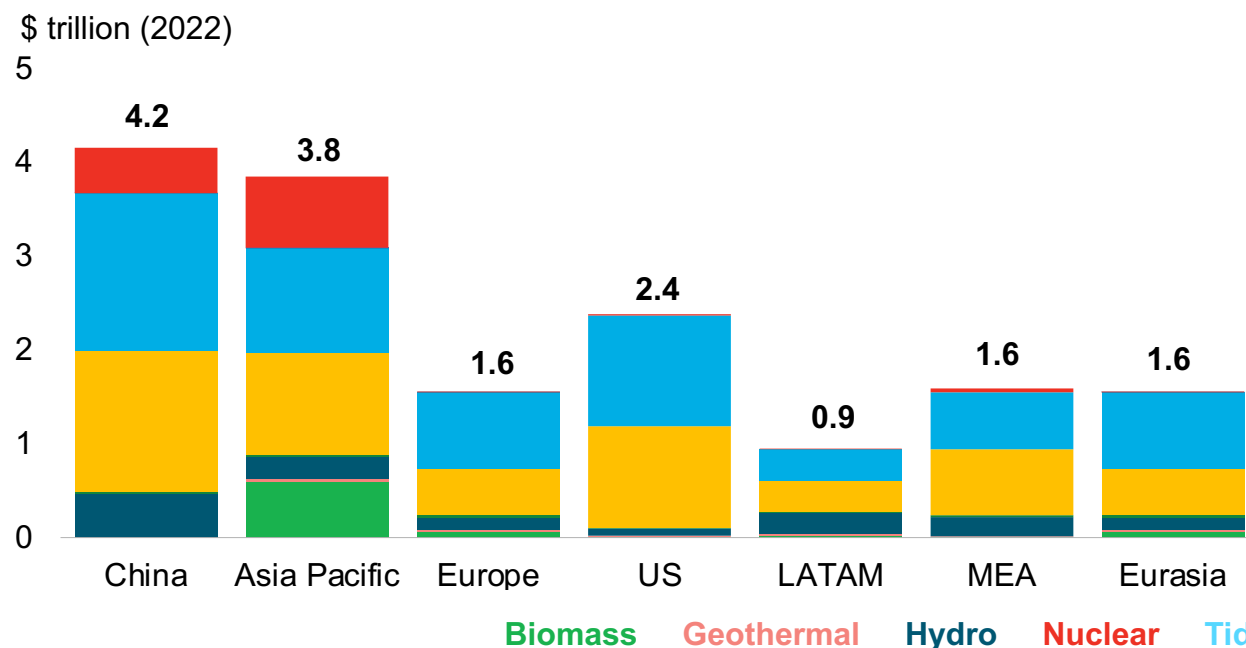


Source: BloombergNEF, NGFS Climate Scenarios Vintage 3. Note: "CCS" refers to carbon capture and storage. Regional investment levels are aggregated by BNEF based on NGFS data. For more information on the methodologies, please see [Appendix 6](#). For more on the designation given towards net fossil fuel importing and exporting regions, please see [Appendix 5](#). \*Asia Pacific excludes China. Based on the NZ by 2050 scenario.

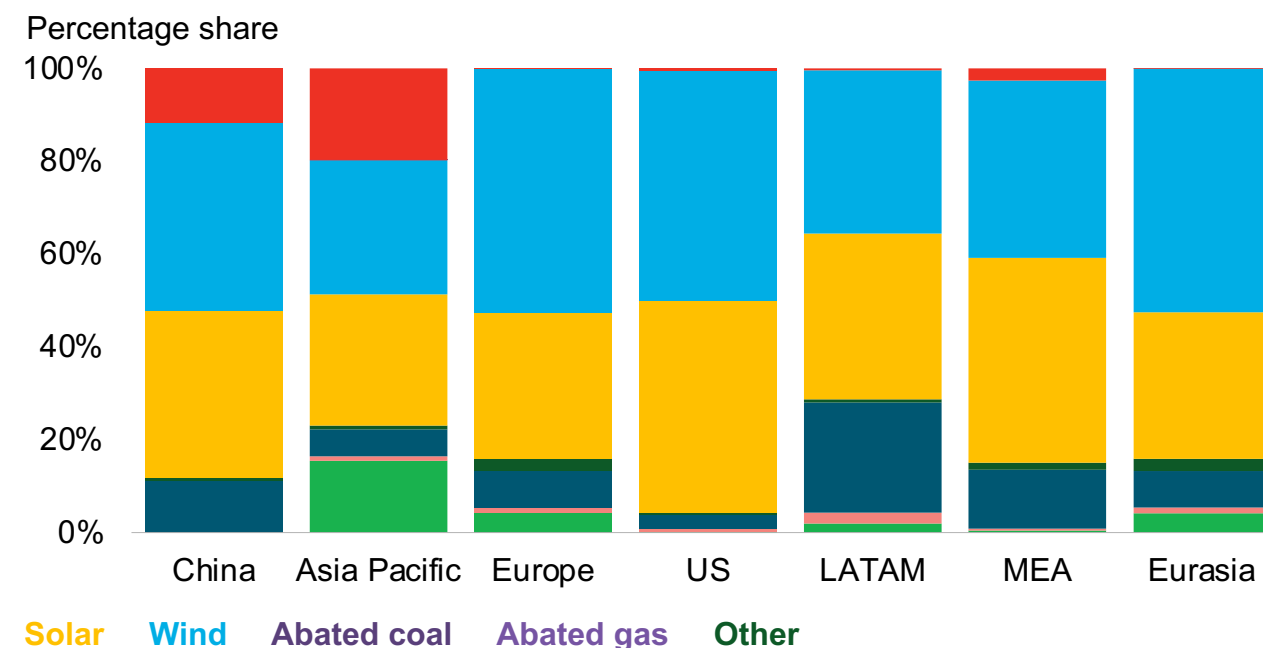
- China is set to have the largest investment in low-carbon energy supply by the end of the decade, racking up \$8.4 trillion across 2021 to 2030 within the NGFS Net Zero by 2050 scenario. Around 91% of this is allocated to renewable energy (primarily wind and solar technologies) and grid systems. Asia Pacific and the US take up second and third spot in the scenario, with low-carbon supply investment needs of \$7 trillion and \$4.7 trillion, respectively.
- Meanwhile the Middle East and Africa, and Eurasia, all fossil-fuel dependent economies, see the highest capital expenditure on hydrocarbons, at \$4 trillion and \$1.7 trillion, respectively. This makes up over 50% of their total energy supply capital outlay.
- Investment requirements will differ across regions due to a multitude of underlying factors, such as economic development, population growth and varying energy mixes. BNEF aggregated these numbers for the different regions based on an underlying dataset from the NGFS scenarios. NGFS numbers were used due to the level of availability and granularity of data, which are not obtainable from the IPCC or the IEA.

# Low-carbon power investment in wind and solar dominates needs across all regions

Investment in low-carbon power across 2021 to 2030, by region and technology



Low-carbon power investment mix from 2021 to 2030

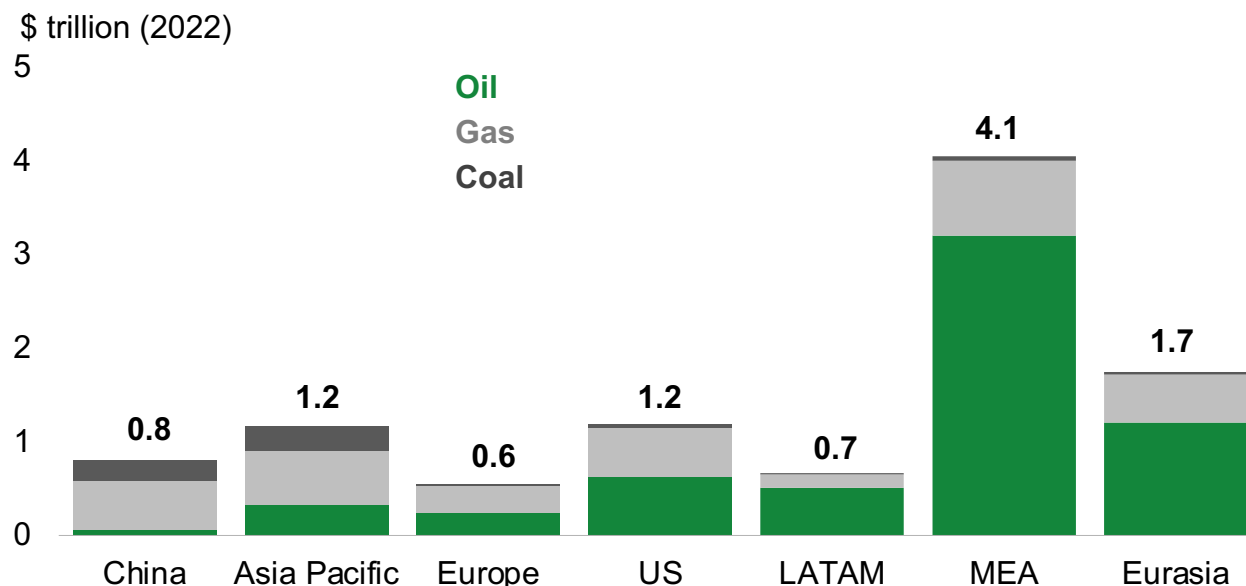


Source: BloombergNEF, the Network for Greening the Financial. Note: Investment figures have been aggregated by BNEF from the underlying NGFS data explorer. "LATAM" stands for Latin America. "MEA" stands for Middle East and Africa. Data based on the NZ by 2050 scenario.

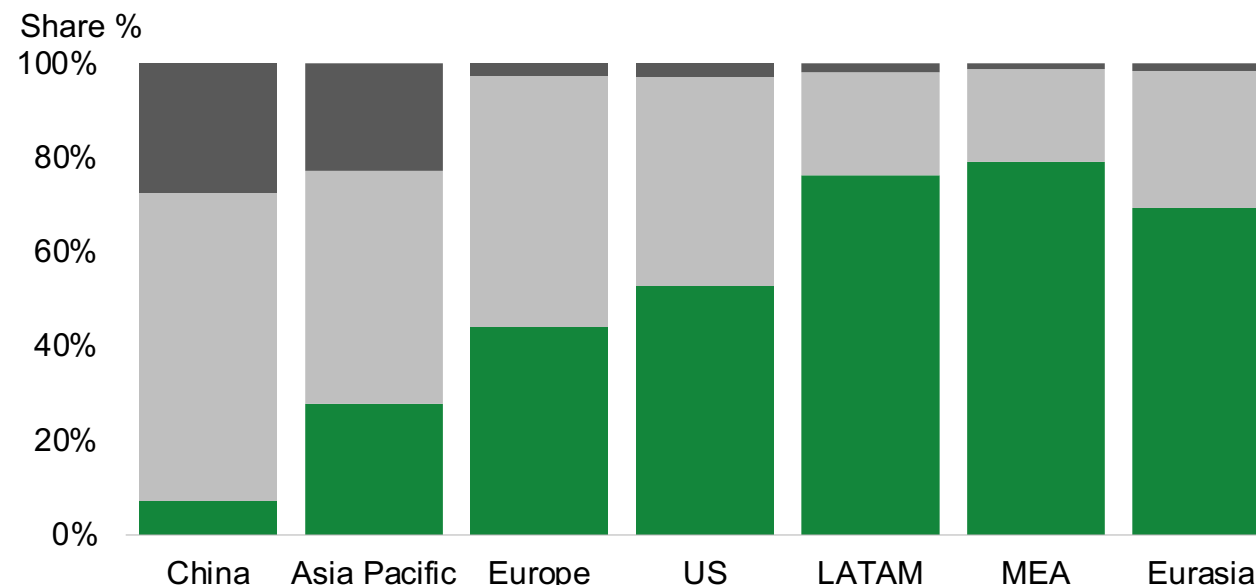
- Capital outlay for low-carbon power could account for 20% to 47% of the overall energy supply investment across different markets from 2021 to 2030. Regions like Asia Pacific, China and Europe sit at the high end of the range, while the Middle East and Africa and Eurasia sit at the lower end given their heavy emphasis on fossil fuels.
- Across the different regions, investment in wind and solar technologies dominate the low-carbon power capex mix, collectively reaching between 57% (in Asia Pacific) to 90% (in the US) as a share of the total volumes. Investment in nuclear energy is earmarked to account for 11% to 20% of the overall mix in Asia Pacific and China, higher than any other region.
- Mobilizing this low-carbon investment will require co-operation between public and private institutions, favorable policies and coherent support frameworks. To date, headwinds including supply chain and regulatory bottlenecks, along with a lack of attractive returns, have slowed down investment flows toward renewable projects, most recently for wind.

# Oil leads the fossil-fuel investment mix to 2030; coal is small in comparison

Investment in fossil-fuel supply across 2021 to 2030, by region



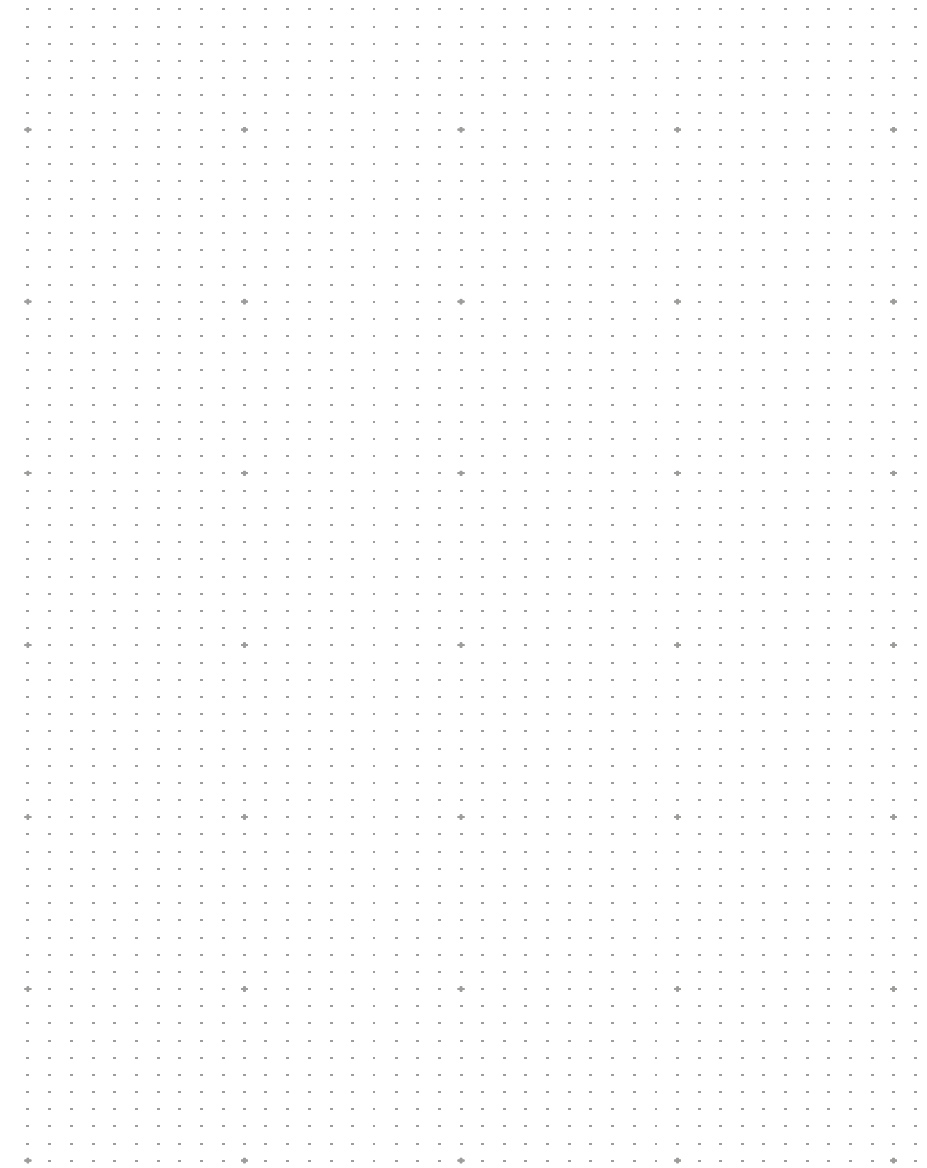
Fossil-fuel supply investment mix from 2021 to 2030



Source: BloombergNEF, the Network for Greening the Financial. Note: Investment figures have been aggregated by BNEF from the underlying NGFS data explorer. "LATAM" stands for Latin America. "MEA" stands for Middle East and Africa. Data based on the NZ by 2050 scenario.

- The Middle East and Africa and Eurasia dominate the investment required for fossil-fuel supply this decade at \$4.05 and \$1.74 trillion, accounting for 40% and 17% of the total capital into fossil fuels globally. Europe has the lowest at \$0.55 trillion over the equivalent time period, given the region's strong stance on transitioning to clean energy and weaning itself off its fossil fuel reliance.
- By fuel type, oil accounts for 61% of the total fossil-fuel investment, followed by gas at 33% and coal at just 6%. Asia Pacific and China account for the highest coal investment required, each at over \$0.2 trillion, whereas all other regions have less than \$0.1 trillion pegged to the end of the decade.
- For oil, petrodollar-heavy regions like the Middle East, Africa and Eurasia lead spending at \$3.2 trillion and \$1.2 trillion, respectively, making up approximately 70-80% of their respective fossil-fuel investment mix.
- Gas sits in the middle ground for most regions, apart from China and Asia Pacific, where it represents the highest of their fossil-fuel investment needs. These two regions see gas as a key bridge fuel in their transition away from coal within their growing power and industrials sectors in the NGFS Net Zero by 2050 scenario.

# Appendix

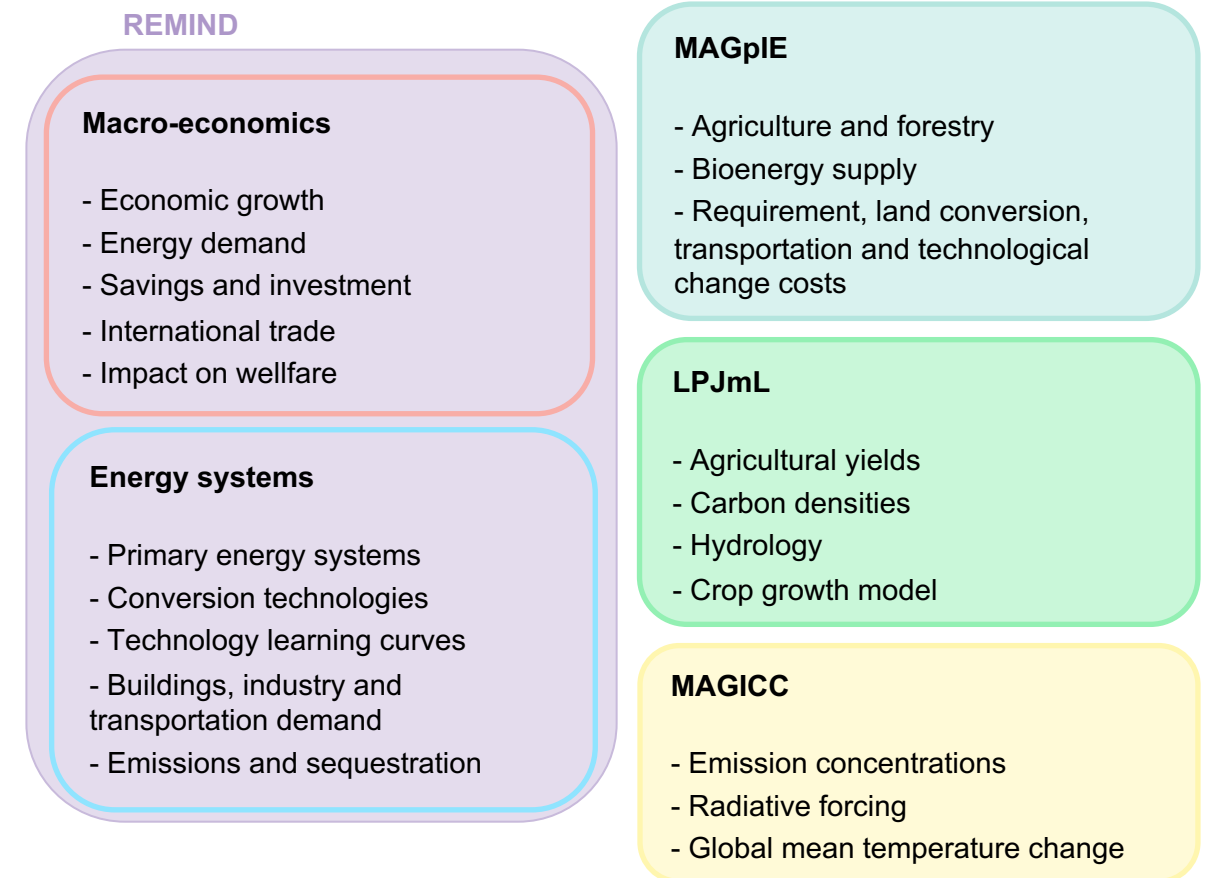


# What is the modeling framework behind the forward-looking scenarios?

## Integrated assessment models

- The forward-looking regional NGFS scenarios used in this analysis are based on the **REMIND-MAgPIE** integrated assessment models. This framework consists of four main components:
  - The *Regional Model of Investment and Development (REMIND)* is a bottom-up general equilibrium Ramsey type growth model. It factors in macroeconomic inputs such as capital accumulation and investment, international trade, energy and material demand, economic growth and engineering fundamentals.
  - The *Model of Agricultural Production and its Impacts on the Environment (MAgPIE)* is a partial equilibrium model optimized to meet agricultural demand under a biophysical and socio-economic constraints. The *Lund-Potsdam-Jena model for managed Land (LPJmL)* is the dynamic global vegetation, hydrology and crop growth model that provides biophysical inputs to MAgPIE.
  - The *Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)* is the model used to calculate the greenhouse gas emissions and other atmospheric variables of the pathways.
  - The geographical granularity spans 12 regions worldwide – including China, India, Japan, and the US. These are the native regions that are modelled to form the bottom-up global view.

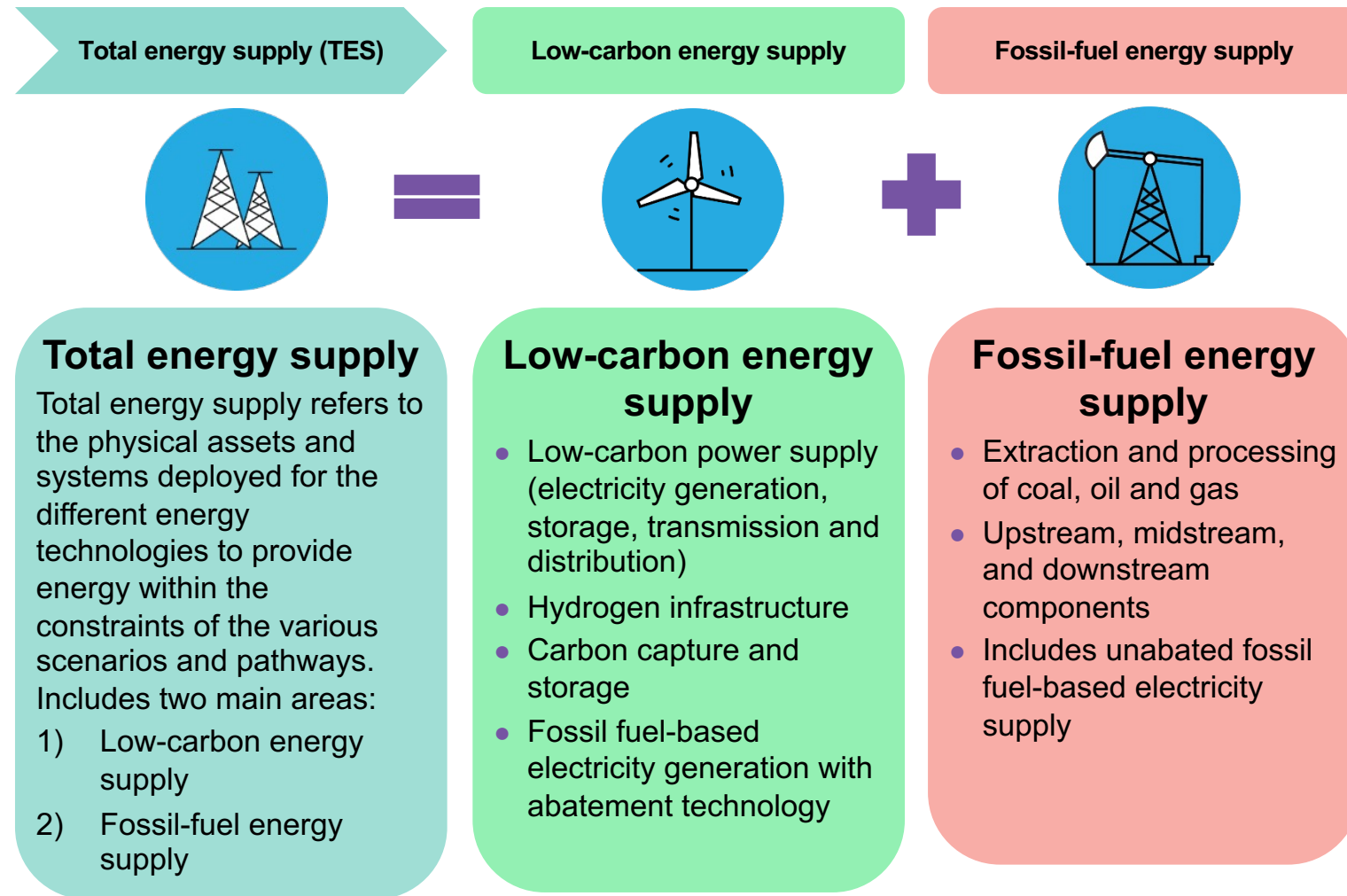
## REMIND – MAgPIE model framework



Source: *The Network for Greening the Financial System (NGFS), Earth System Science Data, BloombergNEF. Note: Analysis and figure adapted from the [NGFS Technical Documentation](#).*

# The use of energy supply ratios helps normalize investment across scenarios

## Scope and sector classification



Source: BloombergNEF.

## Energy supply investment ratio

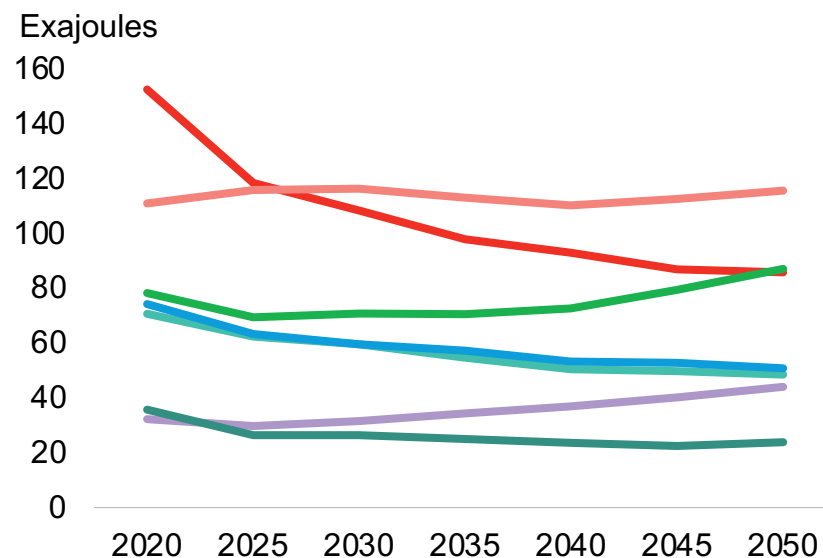
- The ratio of investment in **low-carbon energy supply versus fossil-fuel energy supply** offers a new view on how corporations, governments, state and multilateral organizations and financial institutions' financing activity aligns with climate scenarios.
- The use of energy investment ratios gives a clearer picture of climate scenarios' energy investment expectations by normalizing for population, economic growth and energy demand. The ratios also normalize the different scenario narratives and investment strategies.
- Ratios give a good overview of the **dollar-for-dollar balance** between low-carbon and fossil-fuel energy systems as a guide for climate-aligned energy investment.
- The ratio:

**Low-carbon bucket**  
Low-carbon energy supply

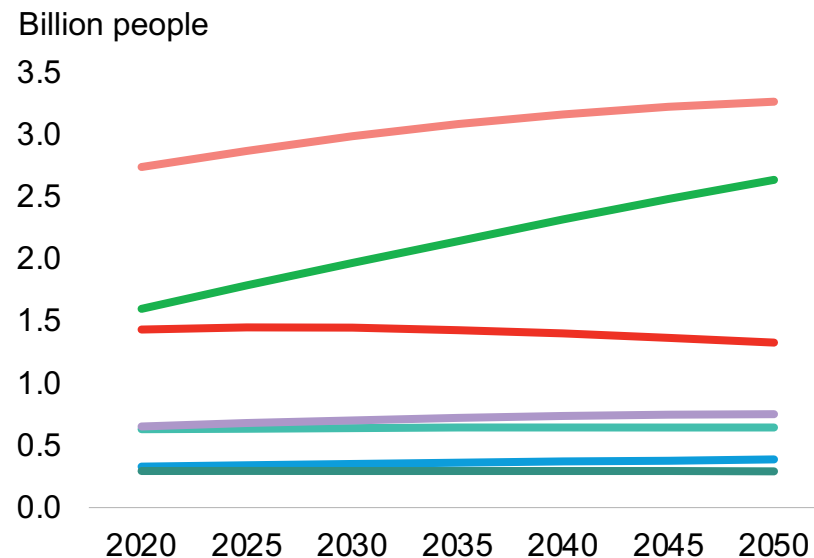
**Fossil-fuel bucket**  
Fossil-fuel energy supply

# Socio-economic variables vary across regions in the NGFS scenarios

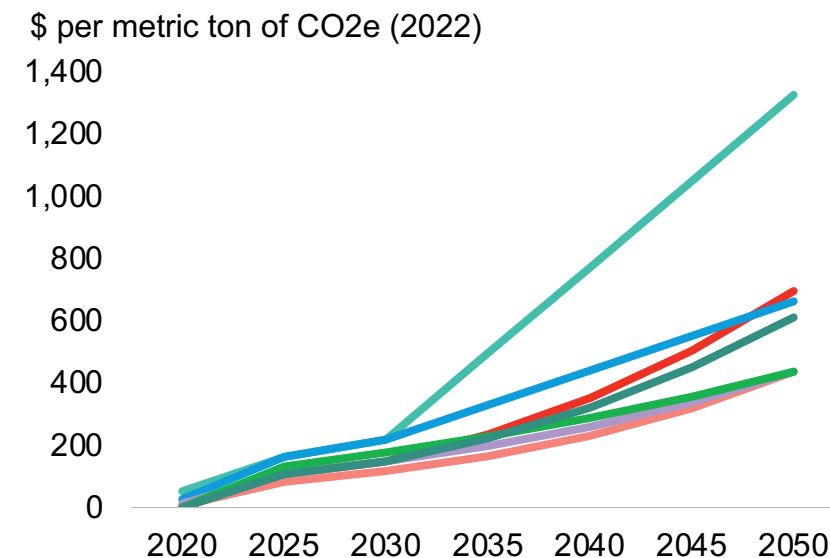
## Primary energy demand



## Population



## Emission prices



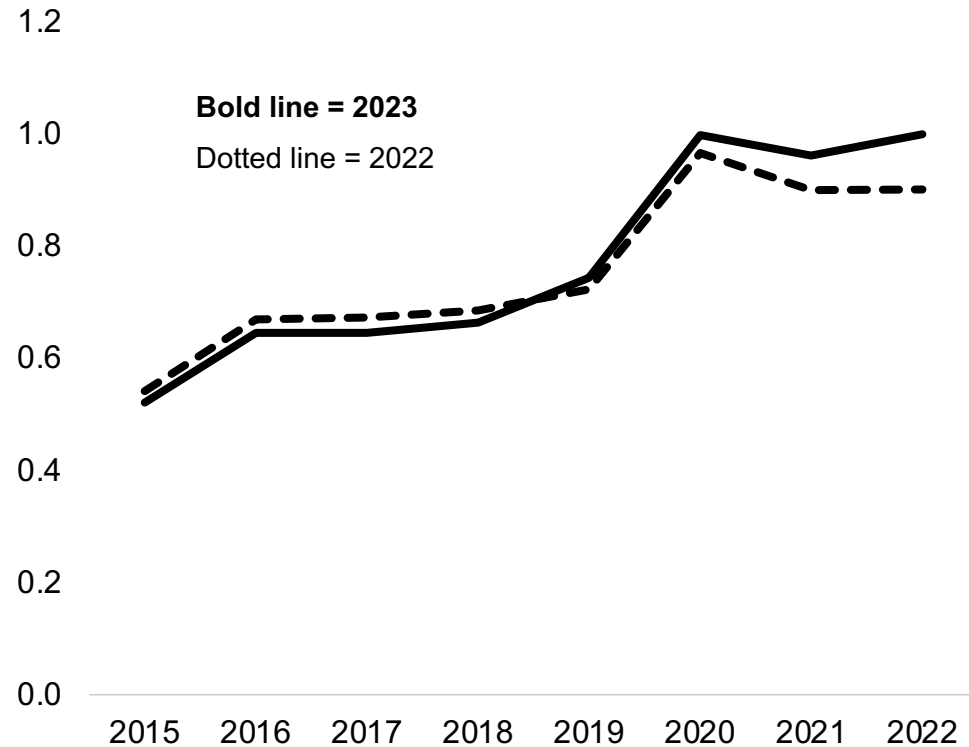
China Asia Pacific\* Europe US Latin America Middle East and Africa Eurasia

Source: The Network for Greening the Financial Systems (NGFS), BloombergNEF. Note: Emission prices have been converted to 2022 US dollars. \*Asia Pacific excludes China.

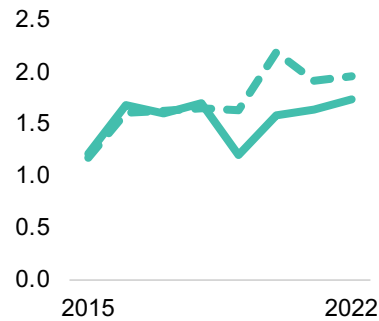
- Aside for Asia Pacific, the Middle East and Africa and Latin America – all of which are developing or emerging in their economic status – primary energy demand gradually reduces towards 2050 on the back of increased energy efficiency. For China, the region with the highest primary energy demand, levels decline by over 40% between 2020 and 2030. However, the 2030 level is still twice as much as that of the US, the second-largest energy consumer.
- In the short term to 2030, all regions see population growth, with the Middle East and Africa and Asia Pacific boasting the two highest growth rates of 23% and 9%, respectively, relative to 2020 levels. After 2030, only Asia Pacific, the Middle East and Africa, and the US experience growth, while other regions are set to see a decline.
- Carbon prices – defined as the marginal abatement costs of a metric ton of greenhouse gas emissions in the NGFS pathways – vary by regions, acting as a key proxy for the stringency of policies. Levels in 2030 range from \$117 per ton of CO<sub>2</sub> equivalent in Asia Pacific to \$218/tonCO<sub>2</sub>e in both Europe and the US, reflecting the higher level of ambition in abating emissions.

# The most recent IEA World Energy Investment revision illustrates higher ratios

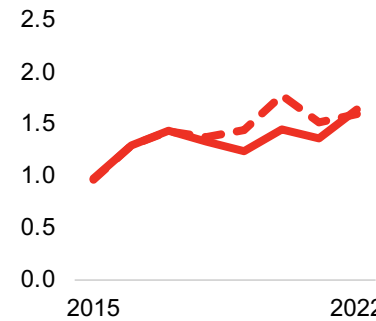
### Global energy supply investment ratio



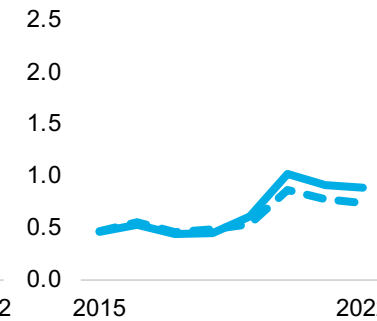
### Europe



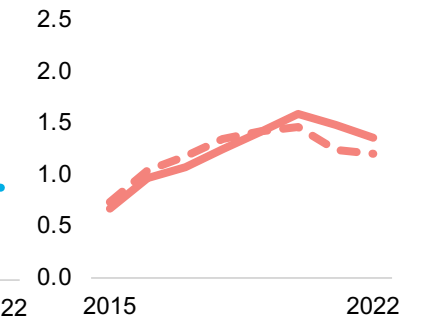
### China



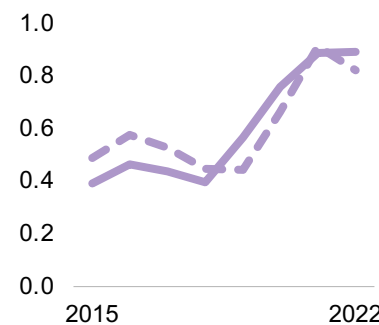
### North America



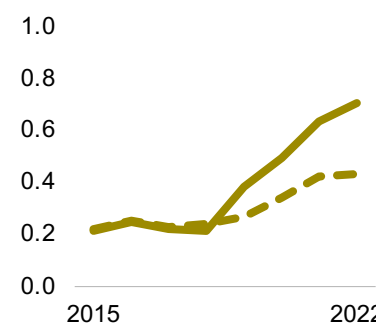
### Asia Pacific



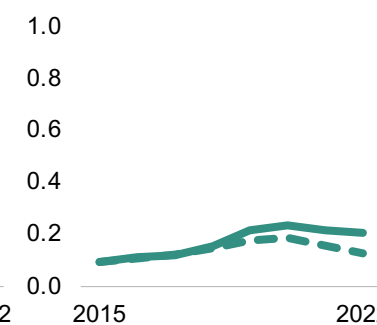
### Latin America



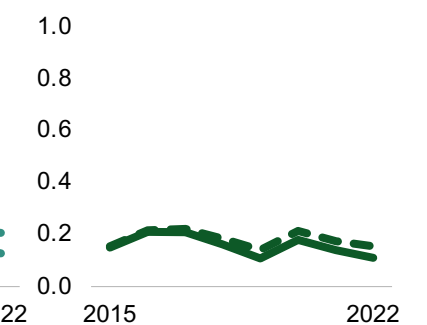
### Africa



### Eurasia



### Middle East



Source: International Energy Agency World Energy Investment 2023 and 2022 Reports, BloombergNEF. Note: The 2022 values for the IEA WEI 2022 are IEA estimates.

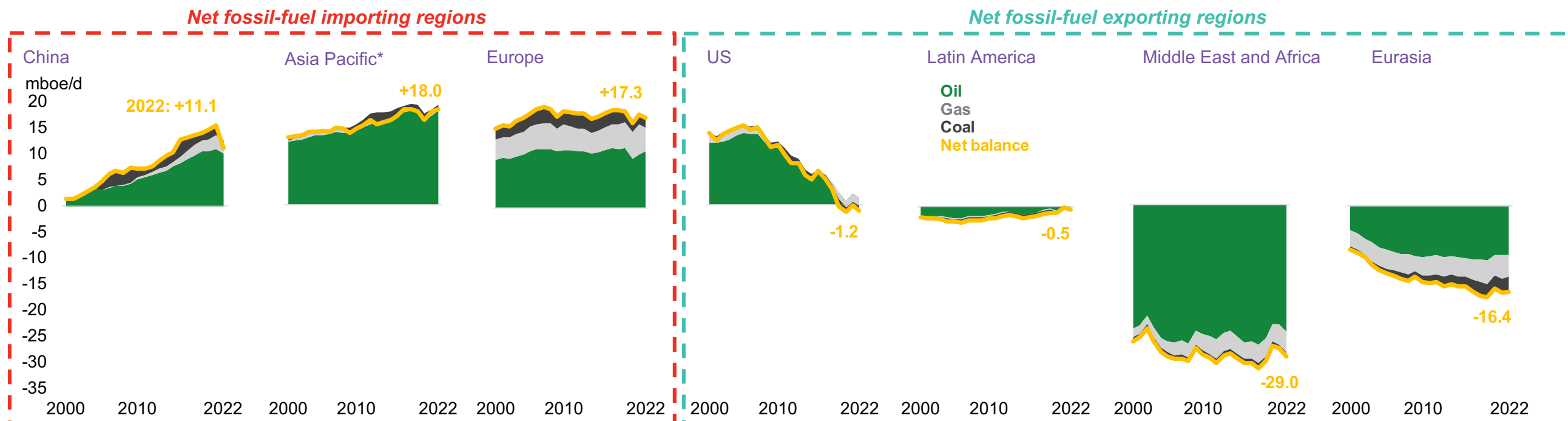
- The 2023 edition of the IEA's World Energy Investment dataset shows an upward revision to the global ratio of low-carbon to fossil fuel energy supply investment since 2019, relative to the 2022 edition.
- Europe and the Middle East were the only regions whose 2022 ratios were reduced. This is in part because developments in the commodity markets over the course of 2022 allowed the Middle East to double down on fossil-fuel supply growth and Europe to bolster its coal supplies as disruptions from Russia hit imports.



# Regional net fossil-fuel balance: Net exporters and importers

This section elaborates on the aggregation for a net fossil-fuel importing and exporting region. It takes into account the balance for oil, natural gas and coal. Negative data indicates net exporting, whereas positive data indicates net importing.

## Fossil-fuel balances



Source: BloombergNEF, Energy Institute. Note: The balance is taken by subtracting production from consumption. Positive indicates net importer, and negative indicate net exporter. Gas and coal production and consumption have been converted from exajoules to barrels of oil equivalent (boe) through the conversion  $1EJ = 163,452,108boe$ . Mboe/d stands for million barrels of oil equivalent per day. \*Asia Pacific excludes China. The aggregation assumes one calendar year = 365 days

- China, the rest of Asia Pacific and Europe are all net fossil-fuel importers, mainly driven by their huge demand for oil. China and Asia Pacific, however, were net producers of coal in 2022. The Middle East and Africa and Eurasia were clear net fossil-fuel exporters, producing more oil, gas and coal to support their economies. Latin America and the US sit on a fine line, with net production of less than 1.5 million barrels of oil equivalent per day over the past five years. Before 2018, the US was a net fossil-fuel importer, driven by high consumption of oil products, although the surplus in balance began to narrow as the shale boom cycle set in motion.

# Methodologies and notes

## Energy supply investment ratio – historical:

The investment numbers were aggregated by BNEF from the IEA's World Energy Investment 2023 dataset. Units are reported in 2022 US dollars.

- **Low-carbon energy supply:** The sum of investment in renewables, electricity networks, and other supply net of investment into clean fuels. The latter was excluded so that the scope and methodology is in line with BNEF's [Energy Supply Investment Ratio](#) publications.
- **Fossil-fuel energy supply:** The sum of investment in oil, gas and coal, alongside power generation from oil, gas and coal.
- **Note on investment sums:** The sum of the underlying regional investment does not equate to the global value due to the underlying data from the IEA's World Energy Investment, in which the regional data do not total the global number. The original dataset has been removed in the IEA's database.

## Energy supply investment ratio – 2030 outlook:

These investment numbers pertain to regional capital expenditure across 2021 to 2030, aggregated by BNEF from the NGFS [Phase 3 data explorer](#). The two net-zero scenarios use are the [Net Zero by 2050 and Divergent Net Zero scenario](#). The modeling framework chosen is the REMIND-MAgPIE 3.0-4.4. For more information on the modeling, please see slide [20](#).

- Investment data is provided for the different technologies (both low-carbon and fossil-fuel supply) and regions and extrapolated by BNEF. Values have been converted into 2022 US dollar terms based on inflation levels collated by BNEF.
- Regional differentiation: Investment for Asia Pacific combines the underlying data for India, Japan, and "Other Asia". Europe consist of both EU and non-EU markets. The Middle East and Africa comprises the Middle East, North Africa and Sub-Saharan Africa. For more information, please see the [regional conventions](#).
- **Note on the regional scale-up:** The historical ratio from the IEA dataset has been matched with the respective regions in the forward-looking investment from the NGFS. As such, the individual markets may not exactly match each other. Specifically, the historical ratio for North America has been used to match the forward-looking investment for the US, and the Middle East and Africa (historical) combined to match the Middle East and Africa (outlook).
- **Note on Russia-Ukraine war:** Due to the limited time period and the long lead time for the modeling to complete, the NGFS scenarios – despite being released in September 2023 – do not reflect the effects of Russia's invasion of Ukraine.

Source: BloombergNEF, International Energy Agency, Network for Greening the Financial System.

# Regional conventions: Historical

## IEA's underlying dataset

The table below outlines the economy-level breakdowns for the regional conventions on the historical energy supply investment and ratios, aggregated from the IEA's World Energy Investment 2023 dataset.

| Europe   | Mainland China and Hong Kong | North America         | Asia Pacific   | Latin America   | Africa   | Eurasia   | Middle East  | OECD+  | Non-OECD   |
|--|------------------------------|-----------------------|--|---|--|---|--|--|--|
| European Union and Albania, Belarus, Bosnia and Herzegovina, North Macedonia, Gibraltar, Iceland, Israel, Kosovo, Montenegro, Norway, Serbia, Switzerland, Moldova, Turkey, Ukraine and UK | Mainland China and Hong Kong | Canada, Mexico and US | Australia, Bangladesh, Brunei Darussalam, Cambodia, North Korea, India, Indonesia, Japan, South Korea, Laos, Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand Vietnam and Other Asia, Afghanistan, Bhutan, Cook Islands, East Timor, Fiji, French Polynesia, Kiribati, Laos, Macau, Maldives, New Caledonia, Papua New Guinea, Samoa, Solomon Islands, Tonga and Vanuatu | Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Venezuela, and other Central and South American countries and territories | Algeria, Angola, Benin, Botswana, Cameroon, Congo, Democratic Republic of Congo, Ivory Coast, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, South Sudan, Sudan, Tanzania, Togo, Tunisia, Zambia, Zimbabwe and Other Africa | Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Russia, Tajikistan, Turkmenistan and Uzbekistan | Bahrain, Iran, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates and Yemen | OECD grouping of countries and Croatia, Cyprus, Malta and Romania. | All the other economies not listed as part of the "Advanced Economies" and mainland China and Hong Kong. |

Source: International Energy Agency. Note: Regional classification obtained from the IEA's World Energy Investment 2023 datafile. Latin America comprises Central and South America.

# Regional conventions: Outlook

## NGFS Phase 3 climate scenarios

The table below outlines the economy-level breakdowns for the regional conventions on the outlook to 2030 for the energy supply investment and ratios, aggregated from the [NGFS Phase 3 scenario and data explorer](#). Note that the economies are listed using ISO ([International Organization for Standardization](#)) codes.

| Europe   | Mainland China, Hong Kong and Macau | US  | Asia Pacific   | Latin America  | Middle East and Africa  | Eurasia  |
|--|-------------------------------------|-----|--|--|---|--|
| <p><b>Non-EU Europe:</b> ALB, AND, BIH, CHE, GRL, ISL, LIE, MCO, MKD, MNE, NOR, SJM, SMR, SRB, TUR, VAT</p> <p><b>EU:</b> ALA, AUT, BEL, BGR, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, FRO, GBR, GGY, GIB, GRC, HRV, HUN, IMN, IRL, ITA, JEY, LTU, LUX, LVA, MLT, NLD, POL, PRT, ROU, SVK, SVN, SWE</p> | CHIN, HKG, MAC                      | USA | AFG, ASM, ATF, BGD, BRN, BTN, CCK, COK, CXR, FJI, FSM, GUM, IDN, IND, IOT, JPN, KHM, KIR, KOR, LAO, LKA, MDV, MHL, MMR, MNG, MNP, MYS, NCL, NFK, NIU, NPL, NRU, PAK, PCN, PHL, PLW, PNG, PRK, PYF, SGP, SLB, THA, TKL, TLS, TON, TWN, TUV, UMI, VNM, VUT, WLF, WSM | ABW, AIA, ARG, ATA, ATG, BES, BHS, BLM, BLZ, BMU, BOL, BRA, BRB, BVT, CHL, COL, CRI, CUB, CUW, CYM, DMA, DOM, ECU, FLK, GLP, GRD, GTM, GUF, GUY, HND, HTI, JAM, KNA, LCA, MAF, MEX, MSR, MTQ, NIC, PAN, PER, PRI, PRY, SGS, SLV, SUR, SXM, TCA, TTO, URY, VCT, VEN, VGB, VIR | <p><b>Middle East and North Africa:</b> ARE, BHR, DZA, EGY, ESH, IRN, IRQ, ISR, JOR, KWT, LBN, LBY, MAR, OMN, PSE, QAT, SAU, SDN, SYR, TUN, YEM</p> <p><b>Sub-Saharan Africa:</b> AGO, BDI, BEN, BFA, BWA, CAF, CIV, CMR, COD, COG, COM, CPV, DJI, ERI, ETH, GAB, GHA, GIN, GMB, GNB, GNQ, KEN, LBR, LSO, MDG, MLI, MOZ, MRT, MUS, MWI, MYT, NAM, NER, NGA, REU, RWA, SEN, SHN, SLE, SOM, SSD, STP, SWZ, SYC, TCD, TGO, TZA, UGA, ZAF, ZMB, ZWE</p> | ARM, AZE, BLR, GEO, KAZ, KGZ, MDA, RUS, TJK, TKM, UKR, UZB |

Source: Network for Greening the Financial System (NGFS), BloombergNEF. Note: Regional market classifications taken from [technical documentation](#). Latin America includes Central and South America. Eurasia is categorized as Reforming Economies in the original NGFS database.

# Further BNEF reading

## Energy Supply Investment Ratios in a Low-Carbon World ([web](#) | [terminal](#))

There remains considerable uncertainty over the magnitude and composition of the required investment in energy supply to achieve meaningful decarbonization. This report outlines the capital spending needed to reach net-zero emissions and limit the global temperature rise to 1.5C from frequently referenced climate scenarios, and introduces the concept of the “energy supply investment ratio”.

## Energy Supply Investment and Bank Financing Activity ([web](#) | [terminal](#))

In this analysis, BNEF utilized public and commercially available data to assess banks’ energy sector financing activity in 2021 and the allocation between low-carbon supply and fossil fuels. Generating this ratio better approximates the extent to which banks’ financing activity is aligned to investment in the real economy and by extension to that needed by 1.5C-aligned climate scenarios.

## What Policy Levers Get the World to 1.5C and Net Zero? ([web](#) | [terminal](#))

Commonly referenced climate scenarios aligned to the temperature goals of the Paris Agreement use policy levers to achieve net-zero emissions goals. However, these vary between outlooks, the combination of which has a very different effect on prices, inflation and commodity fundamentals. This report specifically analyzes the net-zero pathways from the international Energy Agency and Network for Greening the Financial System.

## Mobilizing Capital Into Emerging Markets and Developing Economies ([web](#) | [terminal](#))

Emerging markets and developing economies (EM&DEs) account for nearly half of total global greenhouse gas emissions. Yet, given the size of the climate challenge, the volume of capital currently deployed in these markets to transition to lower-carbon energy is insufficient. This report offers a snapshot of present conditions for energy transition investment in EM&DEs.

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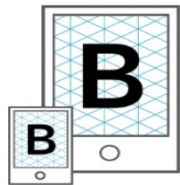
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