UN environment programme | finance initiative

PRI Principles for Responsible Investment

UN-convened Net-Zero Asset Owner Alliance

Unlocking Investment in Net Zero

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Executive summary

The case for net zero made before the COVID-19 pandemic generated momentum to kick-start the transition. The Paris Agreement and the latest reports from the Intergovernmental Panel on Climate Change (IPCC) created an imperative to decarbonise the world. This materialised through numerous net-zero commitments and net-zero pathways, created by institutions such as the International Energy Agency (IEA), the Network for Greening the Financial System (NGFS), the IPCC, the Institute for Sustainable Futures (ISF) scenarios, and the One Earth Climate Model (OECM).

Despite the twin crises of the COVID-19 pandemic and the war in Ukraine, the net-zero transition has displayed remarkable resilience. Both events disrupted the global economy and tested the resilience of corporate value chains, forcing a re-evaluation of global dependencies and raising important questions about our continued reliance on fossil fuels.[1] Countries and international organisations have rallied together to accelerate decarbonisation efforts. For instance, the European Union (EU) allocated significant funds to renewable energy projects from its Recovery and Resilience Facility (RRF), worth EUR 723.8 billion. The RRF is at the heart of RePowerEU initiative, which has played a crucial role in supporting clean energy projects, renewable infrastructure, and sustainable innovation.[2] The Inflation Reduction Act in the United States is also seeking to tackle climate change, lower consumer costs, and grow the clean energy economy. It is doing so by providing unprecedented investment support for clean energy, climate mitigation and resilience, agriculture, and conservation. These targeted investments have not only reinforced the commitment to achieving net-zero emissions in the United States, but have also propelled the country's transition towards a greener and more resilient future in the face of geopolitical uncertainties.

The market momentum behind net-zero is already evident, and the economic case for net zero remains strong. Climate change is imposing enormous costs that are almost certain to rise and could have a substantial impact on returns without sharp reductions in greenhouse gas (GHG) emissions. The risks and costs to returns of a whole-of-economy transition could both be minimised by aligning investment strategies with a net-zero objective. Furthermore, the climate transition could multiply investment opportunities: Keeping global warming below 1.5°C could require investments in climate solutions totalling USD 136–275 trillion by 2050, including USD 20–31 trillion that are

1 NZAOA (2021) Position on the Coronavirus Recovery
2 Investor Agenda (2022) Powering a Green Recovery: How EU recovery funds can support investors and the European Green Deal.

relevant to asset owners.[3] Simultaneously, embracing the net-zero agenda brings positive impacts on social and nature considerations, promoting equitable access to clean energy, creating green jobs, and conserving biodiversity for future generations

The pace of decarbonisation must accelerate to reach the path to net zero. The IPCC and other authorities say the transition is not happening fast enough, and that significant challenges stand in the way of future progress. Many climate scientists warn that a 1.5°C world without a temporary overshoot is likely out of reach already.[4] Preventing the worst impacts of the planetary crisis will require costs. However, the repercussions of delay or inaction carry a far greater price. Asset owners can drive the transition primarily by investing capital into activities that drive deep, absolute decarbonisation. Simultaneously, they can give investment support to technologies and nature-based solutions that remove residual emissions.

Investing in decarbonisation technologies is required for certain industries to cut their emissions footprint. Primary focus must remain on dramatically decarbonising energy, urban, infrastructure and industrial systems, as well as reversing emissions from land-use systems. That said, investments in nascent net-zero technologies and solutions such as carbon dioxide removal (CDR) remain unavoidable if emissions in the energy industry and other hard-to-abate sectors are to be counterbalanced.[5] Such investments need to be made now to ensure that these solutions provide an important, at-scale resource soon.[6]

However, a more enabling policy environment is needed as the economic case for decarbonisation technologies is currently hampered by barriers to their scale-up. Constraints to the adoption of cost-effective technologies include a lack of public and private investment in infrastructure, such as grid upgrades and public chargers for EVs. In addition, while many countries have committed to net zero, few have described their pathways to this goal in detail. Key missing information include the types of solutions to be deployed at scale and the timelines for doing so. Uncertainties also exist in respect to the economic case for less-mature technologies, notable examples of which include carbon capture and storage (CCUS) and sustainable fuels such as green hydrogen. These barriers make it more difficult to invest in emerging climate technologies in the near term.

The need for clear policy frameworks, strong government commitment, ambitious targets, and detailed transition plans that can help overcome the barriers to net zero is immediate and pressing. Financial support from governments can contribute to quickly improving the risk/return profiles of investments and close gaps in the value

3 According to McKinsey Global Institute analysis of the Net Zero 2050 scenario from the Network for Greening the Financial System (NGFS): https://www.mckinsey.com/featured-insights/sustainable-inclusive-growth/chart-of-the-day/the-cost-will-not-be-net-zero

4 Recent findings, such as those of WMO, suggest that the overshoot should be temporary and that a persistent need exists to ensure it remains that way given the scale and scope of risks. WMO (2023) Global Annual to Decadal Climate Update.

5 IPCC (2022) Climate Change 2022 Mitigation of Climate Change, Summary for Policy Makers from Working Group III.

6 NZAOA (2021) The Net in Net Zero: The role of negative emissions in achieving climate alignment for asset owners

chain. Examples of such support include subsidies, grants, and tax credits, among other mechanisms. Likewise, new regulations and standards are required to spur stakeholders to adopt decarbonisation technologies and improve the economic case for investment. Clarifying governmental transition plans is needed to reduce uncertainties about the demand and supply of green assets. Policy support in the form of ambitious carbon pricing mechanisms can internalise some of the externalities relating to the cost of environmental deterioration and incentivise the transition by accelerating the phase-out of carbon-intensive practices and technologies.

This discussion paper highlights key barriers to investment in low-emission technologies. It also presents a suite of policies that could remove current barriers and catalyse investments in net-zero technologies.

The discussion paper focuses on key decarbonisation technologies and identifies potential solutions to investment barriers, but it is not meant to be exhaustive. Potential other decarbonisation options that fall outside the scope of this paper include nature-based solutions, behavioural changes, and efficiency measures. The same is true for challenges to reaching net zero, such as current macroeconomic conditions. Also falling outside this paper's remit is a comprehensive consideration of all potential policies for overcoming the barriers to progress.

1. The climate transition is already underway

The climate transition is creating financial opportunities for asset owners, as adoption and investments in decarbonisation technologies and net-zero business models are rising. This growth is driven by net-zero commitments and implementation by private actors, coupled with government interventions such as regulation, carbon pricing, subsidies, tax credits, and credit guarantees for green investments.

This section highlights decarbonisation trends in technologies that are already cost-effective (section 1.1). It also highlight technologies that are less advanced, but are expected to develop over the longer term (section 1.2). Finally, it demonstrates that investable opportunities for net zero exist today.

1.1 Key decarbonisation technologies are already mature, cost-effective, and deployed at scale

Climate solutions available today at low cost—less than USD 100 per ton of carbon dioxide (CO_2) abated—could cut 45% of emissions by 2030 (see Figure 1), as recommended by the IPCC to remain on a 1.5°C trajectory.[7] Analyses suggest that the costs of clean technologies are likely to keep falling, and that the transition could yield net global savings of at least USD 12 trillion by 2050 compared to current fossil fuel use.[8]

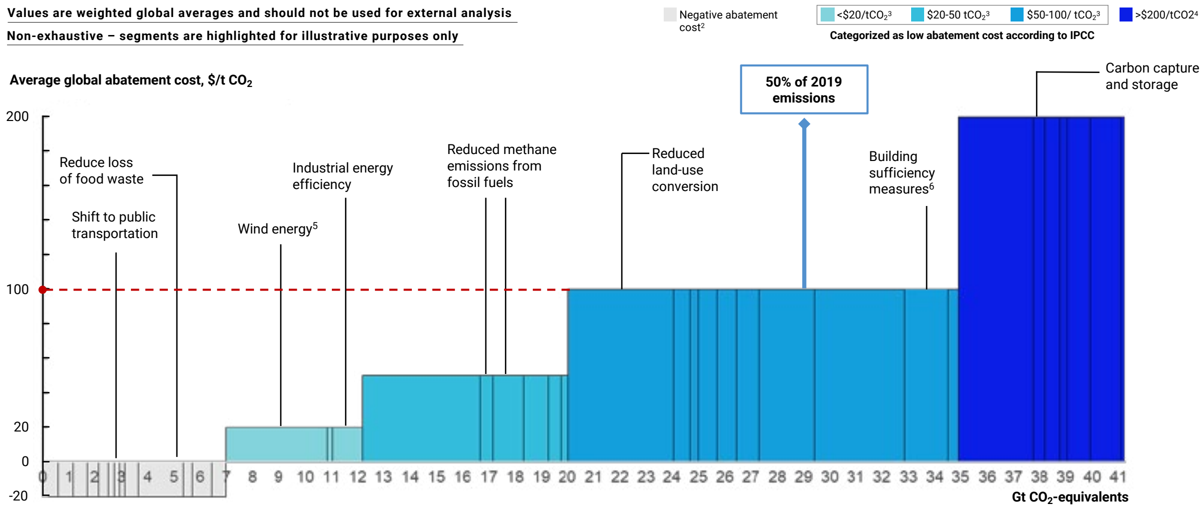
7 IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

8 Way et al. (2022) Empirically grounded technology forecasts and the energy transition. Joule, 6 (9).

2030 mitigation potential (Gt CO2-equivalents[1] per year)

Values are weighted global averages and should not be used for external analysis

Non-exhaustive – segments are highlighted for illustrative purposes only



1. All greenhouse gases are put into carbon-dioxide equivalents to properly assess the relative impact of each gases' contribution to global warming over a 100-year period (GWP 100) | 2. Negative abatement costs means transitioning to the climate technology has lower costs than the conventional alternative | 3. Low abatement costs according to the IPCC, denoted as <$100/tCO2 avoided. For illustrative purposes, the category is split into three ranges <$20, $20-50, and $50-100/tCO2 | 4. High abatement cost is denoted >$200/tCO2 avoided | 5. Includes onshore and offshore wind | 6. Includes upgrade to existing building stock (e.g., insultation retrofits)

Source: International Panel on Climate Change (IPCC) - Sixth Assessment Report - Working Group III -Summary for Policymakers – Section C - Figure SPM.7

Figure 1: High-level overview of mitigation options and their emissions reduction potential (segments highlighted for illustrative purposes only)[9]

The marginal abatement cost curve (MACC) above indicates a wide array of investable technologies and solutions available to private finance, including clean transport, waste, renewables, energy efficiency, building sufficiency, and CCUS. Furthermore, this section focuses on three key decarbonisation technologies that are already cost-effective, widely adopted, and profitable for investors. These provide illustrative examples of the current momentum for investment in these solutions:

- **Renewables:** Renewable adoption is surging. In 2021, renewable electricity accounted for over 28% of global generation, up from less than 20% in 2010.[10] The IEA projects that renewables will become the largest source of global electricity generation (and the only generation source likely to grow) by 2025.[11] Renewable energy is already the cheapest source of energy generation and economically attractive to investors.[12]
- **Electric vehicles (EVs):** Electrification is a key driver of the transition to net zero and has accelerated considerably for passenger and urban light commercial vehicles. Electric vehicles' share of new car sales reached 14% in 2022, more than tripling from 2020 and quintupling from 2019.[13] In Europe, the operational cost advantage of EVs make them roughly on par with internal combustion engine (ICE) cars on a total cost of ownership basis. This is despite recent reductions in subsidies and elevated electricity prices.[14] In the premium segment, EVs can even be cheaper without subsidies.[15]

9 Illustration adapted from Figure SPM.7 (Section C) of the IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
10 IEA (2022) Electricity Sector: Sectoral overview.
11 IEA (2022) Renewables 2022: Analysis and forecast to 2027.
12 IRENA (2022) Renewable Power Generation Costs in 2021.
13 IEA (2023) Global EV Data Explorer.
14 LeasePlan (2022) Total cost of ownership: How electric vehicles and ICE vehicles compare.
15 Bloomberg (2023) Tesla Undercuts Average US Car by Almost USD 5,000 in EV Shakeout.

The electrification of heavy-duty vehicles could play a major role in the next decades but is not yet ready to scale.[16]

- **Heat pumps:** Heat pumps are projected to play a leading role in reducing the emission intensity of buildings, as current models of heat pumps are three to five times more energy efficient than gas boilers. Heat pumps supplied around 10% of the world's space heating needs in 2021 and registered record growth in sales in Europe and in the United States. In Germany, for example, sales more than doubled. This rapid growth was helped by high natural gas prices as well as concerted efforts to reduce GHG emissions. Based on 2021 average equipment and fuel prices, some types of unsubsidised heat pumps are already competitive with gas boilers on installation costs in mature markets such as Canada, Japan, China, and Italy. In such cases, homeowners are witnessing a saving in their annual energy bills of USD 300–900.[17,18] Although this discussion paper focuses on heat pumps for space heating, the technology could help decarbonise heavy industry as it matures.[19]

These technologies started to scale once they became profitable through cost reductions. Between 2010 and 2019, the unit costs of solar energy and wind decreased by 85% and 55%, respectively.[20] Feedback loops in learning curves helped accelerate efficiency improvements.[21] Likewise, the cost of manufacturing EVs dropped in large part thanks to research and development in materials science.[22] Particularly notable in this regard was the price of lithium-ion batteries, which fell by 85% between 2010 and 2019.[23]

Government and policy support have been key enablers of cost reductions. Financial support such as subsidies and tax credits have incentivised demand for these and other technologies while also boosting investment in research. This has had the effect of lowering prices and production costs. Public subsidies and incentives for EVs, for example, doubled from 2021 to 2022 to about USD 30 billion globally. Many countries have now also introduced policies promoting vehicle electrification or ICE phase-outs.[24] Similar support has been observed for renewables. As far back as 2000, for example, Germany introduced grid priority for renewable electricity and feed-in-tariffs for renewable energy. The effect was to quadruple the market for photovoltaics (PV) and catalyse the scale-up of PV manufacturing.[25] China is another example of a government providing substantial support and backing for solar energy. This has proved pivotal in driv-

16 Bloomberg NEF (2022) Electric Vehicle Outlook 2022.
17 IEA (2022) The global energy crisis is driving a surge in heat pumps, bringing energy security and climate benefits.
18 IEA (2022) The Future of Heat Pumps.
19 Marina et al. (2021) An estimation of the European industrial heat pump market potential. Renewable and Sustainable Energy Reviews, 138(1).
20 IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
21 Our World in Data (2020) Why did renewables become so cheap so fast?
22 IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
23 Ziegler et al. (2021) Determinants of lithium-ion battery technology cost decline. Energy and Environmental Science, 12 (1).
24 IEA (2022) Global EV Outlook 2022.
25 IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

ing down the costs of renewables not just in China, but around the globe.[26] In addition, more than 30 countries now offer financial incentives for heat pump installations. As a result, the cheapest heat pumps are now cost-competitive with new gas boilers.[27] These approaches need to be replicated for the less advanced technologies if they are to reach scale quickly. Greater clarity in public policies and governmental transition plans is also required (see more details in Section 3.1).

In the past year, the energy crisis triggered by the war in Ukraine has accelerated the transition from fossil fuels, most notably in Europe.[28] The EU budget is a key part of the EU's wider climate policy landscape. About EUR 605 billion in current prices are allocated to tackle climate change, for instance, marking the highest ever share of the European budget allocated to climate action. The recently devised REPowerEU plan is one example; it will contribute to the energy transition by accelerating renewable energy production to lessen the EU's dependence on Russian fossil fuels.[29] While the conflict led to an increase in fossil-fuel uptake in Germany and a number of other markets, higher fossil-fuel prices have accelerated the deployment of heat electrification through heat pumps, while also making solar PV and wind generation even more cost-competitive.[30,31,32]

1.2 Less advanced technologies necessary for decarbonising hard-to-abate sectors are also gaining momentum

While electricity generation and passenger vehicles are already decarbonising at scale, a longer timespan will be required to meaningfully reduce emissions in hard-to-abate sectors such as cement, steel, aviation, shipping, and heavy-duty vehicles.[33] Energy efficiency improvements and mature solutions can play a role, but other innovative solutions will be required to achieve large reductions in GHG emissions. Progress is underway, as demonstrated by the three types of technology selected as illustrative examples below:

- **Investment in carbon capture, use, and storage (CCUS), especially for industry, is growing, although adoption is constrained by costs and geologic storage monitoring.** Long-term energy outlooks from leading organisations such as the IEA, the IPCC, the International Renewable Energy Agency (IRENA), and Bloomberg New Energy Finance (BNEF) point to the unavoidable usage and rapid expansion of CCUS in order to limit global temperature rise to 1.5°C, specifically for residual emissions and in

26 IEA (2022) Solar PV Global Supply Chains.
27 IEA (2022) The Future of Heat Pumps.
28 IEA (2023) Russia's War on Ukraine: Analysing the impacts of Russia's invasion of Ukraine on global energy markets and international energy security.
29 Investor Agenda (2022) Powering a Green Recovery: How EU recovery funds can support investors and the European Green Deal.
30 Bloomberg (2022) Germany Revives Coal as Energy Security Trumps Climate Goals.
31 IEA (2022) Renewables 2022. Analysis and forecast to 2027.
32 IEA (2022) The global energy crisis is driving a surge in heat pumps, bringing energy security and climate benefits
33 IEA (2021) Net Zero by 2050: A Roadmap for the Global Energy Sector.

hard-to-abate sectors.[34,35,36] Current operational facilities fitted with CCUS can capture approximately 90% of the CO_2 present in flue gas, and additional research can help increase the technological possibility to higher capture rates.[37] Momentum in CCUS deployment has grown in recent years with over 500 projects in development across the value chain. However, deployment levels still remain below what is required in the net-zero scenario.

- **Similarly, the application of carbon dioxide removal (CDR) is steadily growing, although it also faces constraints of cost and steady policy support.** CDR encompasses a range of technologies, practices, and methods designed to remove and securely store CO_2 from the atmosphere.[38] Carbon removals also include nature-based solutions such as forestation, soil carbon sequestration and wetland restoration which aim to preserve and increase carbon storage in ecosystems and on agricultural lands. A range of technological CDR methods can capture and sequester CO_2 such as direct air capture (DAC), bioenergy with carbon capture and storage on ecosystems (BECCS), carbon capture for heavy industries, and enhanced oil recovery.[39] Also gaining momentum is the use of post-capture CO_2 for commercial purposes, such as fertiliser, CO_2-based synthetic fuel, chemicals, and building aggregates. These CDR methods are associated with different implementation options, each of which has different timescales and risk factors. Nature-based solutions stand out as more cost-effective and viable[40] in the short run, while some technological alternatives have the potential to become more relevant later this century.[41] These solutions will be critical decarbonisation technologies to stay on 1.5°C pathways. Two million tonnes of carbon were stored with BECCS in 2022,[42] for example, and ten thousand tons with DAC, compared to almost zero in 2020.[43,44] While investment is growing, high costs stand as a key barrier but could fall sharply. A large-scale DAC facility built has a capture cost of between USD 125–335 per tonne of CO_2, but this capture cost could fall to USD 100 by 2030.[45] The industry is still nascent, but BECCS

34 Smith et al. (2023) The State of Carbon Dioxide Removal—1st Edition.

35 IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

36 International Energy Forum Outlooks Comparison Report

37 International Energy Agency Carbon Capture, Utilisation and Storage

38 IPCC (2022) IPCC 6AR WGIII: CDR Factsheet.

39 While the further development of these technologies needs to be keenly pursued, it is important to recognise associated issues with relevant technical CDR approaches. BECCS can be land- and potentially water-intensive, leading to problems of limited spatial availability, but it can provide carbon removal with appropriate safeguards. Its scale-up should be considered alongside potential negative impacts on food security and rural livelihoods. While DACCS has fewer and less severe ecosystem-competition impacts than BECCS, DACCS can be expensive and cost intensive. It would therefore require cost reductions with economies of scale to realise its full potential.

40 Nature-based solutions with safeguards are estimated to provide 37% of climate change mitigation until 2030 needed to meet the goal of keeping climate warming below 2°C , with likely co-benefits for biodiversity: ipbes.net/global-assessment

41 European Parliament Think Tank (2021) Carbon dioxide removal: nature-based and technological solutions

42 To put in the perspective of global absolute decarbonisation that is needed, this is only 0.0055% of global emissions in 2022.

43 IEA (2022) Bioenergy with Carbon Capture and Storage: Technology deep dive.

44 IEA (2022) Direct Air Capture: Technology deep dive.

45 IEA (2022) Direct Air Capture 2022: A key technology for net zero.

and DACS solutions could capture 2–4 gigatons and over 4 gigatons, respectively, per year by 2030.[46]

- **Hydrogen (H2) produced by low-emission sources is expanding rapidly.** Hydrogen produced from low-carbon sources (green hydrogen), such as renewable electricity or natural gas with CCUS, is likely to become an increasingly important lever for decarbonising sectors including long-haul transport, chemicals, and steel.[47,48] In 2022, 680 large-scale hydrogen project proposals (equivalent to USD 240 billion in direct investment through 2030) have been put forward. This marks an increase in investment of 50% since November 2021 (yet only about 10% of these projects have reached final investment decision).[49] Overall, only 3% of the capital required in hydrogen investment to stay on track to net zero in 2050 has been committed.[50] High capital costs and infrastructure requirements remain barriers to hydrogen adoption but are projected to fall with demand visibility creation, regulatory certainty, and the rollout of support schemes for deployment. The cost of electrolysis manufacturing, for example, could drop by 70% by 2030.[51,52,53]
- **Sustainable fuels are showing early signs of gaining traction and will complement electrification in decarbonising the transport sector.** Low-emission fuels made from renewable energy, green hydrogen, industrial waste feedstocks, or agricultural and forestry residues, will be key to decarbonising aviation and shipping. In 2021, 60 aviation companies committed to use at least 10% sustainable aviation fuel (SAF) in their operations by 2030, and over 50 airlines have already used SAF on more than 450,000 commercial flights.[54,55] SAFs today cost more than twice as much as conventional jet fuel. Production remains low for now. Only 50,000 to 100,000 tons of SAF were produced in 2022, for instance, representing less than 0.1% of global jet fuel demand. However, based on the pipeline of planned projects in July 2022, it is projected that production could supply as much as 8.4 million tons by 2030.[56,57]

As is the case with the scale-up of any new technology, there are uncertainties and potential impacts on resources, biodiversity and the environment, and ecosystem health. Policymakers should therefore avoid a situation where unique or heavy reliance is placed on a single technology. The Alliance recognises the role of long-term carbon removal in achieving net zero but is of the position that immediate efforts must focus on fostering the rapid and deep cutting of GHG emissions as a priority. Annex 1 further explores some of the social and environmental considerations around the above-mentioned technologies.

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46 Coalition for Negative Emissions (2021) The Case for Negative Emissions.
47 IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.
48 One Earth Climate Model (2022) Limit global warming to 1.5°C Sector pathways & key performance indicators
49 Hydrogen Council (2022) Hydrogen Insights 2022
50 Hydrogen Council (2022) Hydrogen Insights 2022.
51 IEA (2022) Global Hydrogen Review 2022.
52 Oxford Institute for Energy Studies (2022) Cost-competitive green hydrogen: how to lower the cost of electrolysers?
53 Hydrogen Council (2022) Hydrogen Insights 2022.
54 International Air Transport Association (2023) Net Zero 2050: sustainable aviation fuels.
55 World Economic Forum (2021) Clean Skies for Tomorrow Leaders: 10% Sustainable Aviation Fuel by 2030.
56 IEA (2022) Aviation.
57 Mission Possible Partnership (2022) Making Net-Zero Aviation Possible: An industry-backed, 1.5°C-aligned transition strategy.

In summary, decarbonisation solutions are gaining momentum and moving towards greater scale, as shown in Figure 2. Uptake in these technologies is influenced by multiple factors, from potential market size and growing policy support through to commitments to net zero. However, barriers to profitability continue to limit the investment case. These extend beyond just cost. A full list is provided in section 2.3.

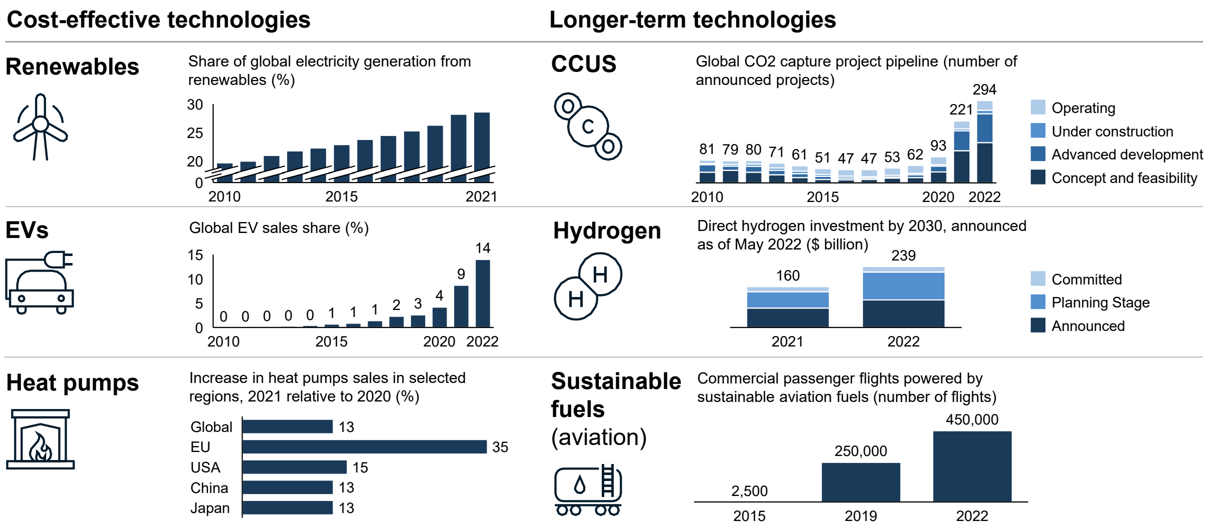

Figure 2: Overview of uptake in decarbonisation technologies

Source: International Air Transport Association (2023), IEA (2022), Hydrogen Council (2022), Mission Possible Partnership (2022), BNEF (2022), Our World in Data (2020)

2. The strong case for net zero

The economic case for reaching net-zero emissions is compelling and clear—it minimises risks and creates diverse investment opportunities. Keeping global warming below 1.5°C will mitigate physical and transition risks (section 2.1) and create significant opportunities for investment in decarbonisation technologies (section 2.2).

While the transition to net zero is underway, it is not happening fast enough. The possibility of staying below 1.5°C is already at risk. Multiple factors are slowing the transition, from high profit margins in the oil and gas sector through to a lack of policy incentives to persuade high emitters to quickly decarbonise.[58] Even cost-effective technologies such as solar PV and EVs need to scale up by a factor of 14 by 2030 to align with net-zero pathways.[59]

Several barriers stand in the way of corporates and investors playing their full role in the transition (section 2.3). Further policy support is essential to overcome these barriers, as detailed in the following section 3.

2.1 A net-zero outcome reduces physical risk, while 1.5°C-aligned portfolios mitigate transition risk

Physical risk from climate change is already materialising and contributing to extreme weather events across the world. In 2022, extreme floods in Pakistan inundated a third of the country's land area, affecting 33 million people and causing almost USD 15 billion in damage,[60] equivalent to more than 4% of the country's 2021 gross domestic product.[61] The same year, record-breaking heatwaves across Europe pushed up energy demand and prices, fuelled disastrous wildfires, and significantly reduced harvests.[62,63] These are just two recent examples of the costs associated with the physical risks of climate change, and impacts will likely worsen. Crucially, the magnitude of changes through 2050 will depend on the emissions pathways that are chosen today.[64]

58 Financial Times (2023) What Big Oil's bumper profits mean for the energy transition.
59 McKinsey (2023) Scaling green businesses: Next moves for leaders.
60 The Government of Pakistan (2022) Pakistan Floods 2022: Post-Disaster Needs Assessment.
61 World Bank dataset
62 Financial Times (2022) Blistering heatwave plays havoc with Europe's strained energy system.
63 Trade Finance Global (2022) 'Heatflation' warning as 2022 EU crop harvests affected by climate change.
64 IPCC (2021) Climate Change 2021: The Physical Science Basis. Contribution to Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

Transition risk is likely to grow as policy responses become more direct and immediate. As highlighted in section 1, transition risk is already a reality, and is likely to rise. The Inevitable Policy Response (IPR) Required Policy Scenario predicts details of future policy developments needed to accelerate emissions reduction to hold global temperature increase to a 1.5°C outcome. It finds that governments need to pursue immediate policy actions that directly intervene in markets to set performance standards, including strict bans, to drive a step change in the energy system.[65] In the absence of net-zero investment strategies, asset owners will become more exposed to risks associated with mismanaged carbon liabilities or investments in stranded assets and projects. For example, as the world transitions towards a low-carbon economy, the risks of stranded assets associated with fossil fuels are significant. Similarly, coal mines and oil reserves may lose their utility and value due to changing climate policies and market dynamics.

Physical and transition risks can impact corporates and asset owners in many ways. For example:

- Inflation-adjusted insured losses from natural disasters topped USD 132 billion in 2022, the fifth-costliest year for insurers since 1900.[66]
- In 2019, US-based utility provider PG&E filed for bankruptcy and paid more than USD 25 billion in liabilities after fires caused by its powerlines burned 300 square kilometres in California.[67]
- In 2019, the private equity-owned British Steel secured a GBP 120 million loan from the British Government to avoid paying a fine for failing to settle its outstanding carbon permits under the EU's Emission Trading System.[68]

The impact of physical risk on asset owners' returns could be significant. The McKinsey Global Institute estimates that USD 4–6 trillion in gross domestic product (GDP) could be at risk globally in an average year by 2050 as heat and humidity cut output in agriculture, construction and mining.[69] In its first climate stress test, the European Central Bank estimated that European GDP growth would be the highest from 2030–2050 in the 'orderly' scenario (NGFS 1.5°C). By 2050, the Bank calculated that the growth rate for an orderly scenario would be 7% higher than that for a 'disorderly' transition (i.e. a delayed transition keeping temperature increase to 2°C above pre-industrial levels). In a 3°C limited transition scenario where no new climate policies are implemented, GDP growth is predicted to be 8% lower than in the orderly case.[70] The precise impact on returns is difficult to model. This is because the magnitude of disruptions depends on a variety of factors, such as the location and nature of assets, the severity and frequency of climate-related events, and the adaptation and mitigation strategies in place. However, the overwhelming consensus is that the impact on returns will be hugely significant.

Similarly, transition risk can have highly disruptive impacts. The magnitude of transition risk will depend on the decarbonisation pathway pursued. However, in all decarbonisation pathways, a substantial share of the global economy is projected to be affected

65 PRI (2021) What is the Inevitable Policy Response?
66 Aon (2023) Weather, Climate and Catastrophe Insight.
67 Utility Dive (2020) Wildfires pushed PG&E into bankruptcy. Should other utilities be worried?
68 Reuters (2019) British Steel gets 120 million-pound state loan to cover EU carbon costs.
69 MGI (2020) Climate risk and response: Physical hazards and socioeconomic impacts.
70 ECB (2022) 2022 Climate Risk Stress Test.

due to its dependence on high-emitting sectors.[71] Climate change presents a significant financial risk for long-term investors due to its impact on people, communities, and ecosystems across the world, coupled with its impact on global economic instability. For instance, by 2050, 1.2 billion people[72] could be displaced globally due to climate change and extreme weather events. If realised, this would pose significant implications for international security, instability, conflict, and geopolitics, as well as global progress in sustainable development.[73]

Physical risk can be mitigated by limiting climate change, but only with a major investment push in an enabling policy environment. Failing to reduce the negative impacts of climate change could increase the costs of investment, leading to lower returns on investors' portfolios in some areas. Hence, the best way to avoid these costs is to limit the negative impacts of climate change in the real economy. This can only be achieved through a combination of climate change mitigation and adaptation. Asset owners have a critical role to play in mitigating physical risks on a broader scale, both through investing in climate solutions and through engaging directly in the development of progressive climate policies.

Transition risk can be reduced by aligning portfolios with net-zero goals. Net-zero portfolios have less exposure to transition risk, and can be achieved both by reducing holdings of high-emission assets and by actively investing in climate solutions. For example, mitigating the risks associated with stranded assets requires providing a clear trajectory towards decarbonisation, including policies and commitments to responsibly manage the transition away from fossil fuels towards low-carbon solutions. The following section outlines some investment opportunities in these solutions.

2.2 The net-zero transition offers major investment opportunities

As shown in section 1, the net-zero transition is underway and generating profits. According to the IEA, approximately USD 2.8 trillion is projected to be invested in the energy sector in 2023.[74] Of this, over USD 1.7 trillion will be allocated to clean energy. This encompasses a broad range of areas, from renewable power, nuclear energy, grid infrastructure, energy storage, low-emission fuels, and efficiency enhancements, through to the advancement of renewable energy sources and electrification at the end-use level. Companies that are leading in this transition are making returns on investments in low-emission ventures in sectors such as energy, automotive, and apparel, among others. Recent research highlights that reducing portfolio emissions by at least half is not costly, and that many green portfolios see higher risk-adjusted returns than tradi-

71 In addition, at the idiosyncratic level, litigation risk poses a significant component of transition risk. Companies may face legal challenges, including lawsuits and regulatory actions related to their climate impact, which can result in reputational damage and financial liabilities.

72 Institute for Economics & Peace (2021) Ecological Threat Report

73 World Bank (2018) Meet the Human Faces of Climate Migration.

74 IEA (2023) World Energy Investment 2023.

tional investment strategies.[75,76] However, to affect the net-zero transition at the sectoral level and towards a whole-of-economy scale, existing barriers—as explored below—need to be systemically unlocked. Only then can financial flows be mobilised and become aligned with the transition at scale.

Investment in net-zero technologies is not only an important tool for achieving 1.5°C,[77] **but also generates secondary investment opportunities.** One such opportunity is the growth of tech education to meet the demand for skilled professionals in renewable energy and clean technologies. This investment not only benefits the environment but also stimulates economic growth, job creation, and human capital development, which is an important tenet of ensuring a just transition. This is exemplified by the Scottish Government's Energy Transition Fund that is match-funded by the industry to accelerate a range of energy transition projects. This programme is expected to deliver GBP 403 billion for the economy and 21,000 jobs by 2050.[78]

Investors are already capturing or planning to capture these opportunities. A survey of 396 senior institutional investors managing more than USD 13 trillion in combined assets found that 24% are targeting net zero and another 29% plan to do so.[79] Investments in green bonds have also grown significantly over recent years. Issuances totalled around USD 1 trillion by the end of 2020 and doubled to about USD 2 trillion two years later—an impressive feat given they only emerged as a distinctive investment class in 2016.[80,81]

The net-zero transition could multiply the number of investment opportunities as the investment gap is wide. Estimates vary, but the opportunities are substantial. The McKinsey Global Institute estimates that USD 275 trillion of capital will need to be invested in physical assets between 2021 and 2050.[82] Other studies are more conservative and foresee an investment gap of around USD 136 trillion over the same period.[83] The gap represents the additional spending needed in addition to historical levels to reach net zero by 2050. This paper relies on the more conservative, lower range of estimates for the rest of the report.

The size of the investment gap varies by region. Figure 3 illustrates the scale-up in capital required by region and sector in a Paris-aligned pathway. The biggest investment gap is foreseen in the Asia-Pacific region, where about USD 58 trillion (around 42% of global need) could be required by 2050 and USD 9 trillion by 2030. Europe and North America come next with roughly USD 25 trillion each in 2050 and USD 4 trillion by 2030. Oppor-

75 Anquetin et al. (2022) Scopes of carbon emissions and their impact on green portfolios. Economic Modelling, 115(1).
76 Whelan et al. (2021) ESG and Financial Performance: Uncovering the Relationship by Aggregating Evidence from 1,000 Plus Studies Published between 2015–2020. Centre for Sustainable Business, NYU-Stern.
77 IPCC (2018) Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development. In: Global Warming of 1.5. An IPCC Special Report on the impacts of global warming of 1.5°C pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.
78 Scottish government (2021) Investing in net-zero technology
79 Bfinance (2022) Global Asset Owners Survey: Traps and Transitions.
80 Climate Bonds Initiative (2020) Green Bond Market Summary Q3 2020.
81 Climate Bonds Initiative (2022) Sustainable Debt Market Summary Q3 2022.
82 MGI (2022) The Net-zero Transition: What it Would Cost, What it Could Bring.
83 IIGCC (2022) Climate Investment Roadmap.

tunities in other regions are smaller but still remain considerable, with investment gaps of around USD 6–8 trillion by 2050.[84]

The largest opportunities may be in electricity, transport, and buildings. Electricity generation from renewables promises to play a very significant role in global decarbonisation efforts, as does electricity storage, transmission and distribution. As such, the financial support required by them is judged to be the greatest, at around USD 59 trillion by 2050. The largest share of this investment could be in cost-competitive technologies such as solar PV and wind, which together could attract over USD 7 trillion in the next decade alone. Experts also foresee significant investments in the transport and real estate sectors, driven by the decarbonisation of road mobility and energy efficiency spending. Of the USD 28 trillion in investments needed by 2050 in the transport sector, nearly USD 25 trillion is required for road mobility and zero emission vehicle (ZEV) infrastructure. Of the USD 19 trillion financing gap by 2050 in the buildings sector, meanwhile, 56% is earmarked for retrofits and more energy-efficient lighting and ventilation. These are followed by heating, which could require USD 3.8 trillion in investment by 2050. Heat pumps are projected to be the fastest growing segment within heating-sector investments.[85] Note, not all net-zero opportunities are investable by asset owners, as certain aspects are limited by behavioural changes that may not be readily quantifiable or achievable through traditional investment mechanisms. Measures to reduce food waste are a case in point.

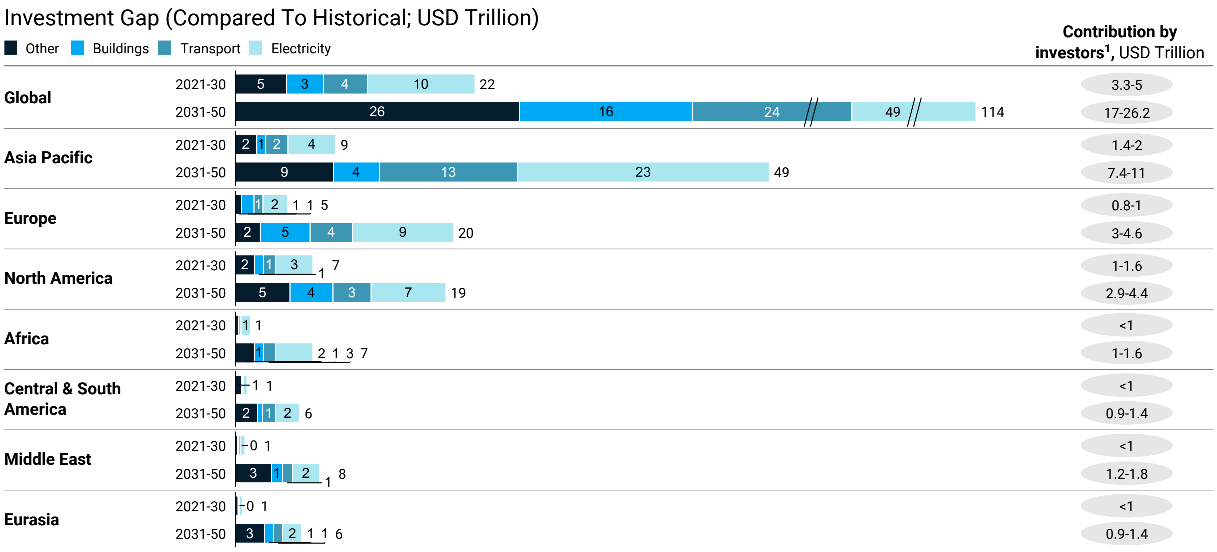

Figure 3: Scale-up in capital required by region, sector, and period in a Paris-aligned pathway

Source: IIGCC (2022) Climate Investment Roadmap

Note: The investment gap figures are estimated from the IIGC's 2022 report, 'Climate Investment Roadmap'. The contributions by asset owners for each region and period are estimated by applying a fixed percentage (15–23%) share to the projected investment gap. This share represents that total average of the annual net-zero investment requirements (2022–2050) that could be financed by institutional investors, private equity, venture capital and infrastructure funds, according to analysis by McKinsey (see, 'Financing the Net Zero Transition—From Planning to Practice', 2022).

84 Ibid.
85 Ibid.

Asset owners can play a meaningful role in mobilising transition finance to support investee companies' transition. About 15–23% of transition financing needs could be facilitated by asset owners,[86] equivalent to USD 3–5 trillion globally between 2021 and 2030. This could increase to another USD 17–26 trillion from 2031 to 2050. Commercial banks and asset managers can facilitate around USD 2 trillion and USD 1 trillion a year, respectively.

2.3 Decarbonisation technologies must overcome barriers to unlock the full potential of the net-zero transition

Technology-based removal and storage solutions need to be implemented at scale in order to achieve scale economies and reduce costs to make them viable. For these solutions to become an important additional tool on the path to decarbonisation, it is necessary to invest in their further research and development, as well as provide financial support for their future expansion. This is especially critical as the permanence of storage is high.

While there has been progress with the development and deployment of cost-effective key technologies, there remain barriers to scaling future markets rapidly in the required net-zero scenario. Consequently, the number of profitable opportunities is limited, reducing investments and the pace of decarbonisation. Table 1 outlines some of the material barriers faced by investors, and the impact on investments in technologies that are cost-effective today and those that may offer promise in the longer term. These assessments are simplified and applied to selected technologies to illustrate that barriers do not have the same implications across all solutions. Impact bands are defined as:

- **High:** Major barrier to adoption and/or scale-up which significantly impacts financing demand or supply.
- **Medium:** Moderate barrier to adoption and/or scale-up which will not block financing alone but could reduce demand or supply.
- **Low:** Not a barrier to technology adoption or scale-up.

These barriers must be overcome to unlock the full economic potential of net-zero alignment. Further policy support is essential, as detailed in the following section. It should be noted that other relevant barriers to net-zero investment exist but that these fall outside the focus of this report. Examples of such barriers include the macroeconomic landscape, lack of awareness about net-zero potential among investors and corporates, and a shortage of relevant skills. While the emphasis of this report centres on the six technologies selected, it should be pointed out that the barriers discussed here also extend to other categories of climate solutions. An apt example is nature-based solutions, which are not explicitly mentioned in this context within the report.

86 Calculated as the share of total average annual net-zero investment needs (2022–2050) that could be financed by institutional investors, private equity, venture capital funds, and infrastructure funds. Source: McKinsey (2022) Financing the Net-zero Transition—From Planning to Practice.

Table 1: Barriers to investment in low-carbon technologies

Barriers	Impact on cost-effective technologies	Impact on less advanced technologies
Lack of value chain maturity: The use of technological solutions depends on the readiness of the full value chain as individual parts cannot work independently. Bottlenecks, such as a lack of infrastructure and raw material sourcing, obstruct the value chains of key decarbonisation technologies.	**Renewables: High.** The technology is ready to scale but limited by interconnection queues. Upgrades in transmission infrastructure are also required, especially in the United States.[87] Existing and planned capacity to source raw materials, including mining and recycling, is insufficient and too geographically concentrated to meet rising demand.[88] **EVs: Medium.** Lack of charging points and costly public charging lower EV demand.[89] Investment is needed to diversify battery production and reduce lead times in raw materials extraction.[90] **Heat pumps: Low.** Few supply chain constraints such as shortages of skilled workers.[91]	**CCUS: High.** While some elements are mature, value chains are not yet sufficiently developed to scale demand for investments. For example, one of the largest DAC projects in the United States is capturing CO_2 but cannot use, store, or sequester it.[92] **H_2: High.** Hydrogen solutions are still at nascent stage, with value chains not yet sufficiently developed to scale demand for investments. **SF: High.** Some existing infrastructure can be reused. However, production and end-use resources, such as adapted aircraft and ships, must further develop to increase investment demand.

87 Federal Energy Regulatory Commission (2023) 2022 State of the Markets: A Staff Report to the Commission.
88 McKinsey (2022) Building resilient supply chains for the European energy transition.
89 ACEA (2022) Research Whitepaper: European EV Charging Infrastructure Masterplan.
90 IEA (2022) Global Electric Vehicle Outlook 2022.
91 IEA (2022) The Future of Heat Pumps.
92 Canary Media (2023) A buzzy new carbon removal plant is catching and releasing CO_2.

Barriers	Impact on cost-effective technologies	Impact on less advanced technologies
Significant upfront costs: Switching to low-emission solutions often requires large, upfront capital investments.	**EVs:** High. High capital expenditure requirements for original equipment manufacturers (OEMs) are reflected in car prices for consumers. **Heat pumps:** High. Costs can vary depending on the energy efficiency of buildings. However, high installation costs could be potentially offset by widespread financial incentives and longer-term gains.[93] **Renewables:** Low. The strong economic case compensates.	**CCUS, H_2 & SF:** High. Significant capital investments are required to develop infrastructure to capture and remove CO_2 from the air and produce sustainable fuels and green hydrogen. These are not yet compensated by future revenues. Infrastructure costs for CCUS can be reduced by retrofitting existing assets such as coal plants.[94] Using renewable energy sources for hydrogen production can reduce costs by reducing the need for fossil fuels in the production process.[95] Policy support and incentives can provide financial backing for sustainable fuel projects.
Cheap and profitable brown alternatives: While fossil fuel infrastructure may become stranded, many projects are still highly profitable in the short term and continue to attract investment.	**EVs:** High. Especially for consumers in the volume segment and OEMs with existing production facilities. **Renewables, heat pumps:** Medium. Brown alternatives are still entrenched and competitive.	**H_2, SF:** High. Fossil-fuel-based applications in industry and transport are still profitable. **CCUS:** Low. No brown alternative.
Low revenues and/or high operating costs: Some transition solutions are not yet profitable, and many investors are unwilling to invest in non-viable business cases, especially if alternative investments can be lucrative.	**Renewables, heat pumps, EVs:** Low. Investments are economically attractive.	**H_2, SF:** High. Future revenues may not cover total costs. **CCUS:** Medium. While technologies are expensive overall, the viability of some investments is increased by regulation and legislation (such as the Inflation Reduction Act in the United States), plus the willingness of customers to pay a premium.[96]

93 IEA (2022) The Future of Heat Pumps.
94 IEA (2022) Bioenergy with Carbon Capture and Storage: Technology deep dive.
95 IEA (2019) The Future of Hydrogen.
96 IEA (2022) Carbon Capture, Utilisation and Storage: Energy system overview.

Barriers	Impact on cost-effective technologies	Impact on less advanced technologies
Uncertainty of outlook: Investors may avoid allocating capital to technologies with uncertain profitability. Several difficult-to-predict factors influence the future price, demand, and supply of solutions and their alternatives: ▪ Demand and costs depend on technological maturity and policy support, which are uncertain ▪ Uncertainty in the competitive landscape ▪ **Lack of efficient and predictable national regulation** with regards to **licensing and approval processes**	**Renewables, heat pumps, EVs: Low.** Investments are economically attractive.	**SF: Medium.** Sustainable fuels are key decarbonisation solutions, and some are mature. But uncertainty remains which fuels will 'win' the race to decarbonisation, especially in shipping.[97, 98] **H_2: Medium.** Despite initiatives to create offtake certainty for investors such as the European Hydrogen Bank and H_2Global, offtake and import arrangements secure only two million tons a year of H_2. As of September 2022, H_2 was part of 40 national strategies.[99,100,101,102] **CCUS: Medium.** Uncertainty varies in technological maturity and local support. Some technologies are not yet proven, as demonstrated by the Petra Nova project failure,[103] but few mature options are available, and government support or private partnerships have de-risked projects such as Northern Lights in Norway.[104]

Note: Sustainable fuels (SF) refer here only to applications in shipping and aviation, while heat pump assessments focus on real estate rather than high-temperature technologies in heavy industry. For EVs and heat pumps, only manufacturing and sales are considered. Renewables include the construction of the assets and grid connection. For CCUS, barriers to capture, use and storage are considered. H2 and SF refer to production and end-use (including short-term storage if needed).

97 Offshore Energy (2023) WFW: Biofuels trump LNG as most popular alternative for the next 5 years.
98 McKinsey (2023) Charting fuel choices as the shipping industry sails toward net zero.
99 Hydrogen Council (2022) Hydrogen Insights 2022.
100 European Commission (2023) Commission outlines European Hydrogen Bank to boost renewable hydrogen.
101 H2 Global Stiftung (2023) The H2Global Instrument.
102 IEA (2022) Global Hydrogen Review 2022.
103 Institute for Energy Economics and Financial Analysis (2022) The ill-fated Petra Nova CCS project: NRG Energy throws in the towel.
104 Northern Lights (2022) annual report.

3. Strengthen enabling policies

As outlined in section 2, strong economic rationales underpin net-zero investment. Barriers limit the role of asset owners today but these can be overcome. This section highlights policies that could help to solve this challenge (section 3.1) and additional enablers to catalyse the transition to net zero (section 3.2).

3.1 Policies could help overcome barriers to investment and unlock the full net-zero potential

Offering robust signals through climate policies plays a crucial role in addressing the barriers described in section 2.3 and guiding investment choices, as credible signalling from governments and the international community can alleviate uncertainties for financial decision makers, thereby mitigating transition risks.[105] This section focuses on a selection of four types of policies with high potential impact, as shown in Figure 4. The list is not exhaustive—other policies such as offtake, power purchase agreements and guarantees could also help but are not detailed in this report.

Policy support	Lack of value chain maturity	Significant upfront costs	Cheap / profitable brown alternatives	Low revenues and/or high operating costs	Uncertainty of outlook
A Increasing financial support for decarbonization solutions and reducing support for high-emitting technologies	✓	✓	✓	✓	✓
B New mandatory regulation and technology standards	✓		✓	✓	✓
C The clarity of governmental transition plans					✓
D Ambitious and homogeneous compliance carbon markets			✓		

Figure 4: Mapping of policy support and barriers addressed

105 IPCC (2022) Climate Change 2022: Mitigation of Climate Change. Contribution to Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.

3.1.1 Increasing financial support for decarbonisation technologies and the transition of emission-intensive industries, and reducing support for fossil fuel technologies

Financial government support refers to policies providing direct financing such as subsidies, grants and tax credits. A supportive policy environment is critical to unlocking green finance and can generate substantial impact. International players have recently been spurred to relocate strategic investments to the United States, for instance, after the passing of its Inflation Reduction Act (IRA) in September 2021.[106] This type of support is increasing, and it could be introduced or expanded in numerous markets. Reinforcing financial support for decarbonisation solutions, while at the same time reducing support for fossil fuel projects and technologies, could help overcome the material barriers described in section 2.3:

- **Lack of value chain maturity:** Direct funding could be used to upgrade public infrastructure, as well as increasing sourcing capacity and managing existing challenges. Funding could improve interconnections with renewables in the short term and help build out essential infrastructures such as public EV chargers.[107] Many economies have underinvested in transmission infrastructure for renewables. That said, some packages have been recently announced to boost grid capacity for renewables. Prominent here are Australia's AUD 5 billion investment and the UK energy regulator's proposed GBP 2.7 billion of upfront funding.[108,109] Early investment in the full value chain would also reduce the likelihood of similar bottlenecks in the deployment of less advanced technologies.
- **Significant upfront and operating costs, plus low revenues:** Tax credits, subsidies, or direct funding can reduce upfront capital requirements, lower other costs, or generate cash. Direct government investment could also boost the uptake of decarbonisation solutions, which may help lower costs via learning and scaling effects—a potentially crucial factor in the success of promising technologies that are not yet cost-effective. The IRA in the United States, for example, includes two new production tax credits to reduce the price difference between clean and more carbon-intensive hydrogen.[110] The EU's Green Deal Investment Plan also encompasses a range of financial instruments and initiatives aimed at mobilising private and public investment to support sustainable projects and technologies.
- **Cheap and profitable brown alternatives:** Phasing out government support for brown assets is critical to incentivising the switch to green technologies.[111] Subsidies for the consumption of fossil fuels reached USD 1 trillion globally in 2022. This repre-

106 Financial Times (2022) US subsidies for green technology ring alarm bells in EU capitals.
107 LaMonaca and Ryan (2022) The state of play in electric vehicle charging services—A review of infrastructure provision, players, and policies. Renewable and Sustainable Energy Reviews, 154(1).
108 FDI Intelligence (2023) Australia invests billions to upgrade grid infrastructure.
109 Ofgem (2022) Ofgem reveals landmark five-year programme to deliver reliable, sustainable energy at the lowest cost to consumers.
110 Resources for the Future (2022) Incentives for Clean Hydrogen Production in the Inflation Reduction Act.
111 Glasgow Financial Alliance for Net Zero (2023) How to reap the rewards of coal phaseout.

sents a significant drain on public resources that could otherwise be channeled into a clean and just energy transition.[112] An example of good practice comes from Morocco, where reforms were introduced in 2014 to cut spending on fossil fuel subsidies and to reinvest the savings in renewable energy projects. Renewables represented 34% of installed electricity capacity by 2019.[113]

- **Uncertainty of outlook:** The announcement of government support for certain technologies generates supply and demand by reducing uncertainty. This can be done via public procurement to strengthen cost competitiveness of key technologies. Government support can be highly effective for less advanced technologies where uncertainty is higher, as described in section 2.3.

Case study 1: Examples of government financial support

- **Europe: The Sustainable Europe Investment Plan (SEIP) and Green Deal Industrial Plan (GDIP)** aim to mobilise public and private financial resources for clean technology development. The SEIP will allocate around EUR 1 trillion in green investment over the next decade, reinforced by the GDIP's enhanced investment support schemes and targeted aid to boost domestic manufacturing of net-zero technologies.[114,115]
- **United States: The IRA** allocates nearly USD 370 billion for climate and energy spending, based on early estimates.[116] Over USD 270 billion is earmarked for clean energy and transport support, including production and investment tax credits for solar and EVs, consumer rebates for heat pumps, enhanced tax credits for CCUS and up to USD 3 per kilo of green hydrogen subsidy in the form of tax credits.[117,118,119]

112 IEA (2023) Fossil Fuel Consumption Subsidies 2022.
113 Morocco: Fuel Subsidy Reform Designed to Support a Just Transition to Renewable Energy.
114 European Commission (2020) The European Green Deal Investment Plan and Just Transition Mechanism explained.
115 European Commission (2023) The Green Deal Industrial Plan: putting Europe's net-zero industry in the lead.
116 US Congress (2022) Inflation Reduction Act of 2022, H.R. 5376.
117 McKinsey (2022) The Inflation Reduction Act: Here's what's in it.
118 IEA (2022) Section 45Q Credit for Carbon Oxide Sequestration.
119 US Department of Energy (2023) Financial Incentives for Hydrogen and Fuel Cell Projects.

- **United Kingdom: The Powering Up Britain Plan** proposes climate and energy policies to meet net-zero commitments. The package includes proposals and announcements for a range of clean technologies, including GBP 160 million for floating offshore wind port infrastructure, GBP 240 million for the Net-Zero Hydrogen Fund as part of the first tranche of projects, and GBP 380 million to expand the country's EV charging network.[120]
- **South Korea: The Green New Deal** pillar of the Korean New Deal allocates 73.4 trillion won (over USD 60 billion) for investments focused on green buildings, renewable energy, and green innovation in industry. The package also includes provisions to foster the commercialisation of large-scale CCUS projects and expand EV charging infrastructure, amongst others.[121]

3.1.2 New mandatory regulation and technology standards

New technology standards, regulations, and laws can spur the adoption of green technologies, support the transition of emission-intensive industries, and help phase out support for fossil fuel technologies. Such measures are in place in only some economies and sectors, but they could help overcome four of the five barriers:

- **Lack of value chain maturity:** New regulation requiring updates of lagging infrastructure or other links in the value chain could help break bottlenecks. Duke Energy, for example, raised its decarbonisation targets and grid investments to comply with North Carolina's new clean energy legislation.[122] Such initiatives could accelerate the scale-up of technologies that are cost-effective but less advanced and thus require time for deployment.
- **Low revenues and high operating costs:** Laws can give corporates new incentives to invest in decarbonisation solutions, boosting the adoption of clean technologies and thereby potentially driving costs down. When implemented through a just transition lens, this type of policy can promote cost-effective and less advanced technologies to reach national targets.
- **Cheap and profitable brown alternatives:** Rules and policy measures that support the transition of emission-intensive industries can promote the use of decarbonisation solutions.
- **Uncertainty of outlook:** Strict rules in favour of decarbonisation solutions, such as EV targets, can assure investors that the technology will be adopted. This reduces uncertainty in supply and demand.

120 UK Government (2023) Press release: Shapps sets out plans to drive multi billion-pound investment in energy revolution.
121 Government of the Republic of Korea (2020) Korean New Deal: National Strategy for a Great Transformation.
122 Duke Energy (2021) ESG report 2021.

Case study 2: Examples of automotive sector regulatory requirement by region

Several jurisdictions impose sector-specific policies or legal standards such as the EU's Fit for 55 package and China's 14th Five-Year Plan on Modern Energy System Planning. The table below highlights examples of such regulation in the automotive sector.

Table 2: Examples of regulatory requirements for the automotive sector by region

EU	United States	China	Chile
Under the EU Fit for 55, cars and vans must have net-zero CO_2 tail-pipe emissions by 2035. Stronger fuel efficiency standards were proposed in April 2023 for heavy-duty vehicles, including making all new city buses zero-emission as of 2030. [123]	Federal CAFE standards set minimum fuel efficiency requirements for automakers.[124] In April 2023, more stringent standards were proposed for light-, medium-, and heavy-duty vehicles.[125] At the state level, California has a target for all new cars and passenger trucks to be zero-emission by 2035. A total of 17 states have followed suit.[126,127]	By 2035, all new vehicles sold must be powered by 'new energy': 50% hybrid and 50% electric, fuel cell or plug-in hybrid.[128]	By 2035, 100% of light- and medium-duty and public transport vehicles sold must be zero emission, as well as 100% of long-haul freight trucks and intercity buses by 2045.[129]

123 European Commission (2023) Reducing CO_2 emissions from heavy-duty vehicles.
124 Center for Automotive Research (2022) Overview and Implications of New CAFE Standards and Penalties.
125 US EPA (2023) Biden-Harris Administration Proposes Strongest-Ever Pollution Standards for Cars and Trucks to Accelerate Transition to a Clean-Transportation Future.
126 California Governor (2020) Governor Newsom Announces California Will Phase Out Gasoline-Powered Cars & Drastically Reduce Demand for Fossil Fuel in California's Fight Against Climate Change.
127 Bloomberg NEF (2022) Zero-Emission Vehicles Factbook.
128 Nikkei Asia (2020) China plans to phase out conventional gas-burning cars by 2035.
129 Government of Chile (2021) National Electromobility Strategy Launch: Government announces that only electric vehicles will be sold in Chile by 2035.

3.1.3 The clarity of governmental transition plans

The clarity of governmental transition plans refers to the creation of detailed transition plans at the national level, including a description of the decarbonisation pathway and underlying solutions that will be used to reach the objective. While many countries have committed to net zero, few have described their pathways to this goal in detail. Key missing information include the types of solutions to be deployed at scale and the timelines for doing so. For example, in its 2022 Energy Transition Plan, Nigeria outlined its pathway to net zero by 2060. It detailed critical investment needs in the power, cooking, oil and gas, transport and industrial sectors. It also highlighted solutions to decarbonising each area, such as ramping up electrification through renewables, relying more on passenger EVs, and using zero-emission fuels for heating.[130] Other countries have announced more immediate targets, as shown in case study 3. In addition to requiring clear and well-defined government transition plans, efficient regulations that facilitate the realisation of those plans are equally essential. The IRA in the United States provides an illustrative example. Clear transition plans could substantially reduce uncertainty:

- **Uncertainty of outlook:** Transition plans provide further clarity regarding the expected demand for climate solutions, allowing investors to take more informed investment decisions. For asset owners, demand certainty implies an improvement in the credit profile for investee companies and therefore an enhanced risk/return profile. This type of policy can be particularly effective for less advanced technologies where uncertainty is high.

Case study 3: Singapore Green Plan

In 2021, Singapore announced ambitious decarbonisation targets and initiatives to strengthen the green investment opportunity landscape by 2030. The Green Plan's objectives include:

- Green 80% of Singapore's buildings by gross floor area by 2030
- All new car and taxi registrations to be cleaner-energy models from 2030
- Install 60,000 charging points nationwide by 2030, including 40,000 in public carparks and 20,000 in private premises
- Increase solar energy deployment five-fold to a peak of at least two gigawatts
- Deploy 200 MWh of energy storage systems beyond 2025, powering more than 16,000 households a day.[131]

3.1.4 Ambitious carbon pricing mechanisms

Ambitious carbon markets refer to carbon prices aligned with best practice principles. Carbon pricing now covers 23% of global GHG emissions, and 70 carbon price initiatives are already in force. Although sectoral and geographical coverage is increasing, there is room for improvement. For example, most carbon prices per ton remain far below the USD 50–100 range aligned with the Paris Agreement, limiting the impact of these meas-

130 Government of Nigeria (2022) Nigeria Energy Transition Plan.
131 Singapore Government (2023) Singapore Green Plan.

ures.[132] The UN-convened Net-Zero Asset Owner Alliance (NZAOA) recommends several key principles to support a 1.5°C pathway, including appropriate coverage and ambition, providing predictable price signals, minimising competitive distortions and promoting international cooperation. Both a carbon tax and an Emission Trading System (ETS) cap can be designed to deliver against these key principles and overcome one of the barriers noted in section 2.3:

- **Cheap and profitable fossil fuel technologies:** Expanding carbon pricing could increase the relative cost of high-emitting assets and incentivise the transition to climate-friendly solutions. The impact could be significant for EVs and less advanced technologies with competitive brown alternatives, such as H2 and sustainable fuels.

To ensure that net-zero solutions are unlocked at a global scale, it is important to bridge the decarbonisation technology gap. Many developing countries and emerging economies have made their Nationally Determined Contributions conditional on receiving climate finance, technology transfer, and capacity-building support. Scaling private capital mobilisation efforts helps to bridge the financing and technology gap in these countries.

Blended finance solutions, guarantees, and insurance (and insurance-like) products can provide important enhancements to a given investment's overall risk-return profile. This enables asset owners to deploy their capital while respecting their fiduciary obligations to clients and depositors. While beyond the remit of this discussion paper, the NZAOA has extensively engaged on the topic of blended finance.[133]

3.2 Additional enablers of the net-zero transition

In addition to policies addressing investors' challenges, further supportive actions could support the implementation of the above-mentioned enabling policies to net zero. Some examples are described next. This section does not intend to be exhaustive as other actions might have a meaningful impact.

Lifting barriers to investment from existing regulation could speed the transition. Streamlining the permitting and approval processes for new projects, for example, could prevent further delays in scaling technological deployment. Sector/value chain engagement is a form of direct influence available to investors. Investors and companies can identify the regulatory and policy hurdles (such as those identified in this discussion paper) and, as a result, conduct direct policy engagement to encourage the development of incentives and frameworks that would accelerate deployment.[134] Globally, permitting processes represent a major source of delays for renewables and other technologies. In Europe, four times more wind projects await permits than those under construction.[135]

132 World Bank (2022) State and Trends of Carbon Pricing 2022.
133 NZAOA (2022) Call on Policymakers to Support Scaling Blended Finance.
134 NZAOA (2022) The Future of Investor Engagement.
135 WEF (2023) Speeding up renewable energy—bottlenecks and how you resolve them.

Increasing the supply of trained workers through publicly funded university programmes, vocational training, or other packages such as the EU's Just Transition Mechanism can reduce bottlenecks due to the lack of specialised talent. In Europe, 85% of companies struggle to fill vacancies, notably for positions requiring green skills.[136] Despite supportive regulation, skilled labour shortages are a major problem for heat pump installation, for example. Germany needs about 60,000 skilled heat pump engineers, and the UK will need 4,000–6,000 more workers every year for the next six years.[137,138] Globally, the renewables industry could require up to 1.1 million additional construction workers for wind and solar projects and another 1.7 million to operate them.[139]

Unified frameworks such as Indonesia's green taxonomy and the EU taxonomy for sustainable activities mitigate market fragmentation, while also improving clarity about investments that can be claimed as green and can support the transition. In this way, they represent a valuable support to the creation of relevant enabling policies.

Consumer behaviour is crucial to enabling successful climate mitigation, as is addressing and lifting resistance from local communities. Behavioural incentives such as low-emissions zones in cities could help to reduce overall emissions and achieve net zero. In addition, when communities do not embrace or support net-zero initiatives, it becomes challenging to secure necessary permits, access land, and gain social license to operate. Overcoming these barriers requires effective community engagement, education, and engagement with local actors to build trust and ensure equity in transition processes and outcomes. Success here depends on low-carbon solutions being beneficial and inclusive for local communities.

Mandatory disclosure requirements and financial regulation reform could improve market clarity for investors in identifying policy action that is required to eliminate barriers and support the scale-up of relevant technologies. Corporate disclosure enables investors to effectively identify, assess, and manage risks and opportunities. By disclosing information on carbon footprint development, climate risks, decarbonisation targets, and other relevant factors within their portfolios, companies can demonstrate that their actions contribute to tangible outcomes. Emerging regulations such as the EU's Corporate Sustainability Reporting Directive require corporates to disclose their carbon footprints, decarbonisation targets, and climate risks. This gives investors more high-quality data to assess their climate-related risks and opportunities. Wider adoption of climate-related financial disclosures and reporting would help investors to weigh risk/return trade-offs with greater consistency when evaluating green and brown alternatives. It would also increase the availability of climate-related information that is both relevant and of a high quality; e.g. based on EU's Sustainable Finance Disclosures Regulation. Similarly, the UK launched the Transition Plan Taskforce in April 2022 to develop the gold standard for climate transition plans by companies.

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136 EIB (2023) Investment report 2022/23: Resilience and renewal in Europe.
137 Spiegel (2023) Heizungsbranche klagt über 60.000 fehlende Installateure.
138 Nesta (2022) How to scale a highly skilled heat pump industry.
139 McKinsey (2022) Renewable-energy development in a net-zero world: Overcoming talent gaps.

While these and other polices can help to accelerate decarbonisation, the world will not limit warming to 1.5°C without a just transition. The IPCC highlights the need for an inclusive and just transition across sectors and regions. As the transition generates investment and employment opportunities, it will also have distributional impacts, and low-income households and communities are naturally most at risk. The benefits of climate action hinge on carefully designed policies that will minimise these negative distributional impacts. For instance, revenues generated from compliance carbon markets could be partially reallocated to policies that support a just transition. Policies to boost job creation in the transition, and improve the quality of these jobs, will also help to build broad-based support for more ambitious climate action.[140] While new policy support could be critical to achieving net-zero objectives, all efforts could be in vain unless the most powerful stakeholders adhere to just transition principles.

Finally, in the transition to net zero, it is crucial to maintain a holistic perspective that considers the broader implications of decarbonisation action. Rushing to implement climate solutions without careful consideration can inadvertently shift the burden to other regions or result in additional social and environmental damage. For instance, the extraction of critical materials for renewable technologies may have adverse impacts on local communities and ecosystems. Water pollution, disruption to natural habitats, and climate migration can arise from poorly planned initiatives. Embracing nature-based solutions is one way to address these challenges as they provide multiple benefits through the safeguarding of ecosystems and through strengthened resilience. Furthermore, the transition to a low-carbon economy should consider the protection of jobs and ensure a just transition for affected workers and communities.

140 Inevitable Policy Response (2019) Why a just transition is crucial for effective climate action.

Annex 1

While technologies outlined as illustrative examples in this discussion paper are important for achieving stringent climate targets, it is also important to acknowledge the environmental implications of their large-scale deployment. The Alliance maintains that the immediate efforts of asset owners—and policymakers—must foster the rapid and deep cutting of GHG emissions as a priority. Doing so will ensure that fewer emissions will enter the atmosphere, thereby requiring less CO_2 removal technologies (CDR) in the future. The focus must be on accelerated action to cut emissions through the reduction of Scope 1, 2 and 3 emissions in line with science-based no/low overshoot scenario pathways to global net zero by 2050, or earlier if possible. Neutralisation via long-term carbon removal will be needed to reach net zero. The Alliance recognises that CDR solutions will therefore need to be developed at scale.

	Description of technology	Social and environmental considerations
Carbon Capture Use and Storage (CCUS)	CCUS is an abatement method of avoiding CO_2 emissions from industrial processes by capturing and using or storing the CO_2, thereby preventing it from being released into the atmosphere. In some cases when a CCUS store is linked to a Direct Air Capture unit (DAC) or through the capture of emissions used in the production and use of bioenergy (BECCS), then CCS can be considered a carbon dioxide removals (CDR) process. A CCUS scheme for abatement, or carbon reduction, typically comprises three processes: (1) capturing CO_2 from stationary emission sources; (2) transporting CO_2 to a storage site, and (3) injecting CO_2 into geological formations deep underground. (Source: UK Government CCUS Cost Challenge Taskforce) Usage (or utilisation) refers to using the captured CO_2 to produce commercially marketable products or services. CO_2 usage does not necessarily reduce emissions, thereby not delivering a net climate benefit. It is important to assess climate impacts of CO_2 utilisation on a lifecycle basis, as CO_2 captured from a fossil fuel origin would impact the overall carbon budget differently than CO_2 captured directly from the atmosphere. CO_2 utilisation remains a key area for future research and investigation, with immediate needs pointing towards securing permanent storage for captured CO_2.	Energy intensive operations makes CCUS expensive when energy costs are high. (Source: European Environmental Agency) **CO_2 leakages** from operations and post closure phases could lead to possible environmental damages and the reversal of emissions savings, thus requiring strong regulations for project management and monitoring. That said, these risks are considered to be relatively small. (Source: Princeton University) **Health and safety** are also a concern in regard to the large chemical inventories and usage at capture plant sites, highlighting the need to not decouple health, safety, and environmental considerations in planning stages. (Source: UK Government)

	Description of technology	Social and environmental considerations
Bioenergy with carbon capture and storage (BECCS)	BECCS involves the capture and permanent storage of CO_2 from processes where biomass is burned to generate energy. This can include power plants using biomass; pulp mills for paper production; lime kilns for cement production; and refineries producing biofuels through fermentation (ethanol) or gasification (biogas) of biomass. (Source: IEA) So far, research and industrial efforts have focused on two main routes of BECCS deployment: (1) BECCS via liquid biofuel production (biodiesel or bioethanol); and (2) BECCS via biomass conversation to heat and power, with direct pulverised combustion of biomass being the most common approach. (Source: Grantham Institute)	**Complex value chains with significant energy and carbon inputs**, different feedstock, and end processes will incur different energy costs and associated CO_2 emissions. **Potential implications exist for land-use, biodiversity, and food supply chains** in the conversion of land for bioenergy production purposes (direct and indirect land use change). Land-use change occurring at the beginning of a BECCS project resulting in emissions would incur a "carbon debt" that needs to be paid off before project brings net negative emissions. This "**carbon breakeven time**" can be between one and two years (in marginal land) up to 60 years (when converting forests). Land-competition and carbon-accounting perspectives are crucial considerations. **Impacts on resources, soil health, and biodiversity** are possible, especially when using high-quality land to grow bioenergy crops instead of food. **Water footprint,** including **water-use intensity** for crop growth and plant site, and **water pollution** from fertiliser application from farm level, can have negative impacts. However, the nature of these impacts is highly dependent on biomass type and region of production. (Source: Grantham Institute)

	Description of technology	Social and environmental considerations
Direct Air Capture (DAC)	Extracts CO_2 from the atmosphere directly at any location (not at point of emissions). This process is done using chemical filters and produces a concentrated stream of CO_2. The CO_2 captured can be permanently stored in deep geological formations or used in applications, such as in concrete, fuels, or permanent geologic storage. (Source: Rhodium Group, IEA)	**Less water and land are required** than for technologies such as BECCS. Being **location-independent** means projects can be located close to storage/utilisation sites and avoid land competition for agriculture or long-distance transportation. Smart siting is therefore required. **More robust, full-cycle environmental metrics** are needed, including those related to construction, transport, operations, and end-of-life. High **energy needs** are difficult to avoid as CO_2 in the atmosphere is more diluted than in point source. Environmental impacts **depend on background electricity sector decarbonisation** to improve sequestration efficiency. **Greater innovation in CO_2-use opportunities,** such as synthetic fuels to drive down cost, is needed. **Overreliance** ahead of absolute emissions reductions represents a risk. (Source: WRI, Nature)

	Description of technology	Social and environmental considerations
Green Hydrogen	Green hydrogen—produced with renewable energy—can help decarbonise hard-to-abate sectors including long-haul transport, chemicals, iron, and steel. (Source: IEA)	**Hydrogen-powered vehicles** could **improve air quality and promote energy security.** The **integration of renewables in the electricity system** is helped by storing energy over longer-periods. **Occupational health and safety** risks must be considered as hydrogen is a highly flammable gas (the transportation of which also poses risks of **community health and safety** in case of leaks or explosions). The production process also involves high-pressure equipment and the handling of hazardous chemicals. **Larger land units for use and cover change** are required. This could have negative impacts on biodiversity and food security, including potential loss of natural buffer areas such as wetlands, mangroves, and upland forests that mitigate against extreme weather events. **Significant water resources** are needed, which raises the risk of water scarcity, as well as introducing risks of freshwater and marine ecotoxicity. (Source: Inter-American Development Bank)

	Description of technology	Social and environmental considerations
Sustain-able/ Low-Emis-sion Fuels (SF)	SF can be grouped into gaseous fuels and liquid fuels. The former includes biogases, hydrogen, and synthetic methane, while the latter includes liquid biofuels, ammonia, and synthetic liquid hydrocarbon fuels. Both types can be produced from plants that absorb CO_2 from the atmosphere or through industrial processes powered by renewa-bles or other low-emission sources. (Source: IEA)	**Availability and accessibility of sustainable feedback** is a challenge, and further research is needed to develop efficient production, stor-age, and usage of gaseous and liquid fuels. **The use of first-generation feedstocks** can compete with food production and divert agricultural land into fuel production (i.e. corn). Growing demand for agricultural produce risks an increase in deforestation as well as a rise in the associated usage of freshwater, fertilisers, and pesticides. **Viability of second-generation feedstocks can depend on oil price fluctuations,** and **third-generation feedstocks** are energy intensive. Other challenges include the gradual increase in soil carbon content, time needed to replace vegetation used as feedstock for biofuels, and the development of global biofuel supply chains. (Source: National Institute of Health, The Royal Society)

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