Investment Requirements of a Low-Carbon World: Energy Supply Investment Ratios

Total energy supply investment and ratio

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BloombergNEF

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Executive summary

There remains considerable uncertainty about the magnitude and composition of global energy investment required to achieve meaningful decarbonization. The most frequently referenced scenarios, under which in most cases the average global temperature rises no more 1.5°C, offer very different outlooks on population growth, energy demand, and technology development.

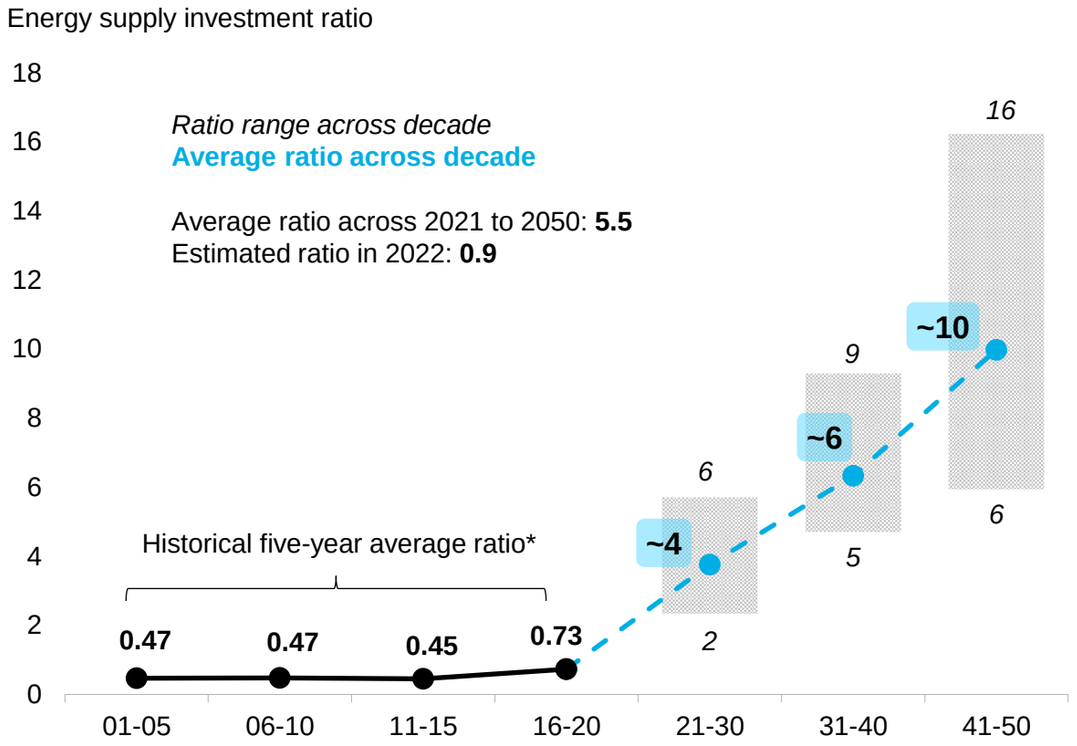
To better understand potential capital flows up to 2050, BloombergNEF (BNEF) has analyzed International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC), and Network for Greening the Financial System (NGFS) long-term scenarios. BNEF compared investment required under each for low-carbon technologies and compared that to potential investment for fossil fuels to produce decadal "energy supply investment ratios". Scenarios assessed included the IEA Net Zero Emissions scenario (NZE), four* IPCC scenarios aligned with a 1.5°C rise and two NGFS Phase 3 net-zero scenarios.

- **Across the scenarios, total energy supply investment into all technologies ranges from $40.2-114.4 trillion by 2050.** Fossil fuel supply spending greatly reduces by 2050, with coal nearing zero beyond 2030.
- **The 2011-2015 low-carbon to fossil energy supply investment ratio was 0.5 low-carbon vs. 1 fossil. For 2016-2020, it was 0.7:1 and in 2022 0.9:1.**
- **Over the next decade, the implied change is considerable. From 2021 to 2030, it reaches roughly 4:1 on average,** meaning for each dollar invested in fossil fuel energy supply, four would be invested in low-carbon energy supply.
- Beyond 2030, the ratio of low-carbon to fossil fuel energy supply investment rises to **~6:1 for 2031 to 2040** and **~10:1 for 2041 to 2050.**

*Note: *IPCC P2 and P3 from the 2018 special report on global warming were excluded as there was insufficient data.*

$114.4 tr	Investment in total energy supply 2021-50 under the IPCC C1 - REN scenario – the highest level among scenarios
$0.9	Estimated investment globally in low-carbon energy supply in 2022 for every $1 spent on fossil fuel energy supply
~ $4.0	Implied 2021-2030 required investment in low-carbon energy supply for every $1 spent on fossil fuel energy supply

Range of decadal energy supply investment ratio, 2001-2050 (all scenarios)



*Source: BloombergNEF, IEA, IPCC, NGFS. Note: * denotes estimated values based on the IEA World Energy Investment reports. The decadal ratio average and range has been rounded to the nearest whole number.*

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Executive summary (continued)

Investment today

- **Total energy supply investment averaged $1.6 trillion per year 2020-2022**, with $766 billion (a 48% share) allocated to low-carbon energy supply.
- **Low-carbon** energy supply spending has grown from $718 billion in 2020 to an **estimated $815 billion in 2022**, indicating the upward trend in the allocation of capital to low-carbon technologies since the Covid-19 pandemic.
- The global energy supply investment ratio has never crossed 1:1, peaking at 0.97 in 2020.

2021-2030 investment

- The **total energy supply investment ranges from $15.2** (IPCC P1) **to $49.4 trillion** (IPCC C1-REN) across 2021-2030. This is equivalent to $1.5 to $4.9 trillion per year. All but the IEA Net Zero scenario front-loads total energy supply investment.
- Across 2021-2030, **the ratio varies from 2.3** (IPCC P1) **to 5.7** (IPCC C1-REN). The average ratio across the decade is approximately 4, indicating the **need to ramp up from 2022 ratio value**, which stands at 0.9. **The scenarios imply a significant scale up in the level of low-carbon energy investment throughout this decade.**

2021-2050 investment

- **Total energy supply investment** varies from **$40.2 trillion** (IPCC P1) **to $114.4 trillion** (IPCC C1-REN) across 2021-2050. The large range is explained by the differing scenario narratives and socio-economic drivers. This is **equivalent to $1.3 trillion to $3.8 trillion per year**.
- Investment in **fossil fuel energy supply from 2021-2050 varies from $5.3 trillion** (IPCC P1) **to $18.2 trillion** (NGFS Net Zero). This equates to $0.2 trillion to $0.6 trillion per year respectively. **This is lower than investment into fossil fuel energy supply in 2022**, estimated at $0.90 trillion. All scenarios depict a deceleration in fossil fuel spending as economies phase out their use and turn to lower-carbon alternatives.
- The **ratio of investment in low-carbon energy supply to fossil fuels ranges from 4.1 to 8.1 across 2021 to 2050**, hitting an average of 5.5. The IEA NZE scenario falls closest to this mean value, with a ratio of 5.8. The two NGFS scenarios have ratios at the lower end of the range, at 4.4 and 4.9.
- **All of the scenarios illustrate a trend where the ratio of low-carbon to fossil fuel energy supply investment rises over the next three decades.**
- Overall, **the average energy supply investment ratios are approximately 4, 6, and 10 across the next three decades, respectively**.
- Investment in low-carbon alternatives to meet energy demand gradually reduces consumption of fossil fuels, limiting risks of price spikes and volatility.

About the analysis

Rationale and scope of work

- There is a large number of scenarios prepared and disseminated by different major organizations and corporations. This work focuses on scenarios that have been evaluated or produced by major intergovernmental bodies, and those produced by networks of bodies with significant authority delegated from national governments. This work does not seek to evaluate the credibility of these scenarios.
- The scenarios are either net-zero or those with no or limited overshoot of 1.5°C. This is in line with the Glasgow Financial Alliance for Net Zero (GFANZ) mission of "achieving the objective of the Paris Agreement to limit global temperature increases to 1.5°C from pre-industrial levels."
- These include pathways published by the International Energy Agency (IEA), Intergovernmental Panel on Climate Change (IPCC), and Network for Greening the Financial System (NGFS). Varying energy and socio-economic assumptions across scenarios underpin the narratives and dictate the transition pathway in each. For more on these see the appendix.
- This work does not seek to evaluate scenarios produced by non-intergovernmental bodies or those without delegated authority such as commercial organizations or universities.

Energy supply investment ratio

- The ratio of investment in low-carbon versus fossil fuels energy supply offers a new view on how corporations, state and non-state organizations and financial institutions can align their financing activity to climate scenarios.
- Decadal views narrow the range of energy investment aligned to low-carbon climate scenarios.

BNEF has published research on investment needs for these scenarios:

Counting Cash in Paris Aligned Pathways (web | terminal).

Investment Needs of a 1.5°C World (web | terminal).

Acknowledgements

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

IEA and NGFS scenario overview

IEA Net Zero Emissions by 2050

- Bottom-up approach where emissions reduction routes are dictated by **costs, technology maturity, policy and market/country conditions**. Assumes **global cooperation**.
- An orderly transition ensures **security of fuel** and electricity supplies at all times. Universal access to sustainable energy is achieved by 2030.
- **Any economic impact is minimized** at the expense of a faster reduction in CO2 emissions from fossil fuel extraction. Aims to **avoid volatility** in energy markets.

IEA Net Zero by 2050 Roadmap (2021)

NGFS Net Zero by 2050

- Limits warming to below 1.5°C by 2100 with no or limited overshoot. Net-zero CO2 reached shortly after 2050.
- An **ambitious, orderly scenario** that seeks to minimize physical risks through **immediate and firm uptake of climate and energy policies**. Transition risks are relatively minimized as policies becomes stringent over time, although technology change is fast through rapid uptake of innovations.
- **Carbon dioxide removal 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.

NGFS Divergent Net Zero

- A similar temperature and net zero trajectory.
- A **disorderly scenario** with more rigid policies in the transport and building sectors. Less emphasis is placed on decarbonizing the energy supply and industry sector.
- Transition risks are high as **policies diverge or are delayed, with failure to implement** their stringencies. Physical risks are relatively minimized through instant changes in technologies used leading to rapid fossil fuel phaseout.
- The **use of carbon dioxide removal is minimized** and lower than the NGFS Net Zero by 2050 scenario.
- Final energy demand by 2050 drops by over 16% compared with 2020 levels.

NGFS Climate Scenarios Phase 3 (2022)

Source: BloombergNEF, IEA Net Zero Emissions by 2050, NGFS Climate Scenarios Phase 3. ***NGFS Net Zero by 2050:*** *REMIND_MAgPIE 3.0-4.4 Net Zero 2050.* ***NGFS Divergent Net Zero:*** *REMIND_MAgPIE 3.0-4.4 Divergent Net Zero.*

IPCC scenario overview

IPCC P1 Lower Energy Demand

- A continued push for **higher living standards. Rapid urbanization**. Very significant near-term fall in energy demand.
- Enabled by a **move away from ownership** of single-purpose goods **to 'usership'**, with flexible, multi-purpose services delivered through digital platforms or sharing economies.
- Lower energy demand allows for **swift decarbonization of the remaining energy system**. **Afforestation** is the only carbon dioxide removal option considered.

IPCC Special Report on Global Warming of 1.5°C (2018)

IPCC C1- SP Shifting Pathways

- Below 1.5°C with no or limited overshoot.
- Ambitious **climate policies**, as well as economic development, education, technological progress and less resource-intensive lifestyles. **Gradual fossil fuel phaseouts** and a broader shift toward sustainable development.
- International climate finance, progressive redistribution of carbon pricing revenues, sufficient and healthy nutrition and improved access to modern energy.
- 180 million people remain in extreme poverty in 2030.

IPCC C1-LD Low Demand

- Below 1.5°C with no or limited overshoot.
- **Final energy demand** by 2050 is around **40% lower** than today, despite rising population, income and activity. Downsizing the global energy system dramatically improves the feasibility of a low-carbon supply-side transformation.
- **Large reductions in future energy demand and rapid fossil fuel phaseouts** enabled by the use of best available technique and efficiency increase.
- Limited reliance on negative emission technologies.

IPCC C1-REN Renewables

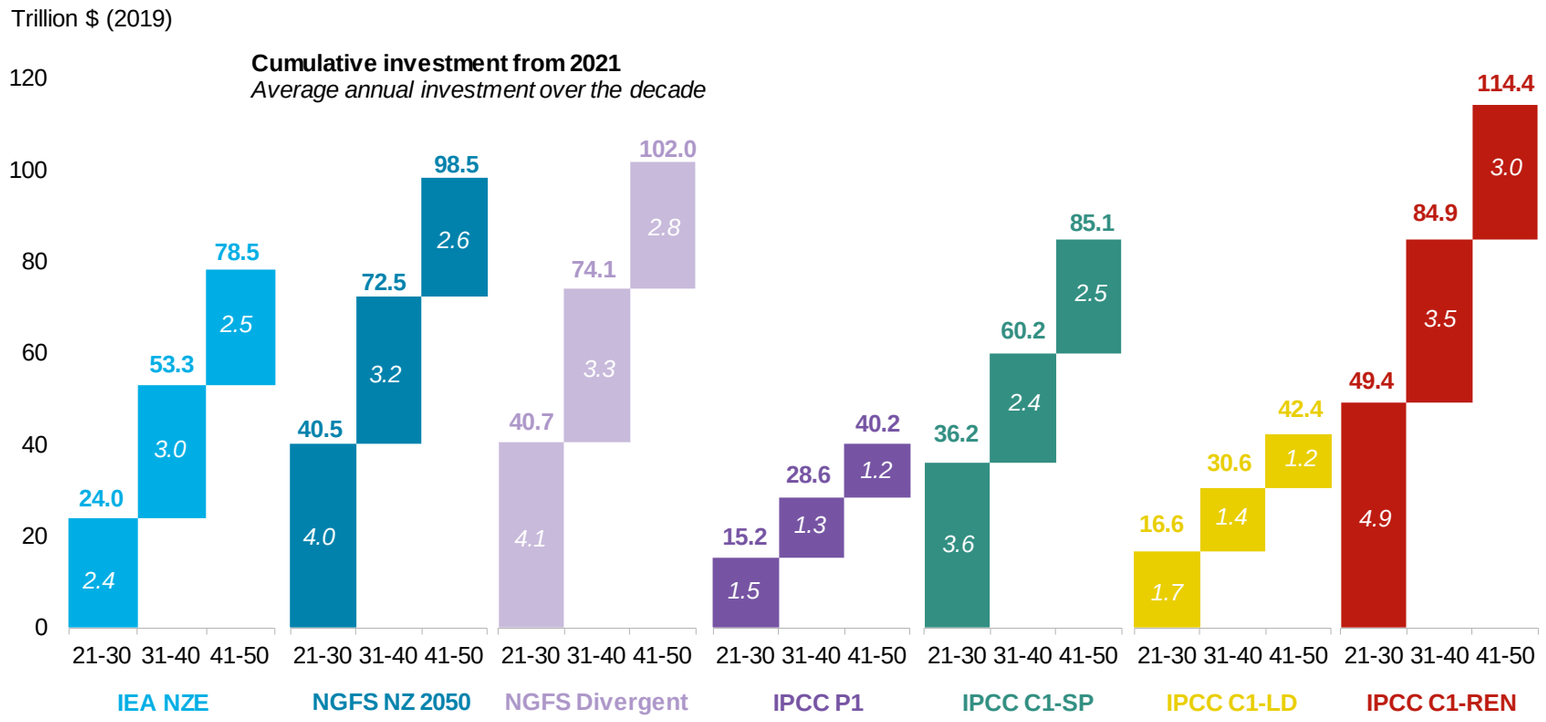
- Below 1.5°C with no or limited overshoot.
- **Rapid phaseout of fossil fuels**, more moderate future energy demand that is primarily met by renewables, plus more limited deployment of carbon direct removals (CDR).
- Policy to limit warming to 1.5-2°C will make carbon-based fuels increasingly scarce and expensive. Demand-side innovation leads to the **predominance of electricity-based end uses**.
- The lower production of bioenergy, high electrification.

IPCC Assessment Report 6 Working Group III (2022)

Source: BloombergNEF, IPCC models. ***P1(LED):*** *MESSAGEix-GLOBIOM 1.0 LowEnergyDemand* ***C1-SP:*** *REMIND-MAgPIE 2.1-4.2 SusDev_SDP-PkBudg1000,* ***C1-LD:*** *MESSAGEix-GLOBIOM 1.0 LowEnergyDemand_1.3_IPCC,* ***C1-REN:*** *REMIND-MAgPIE 2.1-4.3 DeepElec_SSP2_ HighRE_Budg900.*

A low-carbon world requires huge investment in total energy supply to meet climate targets

Total energy supply investment



Source: BloombergNEF, IEA, IPCC, NGFS. Note: total energy supply investment constitutes of low-carbon power supply, hydrogen infrastructures and uses, carbon capture and storage, upstream, midstream, and downstream for oil, gas, and coal and unabated fossil fuel power generation. For more on energy and electricity supply investment, see:

- *Counting Cash in Paris Aligned Pathways (web | terminal).*
- *Investment Needs of a 1.5°C World (web | terminal)*

- The next three decades will require significant investment in the energy sector to reach either net-zero or limit the temperature rise to 1.5°C. Total energy supply investment is projected to range from **$40.2 trillion to $114.4 trillion from 2021 to 2050**.
- The decade from **2021 to 2030 is crucial to accelerate energy supply investment**, with all but the IEA Net Zero by 2050 scenario having the highest annual investment over this decade. Earlier investments lay the foundation for infrastructure to meet increasing demand for low-carbon energy supply over the years.
- IPCC C1-REN requires more investment than others as the pathway accelerates renewables use and electrification, especially in the near term – before costs decline.
- The lowest cumulative investment occurs in the two low-demand scenarios: IPCC P1 ($40.2 trillion) and IPCC C1-LD ($42.4 trillion). This comes as total energy demand and generation capacity are greatly reduced by 2050.
- Total energy supply investment stays high, and in a relatively tight band in both NGFS scenarios, with annual investment decelerating over the decades.

The use of energy supply ratios help normalize investment across scenarios

Scope and sector classification

Total energy supply (TES) = **Low-carbon energy supply** + **Fossil fuel energy supply**

Total energy supply

Total energy supply refers to the physical assets and systems deployed for the different energy technologies to provide energy within the constraints of the different scenarios and pathways. Includes two main areas:

1) low-carbon energy supply
2) fossil fuel energy supply

Low-carbon energy supply

- Low-carbon power supply (electricity generation, storage, transmission and distribution)
- Hydrogen infrastructure and uses
- Carbon capture and storage (CCS)
- Fossil fuel-based electricity generation with abatement technology.

Fossil fuel energy supply

- Extraction and processing of coal, oil and gas
- Upstream, midstream, and downstream components
- Includes unabated fossil fuel-based electricity supply

Energy supply investment ratio

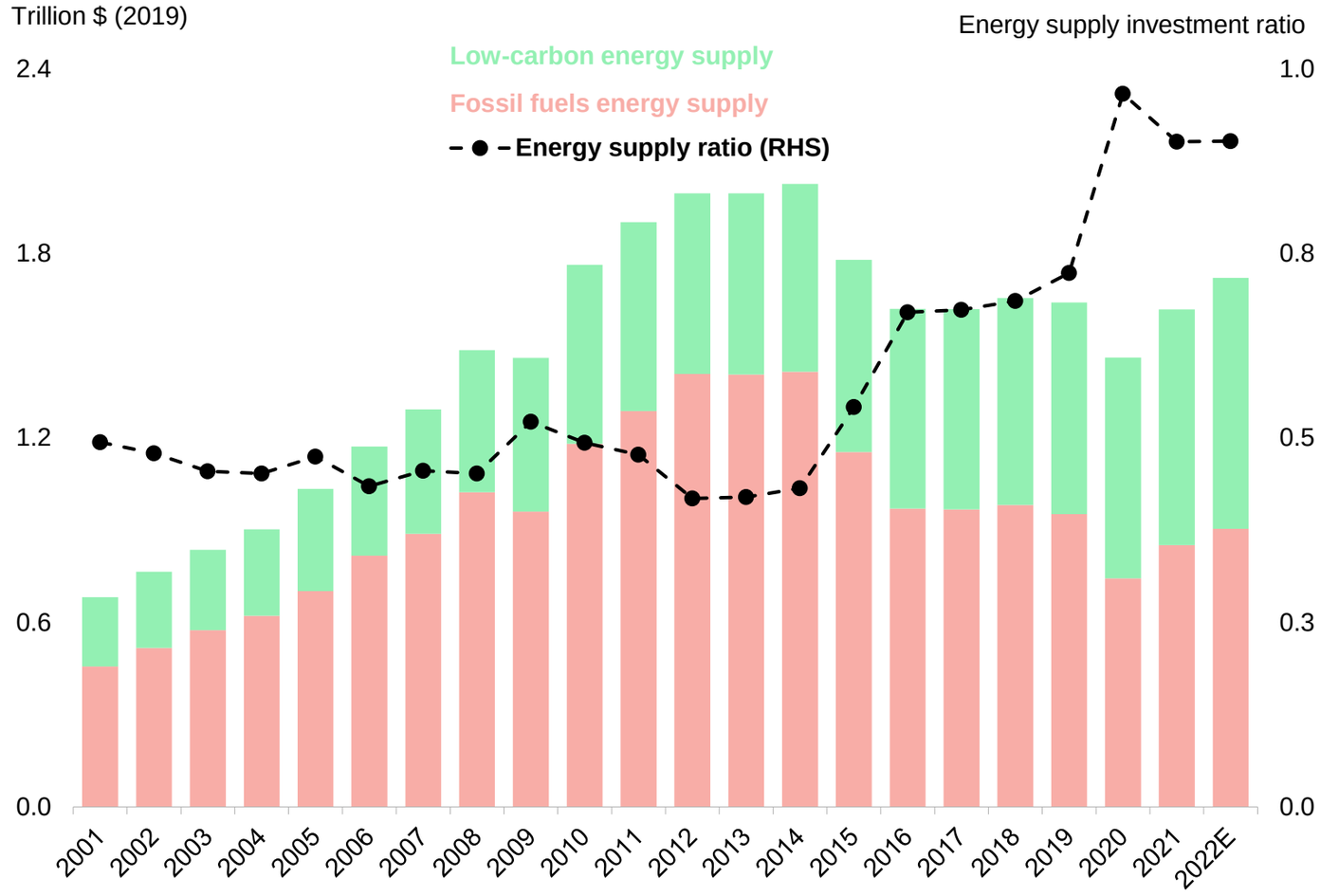
- The ratio of investment in **low-carbon energy supply versus fossil fuel energy supply** offers a new view on how corporations, governments, state and multilateral organizations and financial institutions financing activity aligns with these climate scenarios.
- The use of energy investment ratios 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 scenarios and investment strategies.
- Ratios give a good overview of the **'$ for $' balance** between low-carbon and fossil fuel energy systems as a guide towards climate aligned energy investment.

Low-carbon bucket
Low-carbon energy supply

Fossil fuel bucket
Fossil fuel energy supply

The low-carbon to fossil fuel energy supply investment ratio rose 2012-2020

Global historical total energy supply investment

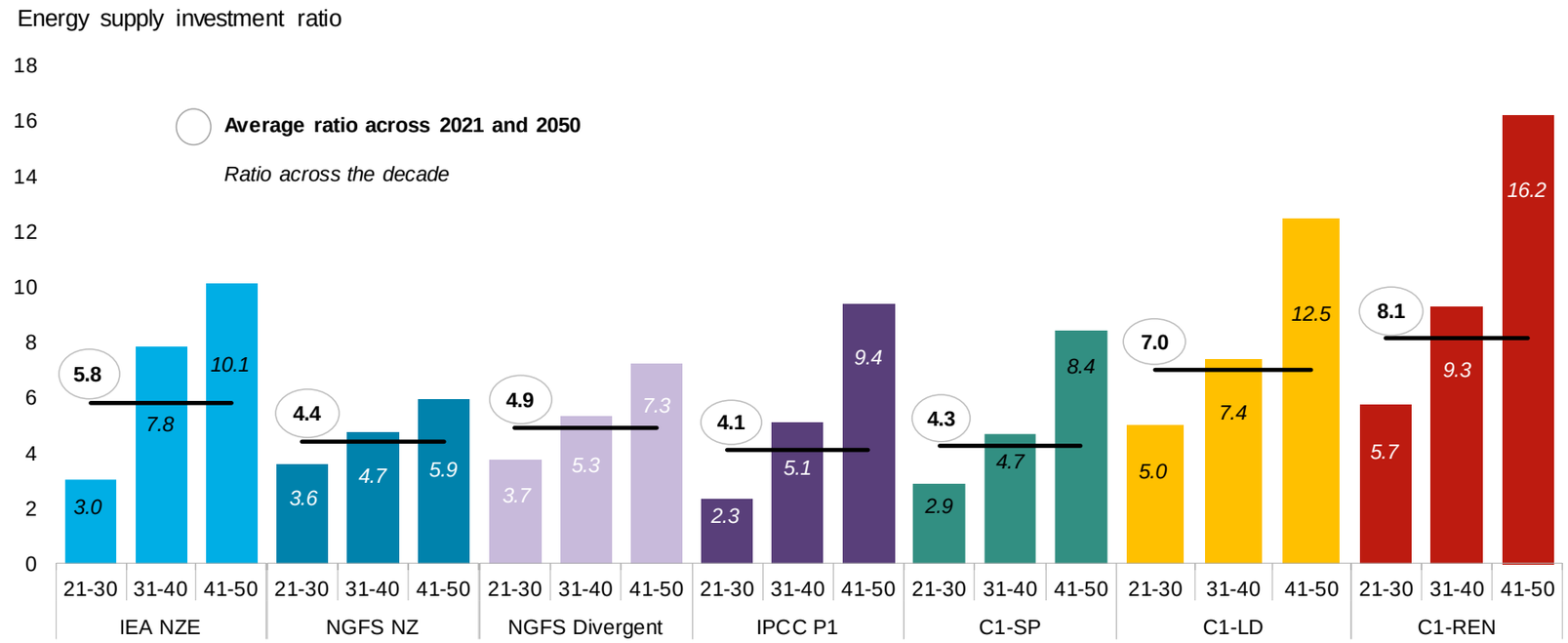


Source: BloombergNEF, IEA World Energy Investment reports, IMF. Note: the investment and ratio in 2022 are estimated values.

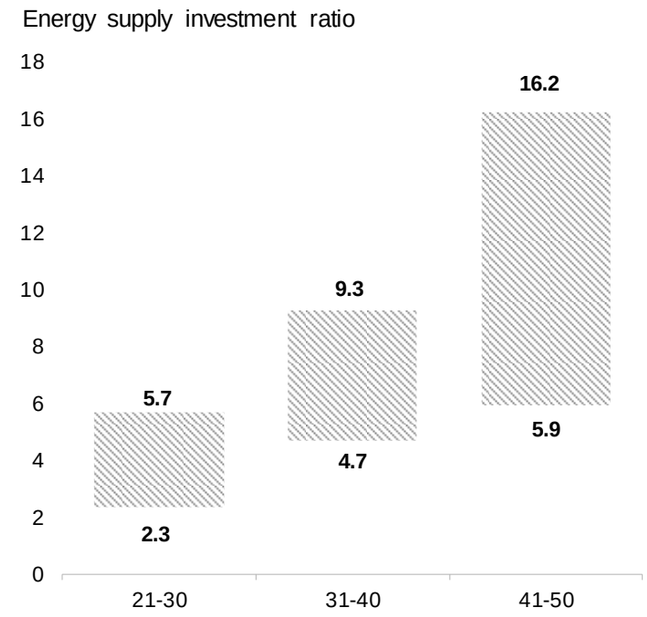
- In 2022, overall **global investment in energy supply is estimated to hit $1.72 trillion according to the IEA.** This would represent growth of 6.3% from 2021 levels and 17.7% from 2020, when a crash in oil and gas prices curtailed industry investment.
- The implied energy supply investment ratio for 2022 is projected to hit 0.9. This is lower than the historical high in 2020 of 0.97.
- In this projection, low-carbon energy supply investment in 2022 hits $815 billion according to the IEA, growing steadily from the 2020 low, jumping by more than 13.5%. This is due to an increase in investment in the power sector, in particular in electricity supply, transmission and distribution, and storage.
- Fossil fuel energy supply investment also increases by 6.3% year-on-year based on IEA projections as companies see windfall earnings from surging commodity prices and invest in energy security in light of geopolitical tensions. This however still lags pre-pandemic values.
- **Energy prices have risen in 2022 on the back of Russia's invasion of Ukraine, leading to inflationary pressures in many countries**, particularly in Europe. Despite disruptions to supply, fossil fuel use has grown year-on-year as demand in regions such as South East Asia rebound from Covid-19. Supply chain disruptions also hiked the levelized costs of renewables.
- The anticipated rise in global investment in 2022 could be muted as higher inflation rates and escalating living costs in various parts of the world damp real spend.

The investment trajectory for low-carbon and fossil fuel energy supply differs by decade

Energy supply investment ratio per scenario



Ratio range per decade



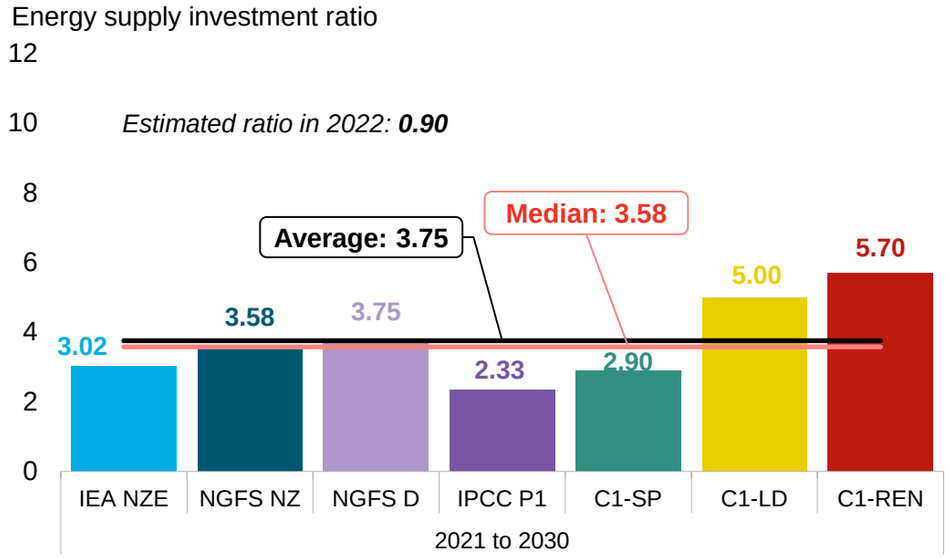
Source: BloombergNEF, IEA, IPCC, NGFS. Note: C1-SP, C1-LD, and C1-REN are IPCC scenarios. For more granular details on investment, see appendix.

- All the scenarios show a **rising ratio of low-carbon to fossil fuel energy supply investment over the next three decades**. Apart from the IEA NZE by 2050 scenario, all also depict an accelerating ratio rise in every decade. The IEA scenario sees most of the energy supply spending in 2031-2040, thus the ratio jump is more visible after 2030 rather than in the last decade.

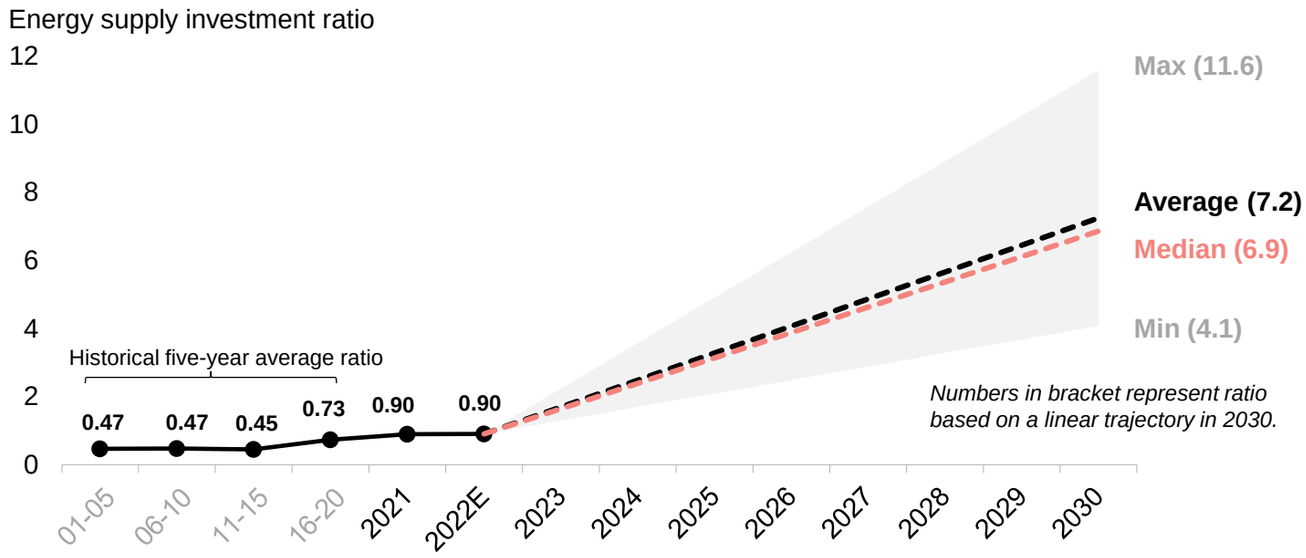
- IPCC C1-REN had the largest change in ratio from 2021-2030 to 2041-2050, mainly because investment into low-carbon technologies and electrification remains elevated while fossil fuel investment declines rapidly after 2030.

The energy supply investment ratio needs to ramp sharply in the 2020s

Energy supply investment ratio, 2021-2030



Linear ratio growth trajectory to meet decadal average targets



Source: BloombergNEF, IEA, IPCC, NGFS. Note: NGFS D is the Divergent scenario. The value in 2022 is an estimated ratio based on the IEA World Energy Investment 2022 report. C1-SP, C1-LD, C1-REN are IPCC scenarios.

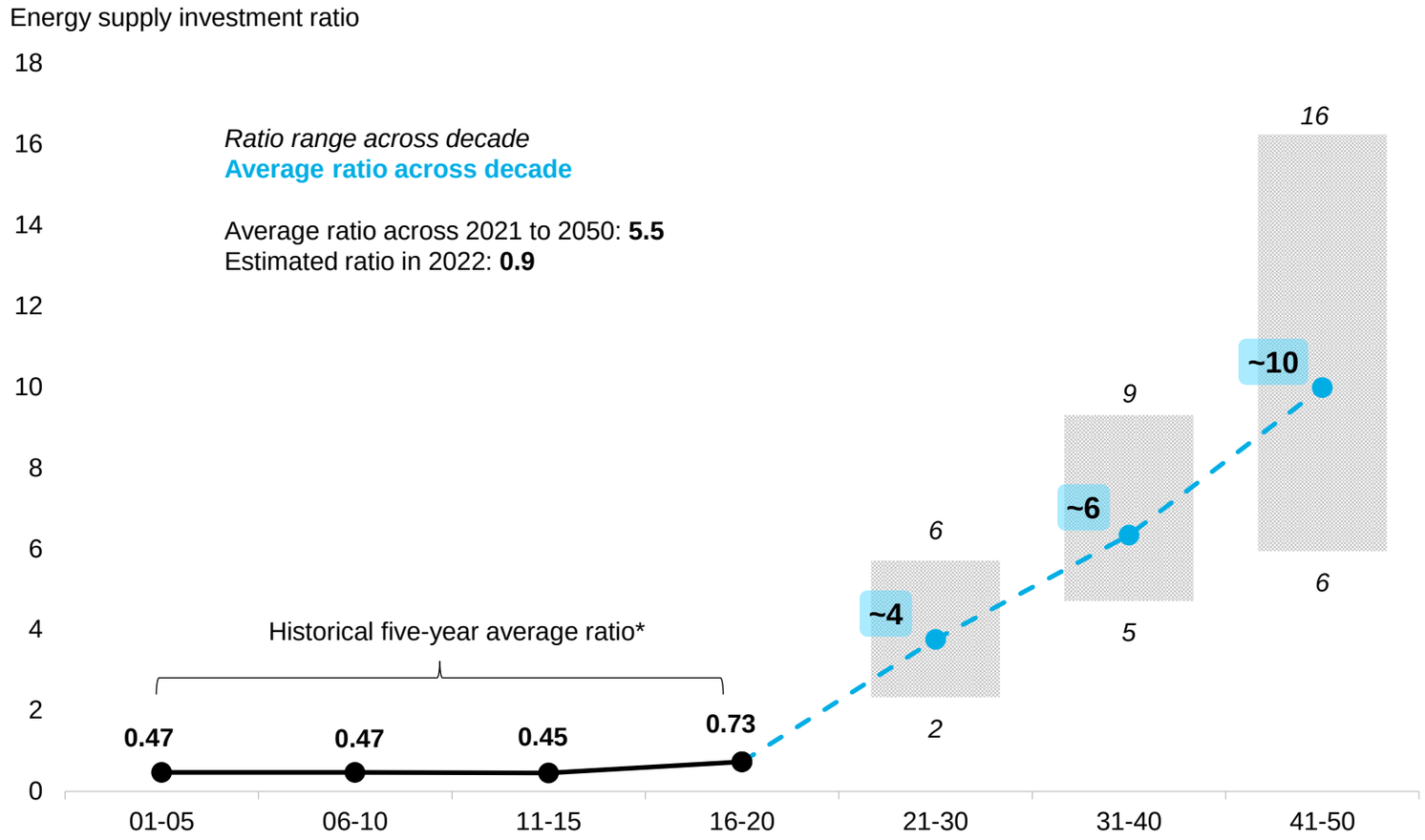
- This decade (2021-2030) is a vital time to kick-start investing in the energy transition and prevent back-loading emission reductions. **Historically, the total energy supply investment ratio has not crossed the 1:1 mark, peaking at 0.97:1 in 2020**, mainly as oil and gas investment dropped due to a price plunge.

- **The ratio range across this decade spans from 2.3 to 5.7**, with an average of 3.75 and a median of 3.58. This range acts as a guide for the different scenarios. IPCC C1-REN and C1-LD have the highest ratio across this decade at 5.7 and 5.0, respectively, driven primarily by front-loading low-carbon supply investment as annual fossil fuel energy supply investment declines.

- The estimated energy supply investment ratio **needs to ramp up** to match both the average and median ratio required for the period ending in 2030. To determine the implied pace of that ramp, a simple linear increase would see the ratio rise by 0.7 per year to a median ratio across the scenarios of 6.9 in 2030, from 0.9 in 2022. At a minimum, growth of at least 0.4 per year is required to reach the lower end of the range in 2030 of 4.1.

The ratio of low-carbon to fossil fuel supply investment then continues to increase to 2050

Energy supply investment ratio by decade

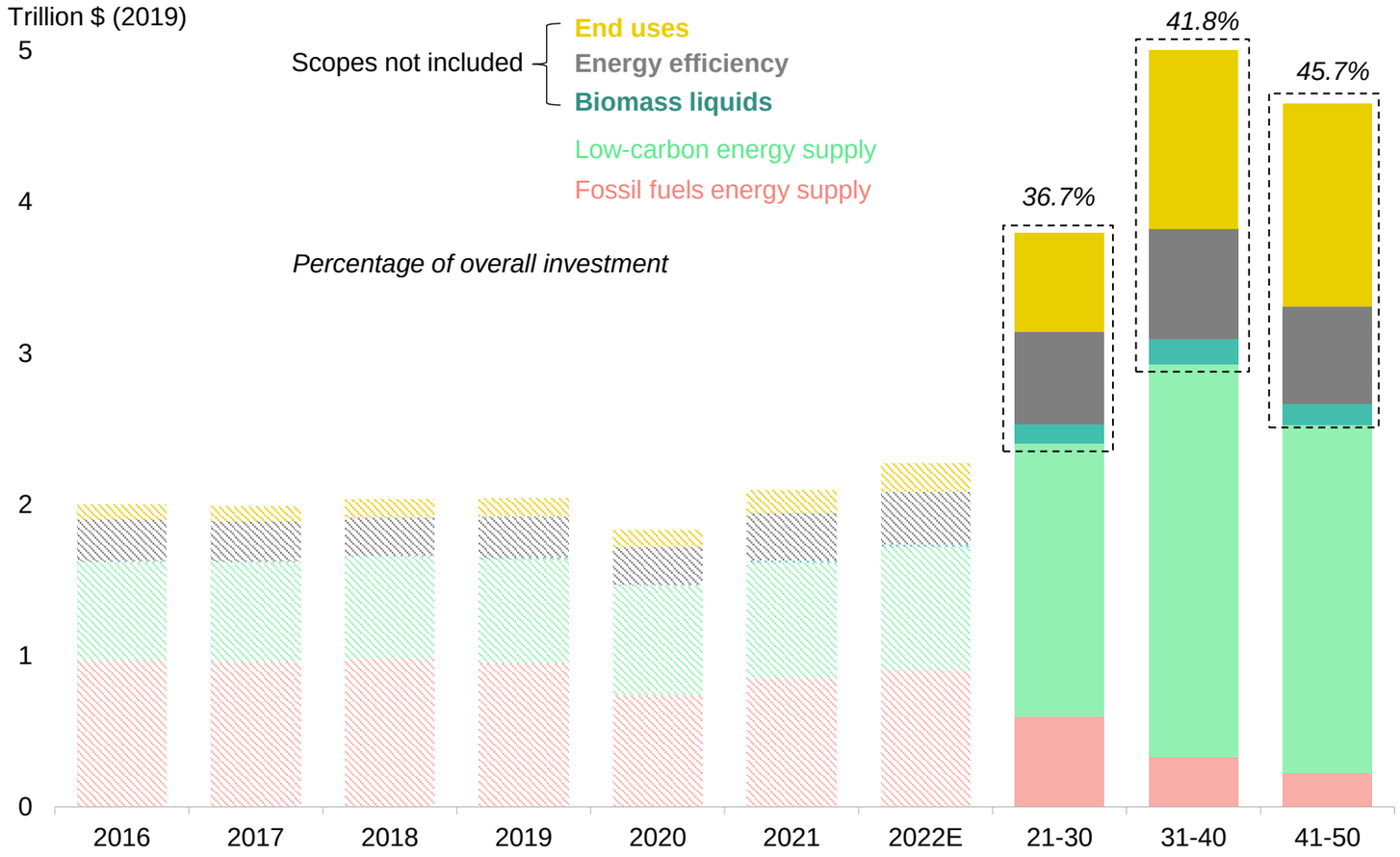


*Source: BloombergNEF, IEA, IPCC, NGFS. Note: the decadal average values and ranges have been rounded to the nearest whole number. * denotes estimated values based on the IEA World Energy Investment reports.*

- The average decadal ratio across all the scenarios jumps roughly by 60-70% per decade from 2030 to 2050 as investment in low-carbon energy supply scales up in the 2020s, before gradually stabilizing then falling, whereas spending in fossil fuel energy supply drifts lower in every consecutive decade.
- The average decadal ratios are roughly at **four, six, and 10** across the next three decades respectively. Meanwhile, the estimated ratio in 2022 stands at 0.9. This will call for more investment flows into low-carbon energy supply systems from both the public and private sectors.
- The range in ratios between the different scenarios **widens over the next three decades**.
- The ratio sheds light on the precedent relative to what's needed going forward and the expected progress regarding the scaling up of low-carbon energy supply.

Other scopes of energy investment are pivotal for the transition

Overall annual total energy investment for the IEA Net Zero Emissions by 2050 scenario



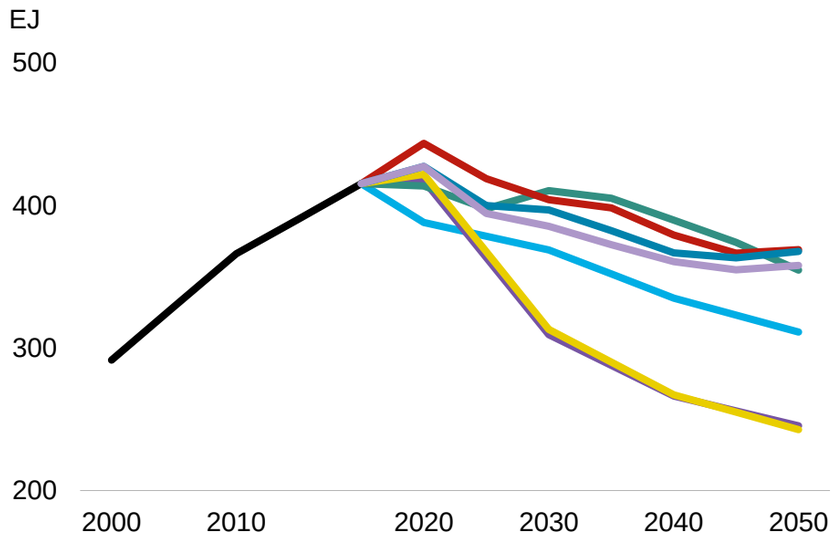
- The total energy supply category forms an integral part of the investment portion of energy transition scenarios, with **clean power supply** generally making up a large share. Conversely, investment on the demand and consumer-side through **energy efficiency, alternative fuels and end uses** needs to also be considered as they play a vital role towards a low-carbon future.
- Energy efficiency, biomass liquids and end uses in the IEA net zero by 2050 account for 41.7% of overall investment from 2021 to 2050. Breaking these down over the next three decades further underscores their **increasing importance**, making up 36.7%, 41.8% and 45.7% of the overall investment, respectively. This equates to $1.4, $2.1, and $2.1 trillion annually.
- Based on current spending, the estimated expenditure on end uses, energy efficiency, and biomass liquids levels in 2022 is $551 billion.
- Since 2015, these demand-side additions have increased their overall contribution in the total energy investment mix, rising from 16% in 2015 to 23% in 2021.

Source: BloombergNEF, IEA Net Zero by 2050, IEA World Energy Investment Report 2022. Note: End uses include renewables end uses, electrification and electric-vehicle chargers, and fossil fuel end uses. Fossil fuel end uses were not explicitly reported for 2016 to 2022. Investment in 2022 is an estimated value.

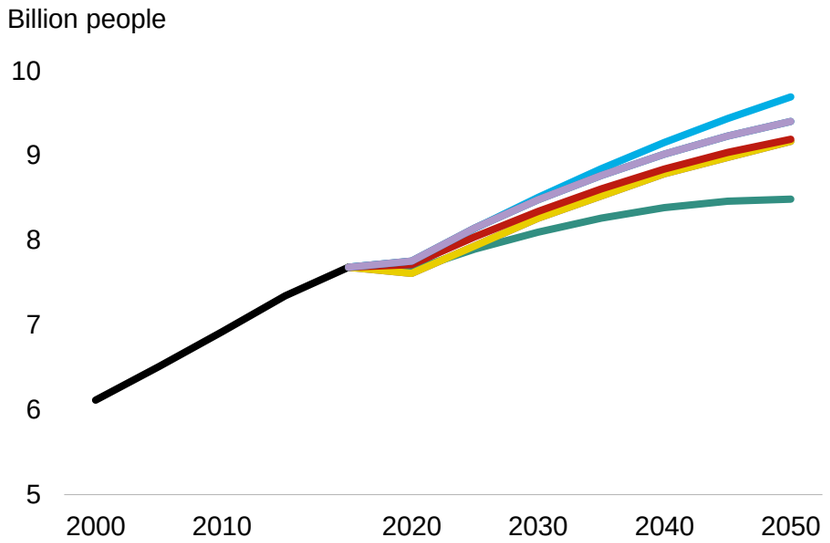
Appendix

Socio-economic drivers all vary in the trajectory to a net-zero world

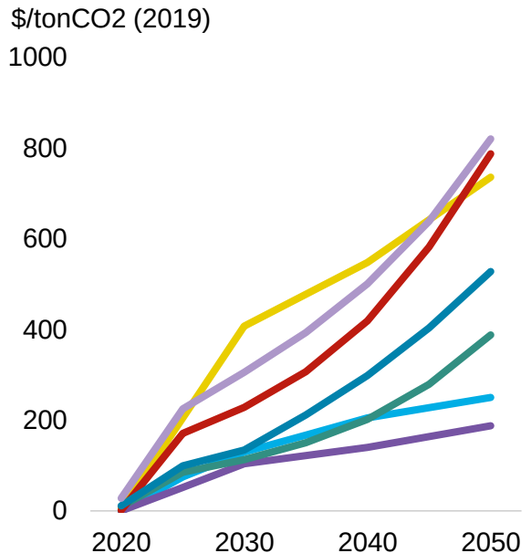
Final energy demand



Population



Carbon price



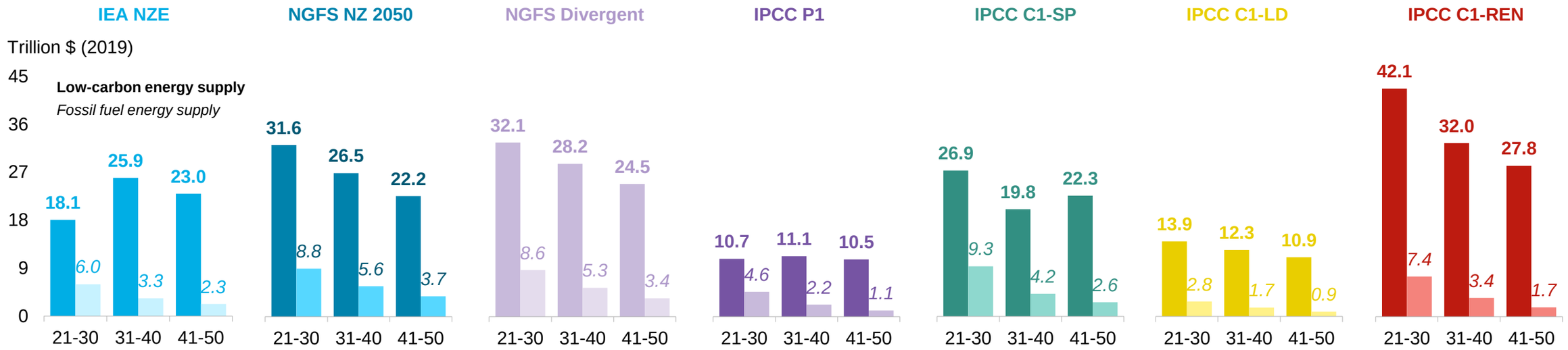
Historic IEA NZE NGFS NZ 2050 NGFS Divergent IPCC P1 IPCC C1-SP IPCC C1-LD IPCC C1-REN

Source: BloombergNEF, IEA, IPCC, NGFS. Note: IEA Net Zero by 2050 carbon prices are directed for electricity, industry, and energy production, and is based on advanced economies. Historic data for final energy demand and population size are extended from 2000 to 2019.

- Final energy demand in both of the low demand IPCC scenarios (IPCC P1 and C1-LD) **drops to below 250 exajoules per year**, signifying a more than 40% reduction from 2019 levels. Conversely, C1-REN has the highest energy demand level at 369 EJ in 2050, followed by the NGFS Net Zero scenario. The general downward trend in final energy demand pertains to improvements in efficiencies.
- The total global population exceeds 9 billion by 2050 for all the scenarios except C1-SP, which lags behind at 8.5 billion. The IEA leads the pack at 9.7 billion, a 26% rise from 2019 levels mainly as the **global economy expands**, particularly in emerging and developing markets.
- Carbon prices range from $187/tCO2 (IPCC P1) to $820/tCO2 (NGFS Divergent). The high carbon price for the latter results from the disorderly and delayed nature of the scenario, and more stringent policies in some sectors imposed. Carbon prices are also used as a proxy for the overall weight of climate policies. Both **C1-LD and C1-REN had the highest carbon prices** of the most recent IPCC scenarios, due to their high level of ambition in a particular area (demand reduction and high renewables uptake respectively).

Low-carbon energy supply investment exceeds fossil fuel investment

Low-carbon and fossil fuel energy supply investment

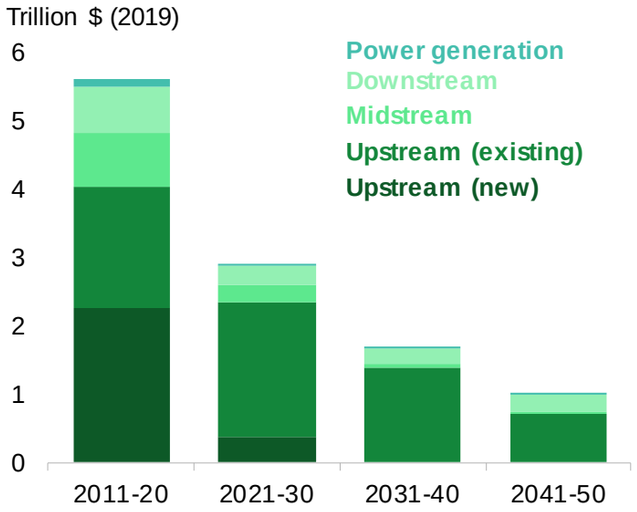


Source: BloombergNEF, IEA, IPCC, NGFS. Note: low-carbon energy supply includes electricity generated from biomass.

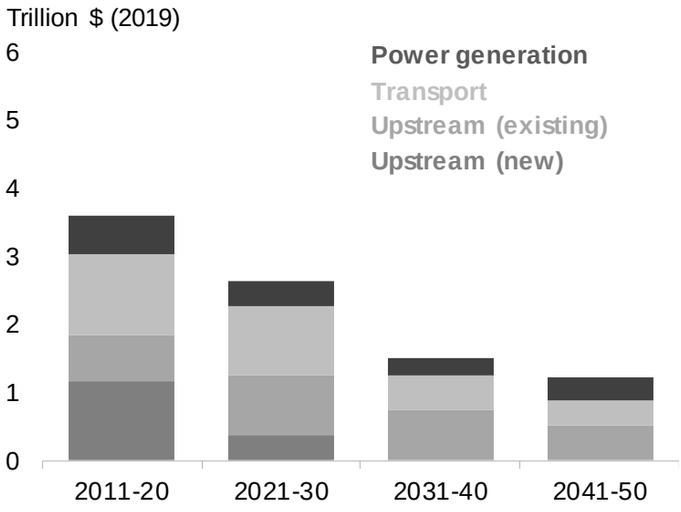
- Disaggregating investments by type reveals the scale and varying speeds of transition on the road to 1.5°C or net zero across the different scenarios. The differences in investment are underpinned by varying assumptions and scenario narratives over the time horizons.
- The overarching trend shows the need to direct spending toward low-carbon energy supply, and shift away from fossil fuel investment over time. However, **investment into fossil fuel energy supply does not cease**. **Power supply, particularly wind and solar, account for most of the low-carbon energy supply investment in all scenarios**.
- The three most recent IPCC scenarios (C1-SP, C1-LD, and C1-REN) accelerate and front-load spend on energy supply in the 2020s. These converge on the idea underpinning the IPCC Assessment Report 6, which urges rapid uptake of low-carbon technologies in order to scale up climate change mitigation.
- Unlike other scenarios, IPCC C1-SP sees an increase in low carbon energy supply spending in from 2041 to 2050. This is as advanced economies decarbonize in the short term, leading to a drop in low-carbon investment in the 2030s, before industrializing economies follow in the 2040s, driving low-carbon investments up again.

New upstream investment halts after 2030, but fossil fuel spend does not decline to zero

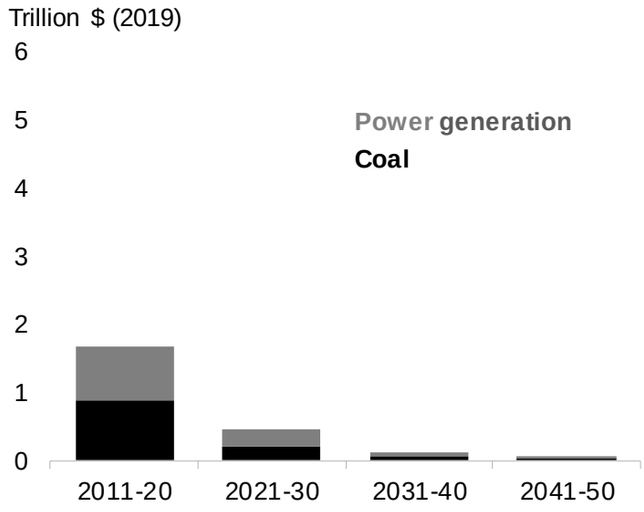
Oil supply investment



Gas supply investment



Coal supply investment

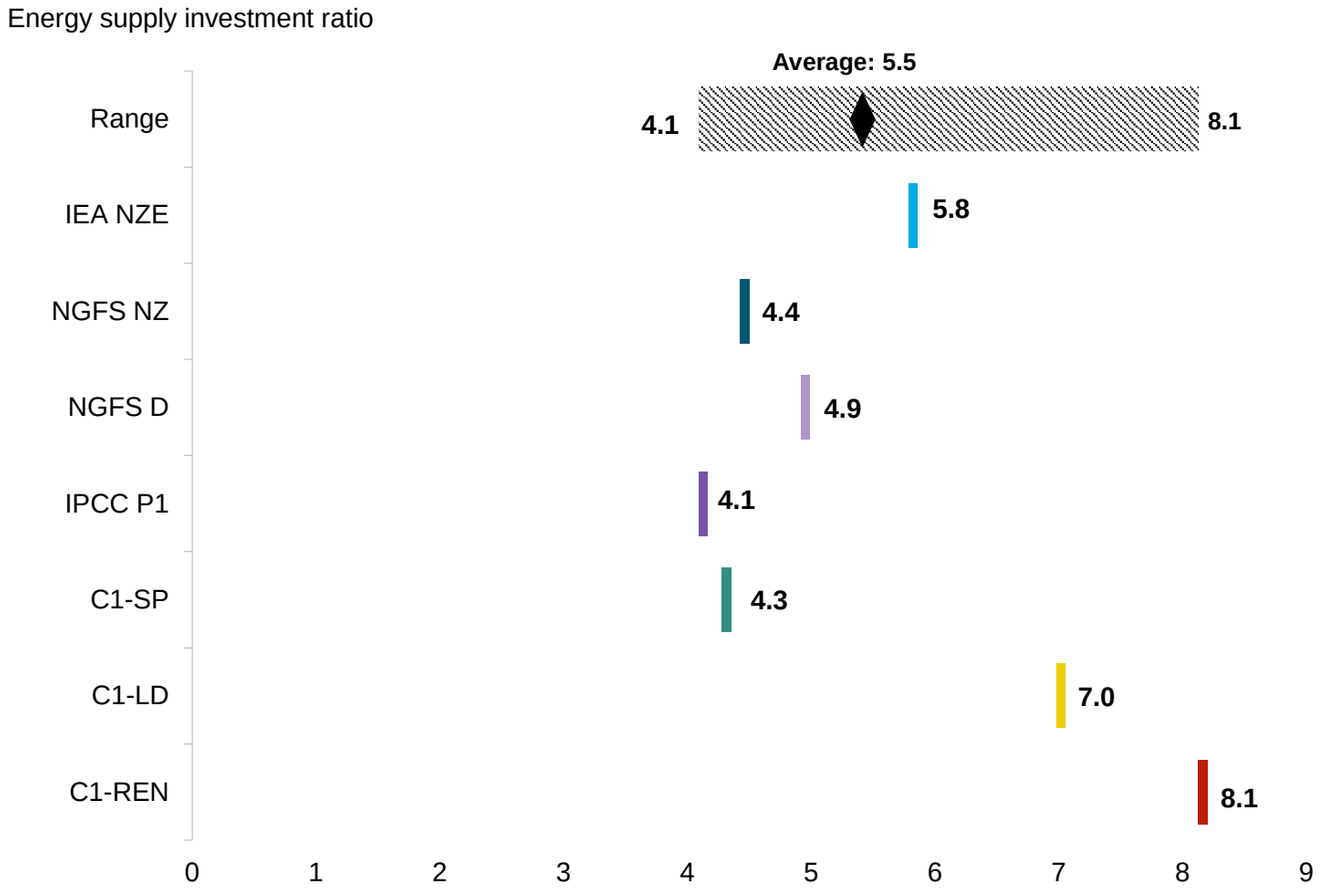


Source: BloombergNEF, IEA Net Zero scenario by 2050 report, IEA World Energy Investment (WEI) reports. Note: future power generation investments have been estimated based on the final IEA Net Zero by 2050 scenario electricity mix. Past power generation investments have been obtained from previous WEI reports.

- In the IEA scenario, if all investment in existing oil fields were to cease, this would lead to a loss of more than 8% of supply each year. Continued investment in current oil fields stems this loss of supply to about 4.5%. This reduction in supply is slightly higher than the decline in demand in the IEA scenario.
- The oil price would be sufficient in principle to cover the cost of developing new fields for the lowest-cost producers, including those in the Middle East, but it is assumed that major resource holders do not proceed with investment in new fields to avoid downward pressure on prices. It could also be the case that new, more carbon-efficient fields remain undeveloped.
- The scenario also sees many LNG liquefaction facilities under construction – or at the planning stage – become underutilized as more than 50% of gas use in 2050 is focused on hydrogen production.
- The downstream segment also requires a significant pivot toward petrochemical feedstocks, with runs down 85% in the IEA scenario by 2050.
- **Coal investment diminishes over the coming decades**, with remaining spending mostly allocated to maintaining current and existing assets and for power generation.

2021 to 2050 energy supply investment ratios vary based on scenario narratives

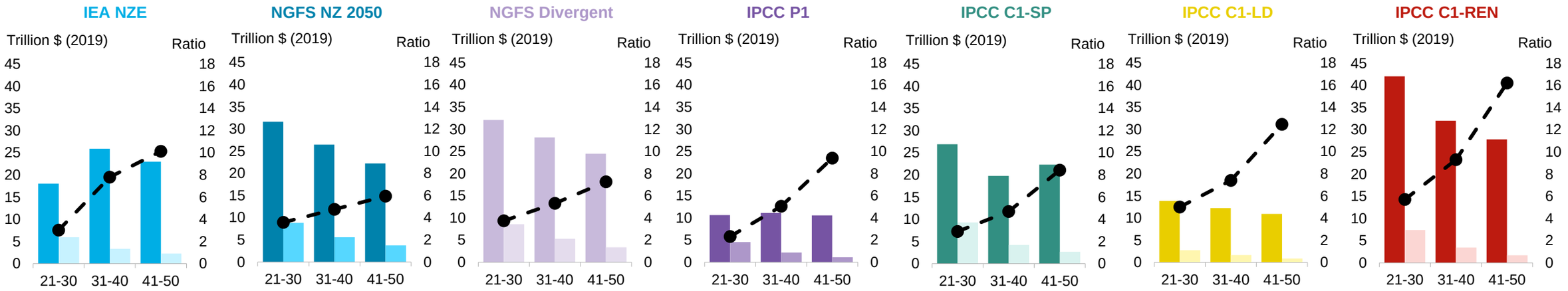
Average energy supply investment ratio across 2021 to 2050



Source: BloombergNEF, IPCC, IEA, NGFS. Note: NGFS D is the Divergent scenario. C1-SP, C1-LD, and C1-REN are IPCC scenarios.

- The average energy supply investment ratios across 2021 to 2050 fall in a band ranging from 4.1 to 8.1. This produces **an average of 5.5** for all the scenarios assessed.
- The high ratio for IPCC C1-LD is driven by the low investment in fossil fuel supply, whereas the high uptake of renewables and clean power systems boosts the ratio for IPCC C1-REN.
- The IEA NZE by 2050 scenario falls closest to the average ratio, with hydrogen investments contributing more than 9% to the overall low-carbon energy supply spending, more than any of the other scenarios.
- IPCC C1-SP has the lowest ratio among the most recent IPCC scenarios, as it relies a lot on **oil as a primary energy source**, while low-carbon energy supply investment falls between the other two scenarios. High energy demand in developing regions allowed fossil fuel use to support sustainable shift.
- **Both of the NGFS ratios are on the lower end of the range** due to the relatively high residual investment flowing into fossil energies, with the two scenarios seeing the highest fossil fuel supply spend. The NGFS Divergent ratio of 4.9 falls closer to the overall average than its Net Zero scenario counterpart.
- IPCC C1-LD has a higher ratio compared with its older low-demand counterpart IPCC P1, accelerating the trend of scaling up low-carbon energy supply investment over the progression of the IPCC reports.

Disaggregating investments by type enables understanding of drivers in each decade



Source: BloombergNEF, IEA, IPCC, NGFS. Note: NGFS NZ 2050 is the net zero scenario. The heavy color represents low-carbon energy supply investment, whereas the light color represents the fossil fuel energy supply investment.

Total energy supply (TES) investment rises in 2031-2040 before falling, as electrification and energy efficiency ramps up low-carbon energy supply investment.

Fossil fuels use declines rapidly, but their use in hard-to-abate sectors, mainly coupled with CCS, leads to low levels of fossil fuel investment. No new upstream investment after 2030.

Ratio increases sharply in 2021-2030, before its growth decelerates as TES investment drops in the last decade.

TES investment is front-loaded in the 2020s before declining until 2050. Low-carbon energy supply investment is driven by solar and wind, with the latter ramping up in the last decade.

Oil dominates fossil fuel supply investment, taking up 18.7% of the overall primary energy mix in 2050. Fossil fuel investment is based on legacy capital expenditures and maintaining operating assets. Coal supply investment drops by 96.2% by the last decade.

The ratio grows consistently 25-33% per decade from a gradual decline for low-carbon and fossil fuel investments.

TES investment is front-loaded in the decade of 21-30, before declining until 2050. Wind and solar make up the majority of low-carbon energy supply investment.

Oil dominates fossil fuel supply investment, taking up 13.3% of the overall primary energy mix in 2050. Reliance on unabated gas for electricity however is higher than the NGFS net-zero scenario, mainly from the more disorderly nature of transition.

Additional risk and lack of policy coordination see the ratio grow slightly faster than the NGFS net-zero counterpart, rising constantly by about 37-42% per decade.

Lower energy demand allows for swift decarbonization, where low-carbon energy investment hovers between $10 trillion and $11 trillion per decade.

Oil supply dominates fossil fuel investment to support higher living standards in the short term and rapid urbanization.

The energy ratio increases by roughly 50% per decade, in line with fossil fuel investment halving each decade.

This scenario aims to reduce inequality. Higher energy demand from industrializing economies leads to a reliance on oil and gas up to 2040.

Advanced economies decarbonize in the short term, leading to a drop in low-carbon investment in the 2030s, before industrializing economies follow in the 2040s, driving low-carbon investments up again.

The energy ratio sees a bigger jump after 2040 as low-carbon energy investment scales up relative to fossil fuels.

A major reduction of energy demand improves the feasibility of a low-carbon transformation, with high uptake of wind and solar energy.

Fossil fuels are phased out rapidly, aided by energy-efficient technologies. Changing consumer demand profiles – including lower meat consumption – help to reduce energy demand.

The ratio accelerates in the last decade as clean energy largely dominates an energy system with reduced demand.

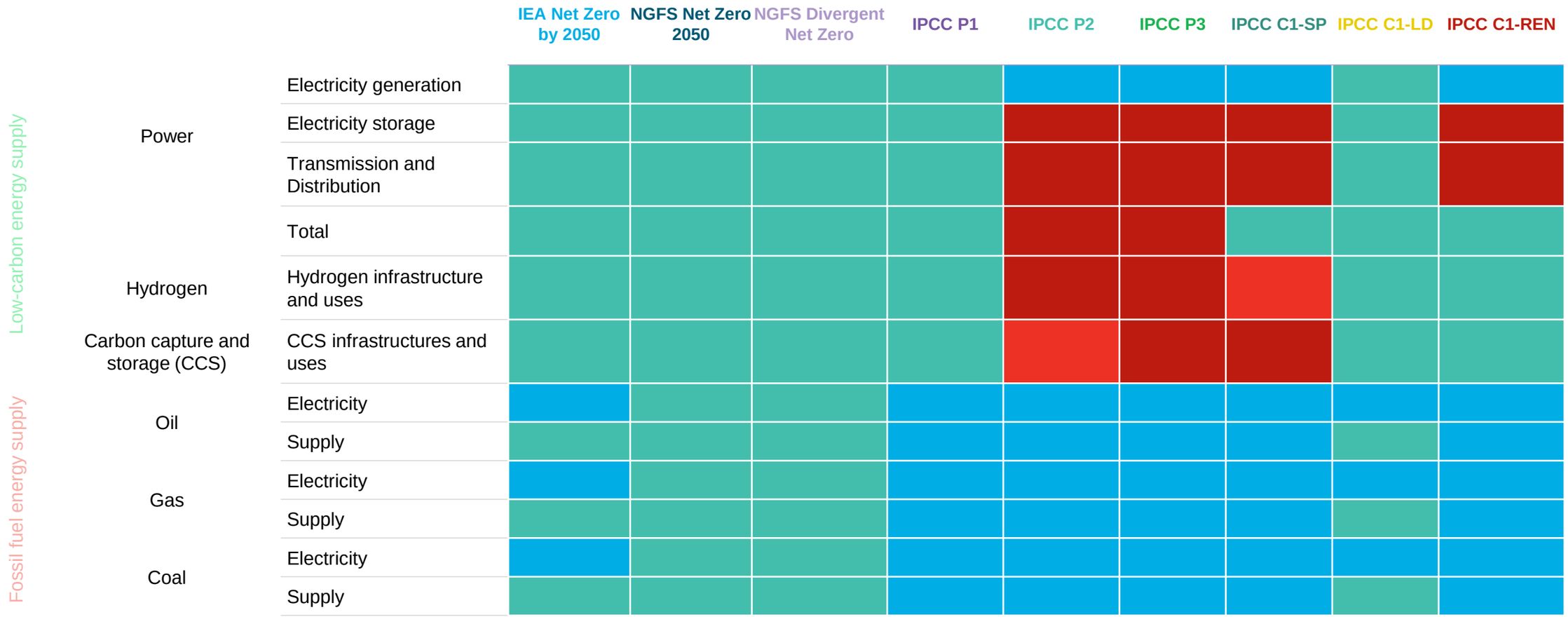
Rapid development of renewables and widescale electrification leads to the highest low-carbon energy investment of all scenarios.

In the 2020s, oil continues to play a role as industries decarbonize gradually.

The final two decades see fossil fuels phased out rapidly and replaced by low-carbon energy sources.

The significant increase in the ratio in the last decade is driven by the near elimination of fossil fuel investments.

Availability of data



Actual given values from dataset (subject to investment value adjusted to 2019 $)

Values based on BNEF estimates

Values not given or incomplete dataset to estimate

Values not given and deemed negligible based on the scenario narrative

Source: BloombergNEF, IEA, IPCC, NGFS. Note: IPCC P2 and P3 were included in previous BNEF research but excluded in this report due to the lack of data available.

Methodology

- Fossil fuel energy supply investment
  - **IEA NZE**: Data is provided by the IEA Net Zero Emissions (NZE) by 2050 report for investment in $ 2019 terms. Investment data for fossil fuel-based power generation for the respective fuels have been based on future electricity consumption mix of the IEA Net Zero by 2050 scenario. Historic values are based on previous the IEA World Energy Investment reports.
  - **IPCC P1, C1-SP and C1-REN**: Investment levels are derived based on dollars per joule of total fuel supplied. The $ value per joule is based on a proxy marginal cost of production, derived from the IEA NZE scenario. This value is mapped to primary fuel demand to reflect the variations in demand levels across scenarios over different time periods. For example, higher demand levels from 2041-2050 in the C1-SP scenario lead to a different $ per joule investment versus the IEA NZE or the P1 scenarios over the same period – reflecting a different marginal cost of producing at that demand level.
  - **IPCC C1-LD, NGFS NZ and Divergent**; Data is provided by the respective IPCC and NGFS reports for investment in $ 2010 terms. Values have been brought to $ 2019 terms based on historic and forecasted inflation levels from the IMF and BloombergNEF data.

- Low-carbon energy supply investment
  - **IEA NZE**: Data is provided by the IEA NZE report for investment in $ 2019 terms.
  - **IPCC P1, C1-LD and NGFS NZ, Divergent** : Data is provided in the respective IPCC and NGFS reports for investment in $ 2010 terms. Values have been brought to $ 2019 terms based on historic and forecast inflation levels from the IMF and BloombergNEF data.
  - **IPCC C1-SP and C1-REN** : The change in generating capacity by fuel type is translated into investment based on the respective IPCC scenario capital expenditures. Average annual capital expenditures were obtained through linear extrapolation for the decade. This method accounts for the net change in capacity, and does not account for the impact of technology retirements, and will therefore underestimate investment levels. Values have been brought to $ 2019 terms based on historic and forecasted inflation levels from the IMF and BloombergNEF data.

Source: BloombergNEF, IEA, IPCC, NGFS, IMF.

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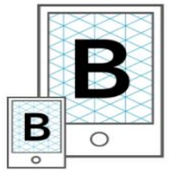

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