Swiss Re Institute

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Decarbonisation tracker

Progress to net zero through the lens of investment

Executive summary

As of 2022, we estimate a USD 271 trillion climate investment gap to reach net zero by 2050.

This study tracks progress on decarbonisation through the lens of investment, as a measure of how far the world is from reaching the Paris Agreement and net zero by 2050 targets. As of 2022, we estimate that a global investment gap of USD 290 trillion, or USD 271 trillion excluding investments in fossil fuels, remains between actual investment *needs* for net zero by 2050 and capital *deployed* as of 2022. The USD 271 trillion investment gap translates into an average annual gap of USD 9.4 trillion between 2022 and 2050, assuming investments are equally spread across the years.

We take a bottom up approach to constructing our investment gap, which is bigger than that of any other study.

We take a bottom-up approach to arrive at our estimate of the investment gap, covering the energy, transport, buildings and industrial sectors. Specifically, we construct estimates of the cumulative investment need for net zero by 2050 using granular estimates sourced from different third-party studies and combine these with data series of actual investments. Our investment need estimate is notably higher than that of other studies on the same topic. However, any investment gap estimate is subject to much uncertainty, and we view ours as a lower bound of what will truly be required for net zero by 2050. Not least because given absence of data on other economic sectors, as well as within the four sectors we cover, our study accounts for at most 70% of global emissions.

Investments are not on track: at the current rate of investment, the investment gap will be closed 20 years too late.

This study is part of our research collaboration with the London School of Economics on resilience. A novelty of the work is that we match estimated investment needs with actual investment flows to date. This provides a window into progress still needed, meaning we can also update our investment gap estimate on an ongoing basis. Tracking investments also captures insights into the actions taken to progress to net zero. This contrasts with focusing, for example, on pledges to track progress, which may or may not materialise, and do not reveal much about actions taken. Tracking investments also directly speaks to the financial and economic risks, and opportunities ahead.

Climate investment must increase in speed and scale for a credible transition to a net zero world.

Closing the USD 271 trillion investment gap between now and 2050 will require a large ramp up of climate spending, from USD 1.3 trillion in 2021 to an estimated annual average of USD 9.4 trillion between 2022 and 2050. By sector, we estimate that this means investment growth will need to increase significantly relative to the rises seen between 2020 to 2021, by about 45-, 19-, 86-, and 27-times in the energy, transport, buildings and industrial sectors, respectively. If investments in decarbonisation were to continue to grow by the 5% annual average of the last five years, net zero would be reached in 2069, almost 20 years behind target.

Closing the gap is possible, and will bring economic benefits beyond decarbonisation.

The numbers are large but closing the investment gap is possible. Maintaining the current spending trend would fill one third of the gap. A further 10% would be filled by re-allocating a share of existing spending from high- to low-emission assets. The remaining investment – an incremental ask of close to USD 5 trillion on average annually – will need to come from the public and private sectors, with the latter in the lead. There is ample scope to increase private sector financing. For example, the size of the green bond market constitutes less than 2% of the total global bond market and green bonds issuance amounted to merely 7% of total new bond issuance in 2021. Moreover, each dollar invested today implies decreased emissions and mitigated GDP loss in the future. The world stands to lose up to 7–10% of GDP by mid-century if warming stays on the current trajectory. Indeed, the GDP losses mitigated by closing the investment gap and adhering to the Paris Agreement target essentially equate the incremental investment ask. The spending will also bring economic benefits beyond decarbonisation such as, for example, future productivity gains, employment and financial stability.

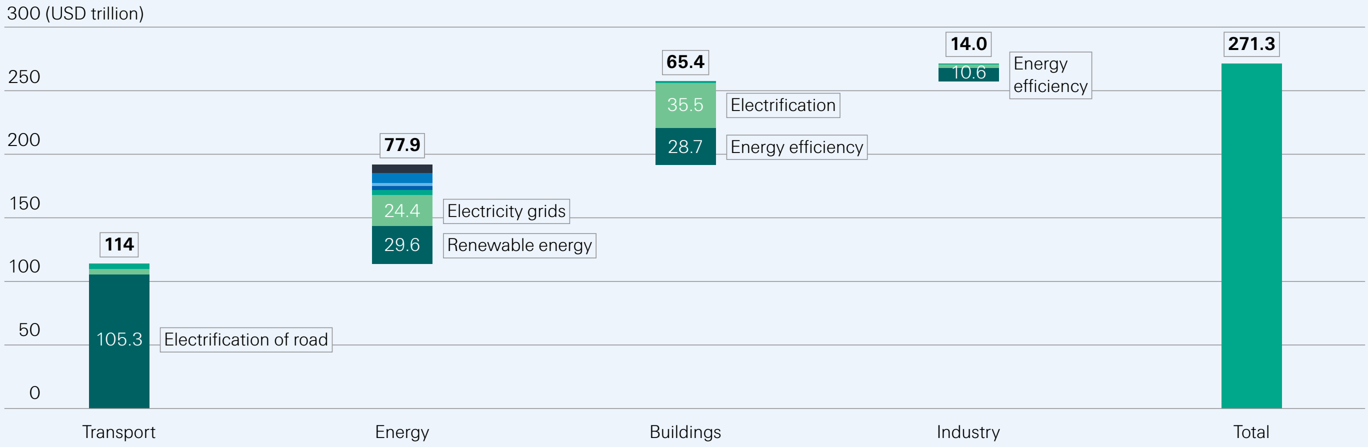
Incentive structures and the removal of investment barriers are critical in mobilising private sector funds.

Main barriers to closing the investment gap and decarbonising the economy include that decarbonisation actions across sectors are closely related, only half of the technology to decarbonise is so far available, and large information asymmetries remain. In addition, macro-financial considerations, such as a limited range of investable projects and a fragmented investment landscape, work against a scaling up of private-sector finance. Governments need to build market confidence with clear policy signals and incentives, and regulators need to set standardised rules on green investment. Re/insurers can also play a key role by aligning their asset and underwriting portfolios with their own net zero ambitions, by sharing risk knowledge and as investors in sustainable infrastructure.

Key takeaways

There is a USD 290 trillion investment gap to net zero by 2050, or USD 271 trillion excluding ongoing investments in fossil fuels

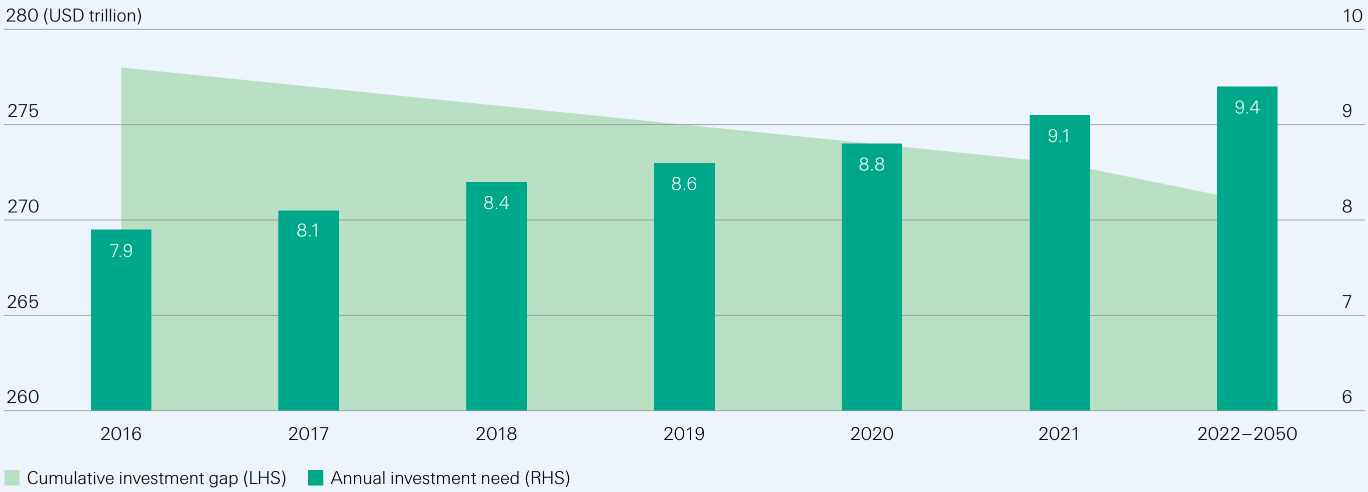
The biggest investment gaps as of 2022 are in transport and energy, at USD 114 trillion and 78 trillion, respectively. The estimated gaps in the buildings and industrial sectors are USD 65 trillion and USD 14 trillion. Assuming investments are equally spread between 2022 and 2050, the USD 271 trillion investment gap translates into an average annual gap of USD 9.4 trillion.



Source: Swiss Re Institute

The investment need is rising over time

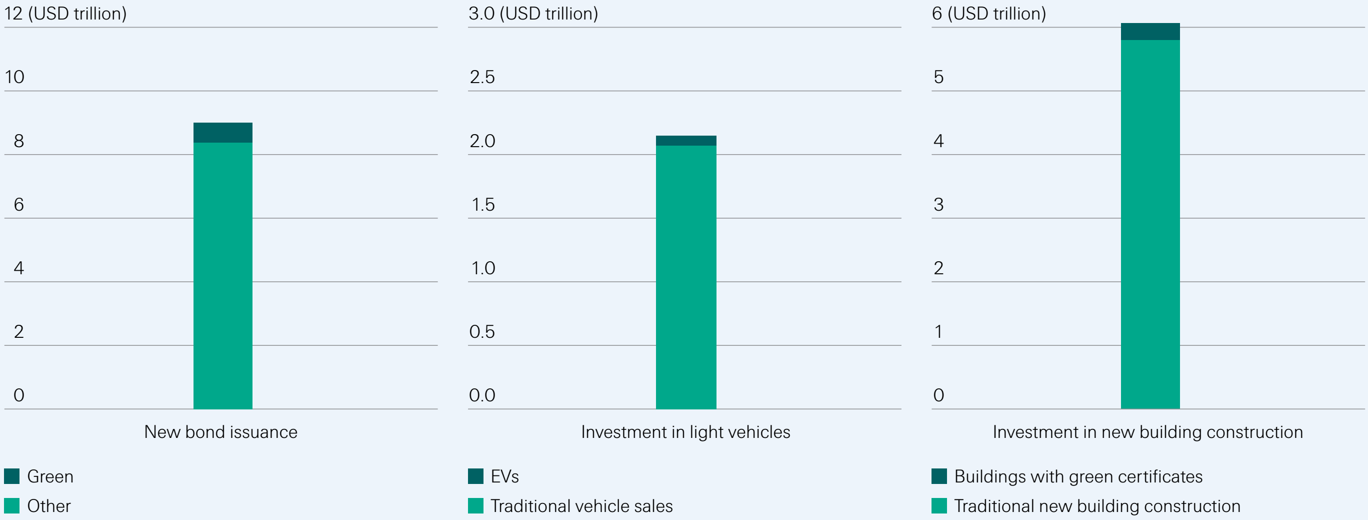
Only 2% progress has been made with regards to providing the investment needed for net zero by 2050. At the current trend, net zero would be reached almost 20 years behind target. Even though every dollar spent contributes to closing the cumulative investment gap, the pace falls short of what is needed, and time is running out. That means the annual ask is increasing over time.



Source: Swiss Re Institute

Closing the gap is possible

More than 40% of the gap could be filled through the combination of maintaining climate spending at current trend and re-allocating a feasible share of existing spending from high- to low-emission assets. Much of the extra investment required – an additional USD 4.8 trillion on average annually between 2022 and 2050 – can be provided by aligning private sector investments with climate ambitions.



Source: S&P Global Ratings, Bloomberg New Energy Finance, Climate Policy Initiative, Swiss Re Institute

Reality check: geopolitics, economics and decarbonisation

Climate goals: the clock is ticking

To meet the Paris Agreement target and net zero by 2050, the global economy needs to be reshaped, rapidly.

Climate change is an existential threat to humanity and a major risk to the global economy. The transition required to meet the Paris Agreement target of limiting global warming to well below 2°C relative to pre-industrial levels, and also net-zero greenhouse gas (GHG) emissions by 2050, is/will be the largest exercise in economic transformation ever attempted.[1,2] Every area of the economy will need to decarbonise,[3] but the transition is not just about substituting one form of energy for another. It is about overhauling the entire global energy system: how we generate, use, transport and store energy.[4] Additionally, global agriculture needs to be reformed, and carbon-capture and carbon-sequestration activities need to be stepped up.[5] This all amounts to a reshaping of the backbone of the global economy, and the clock is ticking. The world stands to lose up to 7–10% of total economic value by mid-century if warming stays on the currently anticipated trajectory rather than hit the Paris Agreement target.[6]

The world is not on track to meet the targets.

As of today, the world is not on track to meet that target, nor the ambition for net-zero emissions by 2050. Lockdowns and mobility restrictions during the peak of the COVID-19 pandemic saw emissions fall, but the benefit was short-lived. They are already back at record highs.[7] Meanwhile, Russia's invasion of Ukraine in early 2022 has sent shock waves through energy markets and brought new dynamics to the journey to net zero. The immediate impact has been to bump energy security up to the top of the policy agenda. As a positive, this has added new urgency to shift from a reliance on fossil fuels to an expansion of renewable energy supply. At the same time, soaring fossil fuel prices render renewables more price competitive.[8]

One fallout of the war in Ukraine is that carbon emissions may well rise in the near term.

However, renewable energy supplies are not yet a sufficient alternative to fossil fuels. For example, in terms of global electricity generating capacity, renewables volumes reached an all-time high in 2021, accounting for more than 80% of new capacity added. But the renewable share of total generation capacity remains below 40%.[9] And further, in 2022 governments are turning to more polluting and cheaper forms of energy such as coal, both to secure energy independence/supplies and to alleviate the current "cost-of-living" crisis facing many households. Germany, for instance, has announced a temporary

1 GHG emissions (notably carbon dioxide, methane, nitrous oxide, and F-gases) due to human activity are the dominant cause of observed climate change since the mid-20th century. See *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (*IPCC*), 2021. Net-zero emissions refers to a situation where global GHG emissions from human activity are in balance with emission reductions, which are necessary to meet the Paris Agreement target. See *The Paris Agreement*, United Nations Framework Convention on Climate Change (UNFCCC), 2022. The economic activities generating GHG emissions are: the production, transport (through pipelines), and consumption (in transport, buildings, industry, and agriculture) of energy; industrial processes; agriculture, forestry, and land use (AFOLU); and waste (see Appendix II).

2 Transition in this paper focuses on mitigation rather than adaptation, or simply stated, the move toward a low-carbon economy.

3 Emissions of the various GHGs are commonly quoted in carbon dioxide equivalents. In this report, "decarbonisation" is used to describe the process of reducing *all* GHG emissions.

4 For example, fugitive emissions (leakages and emissions from pressurised containment of oil, natural gas and coal) account for more than 5% of global GHG emissions (see Appendix II).

5 Carbon capture is the capture of carbon at source (eg, power plants, industrial processes) and storage in non-atmospheric reservoirs (eg, depleted oil and gas reservoirs, un-mineable coal seams, deep saline formations, deep ocean). Carbon sequestration focuses on enhancing natural processes to increase the removal of carbon from the atmosphere (eg, forestation).

6 *The economics of climate change: no action not an option*, Swiss Re Institute, April 2021.

7 *Global CO_2 emissions rebounded to their highest level in history in 2021*, International Energy Agency (IEA), 8 March 2022.

8 For example, in Europe it is expected that in 2022, the lifetime cost per kWh of new solar and wind power generation capacity added in 2021 will average at least four to six times less than the marginal generating costs of fossil fuels. See *Renewable Power Generation Costs in 2021*, The International Renewable Energy Agency (IRENA), July 2022. Also, European gas prices have been pushed so high that green hydrogen is now competitive with gas in the UK and several other European countries. See *Ukraine War Makes Green Hydrogen Cheaper Than Natural Gas*, Bloomberg New Energy Finance (BNEF), June 2022.

9 *Renewable Energy Statistics 2022*, IRENA, 2022.

recourse to coal to reduce gas consumption (and reliance on Russia), and to replenish energy reserves ahead of winter 2022.[10] And the REPowerEU plan entails an extended role for coal alongside growth in clean energy, as the continent seeks to move away from reliance on natural gas.[11] The International Energy Agency (IEA) meanwhile estimates a 10% increase in investments in the global coal supply chain this year, mostly in India and China, and a 10% increase in investment in oil, gas and coal for fuel supply.[12] The upshot of all this is that emissions will likely rise rather than fall in the near term. Over the longer term, as countries increasingly focus on domestic energy and food security, geopolitical shifts towards a more multi-polar world risk hindering global cooperation and thus further stalling transition momentum.[13]

Stronger decarbonisation ambition and action is needed.

The transition to net zero is hindered by other considerations also. First, the pledges in place do not add up to what is needed. Assuming full implementation of the nationally determined contributions (NDCs) [14] submitted by all 192 Parties to the Paris Agreement as of mid-November 2021, global GHG emissions are forecast to increase by about 16% by 2030 relative to 2010, rather than fall by the 25–45% needed.[15] Second, setting targets is not the same as achieving them. Seventy-four percent of national net-zero targets are inadequately designed, according to the Climate Action Tracker (CAT)[16] and, if history is a guide, pledges may not materialise at all. Further, only 50 countries (plus the European Union (EU)) have communicated emission-reducing strategies for beyond 2030.[17] Third, today's economic environment may further constrain implementation with high and persistent inflation, record levels of government debt, looming recession, and low resilience leaving policymakers with limited room for manoeuvre. And fourth, a main barrier to deployment of carbon removal and decarbonisation is lack of a business case. In the absence of carbon pricing in many parts of the world, society disposes of carbon at will.[18] A global carbon price of at least USD 75 per metric ton is needed, according to the International Monetary Fund (IMF),[19] but current carbon pricing instruments cover only about 30% of global emissions and the global average price is around USD 6.[20]

Tracking decarbonisation

Pledges need to align with actions that lower emissions.

The world needs to get on track on climate goals. For this, pledges on decarbonisation need to be aligned with actions that lower emissions. Progress in decarbonisation is typically judged in terms of emission levels or the extent of greening pledges made. However, while emissions are a statement of progress made, they do not provide insight into the specific (lack of) action behind them. Similarly, pledges may or may not materialise, and do not reveal much about actual actions taken. For this reason, in this study we seek instead to track progress on decarbonisation through the lens of investment.[21] This provides insights into the actions taken by both the public and private sectors to advance the transition, and also the risks and opportunities that lie ahead.

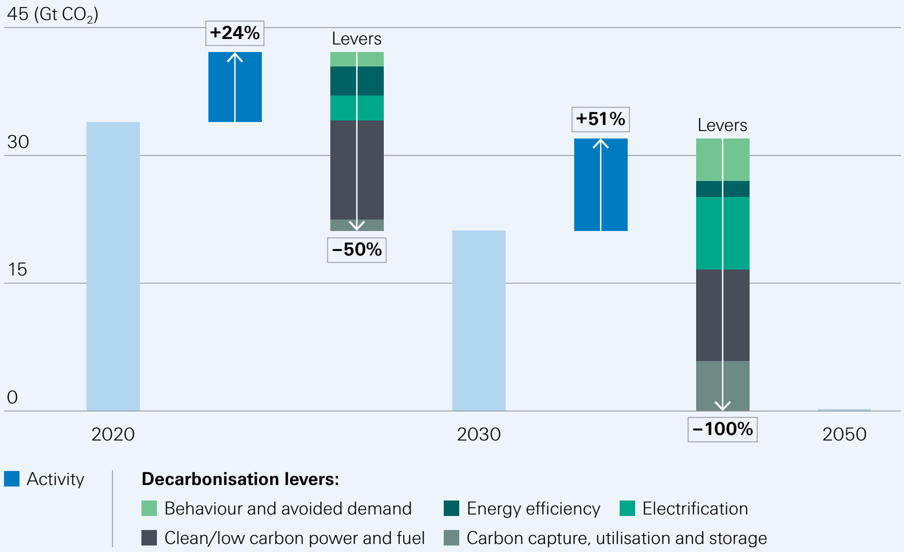
This paper assesses progress on decarbonisation through the lens of investment.

The huge scale of economic transformation necessary to achieve net zero requires investment along each step of the way. As in Figure 1, among the transformation necessities are improving energy efficiency, for instance in buildings and industry; electrification, such as in transport, including a ramping up of electricity-generating infrastructure (eg, grids, storage and hydrogen) and technologies; shifting energy uptake to clean power and fuel, including hydrogen and hydrogen-based fuels, renewables like wind and solar, and bioenergy; and scaling up carbon capture, utilisation and storage

[10] D. R. Habeck, *Wir stärken die Vorsorge weiter und ergreifen zusätzliche Maßnahmen für weniger Gasverbrauch*, German Federal Ministry for Economic Affairs and Climate Action,19 June 2022.
[11] *REPowerEU Plan*, European Commission, 18 May 2022.
[12] *World Energy Investment 2022*, IEA, June 2022.
[13] *sigma* 5/2022 – Maintaining resilience: the role of P&C insurers in a new world order, Swiss Re Institute, 9 September 2022.
[14] NDCs form the basis for countries to achieve the objectives of the Paris Agreement, including national targets, and policies and measures for reducing emissions and adapting to climate impacts.
[15] Based on an analysis of all NDCs submitted up to 12 October 2021. See *Nationally determined contributions under the Paris Agreement*, UNFCCC, October 2021.
[16] *CAT net zero target evaluations*, Climate Action Tracker, September 2022.
[17] *Communication of long-term strategies*, UNFCCC, 2022
[18] *The insurance rationale for carbon removal solutions*, Swiss Re Institute, July 2021.
[19] *Fiscal Monitor: How to Mitigate Climate Change*, International Monetary Fund (IMF), October 2019.
[20] S. Black, I. Parry and K. Zhunussova, "More Countries are Pricing Carbon, But Emissions Are Still too Cheap", *imf.org*, 21 July 2022.
[21] In this paper, climate or climate-positive investments refer to primary investment at the project level to capture spending targeting climate-specific mitigation outcomes. This is distinct from the concept of green or sustainable finance more broadly.

(CCUS) projects. In this study, we call such activities "decarbonisation levers". They are those action items that can be mobilised to reduce emissions. We maintain that if adequate investment flows to the right places and is employed correctly then, all else equal, decarbonisation should follow. To this end, the investment gap – the required cumulative investment for net zero by 2050 minus actual investments – can be deployed as a "decarbonisation tracker".

Figure 1
Emissions reductions (in gigatons CO_2) by decarbonisation lever, 2020–2050



Note: The figure shows the accounting behind getting to net zero emissions in the IEA's "Net Zero Emissions" scenario. The activity block represents increased emissions resulting from ongoing and higher energy demand associated with higher economic activity and population growth. Solar, wind and energy efficiency deliver around half of emissions reductions to 2030, while electrification, CCUS and hydrogen ramp up thereafter.
Source: *Net Zero by 2050: A Roadmap for the Global Energy Sector*, IEA, 2021; Swiss Re Institute

Tracking progress: the investment gap to net zero by 2050

A "pure" climate investment gap of USD 271 trillion

For an estimate of "pure" decarbonisation spend by 2050, we exclude USD 18 trillion in investment still needed in fossil fuels…

We find that as of 2022, the investment gap for net zero by 2050 is USD 290 trillion, a signal of the enormity of the task at hand. We obtain this figure by comparing estimates of the cumulative investment required for net zero by 2050 with data on actual investments (see *A three-step approach for constructing the investment gap*). This number, however, includes investments in fossil fuels. These are included in most third-party study estimates as investment in high-emissions physical assets like fossil-fuel run vehicles and power stations are considered necessary until the time that renewables and clean technologies offer a sufficient and reliable alternative. In the rest of our analysis and to focus on decarbonisation alone, we subtract USD 18 trillion as estimated by the IEA as the amount of investments in fossil fuels that will still be required by 2050.[22] On this basis, we derive a "pure" decarbonisation investment gap estimate of USD 271.3 trillion between 2022 and 2050.[23] Assuming investments are spread equally across those years, this translates into an average annual gap of USD 9.4 trillion.[24]

…rendering an investment gap as of 2022 of more than **USD 271 trillion**.

Our investment gap estimate is notably higher than those of the third-party studies we use in our methodology (see *Uncertainty around the estimated investment gap*). The magnitude of the gap is driven both by the large investment needs and, to date, low actual investments. For example as of the start of 2021, we estimate the cumulative investment required over the next 30 years to reach net zero by 2050 amounted to just less than USD 273 trillion, an average of USD 9.1 trillion annually: actual investments in 2021 were just USD 1.3 trillion.

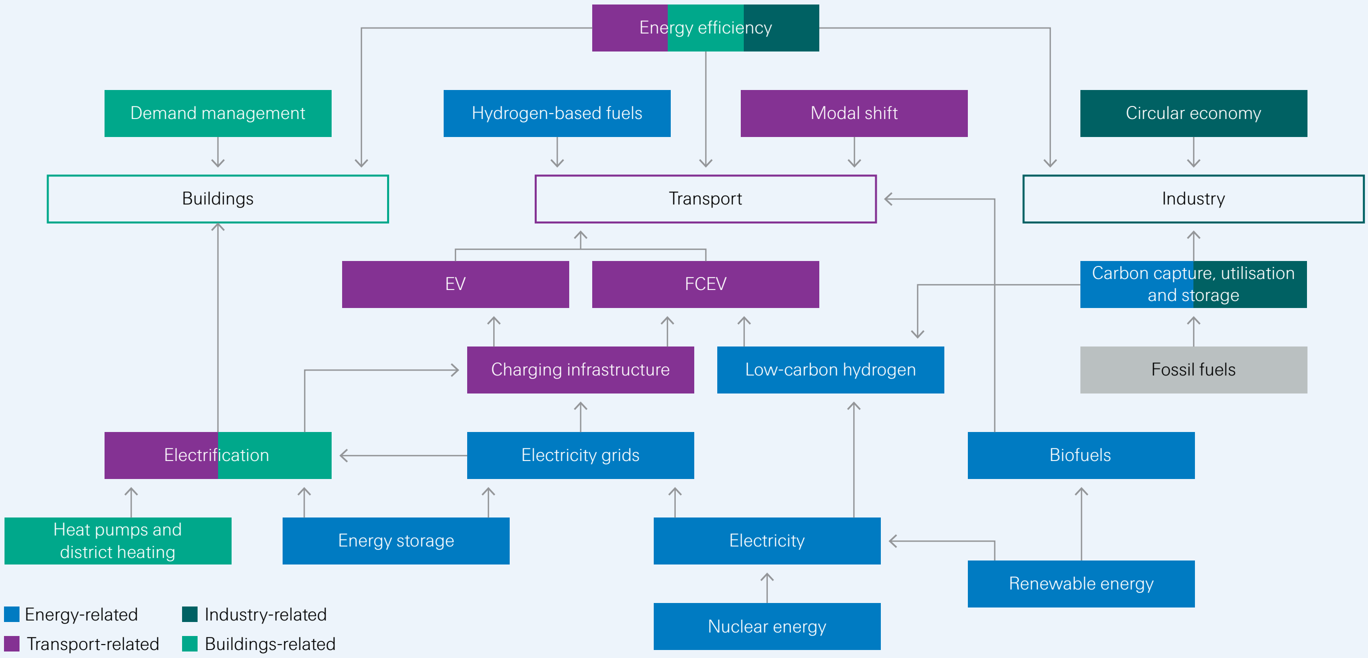
A three-step approach for constructing the investment gap
We follow a three-step methodology to track progress in decarbonisation.[25]

Step 1: build a sectoral and global measure of investment need for net zero by 2050.

1) We take a bottom-up approach and collate estimates from third-party studies of the investment needed as of 2021 to achieve net zero by 2050. We select comparable estimates along the various decarbonisation levers of the four biggest GHG-emitting sectors – energy, transport, buildings and industry (see Figure 2).[26] Aggregating these estimates, we construct a sectoral and global measure of the investment need. This yields an estimated investment need of USD 292 trillion between 2021 and 2050 including fossil fuels, or USD 273 trillion without. The latter implies an average annual need of USD 9.1 trillion as of 2021.

[22] Similarly, in terms of actual investment, the inclusion of fossil fuels could distort inference on decarbonisation progress. For example, any decrease in fossil fuel investment would offset positive growth in decarbonisation investment at an aggregate level, suggesting moderate or even negative decarbonisation progress. As the transition progresses, fossil fuel investments are expected to decrease while all other investments are expected to increase.
[23] Our investment gap, however, does include spending on nuclear energy. See Figure 2 and *The investment gap across sectors* for further details.
[24] Numbers may not add up exactly due to rounding.
[25] Swiss Re Institute's climate economics research is part of our strategic research partnership on resilience with the London School of Economics (LSE). This paper and the methodology used benefited from continuous dialogue with the LSE.
[26] These four sectors jointly account for around 80% of global carbon emissions (see Appendix II). For a more detailed description of the sectors see *Energy, transport, buildings, and industry: definitions and decarbonisation levers.*

Figure 2
The decarbonisation levers of the four sectors, and their interdependencies



Note: This figure presents a stylised schematic of the decarbonisation levers that we cover across the four sectors. The arrows indicate how the levers relate to one another, illustrating the interdependency of decarbonisation efforts across sectors. The direction of the arrows captures how decarbonisation levers feed into other levers and eventually the decarbonisation of a sector. For example, energy efficiency contributes to decarbonising the transport, industry and buildings sectors. The energy sector does not appear as a stand-alone sector but is integrated throughout as clean energy contributes to the decarbonisation of all sectors. EV for electric vehicles; and FCEV for fuel-cell electric vehicles. Source: Swiss Re Institute

Step 2: collect data on actual past investments in decarbonisation projects.

2) We collect data on past investments in each lever across the four named sectors corresponding in both definition and scope to the needs estimate summed up in step 1. We draw on several sources that track climate investments.[27] Our measure of past investments is annual time series covering the period from 2016 until 2021. That timespan is driven by data limitations in earlier periods. Even today, tracking climate finance flows, including investments, remains challenging given non-standardised metrics and definitions, on top of already-limited data and information availability. In 2021, tracked flows reached a record USD 1.3 trillion, up from USD 1 trillion in 2016, but still well short of the average annual estimated need of USD 9.1 trillion as of 2021.

Step 3: construct measures of the investment gap by comparing investment needed (from step 1) with actual investment (from step 2).

3) We construct measures of the cumulative investment gap between 2016 and 2022 by comparing actual investment in 2016–2021 with our estimate of investment need in each year over the same period. For example, for the cumulative 2022 investment gap we subtract from our estimate of the investment need as of 2021 the amount of actual investment in 2021. This yields our investment gap number of USD 271 trillion as of the start of 2022 to reach net zero by 2050.

Our methodology enables transparent tracing of the global investment gap back to individual decarbonisation levers.

Given our bottom-up methodology, we can break down the headline gap into how investments across the decarbonisation levers will need to develop/change in the years to come to achieve net zero by 2050 (see *The investment gap across sectors*). Appendix I provides a full detailed account of our methodology, notably the literature and data sources used in constructing our investment gap series.

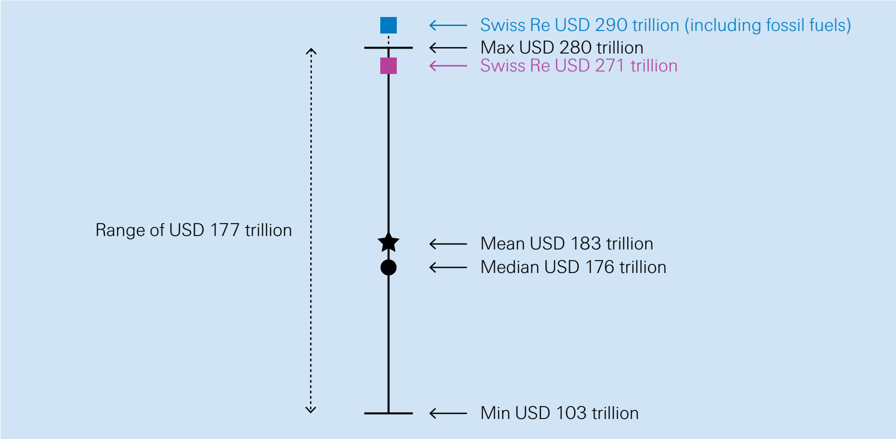
[27] Including BNEF, Climate Policy Initiative, IEA and IRENA.

There is a high level of uncertainty around the point estimate of the investment gap.

Uncertainty around the estimated investment gap

There is significant uncertainty around any point estimate of the investment gap to net zero. A distinguishing feature of our methodology is that it allows us to be explicit about the degree of uncertainty around our USD 271 trillion (excluding fossil fuels) point estimate, with a possible range of USD 103–280 trillion (see Figure 3). This range is obtained by aggregating the lowest and highest estimate we collect of investment needed per decarbonisation lever, which in turn allows for tracing uncertainty back to the decarbonisation lever. It provides the perimeter of estimates across the different studies referenced and reflects the variation in assumptions used in those studies.

Figure 3
Range of uncertainty around our investment gap estimates as of 2022



Note: All amounts are in 2019 USD terms and exclude fossil fuels, unless otherwise indicated.
Source: Swiss Re Institute

Existing estimates of the investment needed vary hugely, with discrepancies of up to USD 5 trillion per year.

The uncertainty is also reflected in the large variation among the headline estimates from different research studies of the magnitude of the investment need to reach net zero by 2050. For example, the Glasgow Financial Alliance for Net Zero (GFANZ) and the UN High-Level Climate Action Champions together with Vivid Economics have estimated that approximately USD 125 trillion of investment between 2021 and 2050 will be needed.[28] More recently, McKinsey put this number at USD 275 trillion.[29] Assuming investments are spread out equally over the next 30 years, these estimates translate into an annual spend of USD 4.2 trillion and USD 9.2 trillion, respectively – an average discrepancy of up to USD 5 trillion per year.[30] This discrepancy is at least quadruple the investment made in decarbonisation in any single year to date, an indication of the enormity of the variation.

We reconcile the headline estimates across the different studies.

We reconcile the headline estimates across different studies by comparing:

- their scope, in terms of coverage and climate target;
- the size of investments and relevant time horizons;
- the distribution assumed over time; and
- the approach used to produce these estimates.

[28] *Financing Roadmaps*, GFANZ, November 2021; and *What's the cost of net zero?*, UNFCCC, November 2021.
[29] *The net-zero transition: what it would cost, what it could bring*, McKinsey, 2022.
[30] Most other existing estimates put the average annual spending need for the net-zero transition between USD 3.0 trillion and USD 4.5 trillion through 2050. The Climate Action Tracker and World Resources Institute estimate a need of USD 4.1 trillion (see *State of Climate Action 2021: Systems Transformation Required to Limit Global Warming to 1.5°C*, 2021). IRENA estimates that about USD 4.4 trillion is needed (see *World Energy Transition Outlook –1.5°C Pathway, 2021).* The IEA estimates that USD 4.8 trillion will be needed (see *Net Zero by 2050: A roadmap for the global energy sector*, 2021). The Climate Policy Initiative estimates USD 4.5–5 trillion is needed (see *Global Landscape of Climate Finance 2021*, 2021). See also Appendix I.

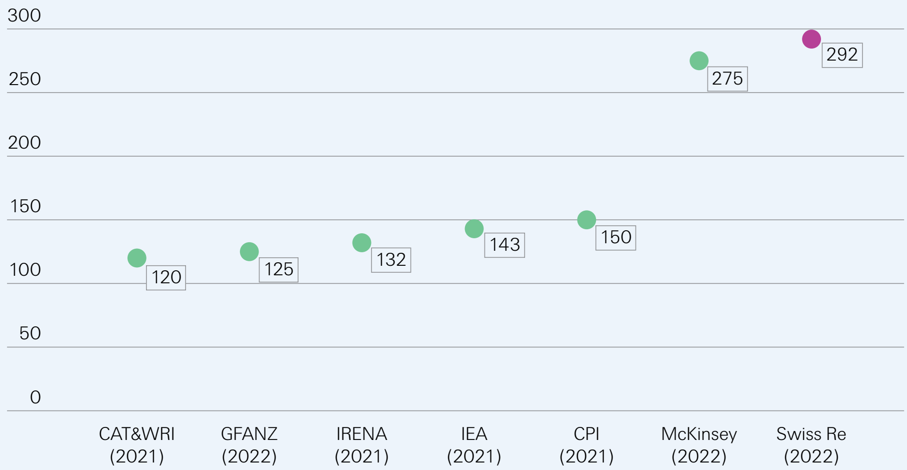
Much of the variation is because estimates are not always directly comparable.

This reveals that much of the variation across headline numbers is because the estimates are not always comparable, particularly in terms decarbonisation levers considered.[31] Moreover, headline estimates from some prominent sources (eg, McKinsey, the IEA and the International Renewable Energy Agency (IRENA) also cover fossil fuel-related investments. The fossil fuel component is one area of the discrepancy between the investment need estimates. Irrespective of the war in Ukraine adding urgency to increase use of renewables in pursuit of energy security, systematic economic dependency on fossil fuels cannot be overturned in the blink of an eye. However, there is no agreement on the magnitude of investment in fossil fuels still required, nor on the length of the phase-out period. The IEA estimates investment of around USD 18 trillion in existing oil and natural gas fields is still needed, mainly for fuel production between 2021 and 2050.[32] IRENA assumes that USD 16 trillion will be invested jointly into fossil fuels and nuclear energy,[33] and McKinsey estimates USD 19 trillion of cumulative investment need in fossil fuels through 2021–2050.[34]

Our estimated cumulative need of USD 292 trillion (including fossil fuels) is notably higher than any estimate from the other studies.

Rather than add an own-modelled number to the plethora of already existing estimates of the investment needed for net zero by 2050, we collate estimates from third-party studies. We err on the side of caution and assume the higher end of estimates, including for investments still to come in fossil fuels (USD 18 trillion). As part of the three-step approach to derive our estimate of the investment gap as outlined above, we estimate the investment need to reach net zero by 2050 is USD 292 trillion. This number includes fossil fuels, and is shown for comparability with the other studies, which all include fossil fuel investments. Our aggregated measure of the investment needed is much higher than any of the estimates from other recent studies (see Figure 4).

Figure 4
Estimates of cumulative investment needs (including fossil fuel investments), as of 2021, to transition to net-zero emissions by 2050 (in USD trillion)



Note: The external estimates shown have not been transformed in any way. All estimates, including ours, include fossil fuel investment (see also *Appendix I*). GFANZ includes fossil fuels jointly with CCUS. All estimates are as of 2021 and in 2019 USD prices.
Source: Climate Action Tracker, World Resources Institute, GFANZ, IRENA, IEA, Climate Policy Initiative (CPI), McKinsey, Swiss Re Institute

There are big uncertainties surrounding technological advances, costs, and synergies or bottlenecks across sectors.

A main source of uncertainty influencing the investment that will be needed and the path to net zero is the speed of technological advancement. According to the IEA, almost 50% of the emissions reductions needed by 2050 depend on technologies that are not

31 For example, McKinsey's comparably high 2022 estimate is explained by the fact that it considers a more comprehensive view of spending by households and businesses on assets that use energy (eg, the full cost of passenger cars and heat pumps); capital expenditures in agriculture and forestry; as well as some spending on fossil fuels, in addition to what other estimates typically include. Our estimate is more comparable to McKinsey's in scope as we draw on theirs as one of our inputs. We, however, do not cover agriculture and forestry. See Appendix II.
32 IEA, 2021, op. cit. In this estimate, the IEA assumes that the use of fossil fuels is paired with CCUS processes by 2050.
33 IRENA, 2022, op. cit..
34 McKinsey, 2022, op cit.

yet available on the market, being either in prototype or demonstration stage.[35] And history tells us that bringing new energy technologies to market can take several decades. For example, successful examples in clean energy technology development like solar PV, lithium-ion batteries or LED took between 10 and 30 years from the first prototype to time of commercialisation.[36] Moreover, these technologies will not become available at scale without further R&D and technical improvements. It is further impossible to predict which technologies may emerge that are unknown today, and so most estimates of investment need are built around energy technologies for which at least a large prototype is already proven today and the pathway to commercial scaling-up is understood. Another not unrelated uncertainty is future costs. For example, the cost of electric vehicles (EVs) depend on battery prices, with price parity between EVs and traditional internal combustion engines at less than USD 100/kWh.[37] Battery prices were USD132/kWh in 2021, but may rise in 2022 given that record-setting prices for key component metals show little sign of moving lower in the near future.[38] And then there is also potential for yet-unidentified synergies or bottlenecks between various decarbonisation solutions.

There is also uncertainty around actual investment, but the magnitude of variation is small relative to the overall gap.

There is also uncertainty stemming from tracking actual investment. There are large data gaps in the tracking of climate finance data, especially in areas other than renewable energy, energy efficiency, and transport.[39] Moreover, in most countries climate data collection and disclosures are not mandatory. Though we do not explicitly capture uncertainty around investment flows, this is in part mitigated by the magnitude of variation likely being small relative to the overall gap.[40]

Despite the large uncertainty, we believe even the upper bound of the estimated range is a likely lower bound in reality.

As above, we derive a pure decarbonisation (ie, excluding fossil-fuels) investment gap estimate of USD 271 trillion between 2022 and 2050 by subtracting USD 18 trillion. Irrespective of the uncertainties, we believe our estimate, which is at the upper bound of the uncertainty range, likely represents a *lower* bound of the true investment need. Reasons include:

- The estimate covers investment needs in the energy, transport, industry and building sectors only. The investment needed to abate global emissions that come from all other sectors, including agriculture, is not captured (see *Appendix II* for more detail of what we do and do not capture).[41]

- Within the four sectors covered, not all decarbonisation levers are captured. For example, our measure of the investment gap for the industry sector does not cover the production of aluminium, non-ferrous metals, pulp and paper, or non-metallic minerals.

- Changes in investment need estimates are likely as understanding of the mitigation actions required to achieve net zero improves, and as data availability and standardisation facilitates more comprehensive scrutiny. Moreover, the cost of developing new technologies is not wholly factored into our estimate.

[35] IEA, 2021, op. cit.
[36] *Energy Technology Perspectives 2020*, IEA, 2020.
[37] *When Will Electric Vehicles Be Cheaper Than Conventional Vehicles?*, BNEF, August 2021.
[38] *BNEF Signposts, 2Q 2022*, BNEF, June 2022.
[39] A. Prasad, E. Loukoianova, A. X. Feng and W. Oman, *Mobilizing Private Climate Financing in Emerging Market and Developing Economies*, Staff Climate Note 2022/007, IMF, July 2022; and *Global Landscape of Climate Finance 2021*, CPI, December 2021
[40] For example, the CPI estimates that average annual global climate finance flows reached USD 623 billion in 2019/2020 (see Ibid). See also Appendix I for how we compare to CPI.
[41] Any limitations in the scope of what we cover, both across and within sectors, is wholly driven by data reliability and information limitations. For example, while needs estimates for decarbonising agriculture are available (eg, from McKinsey), actual investment data is not and we therefore choose to exclude agriculture from our evaluation of the climate investment gap.

Not on track to close the investment gap

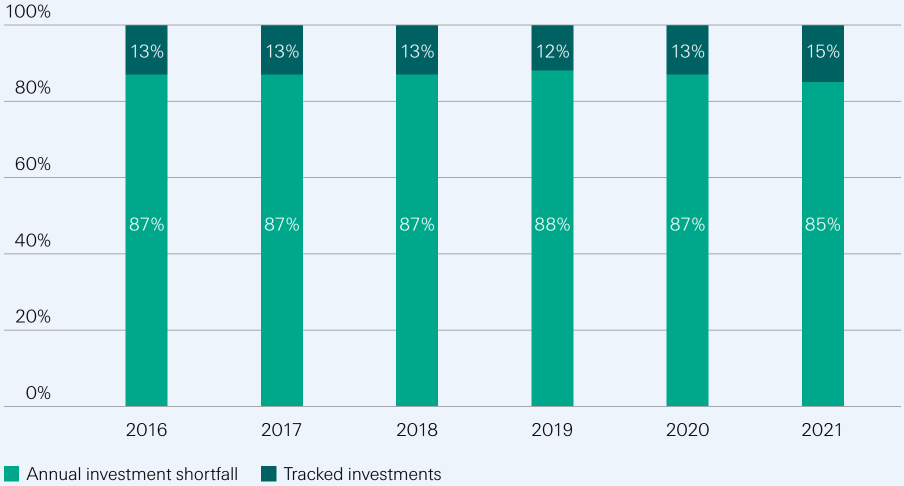
Over the past six years, only 2% of required investment for net zero by 2050 materialised.

From 2016 to 2021, only around 2% of the investment needed to reach net zero by 2050 materialised, leaving an investment gap of 98% at the start of 2022. We estimate that in 2016 the investment ask amounted to USD 278 trillion while the corresponding actual investment since then (until end-2021) *cumulatively* amounted to USD 6.6 trillion, leaving the USD 271 trillion global investment gap as of 2022.

The USD 9.4 trillion average *annual* investment needed from 2022 to 2050 is more than the *cumulative* investment seen over the past six years.

Our estimated USD 271 trillion global investment gap as of 2022 translates into an average annual gap of USD 9.4 trillion between 2022 and 2050, assuming investments are equally spread across the years. This stands in stark contrast to actual past investments of US 1.1 trillion on average per year between 2016 and 2021. We estimate that the annual investment shortfall – the difference between the average annual need in any given year and actual spend – has decreased only marginally over time, from 87% in 2016 to 85% in 2021 (see Figure 5). In 2021, tracked flows reached a record USD 1.3 trillion (vs USD 1 trillion in 2016). However, that constituted only 15% of the average annual need at the time (USD 9.1 trillion).

Figure 5
Annual tracked investment and investment shortfall as shares of estimated average annual need between 2016–2021 (in %)

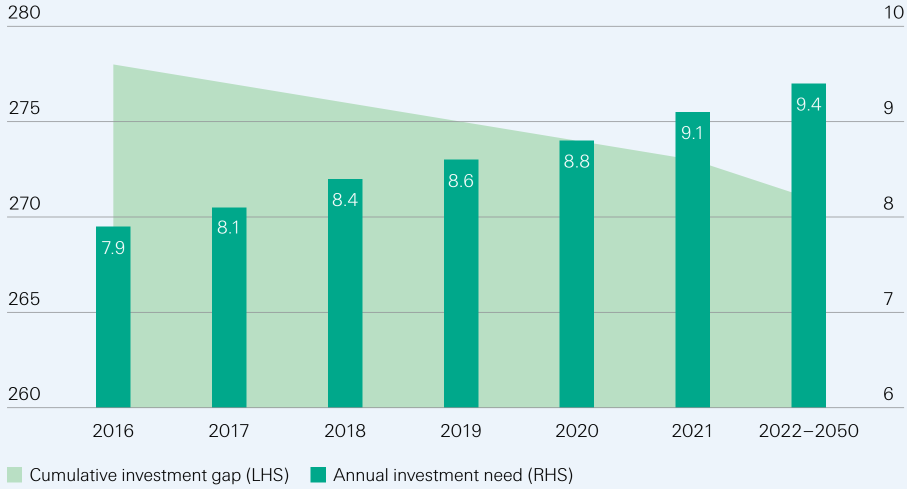


Source: Swiss Re Institute

Every year that investment falls short of what is required, the burden for future years gets larger.

Every dollar spent contributes to closing the investment gap. However, every year that the annual need is not met means the shortfall has to be made up in subsequent years. Hence, while the investment gap is decreasing overall (very slowly), annual investment needs are increasing each year (see Figure 6). For example, the 85% or USD 7.8 trillion investment shortfall from 2021 inflates the annual average need for every year to 2050 from USD 9.1 trillion as of 2021, to USD 9.4 trillion in 2022.

Figure 6
Cumulative investment gap (LHS) vs average annual investment need (RHS) between 2016–2050 (in USD trillion)



Note: All amounts are in 2019 USD terms. Over time, the cumulative investment gap (LHS) closes with every US dollar spent, but the pace falls short of what is needed and time is running out. Hence the annual ask increases over time (RHS).
Source: Swiss Re Institute

There needs to be a big increase in investment to reach net zero by 2050.

Till now, we have assumed the cumulative investment gap between 2022 and 2050 is spread equally over the following 29 years. This implies a jump in annual investment from USD 1.3 trillion in 2021 to USD 9.4 trillion in 2022, a year-on-year (yoy) increase of 609% (see Figure 7, left). And investment would need to remain at USD 9.4 trillion in every subsequent year to 2050. Such a jump in investment from 2021 to 2022 is at best unrealistic. Not only in terms of mobilising adequate financing but also in relation to the availability of investable projects, market capacities and technological readiness.

If investment growth continues to average 5% annually, the investment gap to net zero will only be closed in 2069.

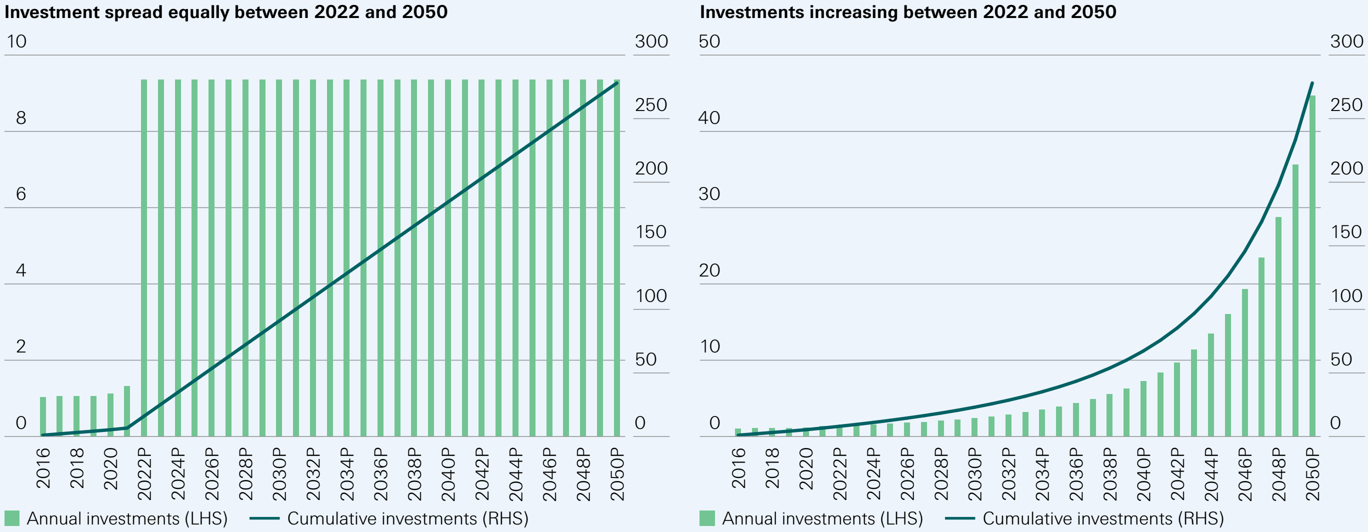
Since 2016, average annual growth in investment has been around 5%, with a most rapid gain of 17% observed between 2020 and 2021. If investment were to continue to grow by around 5% annually, a third of the gap would be filled by 2050 (USD 90 trillion) and net zero would be reached by 2069 only, almost 20 years behind schedule.

Investment schedules with more aggressive back- or frontloading could see the investment gap close by 2050.

There are alternative investment paths that would see the investment gap close by 2050.[42] For example, the gap would close if investment growth itself increases so that yoy investment rises at an accelerating pace, starting from USD 1.4 trillion in 2022 (yoy growth of just more than 5% from 2021), to USD 44 trillion by 2050 (yoy growth of just more than 25% from 2049, see Figure 7, right). Instead of backloading, an investment profile with frontloading of investments, where the bulk of investment is borne in earlier rather than later years, could also close the gap. The typical investment profile in existing studies sees a gradual rise in investments until 2030 and backloading thereafter, with sectoral differences. By looking at past flows and transferring missed spending to future years, we implicitly capture backloading to a certain extent. All things said, focusing on the cumulative gap allows us to bypass the issue of distribution while still providing a metric against which to benchmark progress on conceivable and feasible transition paths.

[42] We consider several examples of such paths, but comprehensive modelling would be needed to obtain an endogenous investment distribution.

Figure 7
Past investment versus alternative future investment profiles (in USD trillion)



Note: all amounts are in 2019 USD terms. P = projections
Source: Swiss Re Institute

The investment gap across sectors

The biggest investment gaps are in the transport and energy sectors, driven by the electrification of road transport and ramping up of renewable energy capacity, respectively.

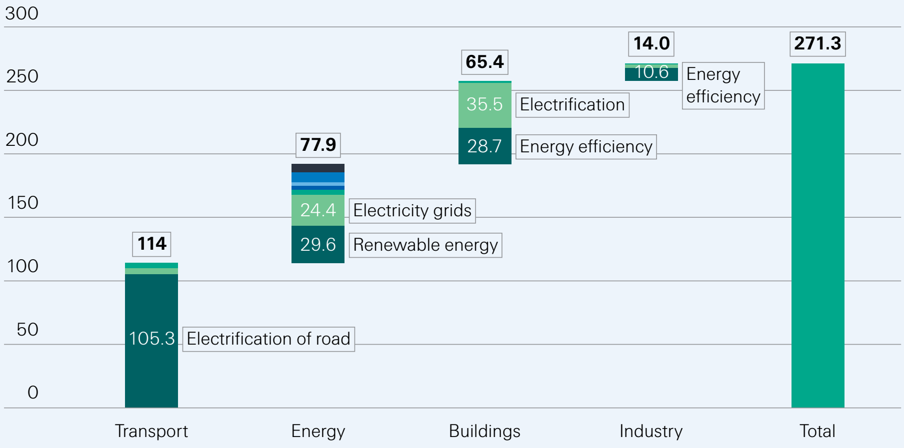
Taking a disaggregated look at our global investment gap, the biggest gaps as of 2022 in absolute terms are in the transport and energy sectors, at USD 114 trillion (42%) and 78 trillion (29%), respectively (see Figure 8).[43] While the investment gap for transport is greatest, that does not detract from the critical importance of the energy sector: without decarbonisation of energy production, no other sector can fully decarbonise (see *Energy, transport, buildings, and industry: definitions and decarbonisation levers).* Within the energy sector itself, the most sizeable investment gaps are for renewables (USD 30 trillion) and accompanying infrastructure (electricity grids, USD 24 trillion). In transport, the electrification of roads (EVs and charging infrastructure) is the main decarbonisation lever, accounting for 92% of the sector's USD 114 trillion investment gap (and almost 40% of the overall gap across all sectors). The estimate is large in part because it includes household investment in EVs,[44] implying that the future (uncertain) cost of EVs will have a significant impact on investment need. In addition, the electrification of transport is inherently tied to the energy sector's capacity to deliver low-carbon electricity.

Energy efficiency is the main decarbonisation lever in both the buildings and industrial sectors.

The estimated decarbonisation investment gap in the buildings and industrial sectors are USD 65 trillion and USD 14 trillion, respectively. The main decarbonisation lever for buildings is energy efficiency, with an investment gap of USD 29 trillion, followed by electrification plus onsite renewables (USD 36 trillion). Like in the building sector, the main decarbonisation lever in industry is energy efficiency, amounting to an USD 11 trillion investment gap, with carbon removal technologies making up most of the rest (USD 3 trillion). Carbon removal technology, however, is still nascent and cost information related to its deployment is not widely available. More broadly, the industrial sector includes some of the hardest-to-abate areas of the economy (eg, production of steel, cement, and chemicals) and accounts for almost a third of global GHG emissions,[45] leading us to regard this sector's comparably benign estimated investment gap of USD 14 trillion as overly optimistic. Indeed, this is the sector where literature and data coverage are most scant, supporting our view that the investment gap estimate is best viewed as a lower bound of need.

[43] Given our bottom-up approach, we can draw insights not only at the global investment gap level, but also at the sectoral and even decarbonisation lever level. See Table 5 in Appendix I for a granular break-down of the decarbonisation levers that we cover.
[44] In this regard, we use McKinsey's estimate as other studies typically do not include private investment in the transport sector.
[45] See Appendix II.

Figure 8
Investment gap by sector and decarbonisation lever (in USD trillion)



Source: Swiss Re Institute

We cover the energy, transport, buildings, and industrial sectors, and around 70% of global GHG emissions.

Energy, transport, buildings, industry: definitions and decarbonisation levers
The majority of GHG emissions arise from the production, transport (through pipelines), and consumption (in transport, buildings, industry and agriculture) of energy. The remainder of emissions are attributable to industrial processes; practices in agriculture, forestry, and land use (AFOLU); and waste.[46] In this study we cover the energy, transport, buildings and industrial sectors, and account for about 70% of global emissions.

The energy sector comprises the supply of energy.

The energy sector comprises the supply of energy, covering production, storage and transport. We capture all investment related to energy supply under the energy sector, rather than attributing these investments to the end-use sectors (transport, buildings, and industry).[47] We also do not break down the share of energy generation investment according to where it is finally used. Decarbonisation levers that we capture include switching to low-emission energy generation and fuels (renewable energy, nuclear energy, and low-carbon fuels), and ramping up the required accompanying infrastructure (electricity grids and energy storage).[48]

The transport sector consists of road, air, ship, and rail transport.

The transport sector comprises road, air, ship and rail transport, covering several industries including air freight and logistics, airlines, marine, road and rail, and transportation infrastructure. Emissions are primarily generated through the use of energy to mobilise transport, most notably road transport, with a marginal share also stemming from electricity and heat consumption in transport equipment and rail. The decarbonisation levers that we capture are the electrification of road networks (EVs[49] and their charging infrastructure), energy efficiency measures (material- and design-related) extended to passenger and freight modes of transport (rail, aviation and shipping), and a modal shift to mass transit (ie, from private to public transport).

The buildings sector consists of the construction and operations of residential, commercial, and public buildings.

The buildings sector consists of residential, commercial and public buildings. About two thirds of emissions generated by this sector are due to the use of electricity and heat. The decarbonisation levers we cover are energy efficiency measures, including advanced envelope design (the design of buildings that enhances adaptability to changing ambient conditions – hot and cold – to conserve energy), efficient electrical equipment (energy-consuming appliances), as well as electrification of heating (heat-pumps or district heating and onsite renewable energy generation), and the enabling demand-management technologies (metres).

[46] See Appendix II.
[47] Investments in the end-use sectors in turn relate to how and which energy is used (the efficiency of energy-use and the choice of energy source), as well as sector-specific infrastructure required for decarbonisation. Others, such as the IEA, often also attribute energy supply to end-use sectors. More broadly, energy plays a fundamental role in the transition but as a sector, it is not always clearly defined across studies.
[48] Our estimate includes USD 2.6 trillion between 2022 and 2050 for nuclear energy. This is in line with the IEA's estimate under its net-zero emissions scenario. See *Net Zero by 2050 – A roadmap for the global energy sector*, IEA, 2021.
[49] For electric vehicles, we include battery-electric vehicles and fuel-cell electric vehicles.

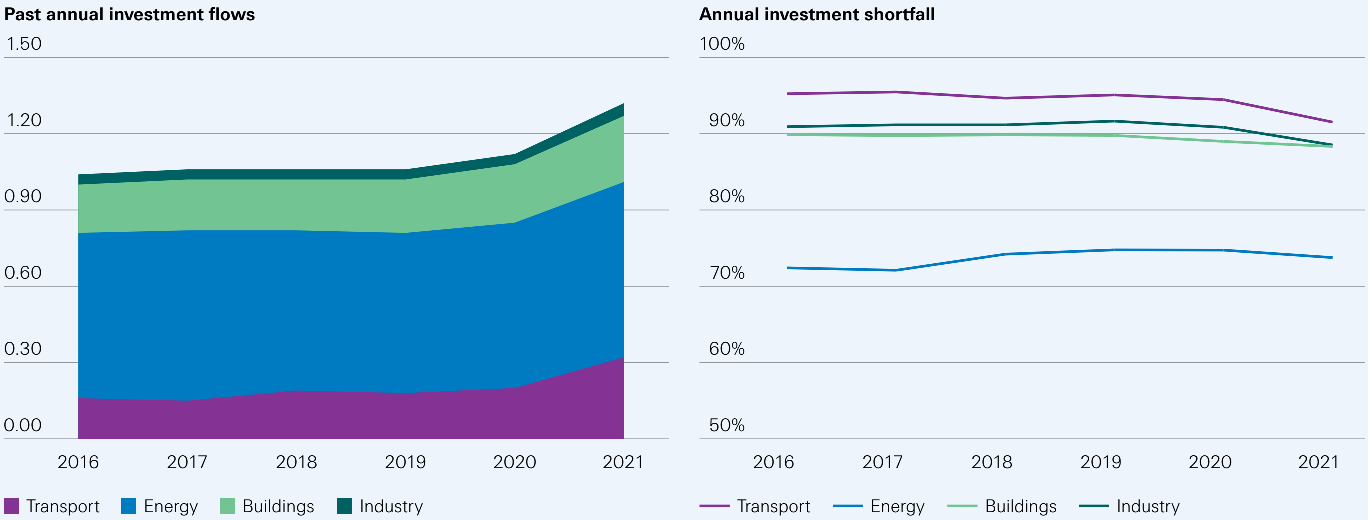
The industrial sector is concerned with the production and manufacturing of goods.

The industrial sector is concerned with the extraction of mineral resources, the conversion of raw materials, and the production of goods. It comprises the following industries: mining and quarrying; construction; iron and steel; non-ferrous metals; non-metallic minerals; transport equipment; machinery; food and tobacco; paper, pulp, and printing; wood and wood products; textile and leather; chemicals and petrochemicals; and various other (smaller) industries. Emissions from this sector are generated through production and manufacturing, electricity and heat consumption, and industrial processes. The decarbonisation levers we cover include energy efficiency measures in industrial processes (including demand-side solutions and efficient motor systems); CCUS and retrofits in iron and steel, cement and chemicals; and material and chemical recycling (circular economy).

The energy sector has benefited from most past investment, but investment growth has been highest for transport while buildings and industry lag.

In terms of past investments, the energy sector has been by far the main recipient in absolute terms (see Figure 9, left), and the annual investment shortfall is far lower than in any other sector (see Figure 9, right). However, as Table 1 shows, the average growth in energy sector investments since 2016 has been the lowest across sectors. In contrast, though transport has the highest annual investment shortfall (92% as of 2021), growth in annual investments has been the highest. Electrification of transport has seen the fastest pace of investment growth. The buildings sector, in turn, has seen comparably moderate levels of investment, but recorded both high levels of annual investment shortfall and slow investment growth. This is despite energy efficiency measures (of buildings themselves and appliances within), electrification, and green fuels or renewables for heating, cooling and cooking, all being technologies that are ready to deploy. Finally, the industrial sector has registered by far the lowest levels of investments.[50] Even though the investment gap is significantly lower than in the other sectors (due to limited information/data availability), the annual shortfall (in percent) is as high as in the transport and buildings sector. While circular economy investments have shown promising growth, the amounts remain very low. And investments in CCUS have been inconsistent, as their negative investment growth shows.

Figure 9
Investment (in USD trillion) and investment shortfall (in %), by sector



Source: Swiss Re Institute

[50] Climate finance in industry is particularly hard to track as its processes are prone to confidentiality restrictions. See CPI, 2021, op. cit.

Table 1
Past and required future investment growth by sector and decarbonisation lever

Sector	2016–2021	2020–2021	2021–2022
All	5%	17%	609%
Transport	18%	58%	1 117%
Electrification of roads	33%	70%	1 302%
Energy efficiency	–4%	23%	150%
Modal shift*	–	–	–
Energy	1%	6%	291%
Renewable energies	4%	3%	194%
Electricity grids	–1%	10%	194%
Energy storage	23%	–10%	1 741%
Carbon capture, utilisation and storage (2018–2021)	27%	6%	4 967%
Nuclear energy	1%	2%	201%
Low-carbon fuels	13%	74%	1 740%
Hydrogen (2018–2021)	18%	62%	73 715%
Buildings	6%	9%	783%
Energy efficiency	5%	8%	413%
Electrification & onsite renewables	10%	13%	1 859%
Demand management	0%	0%	–
Industry	8%	29%	797%
Energy efficiency	0.1%	6%	886%
CCUS (2018–2021)	–36%	–81%	46 393%
Circular economy (2019–2021)	78%	194%	52%

Note: *Separate data for modal shift is not available, but is captured to some to some extent under the other categories in this sector. Growth rates shown are the annual yoy growth rates. The figure for 2016–2021 is calculated as the average of the annual yoy growth rates in that period. The growth rate between 2021–2022 is calculated as the yoy growth rate required to reach USD 9.4 trillion (the average annual ask).
Source: BNEF, IEA, IRENA, Swiss Re Institute

To close the investment gap, investment growth would need to increase in multiples across all sectors.

Looking ahead – and assuming that total investment is not ramped up gradually but rather that in 2022 it jumps to the USD 9.4 trillion required in every year to 2050 – the transport sector would need the greatest yoy investment growth (1 117%) in order to close the overall investment gap. However, considering the more than 58% yoy increase between 2020 and 2021, investment growth would only need to increase about 19-fold. In contrast, the required investment growth in the energy sector is more modest but given historically low growth, it would need to increase by more than 45 times yoy compared to the growth seen between 2020 and 2021. An even higher level of investment growth (more than 86-fold yoy) is required in the buildings sector. The industrial sector would need a 27-fold annual increase.[51]

[51] We again caveat this statement: the lack of data and information for this sector may lead to misleading results.

Closing the gap: possible and with benefits

Funding the investment gap

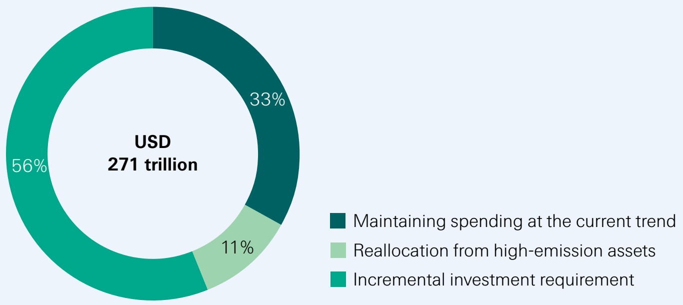
The investment gap is equivalent to around 8% of cumulative GDP forecast between 2022 and 2050.

The investment gap of USD 271 trillion to reach net-zero emissions by 2050 and meet the Paris Agreement target is significant. To give the number some context, we estimate that the amount is equivalent to about 8% of currently forecast global GDP between 2022 to 2050. Expressed on an annual basis, the yearly required spend of USD 9.4 trillion (assuming investments are spread equally over the next 29 years) is equivalent to almost 11% of 2021 global GDP. Natural increases in spending as incomes and populations grow over time would decrease this share, and depending on the extent to which GDP losses from global warming are mitigated, the share could decline to around 5–6% of GDP by mid-century.[52]

Continued spending at the current trend and re-allocating existing funds away from high-emission assets could close almost half of the cumulative investment gap by 2050.

The numbers are large but closing the gap *is* possible. More than 40% of the gap would be filled through the combination of maintaining spending at the current trend with investments growing 5% annually while also reallocating a feasible share of existing spending on high-emission assets to other purposes (see Figure 10). In particular, McKinsey estimates that USD 1 trillion of existing annual spend on high-emission could be reallocated to low-emission assets.[53] The remaining investment – which translates into an incremental USD 4.8 trillion ask on average annually between 2022 and 2050 – will need to come from the public and private sectors (households, businesses and financial institutions), with the latter in the lead.[54] For the public sector, the incremental investment amounts to 44% of annual global tax revenues, and for the private sector a fifth of global gross fixed capital formation, or 10% of global household spending.[55]

Figure 10
Contribution to closing the USD 271 trillion investment gap (in %)



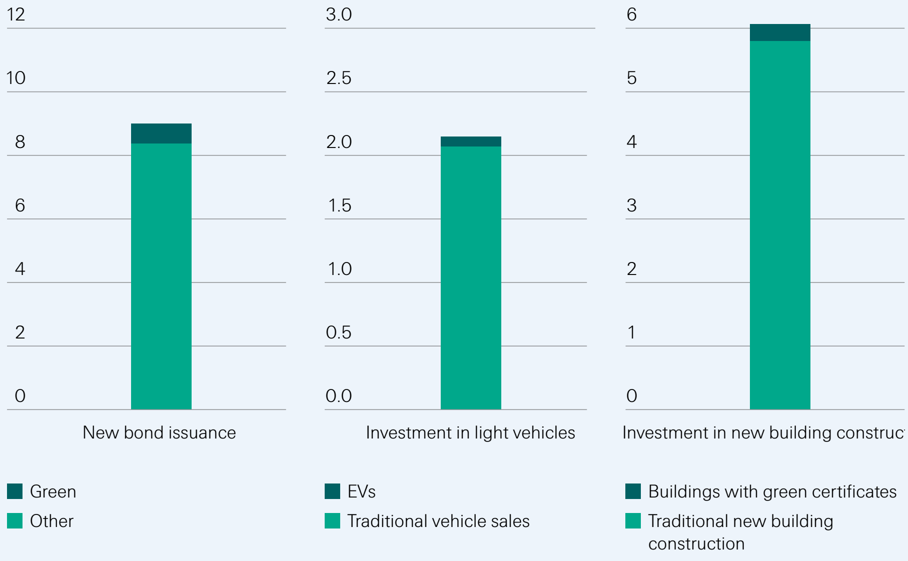
Source: Swiss Re Institute

52 Based on the profile of global GDP through mid-century under various warming scenarios as analysed in *The economics of climate change: no action not an option*, Swiss Re Institute, 22 April 2021.
53 McKinsey, 2022, op. cit. Relatedly, the IEA estimates that the additional income expected for the oil and gas industry in 2022 would be enough to fund nearly a decade of investment in low-emissions fuels and CCUS under its net-zero emissions scenario. See IEA, 2022, op. cit.
54 Our investment gap can only be traced back to sectors (and decarbonisation levers) but not to countries or economic agents.
55 Based on 2019 data from the World Bank.

International capital markets need to be increasingly aligned with climate-positive projects.

The capital available on financial markets would in principle be more than adequate to fill the remaining gap if all spending were aligned with climate-positive projects. As of the end of 2021, the size of the global bond market alone was approximately USD 127 trillion[56] and in 2021 global bond issuance reached USD 9 trillion.[57] However, green bond issuance in 2021, though doubling to more than USD 620 billion with more than 1 000 bonds issued, amounted to merely 7% of total new bond issuance (see Figure 11). More broadly, the market for all *sustainable* debt instruments exceeded the USD 4 trillion mark for the first time in 2021,[58] but still accounts for only about 3% of global bond markets; green bonds account for less than 2%. Moreover, only 11% of sustainable debt to date has been raised by hard-to-abate sectors.[59] In general, climate investment still represents only a small fraction of the annual spend in high-emitting sectors. For example, in 2021 the annual spend on (light vehicle) EVs was less than 4% of total global investment in light vehicles (see Figure 11). Similarly, investment in new building construction was close to USD 6 trillion, but only about 5.5% of these were with green certificates. The Global Infrastructure Hub estimates just more than USD 3 trillion to be invested annually on average under current trends until 2040 in global energy, telecommunications, airports, ports, rail, road, and water infrastructure.[60] A large portion of this spending could serve a dual purpose by building infrastructure that is aligned with climate change mitigation.

Figure 11
Share of green bonds and select climate-positive investment in 2021 (in USD trillion)



Source: S&P Global Ratings, BNEF, CPI, Swiss Re Institute

The private sector will be the dominant source of investment.

Private sector capital needs to align with the Paris Agreement goals. The Climate Policy Initiative finds that in recent years, the public sector has accounted for about half (52% in 2019, 51% in 2020) of tracked annual climate finance.[61] Agency and sovereign issuers have also become major players in the sustainable finance market, accounting for almost a third of new green bond issues in 2021.[62] Public capital will continue to play a role, either through tax proceeds or state-owned/development finance institutions. However, as state budget constraints come into play, an additional and critical contribution of

[56] In US dollar terms, equivalent notional outstanding. See *Research Quarterly: Fixed Income – Outstanding*, Securities Industry and Financial Markets Association, June 2022.
[57] Excluding supranationals and only covering maturities greater than one year. See *Credit Trends: Global Financing Conditions: Bond Issuance Looks Set To Contract 2% This Year As Monetary Policy Tightens*, S&P Global Ratings, 2022.
[58] *1H 2022 Sustainable Finance Market Outlook*, BNEF, January 2022.
[59] BNEF, 2022, op. cit.
[60] *Global Infrastructure Outlook*, Global Infrastructure Hub, 2021.
[61] The public sector is defined as governments, state-owned financial institutions, state-owned enterprises, and national/multilateral development finance institutions. See CPI, 2022, op. cit.
[62] BNEF, 2022, op. cit.

government to the transition is to lower the risks of, and barriers to private capital investment in climate-positive projects, and to foster a supportive policy environment.

Both the supply- and demand-side of private sector investments need to work towards decarbonisation.

The private sector's contribution needs to come from both the supply of financing and investment demand. On the supply side, commercial financial institutions need to decarbonise their practices, and provide investment opportunities if asked for, while (institutional) investors need to provide capital for decarbonisation actions. On the demand side, corporations need to decarbonise their infrastructure (eg, buildings) and production practices/processes through operational capital and fixed asset investments. Meanwhile, consumers (individuals/households) need to switch to low-carbon assets, products and services (eg, EVs, as well as small-scale solar panels, solar water heaters, and heat pumps in homes).

The investments would essentially pay for themselves, being about equal to the GDP losses mitigated by the transition to net zero.

This requires a fundamental shift in mindset, from one that focuses mainly on the "cost" of the changes we need to make, to one that recognises their huge benefits. The main benefit of transitioning to net zero and limiting warming to below 2°C is preventing the build-up of physical risks and reducing the odds of initiating the most catastrophic impacts of a changing climate: each dollar invested today implies decreased emissions and mitigated GDP losses in the future. According to Swiss Re Institute research, the world stands to lose up to 7–10% of GDP by mid-century from the physical risks of climate change alone if warming stays on the current trajectory and the Paris Agreement and 2050 net-zero emissions targets are not met.[63] By extension, and without considering any additional benefits from investment, the GDP losses in cumulative dollar terms that could be mitigated between now and mid-century would, depending on the degree of warming, equal 90–140% of the incremental investment ask with the investment essentially paying for itself. Recent research from the IMF also estimates that by replacing only coal with renewables, the world could realise a net total gain of USD 78 trillion by avoiding damage from climate change, including to peoples' health.[64] IRENA estimates that with the current high fossil fuel prices, the renewable power added in 2021 saved around USD 55 billion from global energy generation costs in 2022.[65]

Closing the investment gap has positive economic implications beyond decarbonising the economy.

The required amount of investment would bring economic benefits beyond decarbonisation, for example in terms of future productivity gains and employment. According to the World Bank, transitioning to a green economy has the potential to unlock new economic opportunities and jobs with every USD 1 invested in resilient infrastructure yielding an average USD 4 in economic benefits.[66] Output multipliers associated with spending on renewable energy investment have been found to be two to seven times as large as those associated with fossil fuel energy investment.[67] McKinsey estimates the number of jobs created by the transition would be greater than those lost, with 15 million jobs added by 2050.[68] In fact, clean energy industries now employ more people globally than fossil fuel sectors.[69] Closing the investment gap could also potentially hold non-quantifiable benefits by fostering global financial stability.

63 Swiss Re Institute, 22 April 2021, op. cit.
64 T. Adrian, P. Bolton, and A. Kleinnijenhuis. *The Great Carbon Arbitrage*", IMF Working Paper, 2022.
65 *Renewable Power Generation Costs in 2021*, IRENA, July 2022.
66 See *Financing Climate Action*, United Nations, and *USD 4.2 Trillion Can Be Saved by Investing in More Resilient Infrastucture, New World Bank Report Finds*, The World Bank, 19 June 2019.
67 N. Batini. M. do Serio, M. Fragetta, G. Melina and A. Waldron, "Building Back Better: How Big Are Green Spending Multipliers?" *Ecological Economics*, vol 193, March 2022.
68 McKinsey, 2022, op. cit.
69 *World Energy Employment Report*, IEA, September 2022.

The way forward: priorities and obstacles

Bridging the gap

Identifying priority areas where action can be taken today can make the challenge of closing the investment gap more palatable.

Closing the estimated USD 271 trillion investment gap will be challenging. Ramping up annual spend from USD 1.3 trillion in 2021 to the required estimated USD 9.4 trillion in 2022 and every year thereafter to 2050 is a big ask. There are other considerations also, including the degree of technological progress, and the availability and ease of investment opportunities. Identifying priorities and areas where action can be taken today can make the challenge of closing the investment gap more palatable.

We qualitatively assess the investment, emissions, and technological and information landscape across the four sectors.

Priority areas and key constraints
Here we consider a more holistic view across the four sectors beyond the investment gap, to identify the key bottlenecks and constraints, and possible high-impact investment areas. Table 2 presents an overview of the size of the investment gap, the availability of information (proxied by the share of emissions we are actually able to capture in this study), an "abatement return" for every trillion US dollars invested per sector (considering the share of emissions vs investment gap), the technological readiness to decarbonise within each sector, and the extent of investment opportunities (proxied by the degree of recent investment).

High priority areas for investment include to increase the deployment of decarbonisation technologies across the sectors.

In our view, key insights that can be derived from Table 2 include:

- **Transport:** Information availability and technological readiness for decarbonisation are high. The priority is closing the large investment gap and further deployment of decarbonisation technologies. Much of the required investment (at least for cars) will come from private spending on electrification as more drivers purchase EVs.

- **Energy:** The investment gap is very high, and key clean energy technologies (eg, hydrogen and CCUS) are not yet in large-scale use. We believe ramping up investment in technological advancement and deployment thereof, will catalyse decarbonisation of other sectors. Improving information and data is also important.

- **Buildings:** Technological readiness is high but deployment is low. More efforts to deploy existing decarbonisation technologies are needed.

- **Industry:** Available information is low and technological readiness lacking. This sector is high priority, with recommended actions being to invest in advancing the technology innovation pipeline. If this occurs, the availability of information (eg, on costs) is also likely to progress. The current relatively low level of the estimated investment gap is misleading as the cost of developing new technologies is not wholly factored in.

- **Other:** Overall, our investment gap covers at most 70% of global GHG emissions. This means that data and information on more than 30% of emissions are not sufficiently available. As such an overarching priority is to improve the availability and reliability of information.

Table 2
The investment gap, information coverage, share of emissions, technological readiness and investment landscape across the four sectors

SECTORS	INVESTMENT GAP		EMISSIONS		TECHNOLOGY		EASE OF INVESTMENT	
	In USD trillion	In %	Maximum share of sectoral emissions captured by our investment gap	Return (abated $GtCO_2e$/ USD trillion)	Maturity category	Deployment	Average annual investment growth 2016–2021	Absolute investment growth 2016–2021
TRANSPORT	**114.0**	**100%**	**90%**	**0.07**	**MARKET UPTAKE**	**MORE EFFORTS NEEDED**	**18%**	**666%**
Electrification of road	105.3	92%			market uptake for cars	on track	33%	1 017%
Energy efficiency	4.6	4%			market uptake	more efforts needed	–4%	385%
Modal shift*	4.0	4%			not a technology	more efforts needed	–	–
ENERGY	**78.3**	**100%**	**80%**	**0.42**	**MARKET UPTAKE**	**MORE EFFORTS NEEDED**	**1%**	**505%**
Renewable energies	29.6	38%			Market uptake	more efforts needed	4%	546%
Solar PV	6.9	9%			Market uptake	more efforts needed	6%	539%
Wind onshore	6.2	8%			Market uptake	more efforts needed	5%	588%
Wind offshore	5.3	7%			Market uptake	more efforts needed	7%	604%
Hydropower excl. pumped hydro	2.5	3%			Mature	more efforts needed	–29%	208%
Geothermal	0.7	1%			Market uptake	not on track	–23%	284%
Solar thermal (including concentrated solar power)	4.1	5%			Market uptake	not on track	2 013%	892%
Marine	1.8	2%			Market uptake	not on track	0%	479%
Biomass	2.1	3%			Market uptake	more efforts needed	–1%	356%
Electricity grids	24.4	31%			Mature	more efforts needed	–1%	458%
Energy storage	4.0	5%			Mature	more efforts needed	23%	968%
Carbon capture, utilisation and storage	3.0	4%			Demonstration	not on track	27%	644%
Nuclear energy	2.6	3%			Mature	not on track	1%	502%
Low-carbon fuels	7.8	10%			Prototype/ Demonstration	not on track	13%	544%
Hydrogen	6.5	8%			Prototype/ Demonstration	more efforts needed	18%	464%
BUILDINGS	**65.4**	**100%**	**90%**	**0.14**	**MARKET UPTAKE**	**MORE EFFORTS NEEDED**	**6%**	**573%**
Energy efficiency	28.7	44%			Mature	not on track/more efforts needed	5%	547%
Electrification and green fuels/renewables	35.5	54%			Market uptake	more efforts needed	10%	677%
Demand management	1.2	2%			Market uptake	on track	0%	0%
INDUSTRY	**14.0**	**100%**	**70%**	**0.82**	**DEMONSTRATION**	**NOT ON TRACK**	**8%**	**561%**
Energy efficiency	10.6	76%			Prototype/ Demonstration	not on track	0%	492%
CCUS	2.7	19%			Prototype/ Demonstration	not on track	–36%	6 272%
Circular economy	0.7	5%			Market uptake	more efforts needed	78%	1 175%

Note: Emissions data as of 2018 from the World Resources Institute is used. Colouring indicates the degree to which the different variables contribute to making investments in decarbonisation levers "high-impact", with green indicating strong facilitation and red hindering. The emissions' abatement return is an estimate of emissions abated per trillion invested; as such, dark green indicates a higher return. The assessment of technology maturity and deployment is based on *IEA classification*. Regarding ease of investment, red indicates that the average annual investment growth of the past 5 years has been less than or equal to zero, or that the absolute investment growth from 2019 to 2021 has been below average (all tracked investments considered). *Separate investment data for modal shift is not available, but is captured to some to some extent under the other categories in this sector.
Source: Swiss Re Institute

Interlinkages, technology and data gaps present physical bottlenecks to decarbonisation progress.

At this stage the main physical bottlenecks to closing the investment gap and further decarbonisation progress are:

- **Decarbonisation actions are closely related to one another.** In many instances, developments and investment need to be coordinated across sectors. For example, when purchasing EVs, consumers must consider the source of electricity and availability of charging infrastructure. On the suppliers' side, the cost and availability of energy storage capacity and electricity grids should be factored in.

- **The technology to decarbonise is not all there yet.** As mentioned before, estimates that around 50% of the emissions reduction capacity/capability needed to reach net zero by 2050 is not yet available.[70] In 2021, public research development and demonstration (RD&D) spending on low carbon technologies increased after five consecutive years of slowdown. Corporate energy R&D spending also returned to growth, and early-stage clean energy start-ups raised twice as much funding in 2021 as they did in 2020.[71] All positive indicators: momentum needs to be sustained.

- **Information asymmetries and large data gaps remain.** Data provision processes often remain manual, cumbersome and costly. Data provision and quality needs to be addressed to improve transparency, verification and reporting processes. The absence of common taxonomies and inadequate classifications for sustainable investment also play a role.[72]

Financial constraints also pose barriers to investment.

Multiple macro-financial impediments further constrain attracting and scaling up of private-sector climate finance by affecting the availability, benefits, costs, risks, and/or competitiveness of investments:

- **Supply constraints**

  - **Supply of investable projects remains limited.** There is a lack of large investment grade projects and liquid markets, resulting in stringent competition for a scarce pipeline of projects and compressed margins.

  - **The share of available sustainable financial assets is growing but still represents less than 4% of global assets.** More specifically, green bonds represent less than 2% of the global bond markets (see *Funding the investment gap*), with even these often carrying concerns of greenwashing.

  - **The investment landscape is fragmented.** Many tools and approaches to aid in scaling climate or sustainable investments more broadly are being developed (eg, definitions, taxonomies, and rating, verification and certification schemes). However, a lack of interoperability and consistency has created a fragmented landscape for deployment, in some cases increasing costs.[73]

- **Demand constraints**
  - **Small-scale investors cannot afford the upfront capital costs** required for some readily available technologies such as retrofits or EVs.

  - **Unattractive risk-return profiles in unproven markets.** High upfront capital and transaction costs and risks associated with climate projects imply insufficient returns for significant project risks. High risk perceptions stem from long timeframes and uncertainties about future climate policies, technological costs and the economic impact of climate change.

Rising interest rates increase hurdle rates, jeopardising projects with high upfront capital costs.

The global macroeconomic context also plays a determining role in climate finance. In the context of monetary policy tightening, high sovereign bond yields, especially in some emerging and developing economies, can raise hurdle rates in project finance, jeopardising projects such as wind and solar with high upfront capital costs. At the same time, higher interest rates in general promise improved investment returns.

[70] IEA, 2021. op. cit.
[71] IEA, 2022, op. cit.
[72] Prasad et. al., 2022, op. cit.
[73] *2021 Synthesis Report*, G20 Sustainable Finance Working Group, 2021.

High-impact investment areas

There are steps that can be taken today.

Within current macro-financial and technological realities, there are areas where investment can be ramped up today without too many obstacles. We refer to these as "high-impact" investments. As showing in Table 2, we have assessed the various decarbonisation levers across sectors and identified areas where: 1) technology is in "mature" or "market uptake" stage; 2) average annual investment growth has been positive over the past 5 years (ie, we assume the economic and/or the financial market conditions are in place for progress to be made); and 3) in absolute terms, annual investments have substantially grown over the past 5 years. We supplement this with an "abatement return" for every trillion invested per sector (considering the share of emissions vs investment gap), and technology deployment.

Investment in the electrification of transport is both a priority and an easy win.

Within the transport sector, the high-impact investment would be electrification of roads, where there has already been strong investment growth. The technology is available, and investment has already grown significantly (see Table 2, columns 5–8). EVs' share of global passenger vehicle sales has grown substantially, standing at almost 9% in 2021.[74] The policy environment also points to a dynamic phase-out of internal combustion engines in favour of EVs (though incentives and subsidies) in many countries.[75]

The energy sector promises considerable emission abatement returns.

Within the energy sector, of the renewables, solar PV, onshore and offshore wind, as well as energy storage and nuclear, are areas of high-impact investments, in our view. Investing in decarbonising levers in energy promises considerable emission abatement return, but for generation capacity from renewables to come online without bottlenecks, additional investment in electricity grids is needed.[76] Moreover, political feasibility and physical availability of different energy sources make the opportunities unequal. Nuclear energy remains the second largest carbon-free electricity provider with an output equal to 10% of global electricity supply in 2018. However, it is not yet clear if nuclear energy can be labelled "green".[77]

The entire buildings sector is a source of enormous efficiency potential.

Within the buildings sector, investments in energy efficiency measures and electrification (of cooking and heating) would likely have high impact. The IEA says investments in efficiency increases (including electrification) would be fully paid back through lower running costs, especially at today's high energy prices. [78] In particular, global household bills could be lowered by at least USD 650 billion a year through 2030, while also supporting job creation in new construction, building retrofits, and manufacturing.[79] Mandatory building energy codes and performance standards are tightening, giving indication of the direction the market is taking.[80] In 2020, emissions reduction policies and stimulus-related government programmes meant investments boomed (especially in Europe). The global stock of heat pumps has increased around 10% per year over the past five years. Heat pumps are becoming common in new-build houses in many countries.[81]

Industry is a hard-to-abate sector.

Within industry, the one area of high impact investment would be the circular economy. Known as the hardest-to-abate sector, no technological breakthrough has yet made this sector investable, although there has been a rise in early-stage funding to avoid use of fossil fuels.[82] The high abatement return reflects, once again, a likely underestimation of the sector's investment gap. Despite the absence of high-impact investment areas, financial institutions have the power to kick-start the market by financing emerging decarbonisation solutions.[83] Once the marginal abatement cost curve becomes economical, a more sophisticated and accurate sizing of the gap is expected.

74 See *Electric Vehicles*, IEA.
75 For example, BNEF estimate that the new EV tax credit policy in the recently passed US Inflation Reduction Act will contribute to propel the EV share of sales in the US from less than 5% in 2021 to over 50% by 2030. See C. Cantor, *US Climate Law Shifts EV Race to Warp Speed*, BNEF, September 2022.
76 See *Smart Grids*, IEA.
77 *Nuclear Power in a Clean Energy System*, IEA, 2019.
78 *The value of urgent action on energy* efficiency, IEA, 2022.
79 Ibid.
80 See *Tracking Buildings*, IEA.
81 See *Heat Pumps*, IEA.
82 *World Energy Investment 2022*, IEA, 2022.
83 *The net-zero transition in the wake of the war in Ukraine: A detour, a derailment, or a different path?* McKinsey & Company, 2021.

Mobilising investment: the role for governments and the re/insurance industry

The private sector has taken encouraging steps to progress the transition to net zero...

The private sector will be the source of much of the investment required to achieve net zero and, in recent years, has increasingly mobilised towards net zero pledges and emission reduction targets. For example, through the Glasgow Financial Alliance for Net Zero (GFANZ), more than USD 130 trillion in private-sector assets under management (AUM) is committed to transforming the economy for net zero.[84] And members of the Net-Zero Asset Owners Alliance, an alliance of institutional investors of which Swiss Re is a founding member, have committed to transitioning their investment portfolios to net-zero emissions by 2050.[85] Further, nearly 40% of Fortune 500 companies have adopted net-zero targets.[86] And 3 400 organisations worldwide support the Task Force for Climate-related Financial Disclosures (TCFD), and several governments are moving towards mandating TCFD-quality disclosures.[87]

...but these have yet to translate into real action at scale.

These commitments, however, are yet to translate into climate investment and real action at scale. As discussed above, several bottlenecks and constraints hamper private investment. Governments and the insurance industry have key roles to play. In addition to direct government investments in climate projects, governments need to build confidence in key markets with clear policy signals and incentives, and financial regulators need to set standardised rules to enforce targets.[88] More broadly, the policy and regulatory landscape needs to provide incentives, lower investment barriers, and improve data transparency and standardisation to foster private sector investment. For example, fiscal incentives in favour of carbon capture and reduction (eg, a carbon tax), would promote more transparency in relation to climate risks in financial markets and generate incentives for private investment in low-carbon projects, including in the research and development of new technologies.[89] A carbon tax, however, changes relative prices but is not (and should not be) a substitute to reduce GHG emissions. Other policies include emissions trading, feebates,[90] clean technology subsidies, and command-and-control regulations.[91] Public and private actors should also consider improving transparency and standardisation around definitions, methodologies and data. Shared standards, allowing for some regional variation, are key for carbon price discovery and could strengthen comparability of corporate reporting.

The US Inflation Reduction Act of 2022 is a big push in the right direction.

President Biden's landmark US Inflation Reduction Act of 2022 is a step in the right direction, in our view. It includes USD 369 billion in climate and energy funding across renewables, EVs and other decarbonisation technologies, and is anticipated to help lower carbon emissions by 31–44% by 2030 (vs 2005 levels), better than the 24–35% reduction expected with existing policies.[92] In addition to the direct climate-related infrastructure spend, it incentivises greater private sector action. Companies can take advantage of the new incentives to reduce costs (sizable credits reduce energy and transportation costs), re-evaluate decarbonisation plans (the bill entails massive shifts in carbon abatement curves and clean technology improvements), capture early mover advantages, and pursue new value pools. Boston Consulting Group (BCG) expects strong multipliers, with total investment potential north of USD 1 trillion.[93]

Other countries are also making headway.

Other countries/regions are also making headway. Europe has long been a leader on climate action. The European Union (EU), for example, launched an ambitious Action Plan on Financing Sustainable Growth as well as a strategy for financing the transition to a sustainable economy in July 2021. Furthermore, the EU has targeted 30% of the whole EU budget for 2021 to 2027 to be spent on climate-related actions, with one third of the

[84] *Amount of finance committed to achieving 1.5°C now at scale needed to deliver the transition*, GFANZ, 3 November 2021.
[85] See *UN-convened Net-Zero Asset Owner Alliance.*
[86] *Fortune Global 500 Climate Commitments*, Climate Impact Partners, 2022.
[87] *Support TCFD*, Task Force on Climate-Related Financial Disclosures, August 2022.
[88] Development banks and international finance institutions can help build strategy, engage with counterparties, and support policy development, while deploying a wider range of instruments that take on more risk, helping to catalyse more private investment in developing economies.
[89] It is still often the case that climate investments do not offer attractive enough financial return or risk profiles.
[90] A self-financing system of fees and rebates used to shift the costs of externalities (emissions/warming) to those responsible. Essentially a fee on inefficient polluting technology and behaviours, and a rebate on efficient and clean practices.
[91] Prasad et. al., 2022, op. cit.
[92] J. Larsen, H. Kolus, N. Daseri, G. Hiltbrand and W. Herndon, *A Turning Point for US Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act*", Rhodium Group, 2022.
[93] *US Inflation Reduction Act: Climate & Energy Features and Potential Implications*, Boston Consulting Group, August 2022.

EUR 1.8 trillion investments from the NextGenerationEU Recovery Plan, and the EU's seven-year budget to finance the European Green Deal.[94] The government of Japan has set a goal of effectively reducing GHG emissions to zero by 2050 and will soon begin to draw up a roadmap for a JPY 150 trillion (approx. USD 1 trillion) investment by the public and private sectors.[95]

The insurance industry also has a threefold role to play...

Given the long-term horizon of their liabilities and the long-term capital they have available to commit, re/insurance companies are ideally positioned to contribute to closing the climate investment in at least three ways:

- **Investing in the transition to net zero:** In 2021, global AUM of long-term investors exceeded USD 112 trillion.[96] Re/insurance companies are long-term institutional investors, and the industry has AUM of approximately USD 34 trillion (close to a third of the total long-term investor asset base).[97] As of end-2021, Swiss Re's infrastructure and real estate portfolios had 23% and 33% green share, respectively. Swiss Re also held USD 3 billion green bonds.

- **Absorbing risk and facilitating capital reallocation:** By moving away from insuring high- in favour of low-emission assets, the re/insurance industry can improve the risk-return profile of climate-positive investment projects, and disincentivise finance directed at activities with a detrimental climate impact. Swiss Re, for example, provides re/insurance solutions for low-carbon transition opportunities, with more than 8 870 wind and solar farms covered as of end-2021. And in March 2022, Swiss Re announced that most new oil and gas projects would no longer be insured, unless developers can demonstrate credible transition plans to achieve net-zero targets verified by an independent third party such as the Science Based Targets Initiative (SBTI). Swiss Re's role as a founding buyer in the NextGen Carbon Dioxide Removal (CDR) facility – a large-scale technical carbon removal project – will further help scale carbon removal technologies.[98]

- **Sharing of risk knowledge and expertise**: The re/insurance industry is in the business of pricing risk. By sharing risk knowledge and expertise, for example, around new technologies and physical climate change risks, it enables market participants to make clearer and more informed decarbonisation and investment allocation decisions.

...and stands to benefit greatly.

Together with investment opportunities, industries that focus on green technology, renewable energy and CCUS also provide new insurance opportunities. For example, Swiss Re research estimates that if countries deliver on building all the renewable energy capacity according to their current targets, investments in green energy could generate additional energy-sector related premiums of USD 237 billion by 2035.[99]

94 *2021–2027 long-term EU budget & NextGenerationEU*, European Commission, 2022.
95 *Government takes first step into green GDP estimates*, Societe Generale Cross Asset Research, August 2022.
96 *From Tailwinds to Turbulence: Global Asset Management*, Boston Consulting Group, May 2022.
97 As of end-2020. See *The Power to Shape the Future*, PwC, 2020.
98 *Swiss Re joins the First Movers Coalition*, Swiss Re, 2022.
99 *sigma* 5/2022, op. cit.

Conclusion

Investment must increase in speed and scale for a credible transition to a sustainable, net-zero and resilient world.

Climate investment flows are far from what is needed to achieve net-zero emissions by 2050s and the Paris Agreement target on global warming. Closing the USD 271 trillion investment gap needed tor each net zero by 2050, will require a significant ramping up of spending from today's levels – from USD 1.3 trillion in 2021 to about USD 9.4 trillion on average annually. At the current rate and pattern of spending growth, the investment gap would close 20 years behind target.

Closing the climate investment gap is possible, but international capital markets need to be increasingly aligned with climate-positive spending.

We belleve closing the gap and reaching net zero by 2050 *is* possible. More than 40% of the investment gap could be filled through the combination of maintaining climate investment at the current trend while also re-allocating a feasible share of existing spending from high- to low-emission assets. For the incremental investment needed to close the gap, the private sector has the capacity to take the lead. The size of the sustainable and/or green bond markets, for example, constitute just a fraction of global bond markets. Green bond issues in 2021 amounted to merely 7% of total new bond issuance and less than 2% of global bond markets.

The current economic and geopolitical reality pose both tail- and headwinds to climate investments.

The current global macroeconomic and geopolitical context makes for a complex mix of tail- and headwinds to climate investment. Higher energy prices have sparked energy security concerns, renewing focus on the urgency to shift to renewables but delaying efforts to spur the low-carbon transition in some countries. Similarly, several minerals that are critical for the transition have seen sharp price increases since the onset of the war in Ukraine. In the context of monetary policy tightening, high sovereign bond yields, especially in some emerging and developing economies, can raise hurdle rates in project finance to very high levels, jeopardising projects with high upfront capital costs, such as solar and wind projects. At the same time, higher interest rates in general promise improved investment returns. In the longer term, geopolitical shifts towards a multi-polar world risk hindering global cooperation and stalling transition momentum as countries increasingly focus on domestic energy and food security.

Governments and the re/insurance industry need to forge ahead in closing the climate investment gap.

Incentive structures and the removal of investment barriers are critical in mobilising private sector funds, even more so in the face of these headwinds. Governments and the re/insurance industry have particular key roles to play in closing the climate investment gap. The scale of investment needed will not materialise by itself. In addition to direct government investments in climate projects, governments need to build confidence in key markets with clear policy signals and incentives, whereas financial regulators need to set standardised rules to enforce targets. Re/insurers can in turn contribute by aligning their individual asset and underwriting portfolios with their own net-zero ambitions, as well as through the sharing of risk knowledge and expertise.

A failure to close the gap is a failure for growth.

Failure to invest is a failure for growth. The world stands to lose up to 7–10% of GDP by mid-century from the chronic physical risks of climate change alone if warming remains on the current trajectory and the Paris Agreement and 2050 net-zero emissions targets are not met. Closing the investment gap will also bring economic benefits beyond decarbonisation, for example in terms of future productivity gains, employment and more financial stability.

Appendix

I: Our methodology

We define the investment gap in any given year as the amount of investment still required as of the start of that year to transition to net-zero emissions by 2050. This is calculated as the difference between the investment needed as of the start of the previous year and actual investment during that *previous* year. We construct an annual global investment gap series for each year from 2016 to 2022, as well as sectoral investment gap series for the energy, transport, buildings and industry sectors over the same period. All data is converted into USD 2019 real terms.

Investment needed
To obtain disaggregated estimates of the investment required to transition to net-zero emissions by 2050 we collate existing estimates of the need as of 2021 across the various decarbonisation levers of the four aforementioned sectors.[100] Rather than come-up with self-produced estimates of climate finance needs, we draw on assessments from third-party studies. This is in itself a valuable exercise as it provides insight into the landscape of existing estimates of climate investment needs, in particular what existing work has covered in terms of the actions needed to decarbonise different sectors of the economy, and the magnitude of the corresponding investment needs. It further reinforces the importance of comparability: for the magnitude of the investment need to be understood, clear and comparable data are essential to avoid confusion, double counting or underestimation. Table 3 presents an overview of the various sources we surveyed and compares the scope (sectors covered and climate target), time horizon, and magnitude of their estimates and distribution over time, and approach taken to produce the estimates.

We select all comparable estimates for each decarbonisation lever of the four sectors that are compatible with a 1.5°C pathway or net-zero emissions by 2050, defined as such by the authors of the reports. This yields between one and five estimates across the different sources per decarbonisation lever. We use this to gauge the possible range of needs by calculating the minimum, median, average (mean) and maximum estimated needs for each of the sectors by always summing, respectively, the minimum, maximum, average or median estimate per decarbonisation lever and sector. The headline numbers we adhere to in this research reflect the maximum.[101]

Actual investment
To capture actual investment that corresponds in definition and scope to the estimates of the investment required to transition to net-zero emissions by 2050, we construct data series of climate investment along the same decarbonisation levers as above for the same four sectors, from 2016 until end 2021. To this end, we use climate investment data from various sources (BNEF, IEA, and IRENA)[102] per sector and decarbonisation lever.[103] The IEA, IRENA, and BNEF all derive their investment data through bottom-up tracking of various sources capturing investment flowing into specific decarbonisation assets or technologies. Estimates are based on publicly available information from utilities, regulators and governments, among others, supplemented with their own

[100] For comparability reasons, earlier estimates are not included. We also only include estimates with a time horizon that extends to 2050.

[101] The exception to this is the "renewable energy" decarbonisation lever in the energy sector. For consistency reasons, we adhere to estimates provided by IRENA, even if a higher estimate is put forth by another source. The investment need number presented for the energy sector is thus strictly speaking not the maximum (although the difference is minor).

[102] All three sources subscribe to slightly different definitions of "investments" but the approach with regards to what is tracked is similar: capital committed to specific assets or projects that have reached the final investment decision.

[103] While the CPI's annual G*lobal Landscape of Climate Finance*" reports provide a comprehensive overview of climate finance flows, we have not used its data in this study. The categorisation of its data has been subject to change over time and also does not match the granularity sought for in this report. For comparison, we estimate USD 1.13 trillion of investment flows in 2020, almost double the USD 640 billion tracked by CPI in 2020. This discrepancy is because we capture more private-sector investments, more decarbonisation levers and, more specifically, also a much larger transmission and distribution of power in the energy sub-sector. Hence, the tracked flows linked to electricity grids is significantly (around USD 300 billion) higher.

analyses where necessary to overcome data disclosure issues. Table 4 contains further detail of the data provided by these sources.

For a decarbonisation lever to be included in our investment gap measures, both estimate(s) of the investment need as well as data on the corresponding actual investment must be available. In several cases, the data remains patchy, and metrics and definitions non-standardised, which results in the absence of past investment data to match exactly to a given investment need estimate. In such cases, we exclude the decarbonisation altogether.

The investment gap: required minus realized investment
We then construct measures of the investment gap at the decarbonisation lever level between 2016 and 2022 by comparing actual investment between those years with our estimate of the cumulative investment needed each year over the same period. Table 5 presents the exact list of decarbonisation levers we captured under the four sectors as well as the sources we used, respectively, for the investment needs and flows associated with each lever to reach the headline (maximum) number. By aggregating across decarbonisation levers, we obtain sectoral investment gaps and, by aggregating across the sectoral gaps we obtain the global cumulative investment gap for the time period 2022–2050.

Our investment gap is a dynamic concept and can be updated on a rolling basis. To obtain the investment gap in 2022 we subtract from our estimate of the investment needed as of 2021 the amount of actual investments made during 2021. Similarly, for 2020 (and earlier years) the cumulative investment gap is calculated by adding to our estimate of the investment need as of 2021 the investment realised during 2020 (or earlier years) that had not yet been spent as of the start of 2020.

Possible caveats
For all the care taken to ensure comparability across sources as well as between estimated needs and investment flows, there are nevertheless still likely to be comparability limitations. In particular, some of the estimates may still not be 100% comparable due to differing assumptions used in the original third-party studies, for example regarding technological development, the timing for fossil-fuel phase-out, future energy demand growth, or reliance on nuclear energy. For this reason, we provide the range of variation (or uncertainty). Moreover, the current coverage/scope of the capital needed to transition to a decarbonised world is subject to change, modifications and updates as data availability, technology costs, climate science understanding and societal shifts change. Our ultimate aim is therefore not to claim a perfect measure, but rather to capture the order of magnitude of the investment gap against which we can then benchmark current trends and progress.

A second possible caveat relates to the issue of double counting investment data. While the sources we use each themselves take different precautions to avoid double-counting (we refer the reader to the respective methodology documents for more detail), the imperfect nature of climate finance data and how interlinked the energy sector is with the other sectors means some double counting is likely inevitable. For example, different sources group decarbonisation levers differently: the IEA's estimate of investment in electricity grids includes public charging infrastructure for EVs (but not private charging infrastructure), while BNEF accounts for public and private charging infrastructure standalone. We believe that we negate the issue of double counting to a large extent by summing up investment from a disaggregated (decarbonisation lever) level. The issue may further be negated by us likely capturing the lower bound of actual investment.

Table 3 (Part 1)
Overview of the sources surveyed to determine the investment need as of 2021 to transition to net zero by 2050

Source	Report	Time horizon	Climate target	Sectors covered	Estimate
McKinsey	The Net-Zero Transition: what it would cost, what it could bring	2050	1.5°C	Power, steel industry, cement industry, mobility, buildings, food and agriculture, forestry and other land use	Estimate: USD 275 trillion Aggregation of the amounts calculated per component per sector.
GFANZ	Race to Zero – Financing Roadmaps	2050	Net-zero emissions	Electricity, transport, buildings, industry, AFOLU, low-emission fuels	Estimate: USD 125 trillion Aggregation of investment needs per energy-related sector.
Global Financial Markets Assocation (GFMA) and BCG	Climate Finance Markets and the Real Economy	2050	Paris Agreement of below 2°C, but goal of 1.5°C limit.	Power, iron and steel, cement, chemicals, light-/heavy-road transport, aviation, shipping, agriculture, buildings	Estimate: USD 121.7 trillion Aggregation of the sectoral investment needs composed of granular estimates.
IEA	Net Zero by 2050 – A Road Map for the Global Energy Sector	2050	Net zero emissions and 1.5°C limit	Fuel production, electricity generation, infrastructure and end-use (buildings, transport and industry)	Estimate: USD 140 trillion Aggregation of 5 years (or 10 years) average annual investments by sector and technology
IRENA	World Energy Transitions Outlook: 1.5°C pathway	2050	1.5°C	Power sector, end-uses and district heat (transport, buildings and industry)	Estimate: USD 114 trillion Aggregation of annual average investments from 2021–2050
BNEF	New Energy Outlook 2021	2050	Net-zero	Only the investment in the energy sector (different power sources, hydrogen, CCS, coal, oil and gas)	Estimate: USD 161 trillion
Goldman Sachs (GS)	Investing in Climate Change 2.0	2050	1.5°C net-zero	Not sectors, infrastructure categories investments	Estimate: USD 56 trillion
CPI	Global Landscape of Climate Finance 2021	2050	1.5°C	Energy systems, buildings & infrastructure, industry, waste and wastewater, transport, AFOLU	Estimate (annual): USD 5 trillion – USD 11 trillion Range of the annual investment from other studies

Source: Swiss Re Institute

Table 3 (Part 2)

Source	Distribution	Approach	Key assumptions	Additional comments
McKinsey	Not flat, backloading from 2031 to 2050, though with sectoral differences	Top-down, use of NGFS' Net Zero 2050 scenario to quantify changes in important activity level variables for each sector	Estimated capital spending on physical assets in the 12 regions in the NGFS dataset	The higher estimate comes from broader scope than typically the case in other studies (eg, private spending on physical assets that use energy, such as EVs)
GFANZ	Not flat, backloading from 2031 to 2050	Top-down, have their own "investment trajectories model" mainly based on IEA's Net Zero by 2050 downscaled to areas, sectors and technologies	Investments per sector are allocated across regions using the sustainable development scenario from the 2020 *World Energy Outlook*	Focus on building a tool that offers 17 region-sector-technology pairings, but the 17 roadmaps cover only a fraction of the stated USD 125 trillion
Global Financial Markets Association and BCG	Not specified, amounts are always given as cumulative to 2050	Bottom-up, leveraging existing industry reports and supplementing with BCG estimations (interviews-based)	NA	NA
IEA	Not flat, tendency to backloading but for the fuels' sector	Top-down modelling combining two models (*World Enery Outlook* and *Energy Technology Perspectives)*	For the *World Energy Oultook*: NZE scenario does not rely on emissions from outside the energy sector to achieve its goals. For the *Energy Technology Perspectives*: all technologies modelled are commercially viable or at prototype stage	Cover the broad energy spectrum, meaning the energy supply, also end-use sectors that are included in the umbrella term of "energy system".
IRENA	Flat, give a yearly average from 2021 to 2050	Top-down, 1.5°C Scenario	Emissions abatement in the scenario mainly comes from renewables, energy conservation and efficiency, and electrification in end-use sectors	Similar breakdown of the energy sector as IEA
BNEF	Not flat, front-loading in power generation capacity and fossil fuels, and backloading in hydrogen and CCS	Top-down, present different scenarios that reach net-zero emissions in 2050, from which we used the green scenario (clean electricity and green hydrogen pathway)	Assumption of hydrogen playing a dominant role in the green scenario (greater role than seen in the other scenarios)	In the green scenario, investment in transport and storage of green hydrogen are very high
Goldman Sachs	Give the distribution for incremental investments: peak in 2033–2037	Top-down, GS 1.5°C net zero model	Global zero carbon scenario that adopts a sectoral approach that leverages the GS Carbonomics de-carbonization cost curve, and allocates the available carbon budget across different industries on the basis of current cost and technological readiness	The speed of de-carbonization in each sector is largely dependent on the current carbon abatement cost and state of readiness of the available clean technologies as per the GS Carbonomics cost curve. The curve is not static, and will evolve over time.
CPI	Backloading, but without clear details	Bottom-up, leveraging data sources and scenarios that explore climate finance needs	NA	The investment needs' table is present in the preview slides but not in the report itself.

Source: Swiss Re Institute

Table 4
Sources used to track investment flows between 2016 and 2021

Sources	Report/platform	Sectors/components covered	Sectors/ elements we use	Time period covered	Designation	Definition
BNEF	Energy Tranistion Investment, Energy Investment Trends 2022	Renewable energy, energy storage, electrified transport, electrified heat, nuclear, hydrogen, CCS and sustainable materials	Almost all	Data since 2004 for certain decarbonisation levers, but generally 2014–2021	"Global energy transition investment",	Money/capital spent to deploy clean technologies, accounting for money that has been committed to a specific project, and does not include money that has not been specifically committed or projects that have not reached the final investment decision.
IEA	World Energy Investment 2021, World Energy Investment 2022	Fuel production, power generation, energy infrastructure, buildings, transport and industry	Electricity grids, low-carbon fuels and energy efficiency in buildings, transport and industry	2014/2016/ 2017–2021	"Investment"	Ongoing capital spending on assets, aligned with the concept of capital expenditure in financial reporting and accounting.
IRENA	World energy transition outlook (1.5C pathway)	Power sector and, end-uses and district heat (transport, buildings and industry)	Electrification and grids and flexibility	Yearly avg 2017–2019	"Historical annual average investments"	None provided
CPI (not used)	Global Landscape of Climate Finance 2021	Energy systems, infrastructure & industry, transport, land-use, others & cross-sectoral	Not used	2012 to 2021 (not all data)	"Climate-related primary investment"	Primary investment into productive assets at the project level to capture new money targeting climate-specific outcomes.

Source: Swiss Re Institute

Table 5
Decarbonisation levers and sources used to construct our investment gap measure

Sectors		Sources	
		Needs	Flows
Transport	Electrification of road (EVs + charging infrastructure)	McKinsey, GS	BNEF
	Energy efficiency	IRENA	IEA WEI
	Modal shift	GFMA-BCG	No separate data
Energy	Renewable energy	IRENA	BNEF
	Solar PV		
	Wind onshore		
	Wind offshore		
	Hydropower (excluding pumped storage hydropower)		
	Geothermal		
	Solar thermal (including concentrated solar power)		
	Marine		
	Biomass		
	Electricity grids	McKinsey	IEA
	Energy storage	IRENA	BNEF
	CCUS	GFMA-BCG	BNEF
	Nuclear energy	IEA	BNEF
	Low-carbon fuels (hydrogen-/bio-based ammonia and methanol + biofuels)	McKinsey, IRENA	IEA
	Hydrogen	IEA	BNEF
Buildings	Energy efficiency	IRENA	IEA
	Electrification and onsite renewables	McKinsey	IRENA, BNEF
	Demand management	IRENA	IRENA
Industry	Energy efficiency	IRENA	IEA
	CCUS	GFMA-BCG	BNEF
	Circular economy	IRENA	BNEF

Source: Swiss Re Institute

II: What we do and do not cover

Out of the ever-increasing quantity of emissions, we focus on the top four GHG-emitting sectors – energy, transport, buildings and industry. These four sectors account for roughly 80% of global emissions, but we do not capture each sector fully. In fact, we capture at most 70% of global emissions (see Table 6) but likely quite a bit less than that, with limitations driven entirely by data availability (either on the side of estimated investment needs or flows, or both). This implies that the investment required to mitigate a non-negligible more than 30% of emissions is not accounted for by our measure of the investment gap and we consequently regard our gap as a lower bound of the true resources that will be required to transition to net-zero emissions by 2050.

Table 6
Sectoral breakdown of global GHG emissions in 2018 (in %)

Source	Use	Sub-sector/ activity
Energy consumption (76.2%)	Transport (16.9%)	Road (12.4%)
		Air (2%)
		Ship (1.8%)
		Rail (0.2%)
		Other (incl. pipeline) (0.4%)
	Electricity and heat (31.9%)	Industry (11.9%)
		Buildings (12.2%)
		Transport (transport equipment & rail) (0.8%)
		Unallocated fuel combustion (6%)
		Agriculture and fishing energy use (1%)
	Buildings (5.9%)	Residential buildings (4.2%)
		Commercial buildings (1.7%)
	Industry (manufacturing and construction) (12.6%)	Iron and steel (4.2%)
		Non-metallic minerals (2.4%)
		Chemical and petrochemical (1.8%)
		Other industries (4.2%)
	Fugitive emissions (5.9%)	Oil and natural gas (3.9%)
		Coal (2%)
	Other fuel combustion (3%)	Unallocated fuel combustion (2%)
		Agriculture and fishing energy use (0.9%)
Industrial processes (5.9%)	Industry (5.9%)	Cement (3.1%)
		Chemical and petrochemical (2.4%)
		Various other industries (0.4%)
AFOLU (14.7%)	Agriculture (11.9%)	Livestock and manure (5.9%)
		Agriculture soils (4.2%)
		Rice cultivation (1.3%)
		Burning (0.6%)
	Land use change and forestry (2.8%)	Cropland (1.4%)
		Burning (0.7%)
		Forest land (0.6%)
Waste (3.3%)	Waste (3.3%)	Landfills (2%)
		Wastewater (1.3%)

Note: The colours in the table indicate the extent to which we capture the (sub)sector in our investment gap measure: dark green = accounted for to a large extent; pale green = accounted for to some extent; red = not captured. AFOLU refers to agriculture, forestry and other land use.
Source: *World Greenhouse Gas Emissions: 2018*, World Resources Institute; Swiss Re Institute

We do not cover agriculture, forestry, and other land use (AFOLU) or waste which are, respectively, responsible for almost 17% and just more than 3% of total emissions. This is driven by a lack of detailed investment data. For AFOLU, estimates of investment needs exist and point towards an additional more than USD 10 trillion.[104] Additionally, as already mentioned, our coverage is not exhaustive within the sectors, driven by a lack of investment data. This is most prominent for industry. For example, the International Aluminium Institute suggests investments of around USD 1 trillion may be needed just to decarbonise electricity supplies used to make aluminium (which account for about 60% of emissions).[105] The two above mentioned examples suggests that the investment gap may ultimately exceed USD 300 trillion.

In terms of the different GHG emissions, we capture primarily but not exclusively the reduction of carbon emissions. When measured in carbon dioxide equivalent units (CO_2e), about 75% of total GHG emissions come from carbon dioxide (CO_2), 17% from methane (CH_4), just more than 6% from nitrous oxide (N_20), and the rest from F-gases. Almost 85% of emissions from AFOLU contribute to the emission of CH_4 and N_20. The four sectors that we cover primarily contribute to the emission of CO_2, except for industry which also significantly contributes to N_20 and F-gases emissions:

- Almost 40% of **$C0_2$ emissions** come from industry. Transport and buildings in turn each generate about a quarter. The remainder stems from unallocated fuel combustion (about 9%), AFOLU (about 5%), and fugitive emissions (<1%).
- Almost half of all **CH_4 emissions** stem from AFOLU and almost a third from fugitive emissions. The rest come from waste and unallocated fuel combustion.
- The majority (three quarters) of **N_20 emissions** stem from AFOLU, with the rest coming from unallocated fuel combustion, industry, and waste.
- 100% of **F-gases emissions** come from industry, specifically chemical and petrochemical and non-ferrous metals.

[104] UNEP, WEF, ELF, 2021. State of Finance for Nature. United Nations Environment Programme (UNEP), World Economic Forum (WEF), The Economics of Land Degradation (ELD). Available *here*

[105] "Aluminium sector needs $1.5 trillion just to decarbonise power" *Reuters*, 26 October 2021.

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