IIGCC
The Institutional Investors Group on Climate Change

Climate Investment Roadmap

A tool to help investors accelerate the energy transition through investment and engagement

IIGCC REPORT 2022

Executive Summary

Institutional investors have an immense opportunity to rapidly align their portfolios with the goals of the Paris Agreement by reducing financed emissions, increasing investment in climate solutions and engaging with companies to ensure timely decarbonisation, as set out in the Net Zero Investment Framework.[1]

Decarbonising portfolios is an imperative for both managing the risks created by the net zero transition, and seizing the opportunities to invest in emerging, competitive low-carbon technologies. Given the damaging costs of climate change, on macroeconomic instability and investor returns, institutional investors have a financial incentive to support real world emissions reductions by reducing financed emissions in their portfolios.[2] At the same time, it is essential that they finance climate solutions, which are critical to the decarbonisation of portfolio companies and offer an attractive investment opportunity.[3] Measuring and reducing financed emissions of a portfolio may indirectly lead to investment in solutions as companies seek to replace emitting technologies, but not at the pace and scale required by the net zero transition.[4] Targets to reduce financed emissions may, for example, incentivise engagement with airline companies, but are unlikely to be successful if there are no commercial low-carbon fuels to decarbonise the sector.

This report aims to mobilise investors to scale up their allocation to climate solutions, showing what investments are needed, how much an asset contributes to closing the financing gap, and how to measure investor contribution. Most importantly, this report underscores the areas where investor engagement is needed, both to help corporates prioritise investments in climate solutions and to ensure corporate disclosures allow for the measurement of investor contributions. First, the report sets out what real economy investments are needed to 2050 at a regional and technology level, using the IEA's *Net Zero Emissions by 2050* scenario and the Food and Land Use Coalition's (FOLU) 'Growing Better' report as a starting point (Section 3).[5, 6] The analysis derives a set of priority technologies and sectors where investment needs and mitigation potential is largest (Section 4). Second, the report sets out the metrics and benchmarks that investors can use to assess how much an asset contributes to closing the investment gap to reach net zero (Section 5). The study finally set outs practical considerations as to how investors can channel finance to where investment needs are largest.

The goals of the Paris Agreement are likely to require over $126 trillion investment in climate solutions to 2050, with over $32 trillion needed in the 2020s, of which over 70% could be provided by the private sector. As can be seen in Figure 1, the scale up in capital needed is over $20 trillion in the 2020s relative to historic levels, with over 60% of this scale up required in non-OECD countries. Power and transport face the largest financing gap relative to historic levels in the next decade ($10 trillion and $4 trillion respectively). Asia Pacific is expected to need nearly 40% of total global investment and faces the largest scale up in financing relative to historic levels, $9.1 trillion in the 2020s. The private sector can play a key role, with the potential to mobilise 70% of total investments, as 70-80% of climate solutions are expected to be more attractive from a risk-return perspective than conventional options by 2030.[7]

Figure 1 - Scale up in capital required by region and sector in a Paris aligned pathway, 2021 – 2030

	INVESTMENT GAP (2021-30 COMPARED TO HISTORICAL; $ BILLION)						
REGION	ELECTRICITY	TRANSPORT	BUILDINGS	INDUSTRY	LOW-EMISSIONS FUELS	AFOLU	ALL SECTORS CONSIDERED
NORTH AMERICA	1,290	736	1,018	240	434	217	3,936
CENTRAL & SOUTH AMERICA	332	138	61	45	239	255	1,071
EUROPE	2,240	816	1,105	239	216	116	4,732
AFRICA	823	127	100	29	42	250	1,372
MIDDLE EAST	493	109	139	80	50	37	907
EURASIA	212	95	64	19	32	183	605
ASIA PACIFIC	4,376	1,992	842	1,117	359	452	9,138
GLOBAL	**9,767**	**4,014**	**3,329**	**1,769**	**1,372**	**1,510**	**21,760**

Note: 'Investment gap' reflects the additional investment needed in 2021-2030 on top of historical levels to reach net zero by 2050. Light and dark shades correspond to lower or higher investment gaps, respectively.
Source: Vivid Economics analysis based on International Energy Agency (IEA) data

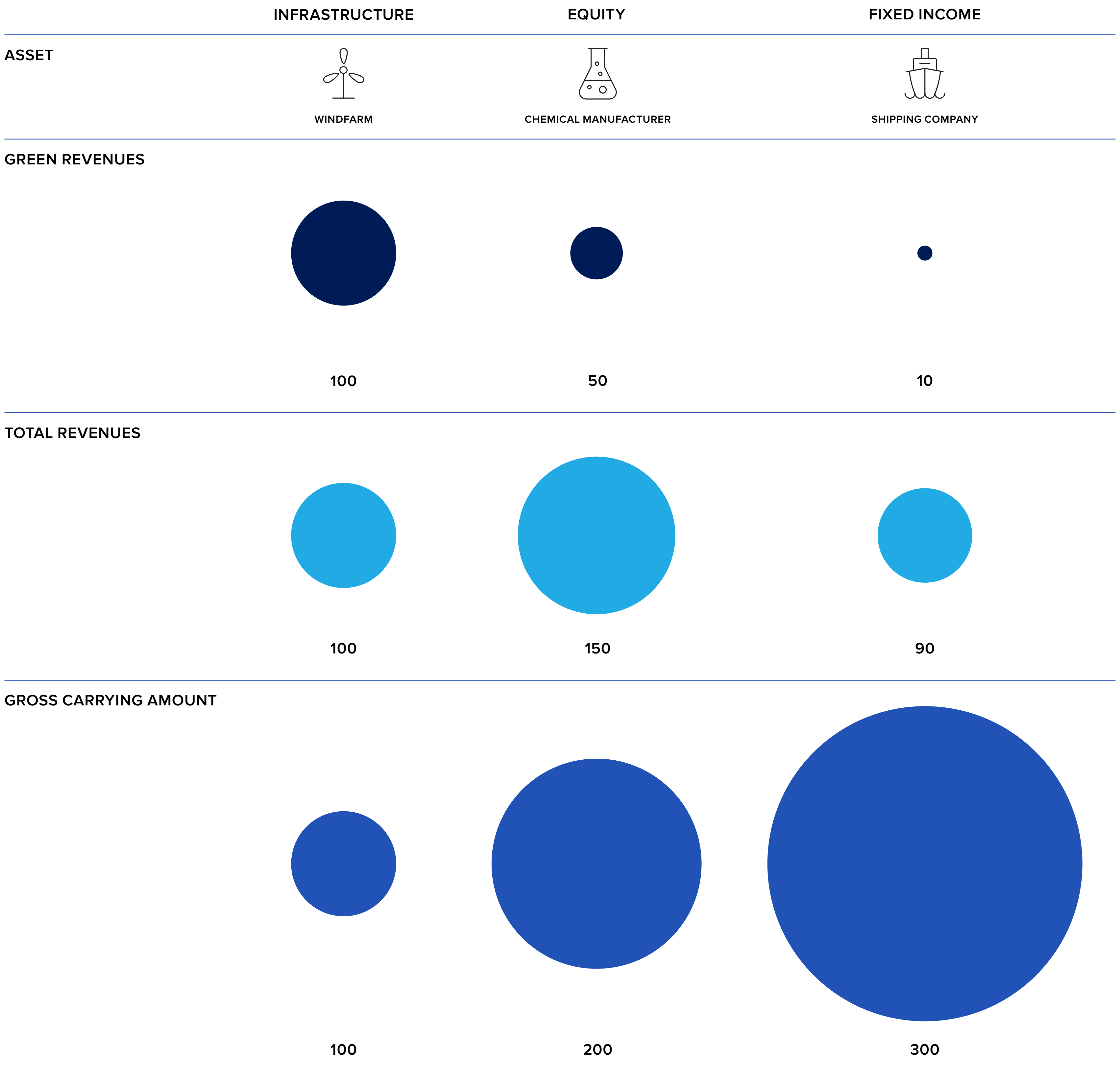
To help investors identify and prioritise the climate solutions most critical for scale up, the report identifies ten priority climate solutions where investors can either rapidly scale up investment or focus engagement efforts with corporates and policymakers. All technologies detailed in this report will require a rapid scale up in investment.[8] To focus investor efforts, however, the report highlights five technologies which require immediate at scale investment across their supply chain in the 2020s: solar photovoltaic (PV), wind, grid-scale electricity storage, new electricity lines and electric vehicle (EV) batteries.[9] The report also identifies five opportunities where investor engagement with policymakers will be essential to reduce barriers to investment: building retrofits, EV charging networks, hydrogen-based electricity, forest restoration and green steel. Engagement needs vary by these five opportunities but could include funding of demonstration projects and dialogue with policymakers to encourage their investment in network infrastructure.

The report then assesses the metrics that institutional investors can use to indicate whether, and how much, assets in a portfolio contribute to closing the net zero investment gap. Investors can use climate solutions metrics to assess which assets are actively contributing to the net zero transition, either by assets reducing their own emissions or enabling emissions reductions beyond the asset boundaries. This report assesses a wide range of metrics that have been proposed and used by leading organisations and initiatives and can be aggregated to the portfolio level. These range from bottom-up projections of emissions abatement associated with an asset compared to a business-as-usual scenario, to asset level indicators of alignment with taxonomies including green revenues, operating expenditures, capital expenditures, and patents. The report assesses the different options against criteria of whether the metrics are additional, easy to understand, science based, incentive-optimal, decision-useful, aggregable, and measurable (see Annex 7.3).

The report finds that in the short term, investors can start using a green investment ratio and a priority net zero investment ratio to measure their current exposure to climate solutions. A green investment ratio measures the share of a portfolio's total investments that are allocated towards climate solutions, as defined by the asset's associated green revenues that meet the criteria set out in sustainable investment taxonomies. The required indicators are increasingly mandated under reporting frameworks.[10] While it provides a comprehensive snapshot of a portfolio's exposure to climate solutions, it may not fully capture the varied impact that taxonomy-aligned activities can have on emissions reductions. Investors could therefore complement this with a priority net zero investment ratio, which measures the share of a portfolio's total investments allocated towards climate solutions with a critical impact on achieving net zero emissions by 2050, as identified in this report (Table 21 and Table 22).[11] These metrics can be calculated using revenues as shown in Figure 2, or using capex as corporate disclosures improve.

The strength of these metrics depends on the strength of the underlying data, which needs to improve significantly in the short term to allow for more accurate tracking of climate solutions. There are four key weaknesses to existing data sources used to calculate the green investment and priority technology ratios. First, sustainable investment taxonomies are mostly under development. There is no widely adopted single taxonomy, the criteria for complying with the taxonomies are often insufficiently clear, and they often do not include critical value chain activities. Second, corporate and investor reporting on these taxonomies is still sparse. Third, the scenarios to derive priority technologies for investors lack regional and technological granularity. The global scenarios in use today, including the IEA NZE scenario used in this report, could be more strongly rooted in national scenarios that capture the specifics of the systems transitions, enabling investors to set regionally specific technology investment targets more accurately.[12] Fourth, the firm level indicators that will be used to report taxonomy alignment (such as revenues) may not give a comprehensive picture of how a firm is contributing to closing the gap. For instance, revenues indicators are skewed by regional price divergences and do not capture R&D in climate solutions.

As the reporting environment evolves, investors can use a range of metrics depending on the type of sectoral transition they are seeking to understand. Ultimately, the net zero transition will look very different by sector and region and different indicators will be better suited at capturing mitigation efforts within each type of transition. Green revenues may be a better indicator in sectors where the net zero transition will be demand-led, such as the transport sector, as they are able to approximate consumer investment. However, revenues offer a weaker approximation of climate solutions in capital intensive sectors, such as electricity generation, where the net zero transition is characterised by a scale up of low-carbon infrastructure. In these sectors, capital expenditure provides a leading indicator of future emissions reductions and green revenues, recognised by the Task-force for Climate-related Financial Disclosures' (TCFD) recent guidance as an area for improved disclosures. The EU Taxonomy's reporting requirements and recent research by the International Sustainability Standards Board point towards better availability of climate-related indicators in future, including green capital expenditure and operating expenditure, as well as potentially a wider range of sector specific indicators.[13]



$$\text{GREEN INVESTMENT RATIO} = \frac{\text{Portfolio Green AUM} = 200 = (100 \times 1) + (200 \times 0.3) + (300 \times 0.1)}{\text{Portfolio Total AUM} = 600 = 100 + 200 + 300} = 33\%$$

Figure 2 - Example investor portfolio: calculation of green investment ratio

Note: Section 5.3 sets out eligible asset classes within the calculation.
Source: Vivid Economics

To illustrate the use of the two proposed metrics, the report sets out climate solution investment benchmarks for power, fuel supply and road mobility. Through a set of simple calculations, the study translates activity indicators and investment needs based on the IEA net zero scenario to sector level metrics. These reflect either green revenues or green capex intensity, depending on the better suited indicator of the sector's net zero transition. Globally, in electricity generation, around 84% of capex could be green in 2030, compared to 59% today; in the fuel supply sector, around 29% of capex could be green in 2030, compared to 1% today; and, in road mobility, around 63% of revenues could be green in 2030, compared to 14% today (see Table 1 for benchmarks by world region).

Investors may want to be careful, however, about relying on portfolio or asset class green investment ratio targets as the sole guide to scaling up climate solutions. Benchmarks based on real economy activity may not easily translate to financial investment in specific asset classes. This is particularly true for emerging economies, in which non-listed companies will play a key role in the net zero transition and where listed companies will most likely need to be ahead of their sector's average green investment ratio. A benchmark based on real world investment needs could therefore fail to set a sufficiently ambitious target for listed equities in a portfolio. Moreover, unless there is a strong assumption that an investor's portfolio represents the global real economy, even ambitious portfolio targets will not be enough to close the real-world financing gap. The latter will require not only targets for the greening of existing investments in a portfolio, but also targets for expanding access to climate solutions in international financial markets, such as renewables in Asia Pacific. In emerging markets, investors can utilise real economy benchmarks for strategic asset allocation purposes, and to channel capital to where it is needed. For instance, using them to scale up alternative investment strategies, such as direct co-financing with development finance institutions and capitalisation of local banks with science-based emissions reduction targets.

Looking ahead, the study highlights that future work focus on improving climate solutions data and strategies to increase institutional investor's exposure to regions and sectors facing the largest financing gap. Improved sustainable investment taxonomies and much wider reporting against them, mandatory disclosure of climate related indicators, and more granular investment trajectories – ideally at the country level, representing buy-in from a wide range of stakeholders – are all necessary to show investors where and how much to invest. However, these strategies will only be able to have an impact if channels exist to increase investor exposure to where the scale up in investment is largest. This could be investments in listed equities and bonds, but, more likely than not, it requires a significantly increased role of the financing of climate solutions in emerging markets through alternative asset classes. This could include dedicated climate funds, co-financing with development finance institutions, and capitalisation of local and regional green banks.

Table 1 - Green revenues intensity (green revenues/ total revenues) in a Paris aligned trajectory for road mobility

GICS	REGION	ROAD MOBILITY GREEN REVENUES INTENSITY BENCHMARKS		
		2020	2025	2030
251020*	North America	3%	37%	65%
	Central & South America	3%	40%	60%
	Europe	13%	43%	68%
	Africa	3%	40%	60%
	Middle East	3%	40%	60%
	Eurasia	3%	40%	60%
	Asia Pacific	22%	46%	63%

Note: The ratio reflects the % of total revenues in each sector that are associated with low-carbon or 'green' activities, defined in the Annex. *GICS 251020 does not include heavy duty vehicles.
Source: Vivid Economics based on IEA Net zero scenario

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Introduction and User Guide

0.1
Context

Institutional investors have an important role in financing the net zero transition, which is likely to require investment of nearly $130 trillion from now to 2050 in activities that support emissions reductions.

The net zero transition will require a substantial increase and shift in investment towards activities that are either low-emissions today or enable emissions reductions in the future. To achieve this scale up in investment is likely to require active ownership strategies to ensure that companies establish credible transition plans to achieve their short- and long-term science-based climate targets. Approximately 61% of investment is expected to be needed in non-OECD regions, with over 15% in technologies that are currently at low levels of technology readiness.[14] Institutional investors could play a vital role in achieving the investment needed, given their ability to direct financing. As at 2019, the top 500 asset managers accounted for over $100 trillion assets under management (AUM), a signal of their critical role in scaling up climate finance.[15]

Asset owners and managers also face a strong financial incentive to mobilise capital into net zero activities, given the large systemic costs they could face from a slow or disorderly transition. All financial institutions face transition risks (and opportunities) due to the net zero transition, which may lead to large shifts in the demand and price of assets in the coming decades.[16] Financial returns will inevitably be closely tied therefore to exposure to assets with transition risks or opportunities. Moreover, portfolios are exposed to the systemic risks arising from a failure to reach net zero, including increased macroeconomic and financial market instability.[17] Due to their longer-term liabilities and wide-ranging asset ownership, institutional investors are highly vulnerable to these systemic risks. Their returns are closely tied to economy-wide performance and, in the context of climate change, these 'universal owners' have a powerful financial incentive to ensure that their portfolios are supporting real-world emissions reductions as part of an orderly transition to net zero.[18]

A growing number of institutional investors are seeking, as a result, to measure and target the alignment of their portfolios with a 1.5˚C pathway. There is a growing commitment among institutional investors that they can and should contribute to achieving the Paris Agreement through their investment portfolios, demonstrated by the membership of net zero commitment initiatives, such as the Paris Aligned Asset Owners, Net Zero Asset Managers, and the Net-Zero Asset Owner Alliance (NZAO). These initiatives advise investors to set targets for carbon dioxide-equivalent (CO_2e) emissions reductions that are consistent with the emissions reductions required for a 1.5˚C pathway. These targets reflect portfolio decarbonisation initiatives, which focus on measuring the alignment over time of the emissions of a portfolio and its associated assets. Measurement of these current and future financed emissions is critical to inform target setting and to guide engagement activities in emissions-intensive areas of a portfolio, as highlighted by the TCFD's technical guidance.[19] However, such efforts are also only a partial guide to scale up net zero finance.

A range of barriers prevents investors achieving portfolio alignment targets or mobilising capital to regions and technologies that face the greatest net zero investment need. To increase finance towards climate investment needs investors can rely on a multi-faceted strategy that overcomes the four challenges that investors commonly report today, namely:

1. **Limited information on Paris-aligned investment needs at a regional level,** which poses a fundamental challenge to understanding where and how to invest. This challenge stems from the lack of national investment roadmaps and consistent sectoral transition pathways.

2. **Limited tools to measure and benchmark an investor's contribution to activities supporting emissions reductions (referred to as 'climate solutions'),** which reduces investors' ability to set meaningful targets or assess their impact on achieving (or obstructing) a net zero transition.

3. **Limited data on existing climate solutions investment opportunities,** which stems from the insufficiency of corporate disclosures and 'transition plans' to assess company strategies towards climate change, and the absence of a global Paris-aligned finance taxonomy.

4. **Limited scale of available climate solutions investment opportunities,** with more capital seeking climate solutions than there are profitable opportunities available. This results from a range of real-world challenges that reduce the risk-adjusted returns of investment into climate solutions, from small transaction size to an insufficiently high carbon price in most regions.

This report seeks to alleviate some of the challenges investors face when understanding where to invest and how to better understand their portfolio's contribution to a Paris-aligned world. In doing so, the report sets out clear investment needs, highlights priority technologies, and examines 'climate solutions metrics' that aim to support investors to implement the Net Zero Investment Framework recommendation to increase allocation to climate solutions. Though decarbonisation approaches are a critical starting point to help investors exert their influence, they are only a partial guide on where and how investors could engage and invest to achieve targets. This is because they do not capture an asset's overall impact on economy-wide emissions.[20] As a result, emissions metrics may highlight the need to engage with the aviation industry, but they do not identify companies that enable the sector's decarbonisation, such as advanced biofuels manufacturers. The focus on climate solutions fills this gap by accounting for the many spillovers that an asset can have on economy-wide decarbonisation beyond its own scope 1 and 2 emissions. This impact can occur through supply of low-emissions alternatives (e.g. plant-based meat substitutes); innovative mitigation technologies (e.g. from wind turbine manufacturers); and network infrastructure to enable uptake of mitigation options (e.g. batteries).

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0.2
Purpose of this Report

This report is directed to institutional investors, both asset owners and asset managers, with the primary aim to help these investors scale up their investments in climate solutions in line with the recommendations of the Net Zero Investment Framework.

To achieve this the report makes three unique contributions to ongoing discussions around investment in climate solutions:

1

Clear, granular investment trajectories to reach net zero at a technology and regional level, set out in the report (see Chapter 2: Investment trajectories).

2

An investor-minded **framework to prioritise technologies** and a suggested set of priority technologies (see Chapter 3: Technology prioritisation framework).

3

A set of **financial metrics to measure and track the contribution of a portfolio and its assets to net zero** emissions reductions (see Chapter 4: Financial metrics).

There are five important use cases this report could have for investors, helping to:

- Improve understanding of the real-world impact of the net zero transition, including the scale of investment opportunities and variations by region and sector, as well as their financial implications for an investor portfolio.
- Set credible and ambitious real-economy targets to finance net zero investment needs, by helping them to measure their portfolio's current exposure and track performance over time.
- Guide engagement and capital reallocation decisions, by providing tools to measure and benchmark the degree to which an asset or portfolio is financing the net zero transition.
- Prioritise technology areas for engagement between investors, corporates and the public sector to accelerate their development and deployment.
- Inform structured conversations between investors, policymakers and data providers on what is required to fill identified investment gaps in suggested priority technologies.

The report's findings can be useful to guide discussions between investors, development finance institutions, policymakers and data providers on how to solve wider challenges of transition financing. The challenges facing net zero investments often extend beyond the reach of any one investor to tackle. These challenges include the lack of data on corporate activity, limitations of net zero taxonomies and insufficient carbon pricing or supporting policy and regulatory frameworks. The report recognises that simply understanding and tracking net zero investments will not be sufficient to increase finance at the scale and pace required for an orderly transition. Though the work does not attempt to address all the wider challenges associated with investment in climate solutions, it makes several contributions to this discussion by highlighting how net zero scenarios, taxonomies and corporate disclosures could improve in order to meet investor needs. The report also provides tools to identify and track net zero climate solutions, helping to show where policy and investment efforts still need to be strengthened. Activities to expand the universe of climate-related investment opportunities and better match capital to investment opportunities continue to be essential, particularly in emerging and developing markets that attract little finance towards climate solutions relative to their expanding investment needs.

0.3
How to use the Report

The report's findings are set out in the following five sections.

Chapter 1.
Global Emission Trajectories

Looks at the emissions reductions required to reach net zero, by sector and region, and explains the deviations between climate scenarios.

Chapter 2.
Investment Trajectories

Sets out the real-world investment needs to achieve net zero emissions reductions, providing information for key technologies and regions.

Chapter 3.
Technology Prioritisation Framework

Highlights which technologies to prioritise and how to increase investors' ability to finance net zero activities.

Chapter 4.
Climate Solutions Metrics

Reviews current methods to track investment in net zero activities and sets out a set of financial metrics that investors can use going forward.

Chapter 5.
Summary of Caveats and Next Steps

Sets out how the report's findings can be implemented and improved upon going forward.

A range of public, regularly updated sources is used as inputs to investment needs analysis. The main source used is the IEA 'Net Zero by 2050' report, whose global investment projections are downscaled to granular investment estimates for all sectors except for AFOLU (due to the IEA's lack of coverage of these sectors). To downscale IEA investment figures, a range of regular IEA publications have been used, including the World Energy Outlook (updated annually), the World Energy Investment report (updated annually), World Energy Balances (updated annually) and the Energy Technology Perspectives report (which has less regular updates), the Global EV data explorer (updated annually), the Mineral Needs for the Clean Energy Transition 2021 report, and the G20 Hydrogen 2020 report. Additional data sources include intergovernmental organisations (e.g. IRENA or UNCTAD), consultancies (e.g. McKinsey), industry bodies (e.g. World Steel Association), research papers published in reputed journals (e.g. *Sustainability*). In addition, investments in AFOLU were included using Vivid Economics analysis of sources such as the FOLU report, FAO data, and the NGFS Divergent Net Zero 1.5°C scenario.

The investment projections are subject to some uncertainty due to assumptions used to allocate investments at a regional level and uncertainty relating to technology uptake. First, as the IEA 'Net Zero by 2050' report provides only global investment estimates, the final investment trajectories rely on assumptions on the regional allocation of investment. The model allocates net zero global investments across major world regions and countries using the 2020 World Energy Outlook 'Sustainable Development Scenario' (SDS) regional analysis. In cases where sector-specific data is missing for certain countries or regions, IEA GDP projections are used instead as a proxy to allocate investment flows. Second, as a forward-looking model, the projections are subject to uncertainty over how a technology and sector will decarbonise and the costs of decarbonisation efforts. Uncertainties that investors could consider include regulatory uncertainty (the competitiveness of different technologies depends on the policy environment); technological uncertainty (various technologies considered are at an early stage in their technology and commercial readiness, such as Carbon Dioxide Removal, or CDR); behavioural uncertainty (as attitudes towards air travel or dietary change are often difficult to predict); and, socioeconomic uncertainty (as different forecasts of population and GDP growth affect both the scale and type of mitigation needed). As a result of these uncertainties each scenario presents only one of many plausible pathways to reach 1.5°C, with the differences between scenarios discussed in detail in Sections 2 and 3 of the report.

Global Emission Trajectories

1.0

1.0 Global Emission Trajectories

This chapter introduces climate scenarios and discusses the emissions reductions required by sector and region in Paris-aligned scenarios, such as IEA's Net Zero by 2050 pathway.

Section 1.1 provides context on current greenhouse gas (GHG) emissions, Section 1.2 introduces the purpose and key components of climate scenarios, which look at how these emissions might develop in the future. Sections 1.3 and 1.4 set out what decarbonisation looks like in a net zero scenario, broken down by sector and geography respectively. This provides the context for investment requirements to meet net zero, discussed in Section 2.

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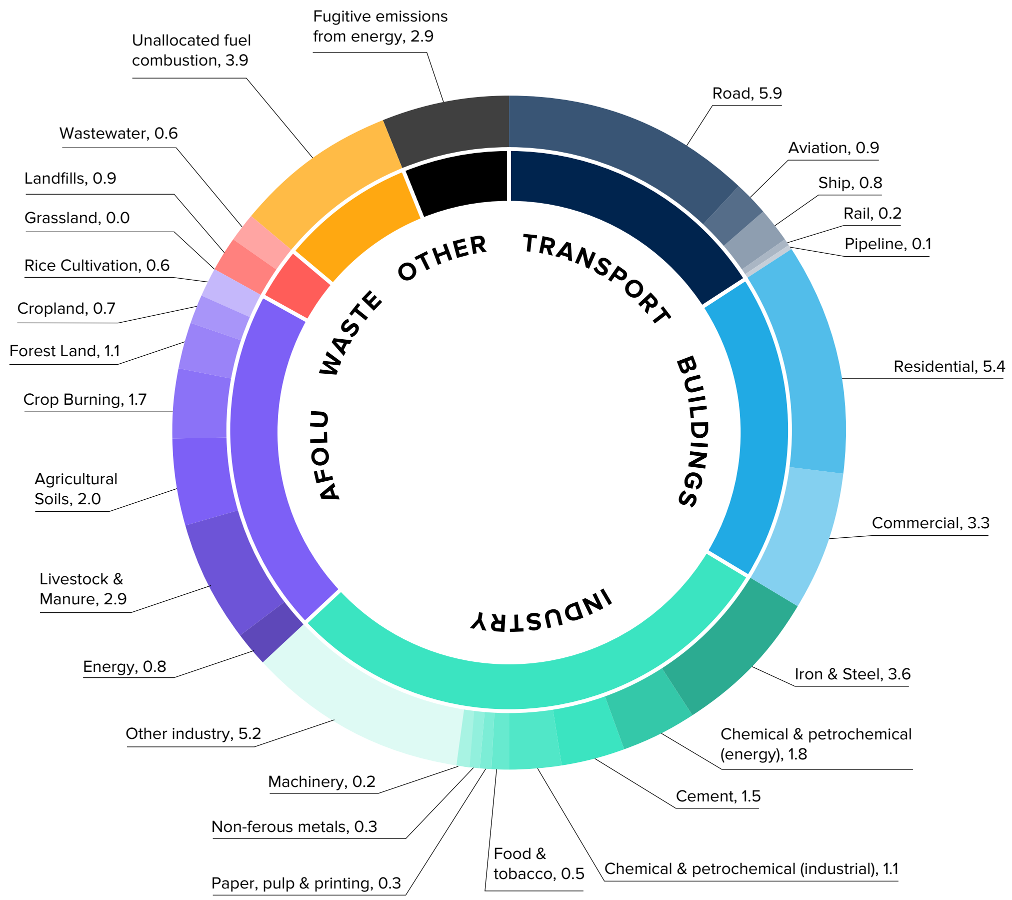
1.1 Overview of Global Greenhouse Gas Emissions

In 2019, CO_2 emissions from the energy sector reached a historic high of 36 Gt.[21]

Despite increasing awareness of the impact of CO_2 and other GHGs on the climate, emissions have continued to rise steadily over the past three decades – a trend that is likely to continue as many developing countries are expected to increase their emissions in coming years as they industrialise and modernise their economies. Since 1850, the world has emitted approximately 2,390Gt of CO_2.[22] Estimates of emissions are subject to high uncertainty: when accounting for non-energy sectors and non-CO_2 GHGs, 2019 emissions have been estimated to be as high as 59Gt CO_2e.[23]

To achieve the Paris Agreement's goal of limiting global warming to 1.5°C above pre-industrial levels, these emissions must fall rapidly. According to the Intergovernmental Panel on Climate Change's (IPCC) 2018 'Special Report on Global Warming', constraining temperature increases to 1.5°C would require limiting additional cumulative CO_2 emissions to 580Gt. In its latest 2021 report (AR6), this has fallen to just 500Gt from the start of 2020.[24] At current levels of emissions, and under scenarios which assume that only current policy commitments are implemented, this budget would be exhausted within 15 years. If emissions from non-energy sectors and non-CO_2 GHGs are fully accounted for, the time remaining may actually be much shorter. The remainder of this chapter discusses climate scenarios that have been developed to better understand emissions and technology pathways to limit warming to 1.5°C. The implications for investment trajectories are discussed in Chapter 2.

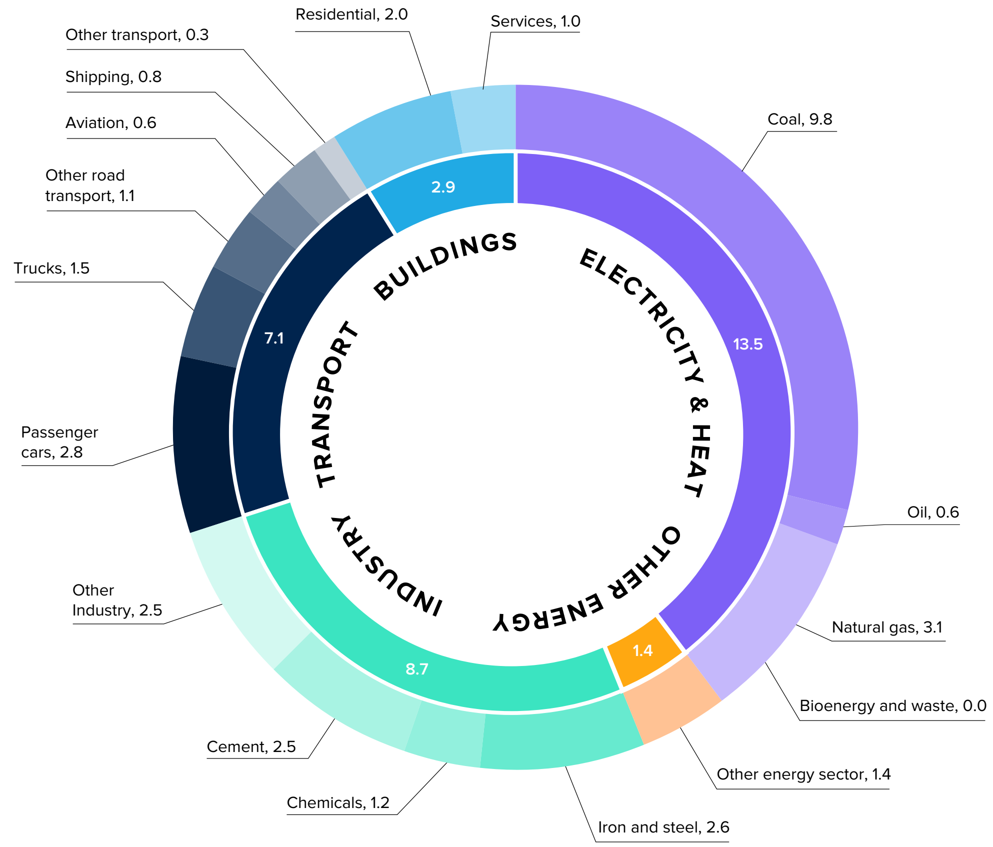
Figure 3 - GHG emissions by sector in 2016, Gt of CO_2



Note: Global GHG emissions in 2016 were estimated at 49.4 billion tonnes of CO_2e.

Source: Adapted from Our World in Data (2020), based on data from Climate Watch and the World Resources Institute.

Figure 4 - Energy-sector CO_2 emissions in 2020, Gt



Note: Shows total energy sector-related emissions (excluding AFOLU). Global energy sector-related CO_2 emissions were estimated at 34.2Gt in 2020.

Source: IEA Net zero scenario (2021)

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1.2
Climate scenarios: aims, methods and constraints

Scenarios can be a useful tool for investors, to help them understand both how they might be affected by climate change, and how they can contribute to achieving better climate outcomes.

Despite the inherent uncertainty of scenario modelling, scenario analysis can be helpful for an organisation to consider the impact that a range of plausible future states might have on their operations. For investors, this might include understanding how physical and transition risks vary by region, sector and asset class, allowing them to diversify their portfolio and improve risk management.[25] In addition, understanding the inputs required to achieving a particular climate outcome can help to explore where additional investment is needed, and so improve the mobilisation and allocation of capital towards this goal.

This section sets out the aims, approaches and components of climate scenarios. The section notes the key uncertainties which can contribute to differences between scenarios, and what is required to describe a scenario as 'aligned with the Paris Agreement'. It then discusses some of the most prominent scenarios, and motivate our choice of the IEA's NZE scenario as the basis for the remainder of this report.

A climate scenario is defined as 'a plausible representation of future climate that has been constructed for explicit use in investigating the potential impacts of anthropogenic climate change'.[26] Climate scenarios typically combine economic Integrated Assessment Models (IAMs), which give projections of human activity and associated GHG emissions, with scientific climate models, which translate these cumulative emissions levels into expected temperature changes. The IAMs can often be further broken down into separate modules: for example, an energy module and a land use module. Combined, models provide a scenario which describes a single path of development leading to a particular outcome.[27]

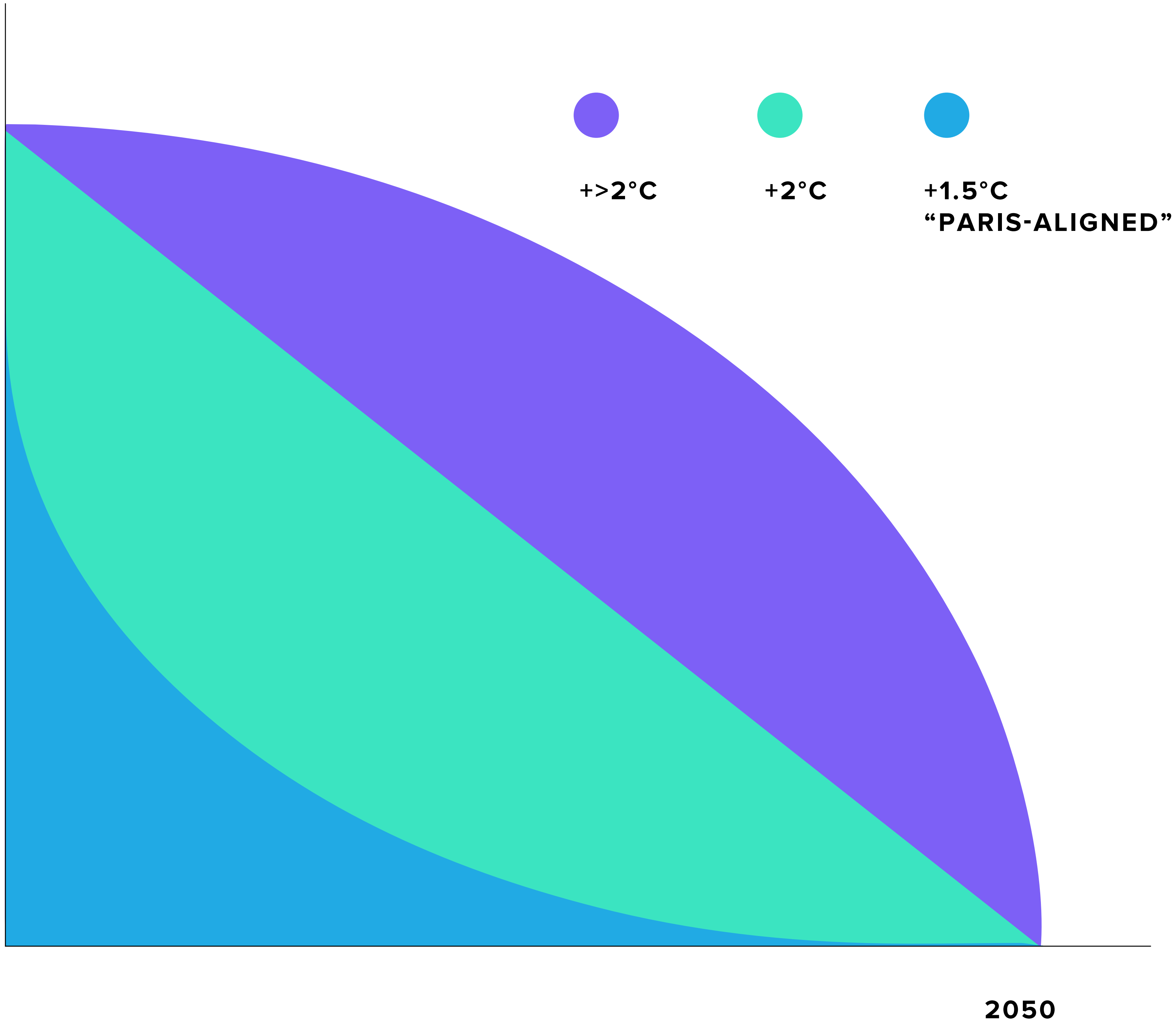
A scenario provides one coherent picture of how the world could look in the future, characterised around socioeconomic assumptions (e.g. GDP growth), activity levels (e.g. oil production, EV sales, green steel production) and a temperature outcome (e.g. a 1.5°C increase). One common approach to scenario analysis is to set a 'carbon budget'.[28] A carbon budget is the cumulative amount of CO_2 and other GHG emissions which are permitted under a given scenario. Because temperature is determined by atmospheric concentrations of GHGs, carbon budgets correspond to a given probability of meeting a particular temperature target. In 'net zero' scenarios, this is often a 50% likelihood of limiting temperature increases in 2100 to 1.5°C over pre-industrial levels (including the possibility of temperatures initially overshooting and then falling back by 2100), in line with the Paris Agreement targets. Scenarios are also shaped by assumptions around socioeconomic trends. Each of the five IPCC's Shared Socioeconomic Pathways (SSPs), for example, offer a broad narrative of future socioeconomic trends, ranging from sustainable growth and increasing equality, to resurgent nationalism and growing inequality.[29] Each narrative implies a different trajectory for factors such as GDP growth, population growth, and resource availability, which then form inputs to IAMs to generate a set of economic activity pathways for a specific temperature target.

Climate scenario outputs are highly sensitive to the input assumptions that are fed into their component models. For example, models may make explicit assumptions regarding cost projections of various technologies, including CDR technologies, that are not yet widely commercially available.[30] Differing assumptions about how these technology costs develop over time could lead to different investment choices to minimise the cost of reaching net zero. Models which rely on currently immature technologies being rolled out rapidly and deployed with high levels of effectiveness may also appear to allow higher levels of economic activity relative to models which make more pessimistic technology assumptions. Moreover, economic models which focus on cost minimisation can struggle to capture the impact of policy or behaviour changes. The scale and complexity of climate scenario modelling, and the wide range of input assumptions required, mean that there is inevitably a high level of uncertainty surrounding their projections.

Additionally, carbon budgets are themselves subject to assumptions and can differ between models. The IPCC's 2021 report gave a remaining carbon budget of 500Gt of CO_2, but key uncertainties relating to non-CO_2 emissions, levels of recent historical emissions, and the relationship between CO_2 emissions and warming created uncertainties of several hundred Gt in either direction.[31] Recent research has built on this analysis to quantify the remaining carbon budget in 2020 at 230–670Gt of CO_2 (for a 67–33% probability of not exceeding 1.5°C), although differing levels of other GHG emissions may increase or reduce this figure by approximately 170Gt.[32] The IEA's NZE scenario estimates the remaining carbon budget at 500Gt, which is broadly consistent with these parameters.[33]

An important consideration for climate scenarios is whether they limit cumulative GHG emissions to within the remaining carbon budget – rather than the date by which they achieve net zero. Scenarios which reduce emissions linearly to 2050, or increase emissions in the short term before enforcing rapid cuts in later decades, result in higher cumulative emissions than those which enact more rapid reductions. They are therefore more likely to exceed the carbon budget associated with limiting warming to 1.5°C. Consequently, 'net zero by 2050' alone does not imply Paris alignment, and may be insufficient to prevent negative climate outcomes. Negative emissions after 2050 can also be important drivers of the eventual temperature outcome.

Figure 5 - Cumulative CO_2 emissions under three net zero scenarios



Note: Figures are illustrative only.
Source: Vivid Economics

1.2.1 Scenario Selection

This report focus on a net zero pathway which is aligned with the Paris Agreement.

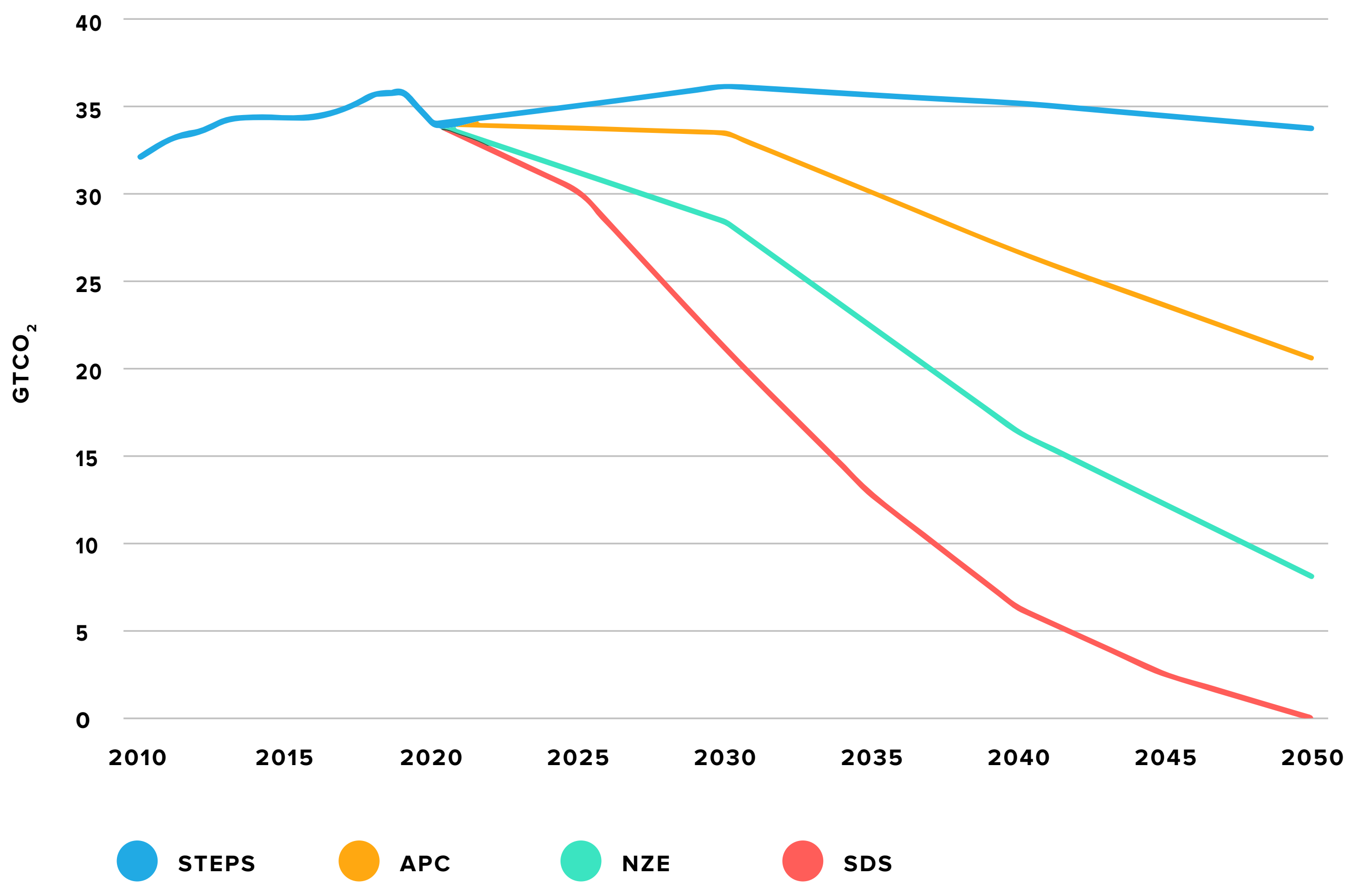
The report uses the Paris Aligned Investment Initiative (PAII) definition of Paris Alignment, which requires a high probability of limiting warming to 1.5°C. In particular, the pathway must:

1. Be associated with limiting warming to 1.5°C above pre-industrial levels with at least 50% probability;
2. Reach global net zero emissions by 2050, or sooner;
3. Have a global peak emissions year of the current year or later; and
4. Rely on a limited volume of Negative Emissions Technologies (NETs) to 2050.[34]

Many alternative scenarios are available, although not all of these are Paris-aligned. The International Institute for Applied Systems Analysis (IIASA) hosts a database of 1,184 peer-reviewed scenarios across 31 different models, which were reviewed in the IPCC's Fifth Assessment Report.[35, 36] Important differences between these scenarios include level of ambition (i.e. carbon budget and level of warming achieved), and sectoral coverage (i.e. whether they include emissions from AFOLU, or from the energy sector only). Inclusion of AFOLU emissions is particularly important as this sector is responsible for just under a quarter of anthropogenic GHG emissions.[37] A selection of prominent scenarios is presented in Table 2 at the end of this chapter.

This report focuses on the IEA NZE, supplemented by the SDS. The IEA scenarios have several key advantages. They are peer-reviewed by sources from academia, government and industry, which strengthens their credibility and facilitates comparison and integration with other work. The scenarios generally provide some breakdown of economic activity and CO_2 emissions by region and sector, allowing the development of a more granular picture of investment needs. The NZE in particular is fully aligned with the Paris Agreement, and provides a clear indication of a likely path to net zero by flagging both key technology investments and the sectors that are harder to abate. Moreover, the NZE makes very limited use of offsets and NETs such as Direct Air Capture and Storage (DACCS). However, due to the recent development of this scenario, full regional breakdowns are not yet available. Where necessary, analysis is therefore supplemented with the SDS, for which greater granularity is available. Both scenarios are contrasted with Stated Policies (STEPS), which set out the current global trajectory based on Nationally Determined Contributions (NDCs) and policy commitments.

Figure 6 - Global net CO_2 emissions by IEA scenario



Source: Data from IEA World Energy Outlook (2021) and IEA Energy Technology Perspectives (2020).

The report compares the IEA's NZE with alternative 1.5 °C scenarios, such as the Divergent Net Zero scenario of the Network for Greening the Finance Sector (NGFS), to highlight key uncertainties in reaching net zero.

The IEA's NZE represents one of many possible paths to achieve a 1.5°C target. Though this scenario is core to our discussion of how to reach net zero, the study recognise that there are numerous uncertainties that affect the IEA's results. For example, comparison with the IPR 1.5 and NGFS 1.5°C scenarios shows that while core mitigation levers and technologies are consistent, the degree to which they are used can differ substantially. Both the IPR and NGFS 1.5°C scenarios are less reliant on carbon sequestration, both carbon capture, utilisation, and storage (CCUS) and land use, requiring much greater policy stringency and a stronger switch to low-carbon energy sources to meet emissions targets. The NGFS 1.5°C scenario exhibits a slightly greater renewables share in electricity generation (solar and wind's share of electricity generation is 4% higher in 2050) and higher electrification in buildings, industry and transport sectors (an 8% higher share of electricity in final energy consumption). In comparison, the IPR's RPS exhibits a lower renewable share (solar and wind's share is 13% lower in 2050 than the IEA's results) and similar level of electrification (both have a share of 49% electricity in final energy consumption). The IPR scenario projects higher deployment of hydrogen-based electricity relative to the IEA to achieve similar emissions reductions in the power sector (5% higher hydrogen-based electricity in 2050 relative to the IEA's results). Final energy demand in the NGFS scenario is reduced by nearly 10% relative to IEA NZE energy use in 2050, reflecting higher carbon costs (approximately \$630/tCO_2 in 2020 real prices, relative to around \$250/tCO_2 in IEA NZE) and greater energy efficiency improvements. Hydrogen adoption is moderate, on the other

Table 2 - Comparison of key climate scenarios

SOURCE	SCENARIO	SECTOR COVERAGE	TEMPERATURE OUTCOME (°C)	DESCRIPTION
1.5˚C SCENARIOS				
IEA	Net Zero Emissions by 2050 (NZE)	Energy sector (excludes AFOLU)	1.4	Assumes higher shares of carbon sequestration to achieve net zero, with approximately 7.6Gt CO_2/year by 2050, including CO_2 removal from bioenergy with carbon capture and storage (BECCS) and DACCS. 49% of final energy demand comes from electricity generation in 2050, and hydrogen use is 20EJ/year.[38]
NGFS	Orderly: Net Zero 2050	All sectors	1.5	Assumes stringent climate policies are introduced early and a high innovation environment is cultivated, limiting warming to 1.5°C. Electricity provides 53% of final energy demand in 2050 while hydrogen use is 18EJ/year. CCS delivers around 8.5Gt CO_2/year by 2050.
NGFS	Disorderly: Divergent Net Zero	All sectors	1.5	Assumes policies are delayed and divergent across countries, but sufficiently stringent to reach 1.5˚C. 58% of final energy comes from electricity in 2050 while hydrogen use is 16EJ/year. CCS delivers around 6Gt CO_2/year by 2050. There are particularly high transition costs associated with this scenario, which assumes a carbon price of ~\$630/tCO_2 per year (2020 real prices).
IRENA	1.5°C Scenario (1.5-S)	Energy sector (excludes AFOLU)	1.5	Assumes relatively higher renewable penetration and hydrogen deployment to reduce emissions.
PRI	Inevitable Policy Response: Required Policy Scenario	All sectors	1.5	IPR's assessment of future policy developments needed to accelerate emissions reduction and hold the global temperature increase to a 1.5 degree outcome.
2˚C CONSISTENT SCENARIOS				
IEA	SDS	Energy sector (excludes AFOLU)	1.6	Assumes actions are taken to meet the energy-related UN Sustainable Development Goals by 2030, leading to significant reduction in global warming.

hand, approximately 20% lower in 2050 relative to the IEA NZE scenario. In comparison, final energy demand in the IPR scenario is reduced by only 2% relative to IEA NZE.

Though differences between any 1.5°C scenario are inevitable, there are often more commonalities than differences in reaching net zero and these ought to be recognised. First, to be credible, the IEA and NGFS both apply similar limits on the plausibility of key levers, in line with the IPCC's scenario analysis and assumptions around technical feasibility. In both scenarios, sustainable bioenergy potential is limited to approximately 100EJ in 2050, and carbon capture and storage (CCS) potential is limited to 5–6 $GtCO_2$ per year by 2050. Second, across all 1.5°C scenarios, the scale of emissions reductions needed implies the use of nearly all mitigation options across the economy. In the case of the IPR's RPS, a similar limit is applied to sustainable bioenergy potential; while no limit is applied to CCS potential in the IPR scenario it falls within the 5-6 $GtCO_2$ per year by 2050 range. Core mitigation levers include the decarbonisation of electricity through a high penetration of renewable energies, increased electrification of end-use sectors such as transport and buildings, more efficient use of resources, and adoption of new technologies, including carbon sequestration, to tackle remaining hard-to-abate emissions. Third, the IEA, NGFS and IPR scenarios all adopt a 'middle of the road' socioeconomic pathway as a basis for economic growth, which assumes that society evolves broadly in line with past trends and that global population stabilises towards the end of the century.

NGFS	Orderly: Below 2°C	All sectors	1.7	Assumes climate policies are introduced early and gradually become more stringent, leading to reduced transition costs compared to the NGFS's delayed transition scenario.
NGFS	Disorderly: Delayed transition	All sectors	1.8	Assumes that policies are delayed and divergent across countries and sectors leading to higher transition risks of reducing global warming to below 2˚C.
PRI	Inevitable Policy Response: Forecast Policy Scenario	All sectors	1.8	IPR's assessment of what is anticipated, in terms of future policy developments and the subsequent impact on emissions reduction and temperature outcomes.
2.5+˚C SCENARIOS				
IEA	STEPS	Energy sector (excludes AFOLU)	2.6	Assumes current policies and commitments, including NDCs and stimulus packages in response to COVID-19.
NGFS	Hot house world: NDCs	All sectors	~2.5	Assumes that some climate policies are implemented in some jurisdictions, but globally efforts are insufficient to halt significant global warming.
NGFS	Hot house world: Current Policies	All sectors	3.0+	Assumes that climate policies are implemented in some jurisdictions, but globally efforts are insufficient to halt significant global warming.
IEA	Announced Pledges	Energy sectors (excludes AFOLU)	2.1	Assumes current policies and commitments, including NDCs and stimulus packages in response to COVID-19, plus all high-level announced pledges are achieved.

Note: Temperature outcome refers to having a 50% likelihood of limiting warming to this amount over pre-industrial levels by 2100.
Source: Vivid Economics

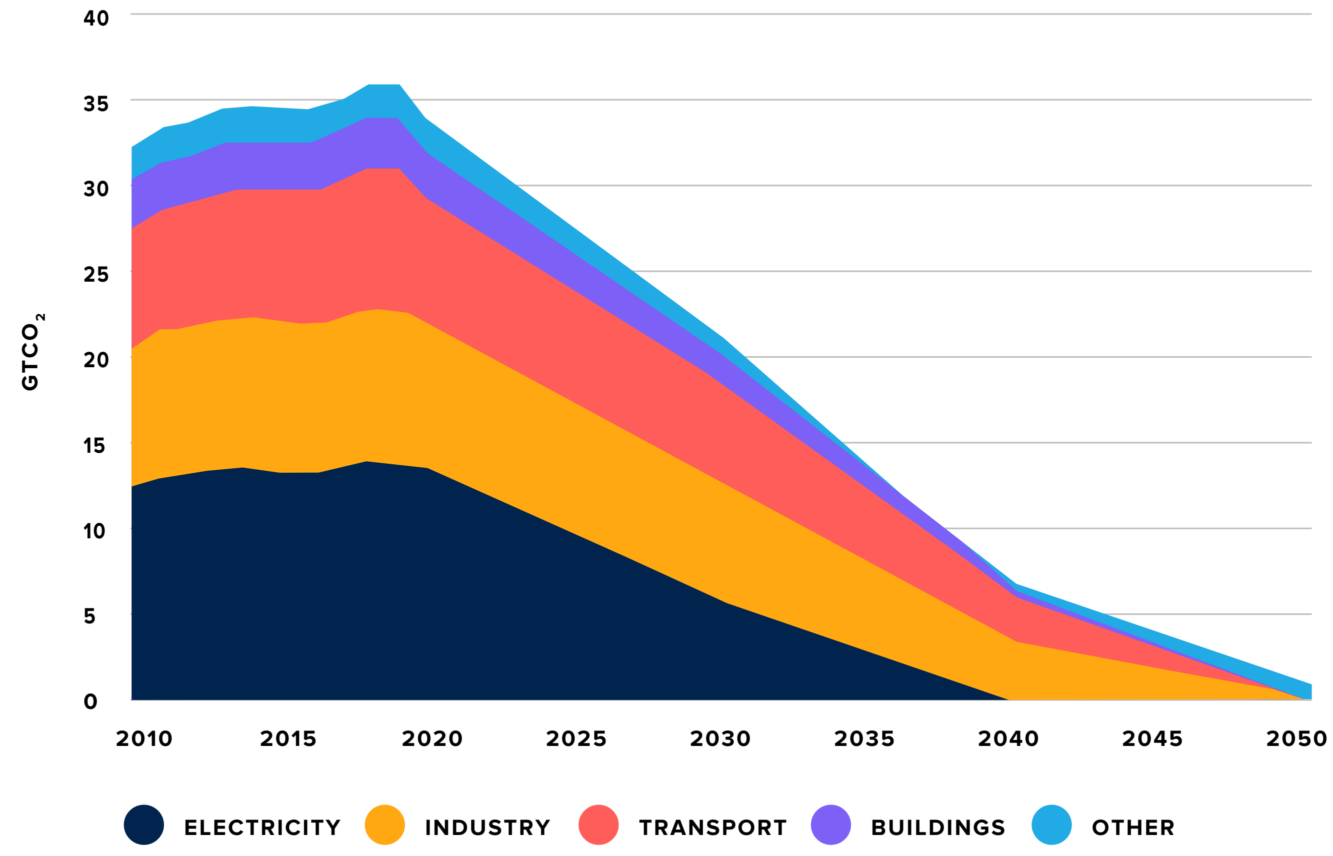
1.3 How the IEA NZE reaches net zero

The NZE achieves net zero CO_2 emissions around 2045 in major economies, and by 2050 on a global scale.[39]

For the SDS, these milestones are achieved in 2050 and 2070 respectively. In contrast to STEPS, where CO_2 emissions remain elevated until the 2040s, in the NZE and the SDS energy-related CO_2 emissions peak at 35.9Gt in 2019. Under the NZE, they fall to 21.1Gt by 2030 and 6.3Gt in 2040.

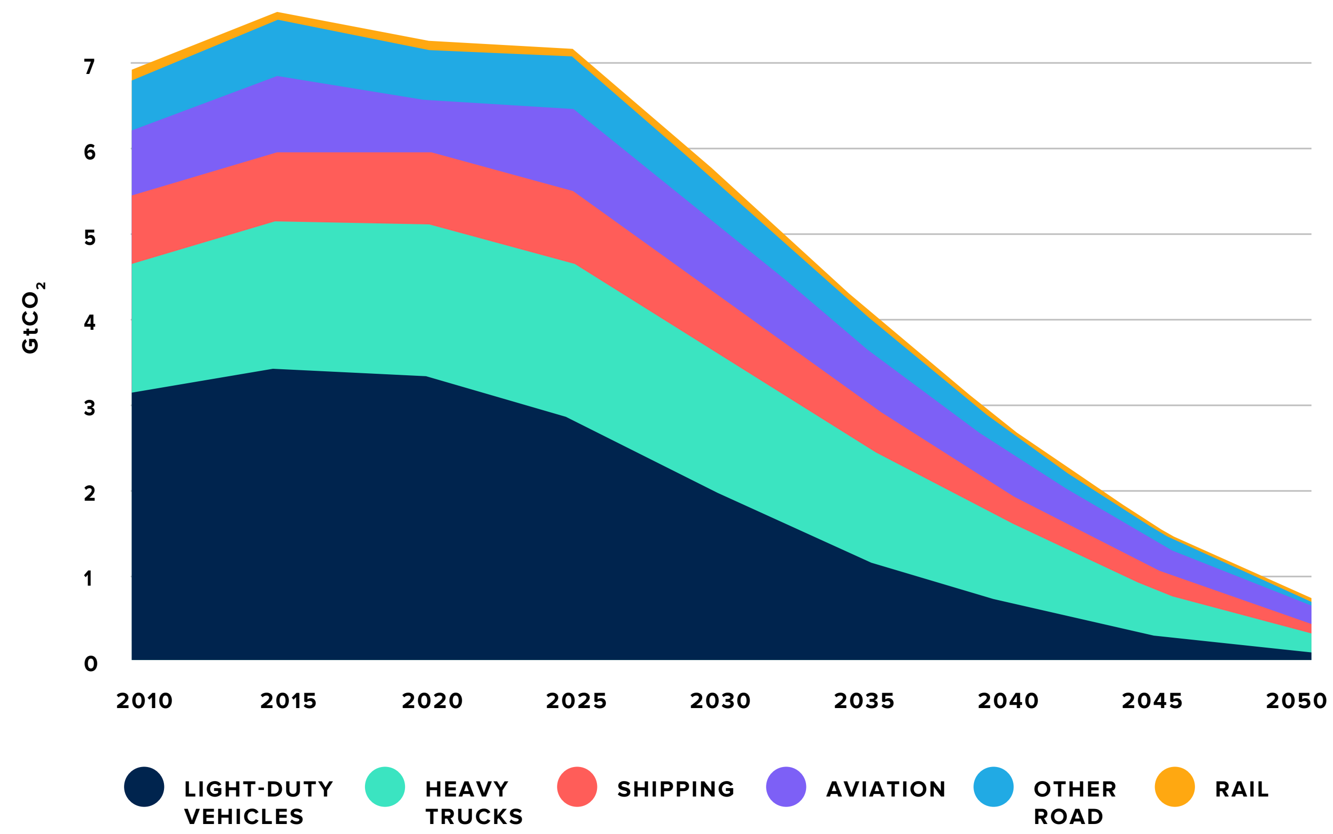
Emission reductions are front-loaded in sectors with commercially mature technologies, particularly electricity and light transport. Between 2020 and 2030, electricity sees a 7.7Gt fall in CO_2 emissions (greater than the reductions from all other sectors combined, as shown in Figure 7). This is achieved primarily through reductions in coal-fired power plants, supported by switching to renewable energy sources. Electrification is also prevalent in decarbonising lighter modes of transport. Heavy transport, buildings and industry reduce their emissions more slowly, as they rely on commercially immature technologies to do so.

Figure 7 - NZE CO_2 emissions trajectories by sector



Note: 'Other' includes other energy sector emissions. The IEA considers only CO_2 emissions and only from the energy sector, and so excludes AFOLU emissions and non-CO_2 GHG emissions.
Source: IEA NZE (2021).

Figure 8 - Global CO_2 transport emissions by mode and share of emissions reductions to 2050



Source: IEA NZE (2021).

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1.3.1 Cross-cutting technologies and approaches

The change in the energy mix drives down emissions. 'Clean' energy sources (solar PV, bioenergy, wind, hydro, other renewables, and nuclear) account for 17% of energy demand in 2020, but 78% by 2050 under the NZE.[40] Final energy demand by hydrogen increases to approximately 20EJ use in 2050, across sectors. Notably, hydrogen final energy demand is approximately 21% higher than in the NGFS Divergent Net Zero scenario, which forecasts around 16EJ in 2050.[41] Biomass use is similar between the scenarios, at 80 EJ for IPR, 102 EJ for IEA and 118 EJ for NGFS. The remaining coal, oil and gas sources are concentrated in hard-to-abate sectors, such as heavy industry and long-distance transport.

The fall in emissions intensity of energy consumption is largely attributed to efficiency measures and electrification. Improvements in the efficient use of materials, for example through building retrofits and new industrial processes, initially help to stem the growth in energy demand. Energy efficiency improvements and electrification of end-use sectors are also front-loaded, which contributes to the plateau in energy demand in the second half of the scenario.

Cross-cutting technologies, fuels and policies play an important role in emissions reductions across multiple sectors. Electrification across end-use sectors makes up 22% of the reduction up to 2050. CCUS – initially applied to the power sector and heavy industrial processes, and later used for CDR – accounts for a further 14% of reductions. The NZE additionally assumes that behavioural changes to reduce energy demand, encouraged by supportive government policies, cut emissions by 2.6Gt in 2050.[42]

1.3.2 Transport

Lighter, short-distance transport makes large early contributions to decarbonisation under the NZE and SDS. Combined emissions from light duty vehicles, two- and three-wheelers and buses fall from 3.9Gt in 2020 to 2.5Gt in 2030 and 0.1Gt in 2050.[43] Switching from the internal combustion engine (ICE) to EVs, hybrid EVs and fuel cell electric vehicles (FCEVs) allows vehicles to take advantage of clean energy and material efficiencies.

The benefits of electrification are delayed for larger, surface transport, which need to store fuel for longer-distance travel. Heavy trucks initially adopt biofuels, before infrastructure investments and technology improvements allow larger-scale electrification post-2030. While emissions from heavy trucks fall from 1.8Gt in 2020 to 0.2Gt in 2050, their share of transport emissions increases over the same period.[44] Rail transport is scaled up for both passenger and freight purposes: by 2050, 90% of rail energy comes from electricity.

Aviation emissions are hard to abate; reductions rely on cleaner fuels, material efficiency improvements and improved demand management. Jet kerosene is gradually supplemented by as-yet immature sustainable aviation fuels (SAF) such as bio jet kerosene. Efficiencies in aircraft design also reduce fuel demand. The NZE additionally assumes substantial behavioural change in transport modes (e.g. replacing all short-haul flights with high-speed rail, and holding business travel at 2019 levels), which are likely to require supportive government policies. Nonetheless, aviation accounts for 10% of overall residual emissions in 2050.

Reductions in shipping emissions are likely to depend on new marine propulsion techniques and switching to advanced biofuel or ammonia fuels, which are currently immature technologies. Over the next decade, efficiency improvements make the most significant contribution to cutting emissions, for example slow steaming to reduce vessel speed. However, in later years low-carbon fuels such as ammonia, hydrogen and biofuels are likely to be scaled up, collectively providing 83% of total shipping energy needs.[45]

1.3.3 Buildings

The increase in energy demand in buildings is offset by radical efficiency improvements and electrification. Floor area increases by 75% to 2050, while emissions fall by 95%. Achieving these emissions cuts is estimated to require retrofit rates of 2.5% per year by 2030, in addition to making all new builds 'zero carbon'-ready from the same date. Specific investments include building envelope improvements; electrification combined with generation from renewables; and rapid global rollout of best-in-kind efficient appliances and lighting.

1.3.4 Industry

Industrial emissions reductions is likely to require technologies that are currently only at the demonstration and prototype stages. Emissions from heavy industry are expected to remain high for longer due to factors including high temperature requirements, substantial process emissions, and 'lock-ins' of emissions from ageing capital assets. Reducing material demand is also challenging during the transition, as constructing energy-related infrastructure requires increased industrial outputs. The majority of emissions reductions consequently occur after 2030, and rely on widespread deployment of as-yet immature technologies.[46]

Decarbonising the chemicals sector is expected to depend on deployment of CCUS and hydrogen. Emissions fall very marginally between 2020 and 2030, which is achieved using existing technologies such as plastics recycling and energy efficiency measures. After 2030, the NZE requires deployment of CCUS and, to a lesser extent, electrolytic hydrogen generated from renewable electricity. Long capital asset lifespans imply that large-scale retrofits are essential to achieving emissions reductions.

Reducing steel emissions may initially require material and process efficiencies, but ultimately most savings are likely to be achieved through electrification and CCUS deployment. Limited reductions are achieved by 2030, primarily though material and energy efficiency measures and increases in more scrap-based production. In later years, technologies such as scrap-based electric arc furnaces (EAF), hydrogen-based direct reduced iron (DRI) facilities, and iron ore electrolysis, all enable a move away from coal power and towards electrification. By 2050, CCUS is used for over half of steel production.

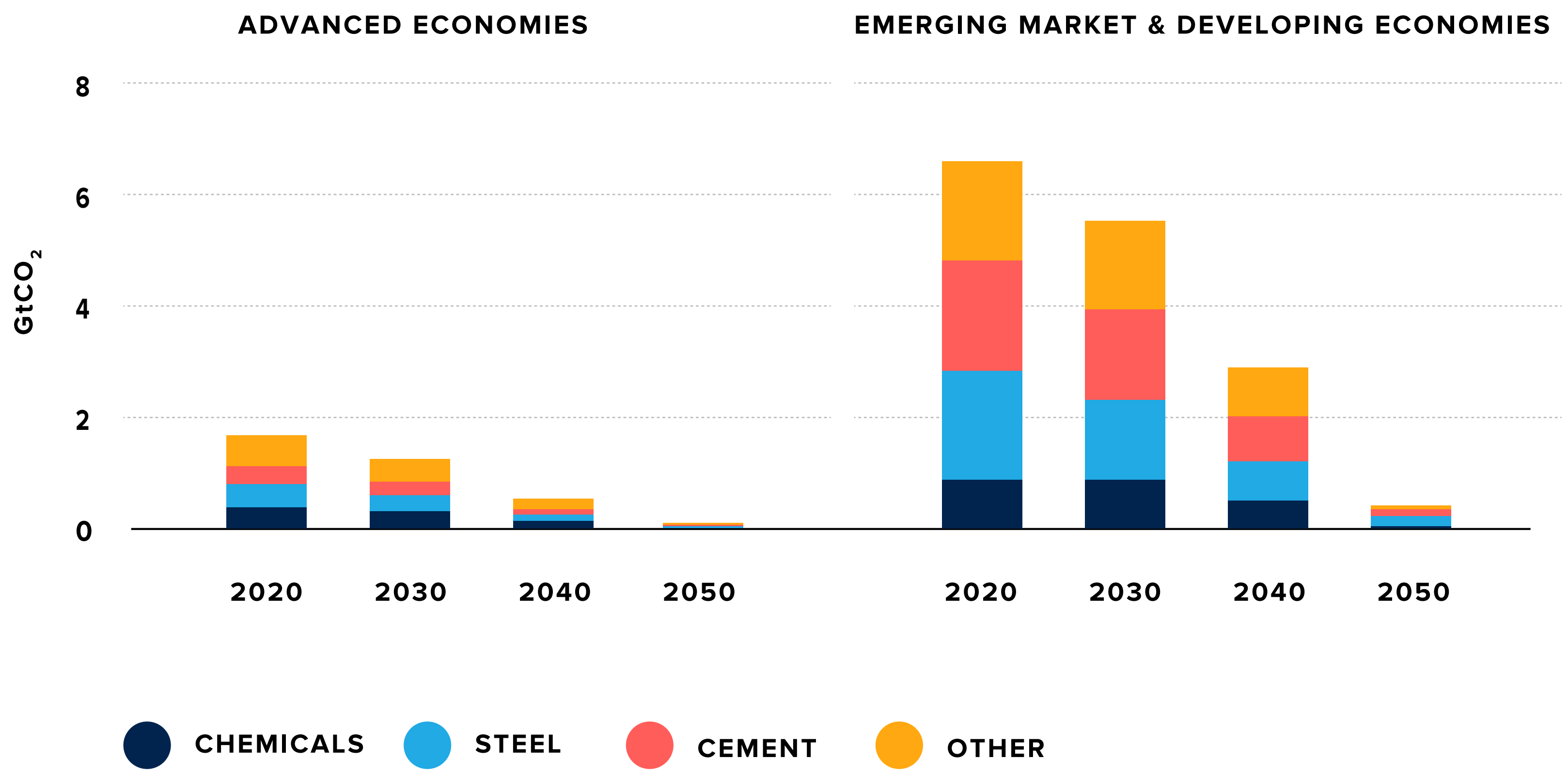
For cement, reducing the clinker-to-cement ratio is essential in the early years, while later gains are mainly achieved by CCUS deployment. Blending in materials that are less emissions-intensive reduces the clinker-to-cement ratio from 0.71 in 2020 to 0.65 in 2030 and 0.57 in 2050. Energy and material efficiencies also contribute to early emissions reductions. Cement demand becomes increasingly concentrated in developing countries that are still investing in new infrastructure; it falls in more advanced economies, including China, which are focused on infrastructure maintenance and replacement. After 2030, CCUS is deployed on a large scale. Notably the level of emissions removed via CCUS is approximately 20% higher in the IEA NZE scenario relative to the NGFS Divergent Net Zero scenario (7,600MtCO_2 versus 6,000MtCO_2 in 2050, respectively).

The technologies needed to decarbonise light industries are already largely commercially available. Subsectors such as mining, construction, food, machinery, vehicles, textiles and wood can reduce their emissions more easily due to the lower temperatures required. The majority of this is achieved through electrifying 65% of heat demand by 2050.[47]

1.3.5
Agriculture, Forestry and Other Land Use

The NZE assumes that forestry-based changes reduce AFOLU CO_2 emissions from 6Gt in 2019 to negative emissions of 1.3Gt in 2050.[48] Policy assumptions include reducing deforestation by two-thirds, improving forestry management and planting 250MHa of new trees ('afforestation'). However, the NZE does not provide a detailed breakdown of AFOLU emissions reductions equivalent to its energy sector analysis. Consequently, the analysis supplements IEA AFOLU outputs with insights from other sources.

Figure 9 - Global CO_2 emissions from industry by sub-sector



Source: IEA NZE (2021).

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FOLU's 2019 'Growing Better' report sets out ten critical transitions to limit warming to 1.5°C while ensuring food security and protecting biodiversity.[49] Key climate-related interventions focus on restoration of forests, peatlands and mangroves for carbon sequestration; reducing the carbon footprint of agriculture through regenerative farming and precision agriculture; supporting diet shift away from emissions-intensive livestock; and cutting food waste by 25%.

The partial treatment of AFOLU by many climate scenarios makes it challenging to compare key assumptions; nevertheless, there are several important points of uncertainty. Assumptions regarding land use affect food supply, bioenergy feedstocks, and the potential for carbon sequestration by forests, mangroves and peatlands. Technological improvements which increase land productivity also affect the proportion of land that needs to be devoted to agriculture to achieve sufficient food supply. Finally, assumptions relating to the extent and nature of diet shift can have significant impacts on emissions outcomes, as protein-rich diets can be achieved with relatively low emissions if people are assumed to move away from ruminant 'red' meat consumption and towards poultry or alternative proteins.

1.4
Geographical Breakdown of Emissions Trajectories

Countries and regions will reduce emissions at different speeds and using different methods, dependent on factors such as their current level of development and economic specialisation.

One key distinction is between decarbonisation in advanced economies and in emerging market and developing economies. In the NZE, CO_2 emissions fall to net zero in major advanced economies by 2045 and globally by 2050. In the SDS, these milestones are achieved by 2050 and 2070, respectively.

Advanced economies decarbonise fastest across most sectors, although emerging markets make some fast emissions reductions through electrification and low-carbon power systems. Advanced economies decarbonise the electricity sector by 2035, with other countries following five years later. This is supported by the price competitiveness of renewables generation, much of which is located in developing countries.[50] Consumer uptake of mitigation technologies, such as EVs and efficient appliances, is slower in developing economies, delaying emissions reductions. Industrial activity and related emissions remain concentrated in developing countries, which account for 84% of the electricity [energy?] sector's emissions in 2050. Developing countries are also assumed to rely more on direct policy interventions to transform their energy systems.

There are many policies which are assumed to be near-universally adopted. The SDS and the NZE both assume implementation of carbon prices, although the NZE goes further in terms of regional coverage and price levels, making much fossil-fuel production uneconomic (see Table 3). Fossil-fuel subsidies are also phased out by 2025 in the NZE. Across sectors and geographies, efficiency and emissions standards are used to motivate retrofits and direct new investment towards more sustainable capital assets.

Due to limited data availability at the time of writing, this section uses IEA SDS regional emissions data to estimate regional emissions under the IEA NZE. While the NZE requires both advanced and developing economies to reach net zero by 2050, under the SDS, emerging markets and developing economies do not achieve net zero emissions until 2070. Consequently, the trajectory for emissions reductions in developing countries may need to be more rapid than these estimates imply.

Table 3 - Carbon prices and percentage change in CO_2 emissions under IEA scenarios, $ 2019 per tonne of CO_2

	STEPS		SDS		NZE	
YEAR	2025	2040	2025	2040	2025	2040
Advanced Economies' Carbon Prices ($)	0–34	20–52	63	140	75	205
China, Russia, Brazil and South Africa Carbon Prices ($)	0–17	0–35	43	125	45	160
Other Emerging Market and Developing Economies' Carbon Prices ($)	0	0	0	0	3	35
Total Percentage CO_2 Emissions Change From 2019	-1%	+1%	-15%	-53%	-16%	-82%

Source: Data from IEA World Energy Outlook 2020 and IEA NZE 2021 Special Report. STEPS prices are for Canada, Chile, China, the EU, Korea and South Africa only, and apply only to selected sectors. Data from IEA World Energy Outlook 2020 and IEA NZE 2021 Special Report. STEPS prices are for Canada, Chile, China, the EU, Korea and South Africa only, and apply only to selected sectors.

1.4.1
North America: US, Mexico and Canada

North America's CO_2 emissions fall by 50% between 2020 and 2030, and a further 81% between 2030 and 2040. Energy demand falls by 27% over the same period. Energy from renewables increases by 137% ahead of 2030, which is slightly below the global average change. Decarbonisation of the transport sector also leads to oil consumption halving.[51]

As the largest energy consumer and CO_2 emitter within North America, the USA also makes the largest contributions to decarbonisation. Renewables supply increases from 19% in 2020 to 76% in 2040, compared to 59% for the region as a whole.

1.4.2
Central & South America: Brazil, Caribbean, and rest of Latin America

Most Central & South American countries are emerging markets, which continue to develop well into the 2030s. While energy demand increases, CO_2 emissions fall 37% by 2030 and 58% between 2030 and 2040. Coal and oil are almost eliminated from the power sector, where increased demand is met mainly by nuclear, hydro and bioenergy.

Brazil accounts for over a third of Central & South America's energy demand and emissions. Brazilian bioenergy is particularly important for agriculture and transport, which is likely to require investment in infrastructure capable of supporting higher fuels blends, as well as policy support to set standards for and promote sustainable biofuel development.

1.4.3
Europe: EU, UK, Turkey, Israel, and other European countries

European emissions fall by 53% by 2030, and a further 76% by 2040. This is driven by a sharp reduction in coal demand, which is replaced in the fuel mix by bioenergy and other renewables. While energy demand decreases overall and in end-use sectors, energy use in the power sector increases slightly towards 2040.

The SDS and NZE assume that the EU and the UK implement their net zero commitments in full. The EU retires ageing coal plants and redirects investment towards renewables capacity within solar PV and wind. Emissions reductions are slower in hard-to-abate sectors, including heavy duty trucks, shipping, aviation, cement, chemicals, and space heating.

1.4.4
Asia Pacific: China, India, Japan, Korea, Central and SE Asia, Australia and New Zealand

Asia Pacific, the highest emitting region, ramps up decarbonisation efforts in the 2030s. Emissions reductions increase from 36% between 2020 and 2030, to 73% in the following decade. This is driven by China's move away from coal in the power sector, which is replaced by renewables and nuclear. Renewables increase from 10% of total energy supply in 2020 to over 50% in 2040; their use is particularly concentrated in the power sector.

India increases its renewables capacity twelvefold between 2020 and 2040.[52] Across the region, energy demand remains flat, as reductions in China and Japan are offset by increased energy use in India and ASEAN countries, especially for industrial uses.

1.4.5
Eurasia: Russia and the Caspian Region

Eurasia's emissions are already low, and decline moderately between 2020 and 2040. Energy use drops initially in the power sector; industry and transport see stagnating demand in early years, before some energy reductions between 2030 and 2040. Renewables energy supply ramps up tenfold from 1.3EJ in 2020 to 13EJ in 2050. Russia accounts for approximately three-quarters of Eurasia's energy demand and emissions, and it follows a similar trajectory.

1.4.6
Africa: North Africa and Sub-Saharan Africa

Africa increases its energy use to drive economic growth, while modernising its fuel mix, reducing CO_2 emissions moderately compared to other regions. The fall in 'traditional' bioenergy consumption, associated with the move to clean cooking, reduces bioenergy demand by two-thirds between 2020 and 2040. This primarily occurs within the buildings sector.

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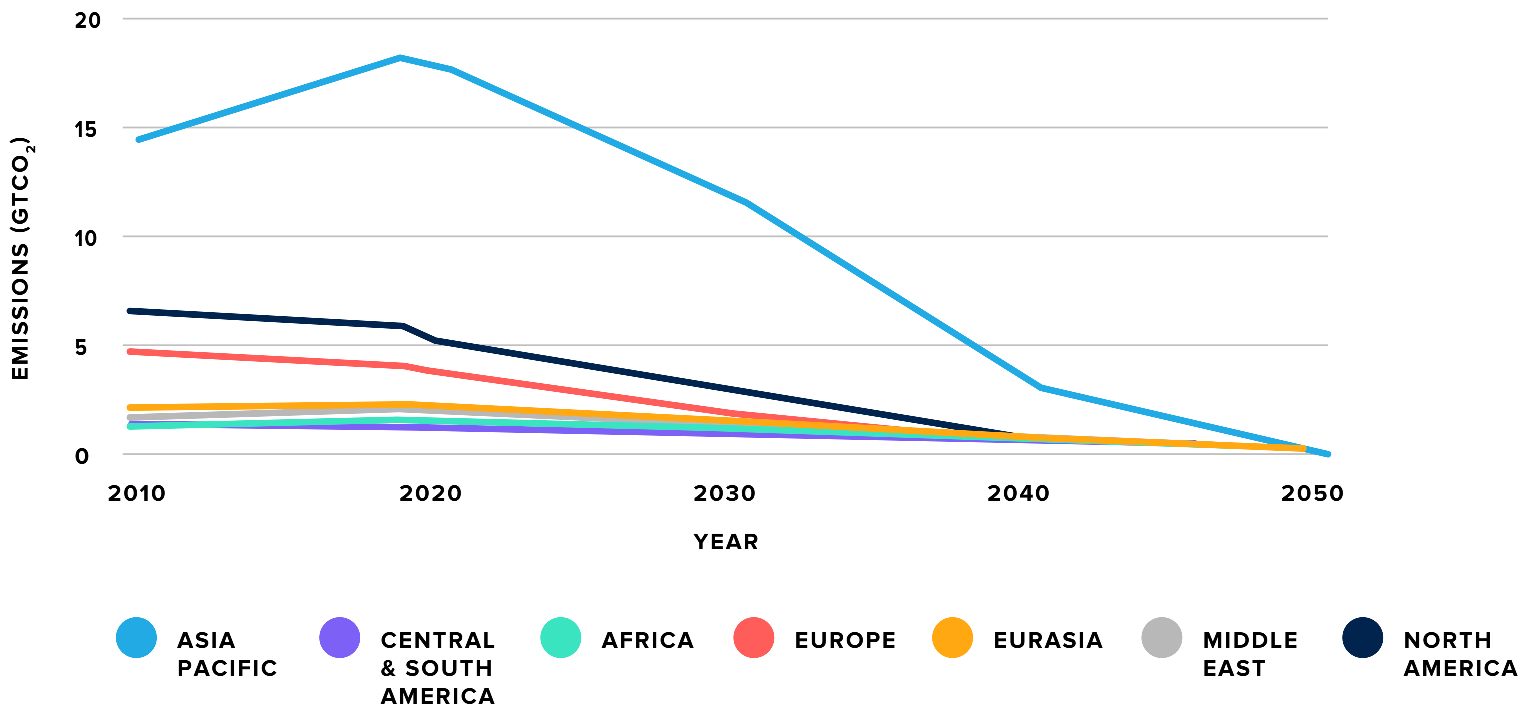
1.4.7
Middle East

Emissions fall by 32% in the Middle East by 2030, despite overall energy demand rising by 5%. A significant challenge for oil and gas exporters is the impact of decarbonisation on both economic activity and tax revenues, which may risk knock-on effects for investments in green technologies. In the Middle East, oil and gas combined accounted for 99% of energy demand in 2019. By 2040, this falls to 69%, with new capacity having been added in renewables, nuclear and bioenergy.

Figure 10 - NZE regional emission trajectories



Note: NZE total emissions downscaled by SDS regional emissions.
Source: IEA World Energy Outlook (2021)

Investment Trajectories

2.0

2.0 Investment Trajectories

This chapter sets out the real-world investment needs to achieve net zero emissions reductions, providing information for key technologies and regions.

Section 2.1 summarises the scale of investment across sectors, and the scale-up required at a sectoral and region level. Section 2.2 introduces the methodology and considers uncertainties and limitations. The next two sections present the results of the modelling. Section 2.3 discusses investment needs by sector and technology, setting out the size of the investment gap and changes in production and sale volumes. Section 2.4 presents investment needs within each major world region. Finally, Section 2.5 discusses the role that private and public investors can play.

2.1 Investment Trajectories Summary

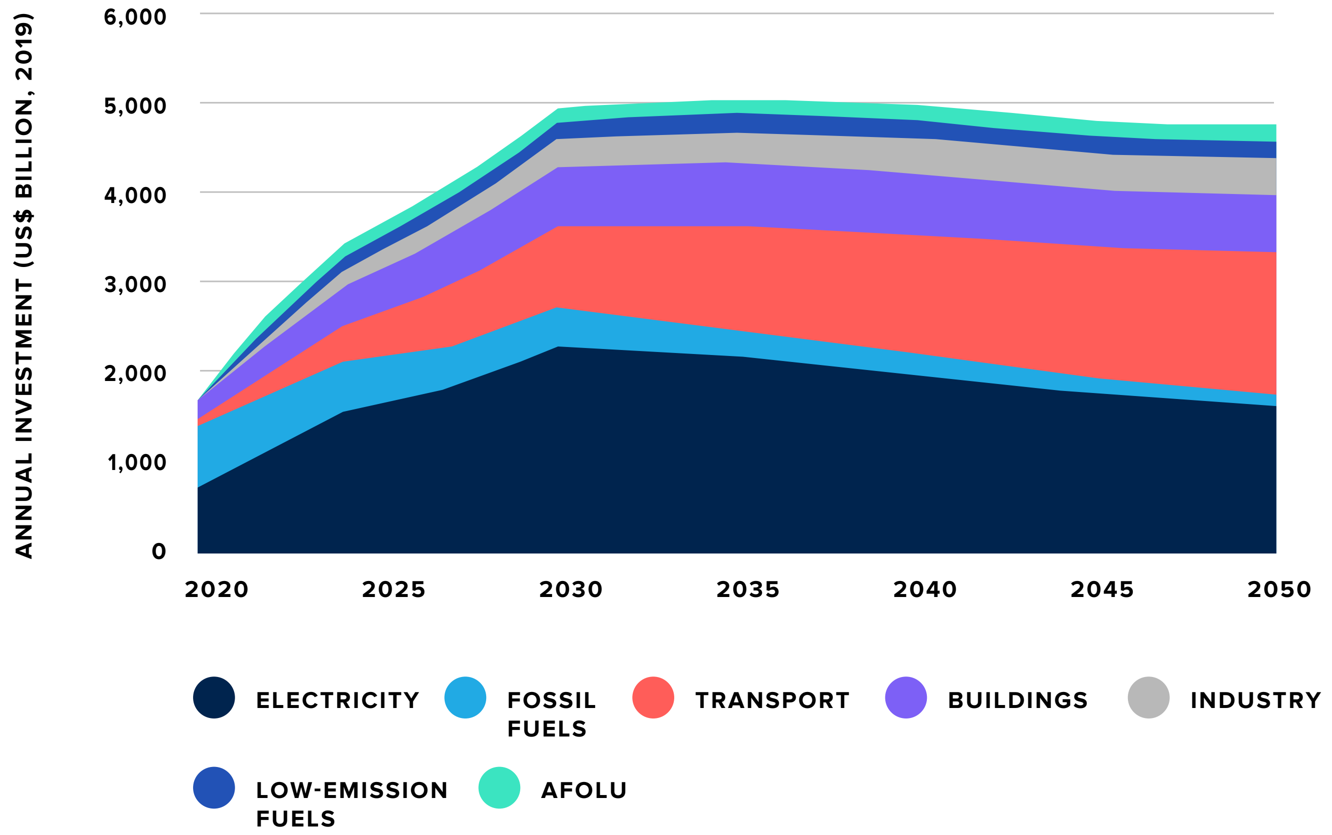
Achieving net zero emissions by 2050 requires a massive increase in energy-related investment.

The report estimates global and regional investment needs, covering capital expenditure, for more than 100 technologies across 27 sub-sectors, using the IEA and from the FOLU as our starting point.[53] The IEA projects annual investment to grow from less than $2 trillion in 2016–20 to around $4.6 trillion in 2041–50.[54] Total investment required to 2050 amounts to $136 trillion, with investment projected to peak in the 2030s to deliver the emissions reductions outlined in Section 1.

Seven sectors are likely to face the greatest scale-up and shift in investment, shown in Figure 11. Four sectors are estimated to see a sharp shift from emissions-intensive investment to low-emissions investment: electricity, transport, buildings and industry. At the same time new sectors and investment opportunities are expected to emerge, for instance investment in the low-emissions fuel supply sector will rise to replace fossil-fuel supply. Investment opportunities emerge in the AFOLU to meet growing nutrition needs while limiting emissions and to deliver carbon sequestration.

The ramp-up in investment is likely to be particularly significant in the 2020s, with total investment on green technologies across these sectors estimated to more than quadruple between 2020 and 2030. The largest investment gap is expected to occur in Asia Pacific, at $9.1 trillion in the next decade, with around 22% occurring in transport, 48% in electricity, and 12% in industry. Figure 12 provides detailed information on the investment gap in each region and sector over the next decade.

Figure 11a - Average annual investment amounts needed to reach net zero in 2050, by sector



Note: The analysis follows the IEA definition of 'energy investments'. They include investments in energy generation, energy infrastructure, fuel supply, and 'energy efficiency investments' in end-use sectors (transport, buildings, industry), which comprise spending on energy-efficient equipment and on refurbishments reducing energy use. In addition to capex, the IEA definition includes spending categories usually classified as 'consumption'.

Source: Vivid Economics analysis based on IEA, FOLU, FAO and NGFS data

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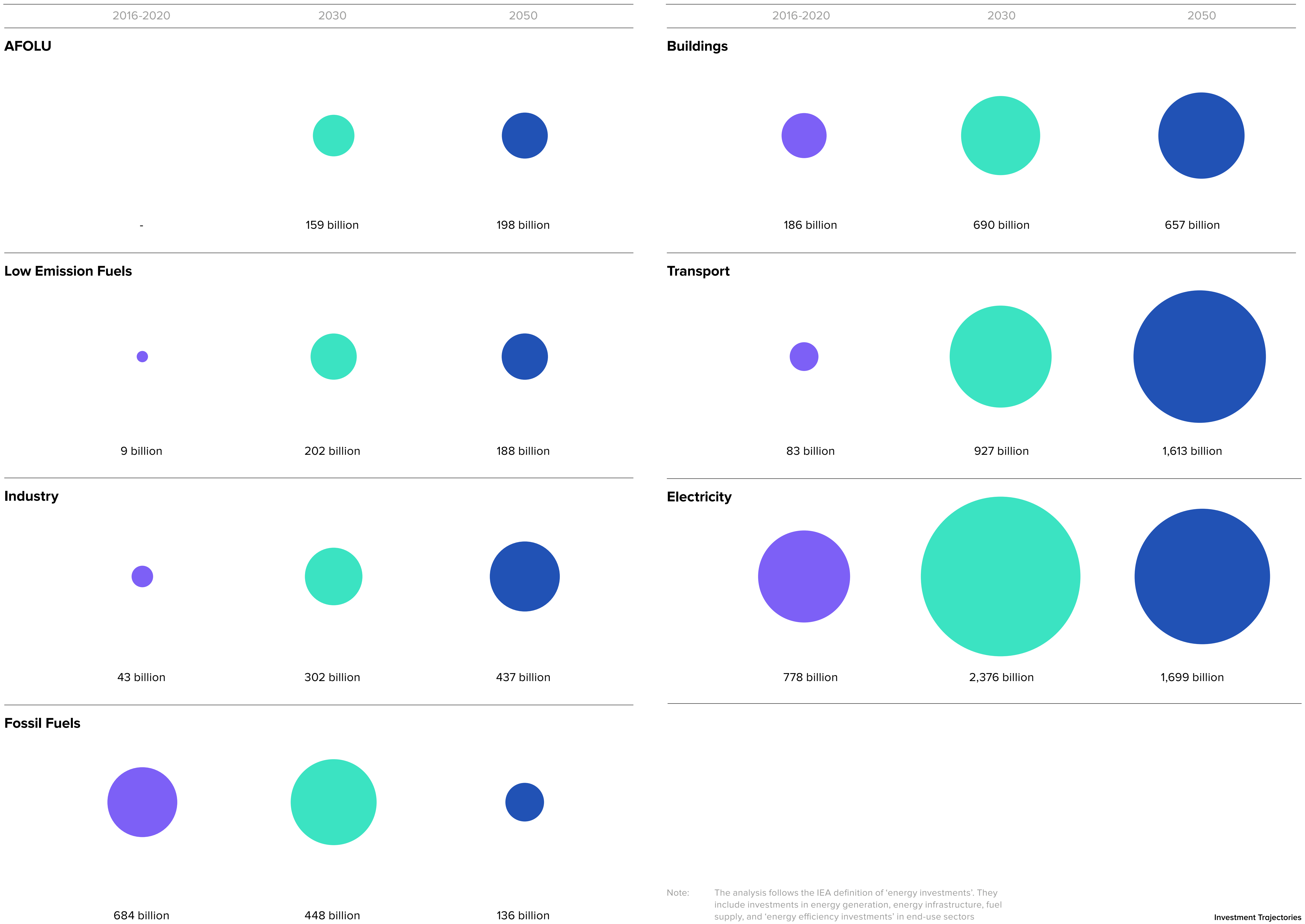
Figure 11b - Average annual investment amounts needed to reach net zero in 2050, by sector



Note: The analysis follows the IEA definition of 'energy investments'. They include investments in energy generation, energy infrastructure, fuel supply, and 'energy efficiency investments' in end-use sectors

Figure 12a - The electricity sector is estimated to attract the largest investments in an absolute sense, while low-emissions fuels are likely to require the largest proportional increase in capital

REGION	ELECTRICITY	TRANSPORT	BUILDINGS	INDUSTRY	LOW-EMISSION FUELS	AFOLU
Investment Gap (2021-30 Compared to Historical; $ Billion)						
North America	1,345	736	1,018	240	434	217
Central & South America	338	138	61	45	239	255
Europe	2,056	816	1,105	239	216	116
Africa	833	127	100	29	42	250
Middle East	537	109	139	80	50	37
Eurasia	258	95	64	19	32	183
Asia Pacific	4,436	1,992	842	1,117	359	452
Annual Scale-up Needed - Investment CAGR (2020-30)						
North America	11%	24%	12%	27%	38%	
Central & South America	12%	34%	18%	18%	41%	
Europe	14%	22%	13%	23%	23%	
Africa	24%	34%	16%	17%	50%	
Middle East	23%	33%	20%	24%	56%	
Eurasia	16%	33%	22%	18%	50%	
Asia Pacific	13%	27%	15%	21%	41%	

Note: 'Investment gap' corresponds to the additional investment effort needed in the years 2021–30 over and above historical levels. 'Investment CAGR' is the average annual growth rate needed over 2021–30 for investment projections. Light and dark shades correspond to lower or higher investment gaps respectively. Historical data for AFOLU is not available at the regional level, so CAGR cannot be computed.

Source: Vivid Economics analysis based on IEA data

Figure 12b - The investment gap for electricity globally

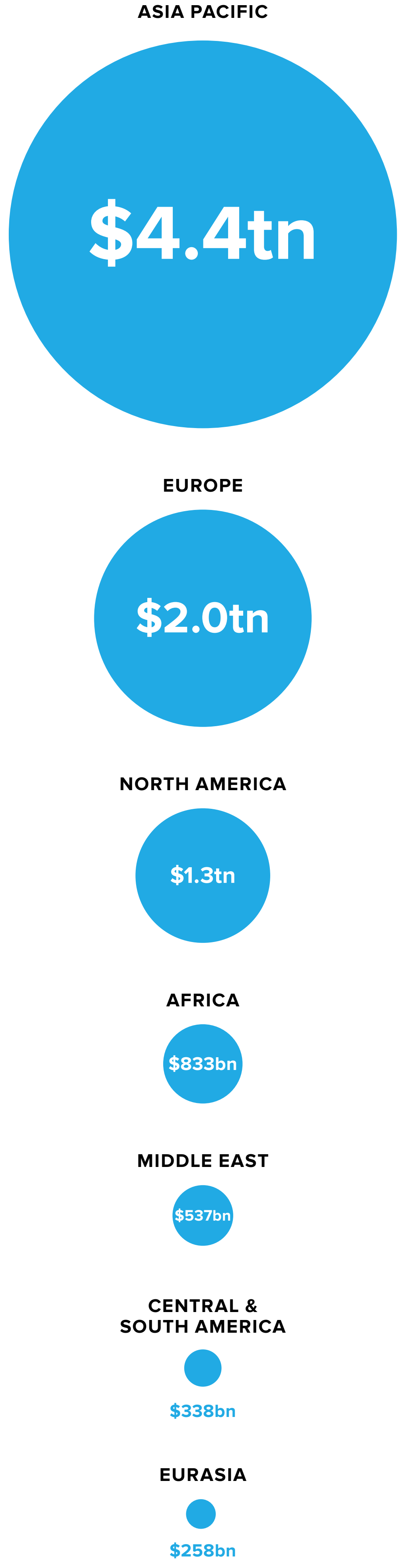


Figure 12c - Investment Gap (2021 - 30 Compared to Historical; $ Billion)

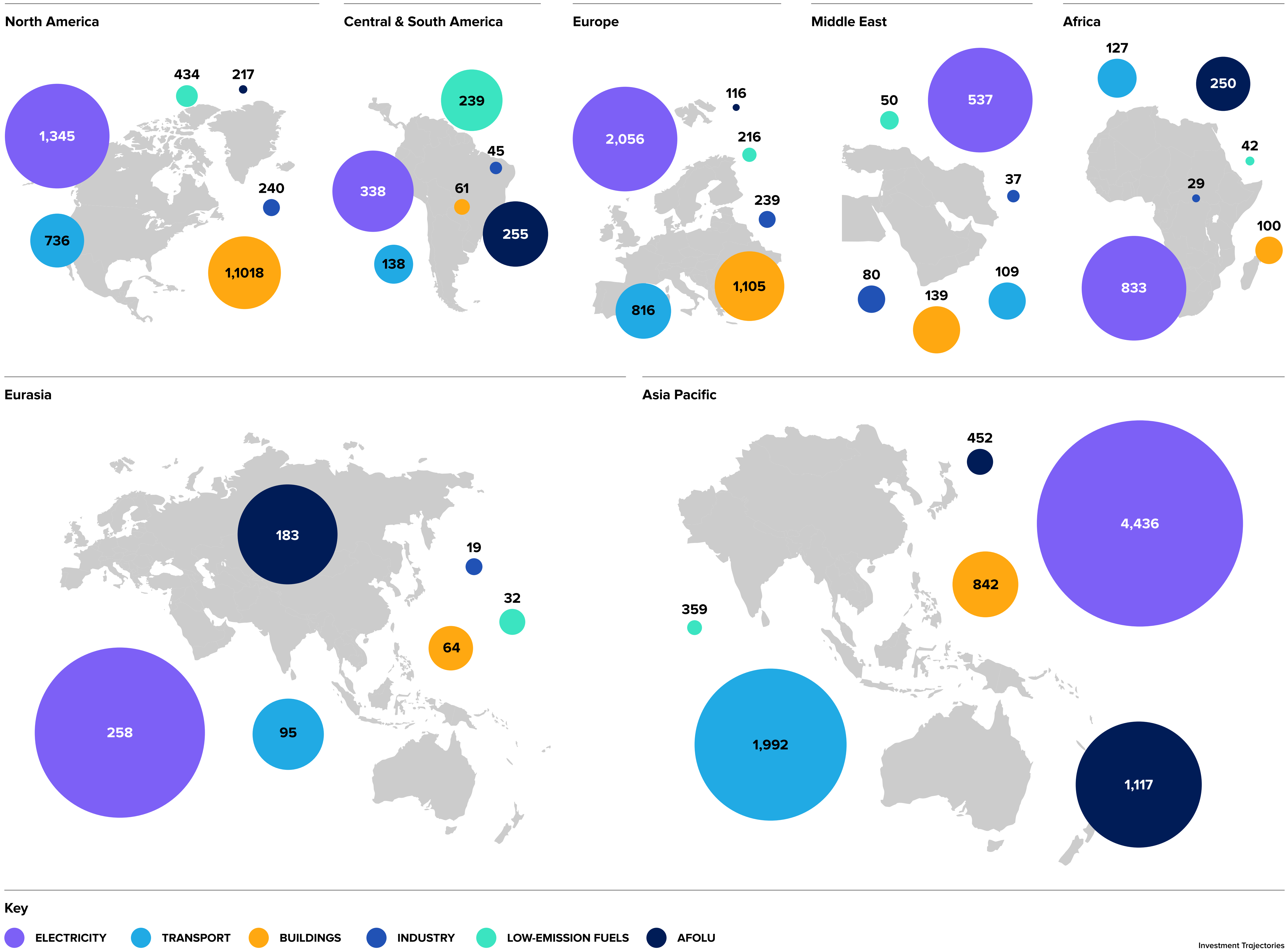


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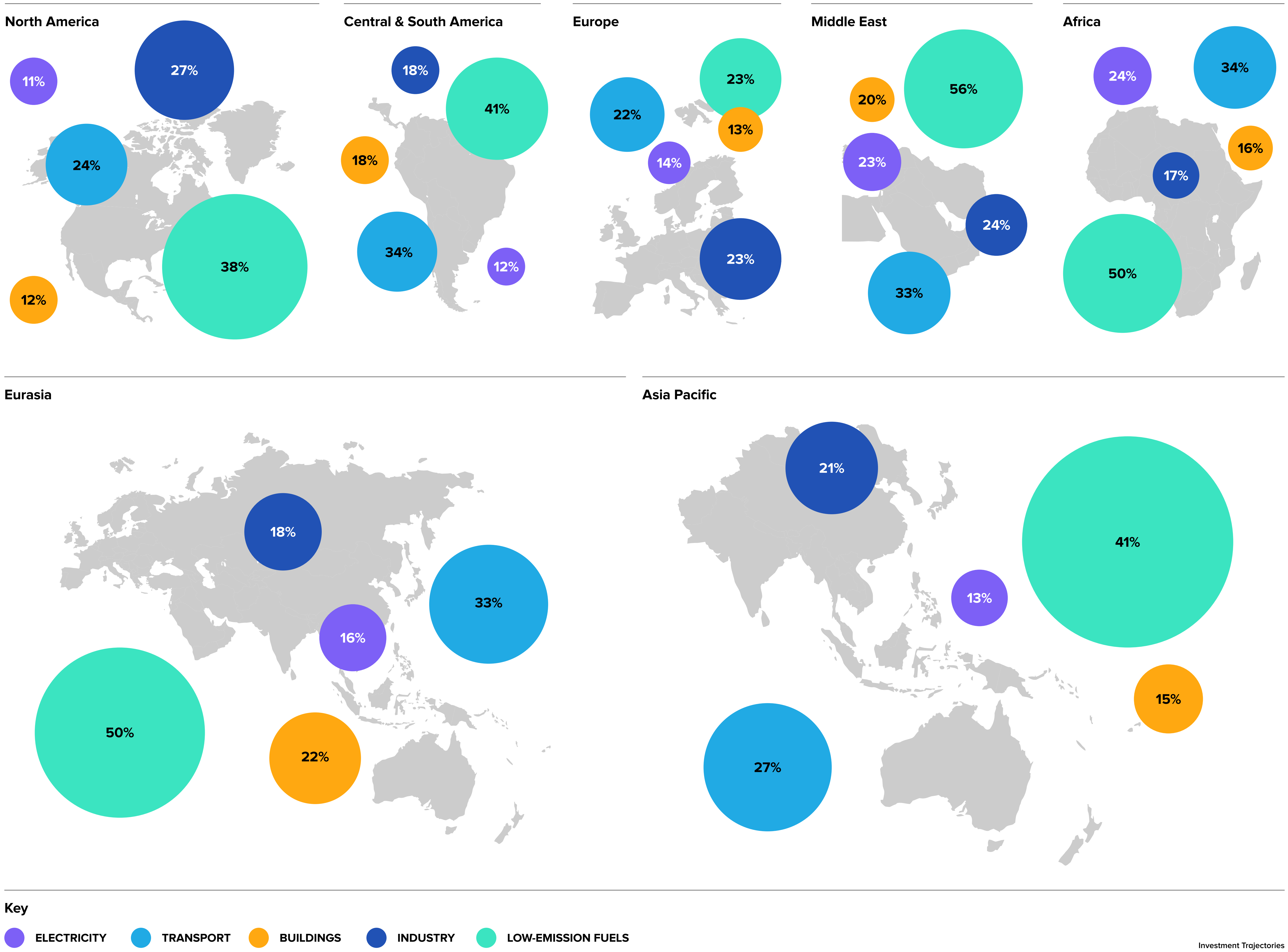
Figure 12d - Annual Scale-up Needed - Investment CAGR (2020 - 2030)



2.2 Methodology and Key Uncertainties

The analysis on investment trajectories is based on the investment projections of the IEA NZE scenario.

The IEA analysis considers 'energy investment', defined as 'the ongoing capital spending in energy supply capacity, energy infrastructure and energy end-use efficiency'.[55] It excludes opex, and focuses on different categories of assets depending on the sector under consideration. In the case of energy generation, fuel supply, and industry, 'energy investment' refers to capital expenditure on production facilities and infrastructure. In the buildings and road mobility sectors, it refers to spending on end-use equipment, such as vehicles in the case of road mobility or heating units in the buildings sector.[56]

The IEA projections provide only global estimates and have limited granularity on a technology level. Therefore, regional and technological granularity has been added to the projections using a variety of additional data series. These include estimates of present and future production volumes, energy demand, and unit capex across sub-sectors, technologies and world regions. The sources considered include reports by the IEA, such as the 2020 and 2017 Energy Technology Perspective reports, the 2021 and 2020 World Energy Outlook reports, and the 2020 World Energy Balances. A variety of third-party sources has also been considered, such as IRENA reports. In addition, investments in AFOLU are based on FOLU data, FAO data and estimates from the NGFS Divergent Net Zero 1.5°C scenario.[57]

Projections of investment needed over the next 30 years face several uncertainties, driving considerable variations between different projections. There are four key sources of uncertainty in modelling the transition to net zero:

Regulatory uncertainty. The viability, cost-competitiveness and deployment of different technologies will depend on the implementation of environmental policies (e.g. carbon prices, EV subsidies and associated phase-out of ICE vehicles).

Technological uncertainty. In hard-to-abate sectors, such as aviation, shipping, steel, and cement, many technologies are at the prototype or demonstration phase. They have not yet been proven at scale and there are uncertainties about which technologies will be dominant in different regions. In particular, electricity storage, CCUS and hydrogen are key technologies for the transition whose deployment is subject to significant uncertainty. Even for more mature technologies, the degree of cost reduction could vary from projections, leading to different relative costs between competing technologies, and therefore different adoption outcomes.

Supply chain and infrastructure uncertainty. Downstream sectors are affected by the development of technologies in their supply chain. For example, the comparative viability of technologies in steel and cement depends significantly on electricity and hydrogen prices. Input prices may also be affected by the availability of raw materials, such as rare earth metals in renewable energy hardware and lithium for batteries. Aside from input prices, technology adoption may also depend on infrastructure rollout, which in turn depends on enabling financing as well as coordination (e.g. low-emissions shipping corridors to allow for hydrogen refuelling). Human capital and the ability to overcome socioeconomic inertia is also crucial.

Behavioural uncertainty. Behavioural change, both in the form of demand reduction (e.g. reduced air travel) as well as changing technology adoption (e.g. switching to EVs or to electric stoves), may vary between projections. For example, investment needs in agriculture would differ greatly depending on the degree of diet shift away from ruminant meat.

To highlight the uncertainty surrounding the IEA NZE projections, the chapter compares outputs with alternative net zero scenarios by IPR, McKinsey, NGFS, IPCC and IRENA.[58] The comparison focuses on technologies at the prototype or demonstration stage that are most affected by technology risk: electricity storage, CCUS, and hydrogen.

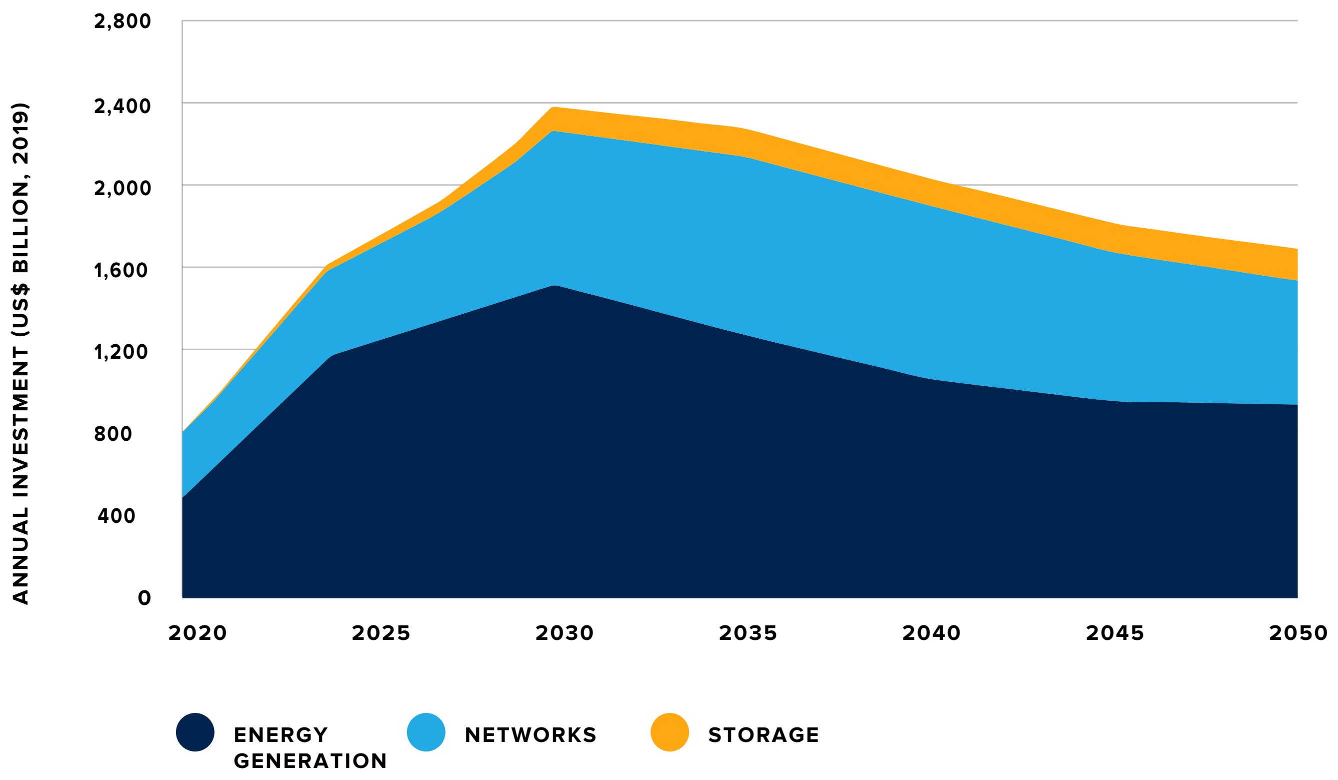
2.3
Investment Needs by Sector

2.3.1
Electricity Sector

The electricity sector is the main driver for investment in the NZE, attracting 42% of total investments, equivalent to $59 trillion to 2050.[59] Energy generation accounts for the majority (58%) of investment needed in sector, as a result of both increasing energy demand and rising electrification in end-use sectors. Notably, investment in power generation starts to decline in the 2030s, due to a decline in the cost of renewable technologies. Investments in electricity networks meanwhile remain high (around 36% of the sector) for the whole period under consideration. This is due to the need to satisfy increasing energy demand and support higher variability from renewable energy generation sources.[60]

Commercially mature, cost-competitive renewable technologies (PV, wind and hydropower) attract nearly 70% of energy generation investment and could be attractive to institutional investors. The cost of solar PV projects has decreased sharply in the last decade, and as at 2019 it has been equal to or lower than that of new coal- and gas-fired power plants.[61] Together, solar and wind attract the largest share of investments in the next decade: $7.1 trillion globally. Due to their maturity and commercial viability they face lower technology and regulatory risks compared to alternative generation technologies, such as hydrogen or concentrated solar power (CSP).

Figure 13 - Energy generation and electricity networks are key drivers of investment in the IEA NZE scenario



Source: Vivid Economics analysis based on IEA data

The transition to net zero generation reflects an even larger shift in real-world resources mobilised. Investment projections may not paint a full picture of the challenge associated with the transition, for two reasons. First, multiple technologies are at the prototype or demonstration stage, with significant uncertainty over future deployment. Second, installation of renewable generation capacity may need to be accelerated due to the stranding of fossil-fuel-based plants, which may be unprofitable at the emission prices of a net zero scenario.

To satisfy the needs of the transition, installed renewable generation must increase 80% in the next decade, and tenfold in the next 30 years. Installed generation capacity, currently at around 8TW, needs to triple by 2040, and to increase fourfold by 2050, when it is projected to reach 30TW. This is driven by the global increase in energy demand and by the electrification of end-use sectors. Renewable generation needs to increase at a faster pace, both to satisfy new demand and to replace fossil-fuel-based generation. Installed PV capacity must increase by seven times in the next decade, and by 20 times to 2050.

Note: Investment gap' corresponds to the additional investment effort needed in the years 2021–30 over and above historical levels. Negative investment gap estimates imply that the investment need in 2021 – 2030 is expected to be lower than historic investments but does not imply a negative investment need. 'Investment CAGR' is the average annual growth rate needed over 2021–30 for investment projections. Light and dark shades correspond to lower or higher investment gaps respectively.

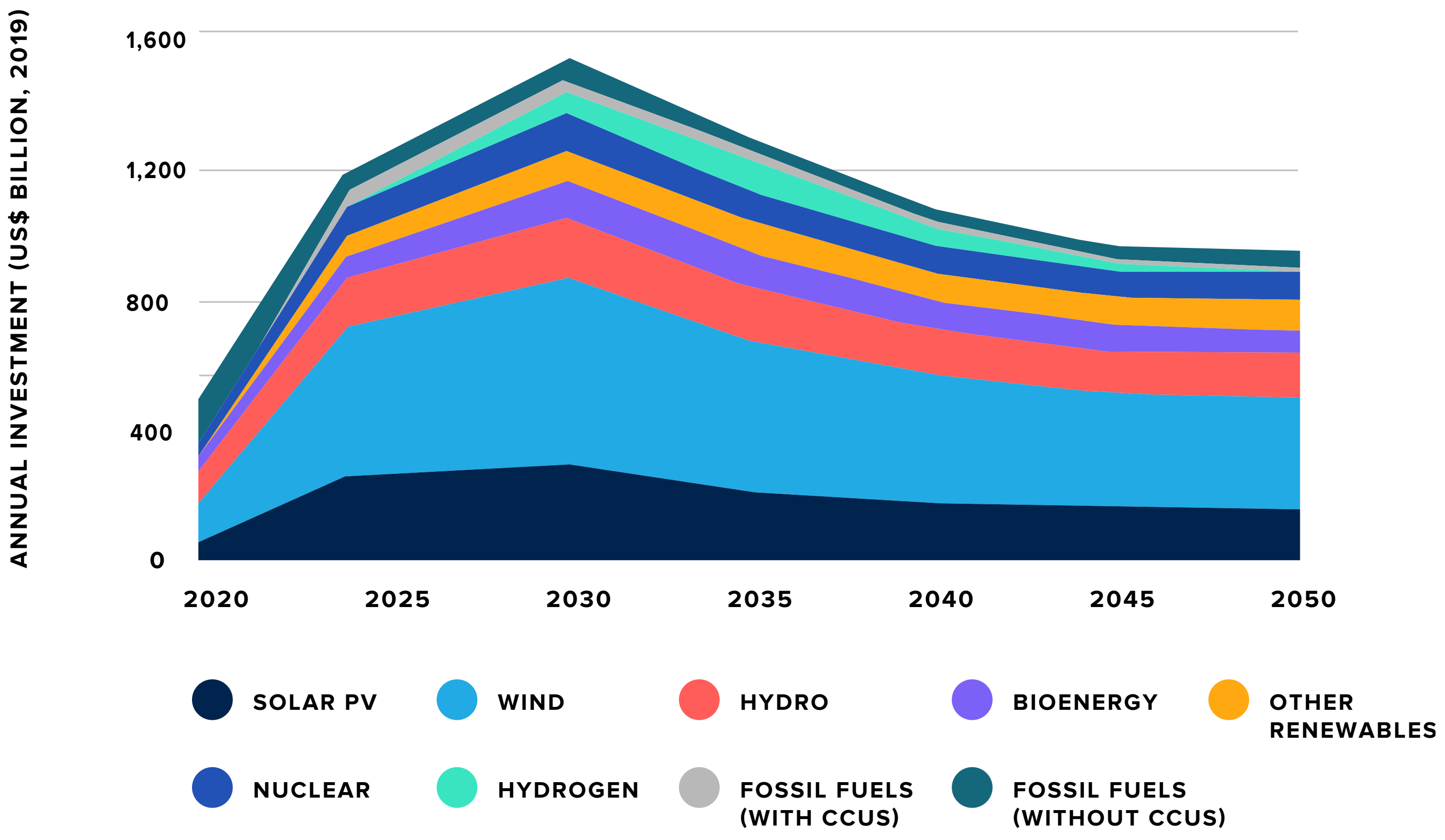
Source: Vivid Economics analysis based on IEA data

Figure 14 - Electricity generation is the sub-sector with the largest investment needs; electricity storage is the sub sector projected to grow at the fastest rate

REGION	GENERATION	TRANSMISSION & DISTRIBUTION	STORAGE
Investment Gap (2021-30 Compared to Historical; $ Billion)			
North America	1,221	4	4
Central & South America	238	79	79
Europe	1,395	807	807
Africa	494	300	300
Middle East	447	33	33
Eurasia	203	-4	-4
Asia Pacific	2,857	1,209	1,209
Annual Scale-up Needed - Investment CAGR (2020-30)			
North America	13%	4%	38%
Central & South America	11%	9%	65%
Europe	12%	14%	26%
Africa	17%	22%	86%
Middle East	18%	7%	59%
Eurasia	11%	3%	60%
Asia Pacific	11%	10%	42%

The transition to net zero generation also relies on the rapid deployment of technologies at the prototype or demonstration stage, including hydrogen and energy storage. The IEA projects the total installed capacity for hydrogen-based and CCUS-equipped fossil-fuel generation to be 1.8GW in 2040, equivalent to the current global installed capacity for natural gas generation. The IEA also expects a large increase in grid-scale electricity storage to integrate variable renewable generation technologies, such as solar PV and wind. While storage accounts for only 5.5% of total investment in the electricity sector over 2021–50, the pace of its deployment could have large indirect effects on investment in generation: the higher the storage capacity, the greater the reliance on wind and solar power can be, and vice versa.

Figure 15 - Traditional renewable generation technologies play a key role in achieving net zero



Source: Vivid Economics analysis based on IEA data

Figure 16 - While there are significant regional differences, PV and wind generation are likely to be the generation technologies attracting the largest investment amounts

REGION	SOLAR PV	WIND	HYDRO	NUCLEAR	BIOENERGY	OTHER
Investment Gap (2021-30 Compared to Historical; $ Billion)						
North America	496	569	7	-3	77	146
Central & South America	59	100	58	17	3	29
Europe	212	874	26	164	1	116
Africa	145	121	119	24	36	89
Middle East	86	216	11	7	17	164
Eurasia	7	70	78	38	81	28
Asia Pacific	947	1,401	197	294	116	308
Annual Scale-up Needed - Investment CAGR (2020-30)						
North America	18%	15%	3%	2%	19%	39%
Central & South America	24%	19%	7%	42%	6%	53%
Europe	13%	16%	4%	14%	5%	25%
Africa	37%	30%	17%	N/A	45%	22%
Middle East	34%	56%	9%	5%	70%	53%
Eurasia	20%	60%	17%	11%	45%	64%
Asia Pacific	13%	17%	6%	15%	10%	35%

Note: 'Other' renewable generation technologies include CCUS-equipped fossil-fuel generation, hydrogen-based generation, geothermal, CSP, and marine generation. 'Investment gap' corresponds to the additional investment effort needed in the years 2021–30 over and above historical levels. Negative investment gap estimates imply that the investment need in 2021 – 2030 is expected to be lower than historic investments but does not imply a negative investment need. 'Investment CAGR' is the average annual growth rate needed over 2021–30 for investment projections. Light and dark shades correspond to lower or higher investment gaps respectively.

Source: Vivid Economics analysis based on IEA data

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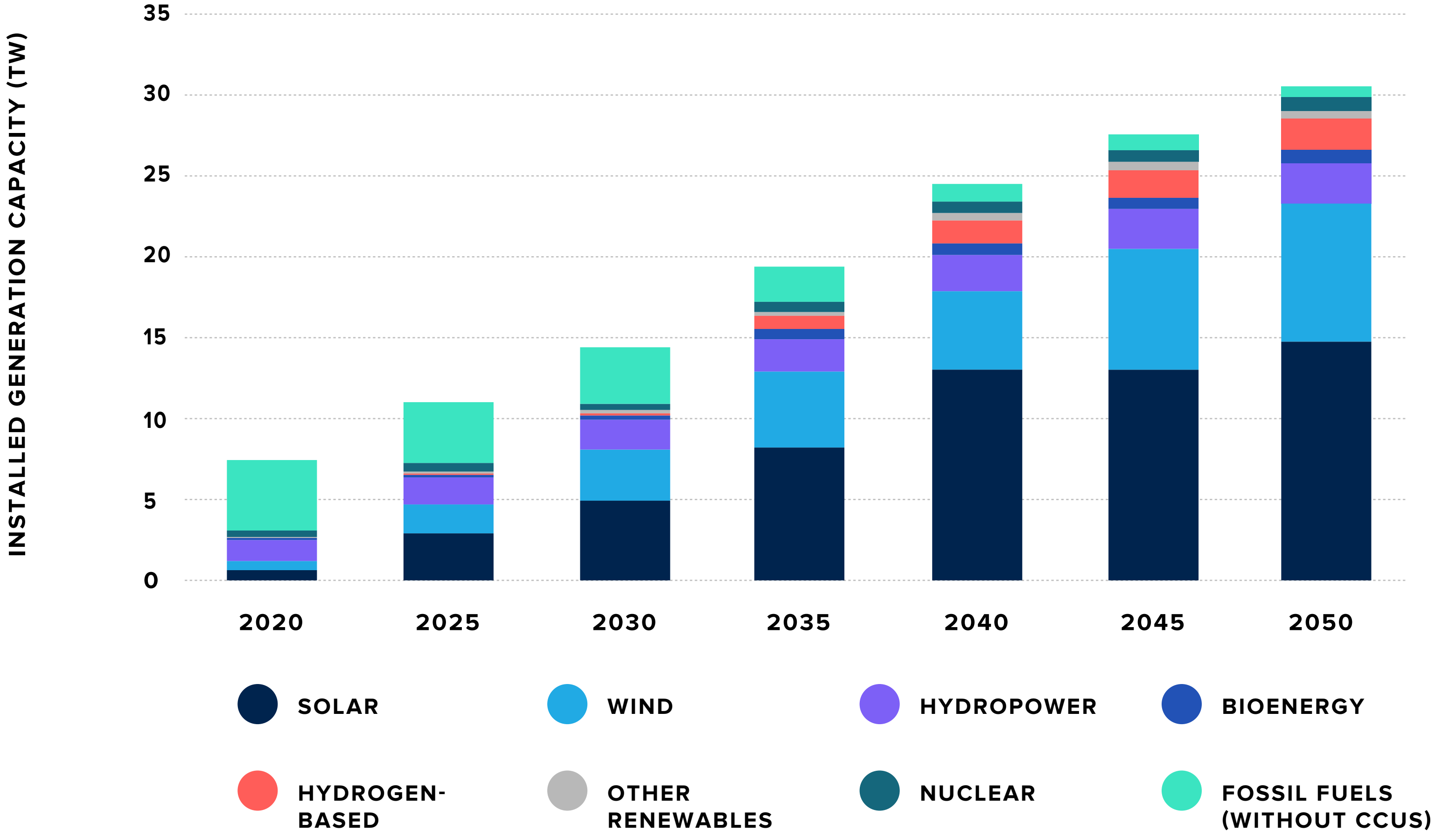
Technology uncertainty leads to differences between scenarios, with the IEA expecting a slower deployment of electricity storage in the net zero transition compared to McKinsey and IIASA, shown in Table 4. If the IEA projects lower expected deployment of this technology, it may be underestimating not only the investment needs of electricity storage, but also those of PV, CSP and wind power generation.

Figure 17 - Renewable generation capacity must increase tenfold to satisfy electricity demand in a net zero world



Source: Vivid Economics analysis based on IEA data

Table 4 - The IEA projects lower capacity of electricity storage in 2050 than McKinsey and NGFS

	IEA NZE	MCKINSEY 1.5 PATHWAY	NGFS NET ZERO 2050 (ORDERLY)	IPR 1.5 REQUIRED POLICY RESPONSE	IPCC 1.5˚C (MEDIAN SCENARIO)	IRENA
% of intermittent energy generation	70%	82%		62%	50%	63%
% of intermittent capacity installed	75%		80%	73%		
Electricity storage (TW)	3.1	9.0	4.7	5.4		

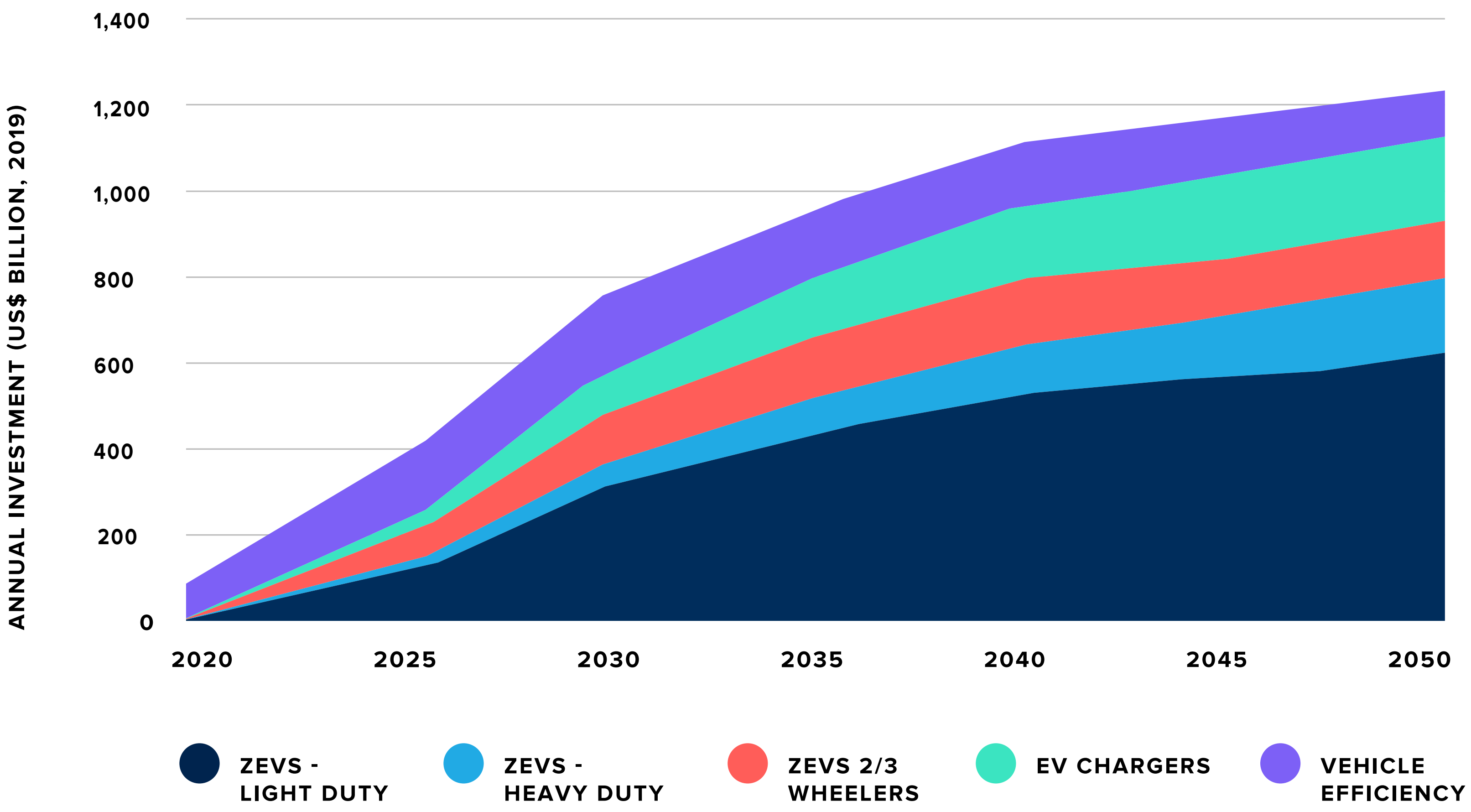
Source: Vivid Economics analysis based on IEA, McKinsey, NGFS, IPCC and IRENA data

2.3.2
Transport

The main driver for investment in the transport sector is road mobility, which requires an estimated $25 trillion to 2050.[62] The high upfront cost of EVs, together with the scale of fleet turnover, implies that the transition from ICE vehicles to zero emission vehicles (ZEVs) is likely to require significant expenditure in the coming decades.[63] This is despite the fact that the NZE scenario assumes a decrease in car ownership by 35%, due to behavioural changes, diffusion of car sharing, and increased use of public transport. If these developments do not materialise, aggregate spending on ZEVs is expected to be even higher than the projections in Figure 18.[64] Beyond the upfront investments in EVs, which are borne directly by consumers, investment in EV charging infrastructure is also required, equivalent to 14% of the investment in road mobility. From a regional point of view, the Asia Pacific region is estimated be the largest market for electric mobility in the next decade, followed by Europe and North America, as shown in Figure 19.

Forecast cost reductions imply that EVs are expected to reach cost parity with ICEs by 2025, contributing to expected uptake.[65] Currently, EVs have a higher total cost of ownership (TCO) compared to conventional ICE cars. However, improved equipment efficiency and economies of scale could lead to EV–ICE vehicle cost parity by 2025. The main driver of cost reductions is the decreasing cost of battery units.[66] Therefore, the electric mobility sector may present a valuable potential investment area for the next decade.

Figure 18 - Aggregate spending on ZEVs is the main driver for transport investment in the IEA NZE 2050 scenario



Source: Vivid Economics analysis based on IEA data

Despite the growing cost-competitiveness of EVs, significant regulatory support and investment in enabling infrastructure are necessary for the transition to electric mobility. The adoption of EVs continues to rely on ease of use (affected by the availability of the EV charging infrastructure), cost (affected by reductions in the cost of battery technologies), and the rate of turnover from ICEs (affected by the scale of disincentives relating to the consumption of fossil-fuel-based road transport). Governments can play a key role over the next decade by promoting large-scale deployment of EV chargers in urban areas, and signalling the phase-out of ICE-powered vehicles. The sale of passenger ICE vehicles is expected to end by 2035.[67]

Production of EVs are estimated to increase tenfold from now to 2050 to satisfy the needs of the net zero transition. Electrification is likely be faster for smaller vehicles: as at today, EVs already account for around 40% the sale of 2 and 3 wheelers, while heavy duty vehicles are not likely to be fully electrified until around 2050.

Figure 19 - The Asia Pacific region is expected to be the dominant driver for the increase in road mobility spending

REGION	2/3 WHEELERS	LIGHT DUTY	HEAVY DUTY	EV CHARGERS
Investment Gap (2021-30 Compared to Historical; $ Billion)				
North America	53	474	65	73
Central & South America	34	64	9	14
Europe	71	534	74	77
Africa	31	59	8	12
Middle East	27	51	7	11
Eurasia	25	46	6	10
Asia Pacific	508	821	114	153
Annual Scale-up Needed - Investment CAGR (2020-30)				
North America	13%	23%	24%	50%
Central & South America	35%	29%	30%	80%
Europe	12%	22%	24%	30%
Africa	35%	29%	30%	80%
Middle East	35%	29%	30%	80%
Eurasia	35%	29%	30%	80%
Asia Pacific	22%	26%	27%	44%

Note: Investment refers to spending on EVs and on energy-efficient vehicles. 'Investment gap' corresponds to the additional investment effort needed in the years 2021–30 over and above historical levels. 'Investment CAGR' is the average annual growth rate needed over 2021–30 for investment projections. Light and dark shades correspond to lower or higher investment gaps respectively.

Source: Vivid Economics analysis based on IEA data

This market scale-up will create additional investment opportunities upstream in the automotive value chain and in the aviation and shipping sectors.[68] Investments in green technologies for shipping and aviation are small compared to investment in road transport, but crucial to the decarbonisation of these hard-to-abate sectors, as shown in Figure 31 and Figure 32. Investment in these sectors focuses on engines optimised for green fuels, such as biofuels, ammonia, and hydrogen-based synthetic fuels.[69]

Note: Spending on 'Innovative green technologies' refers to investment in engines optimised for the use of green energy sources. For shipping, these engines include those that rely on bioenergy (e.g. biodiversity-methanol), electricity, and on hydrogen and hydrogen-based fuels (ammonia and synthetic fuels). For aviation, they include hydrogen-powered and electric engines.

Source: Vivid Economics analysis based on IEA data

Figure 20 - Electrification in the road transport sector is expected to be faster for smaller vehicle classes

Source: Vivid Economics analysis based on IEA data

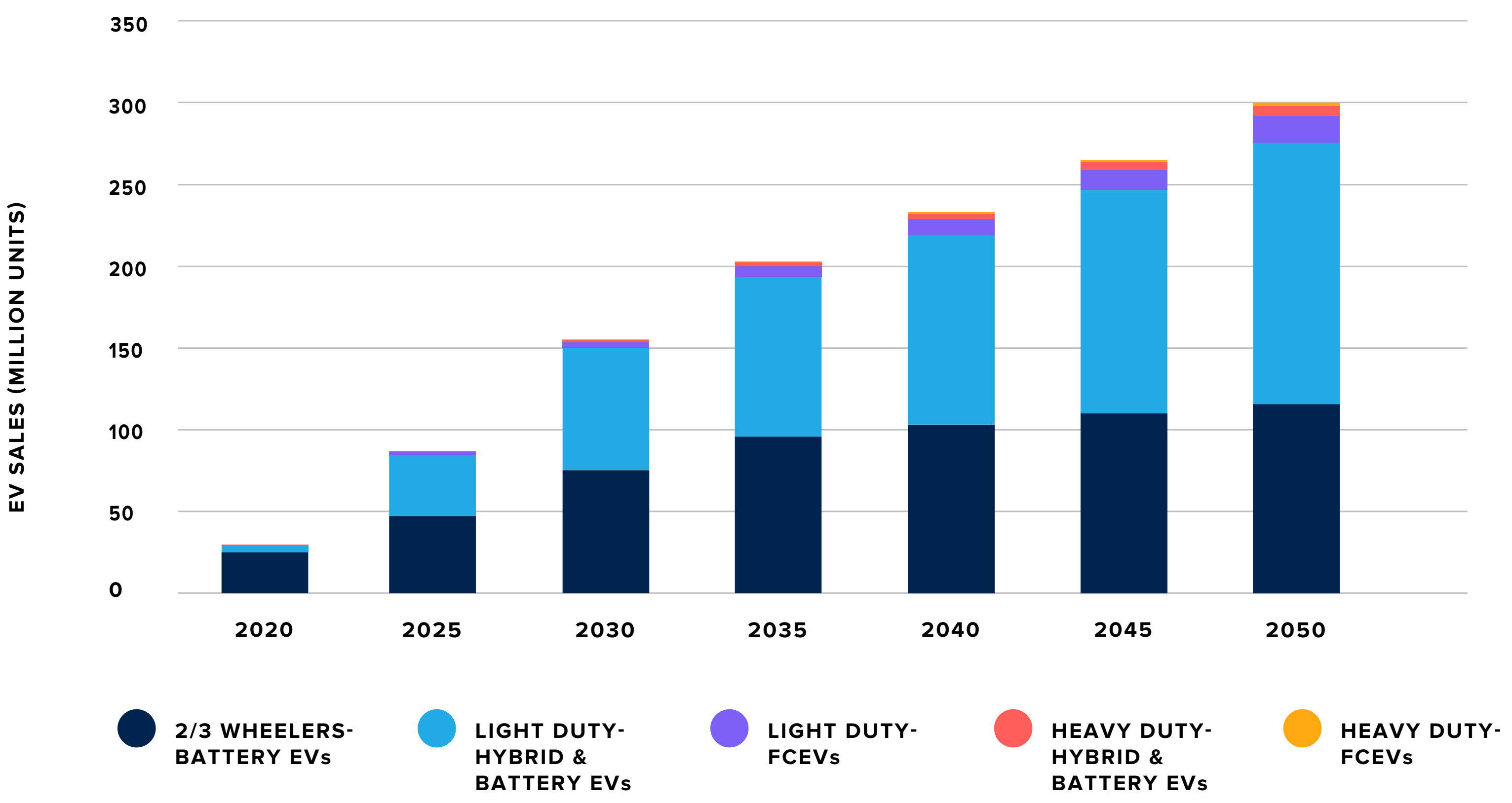
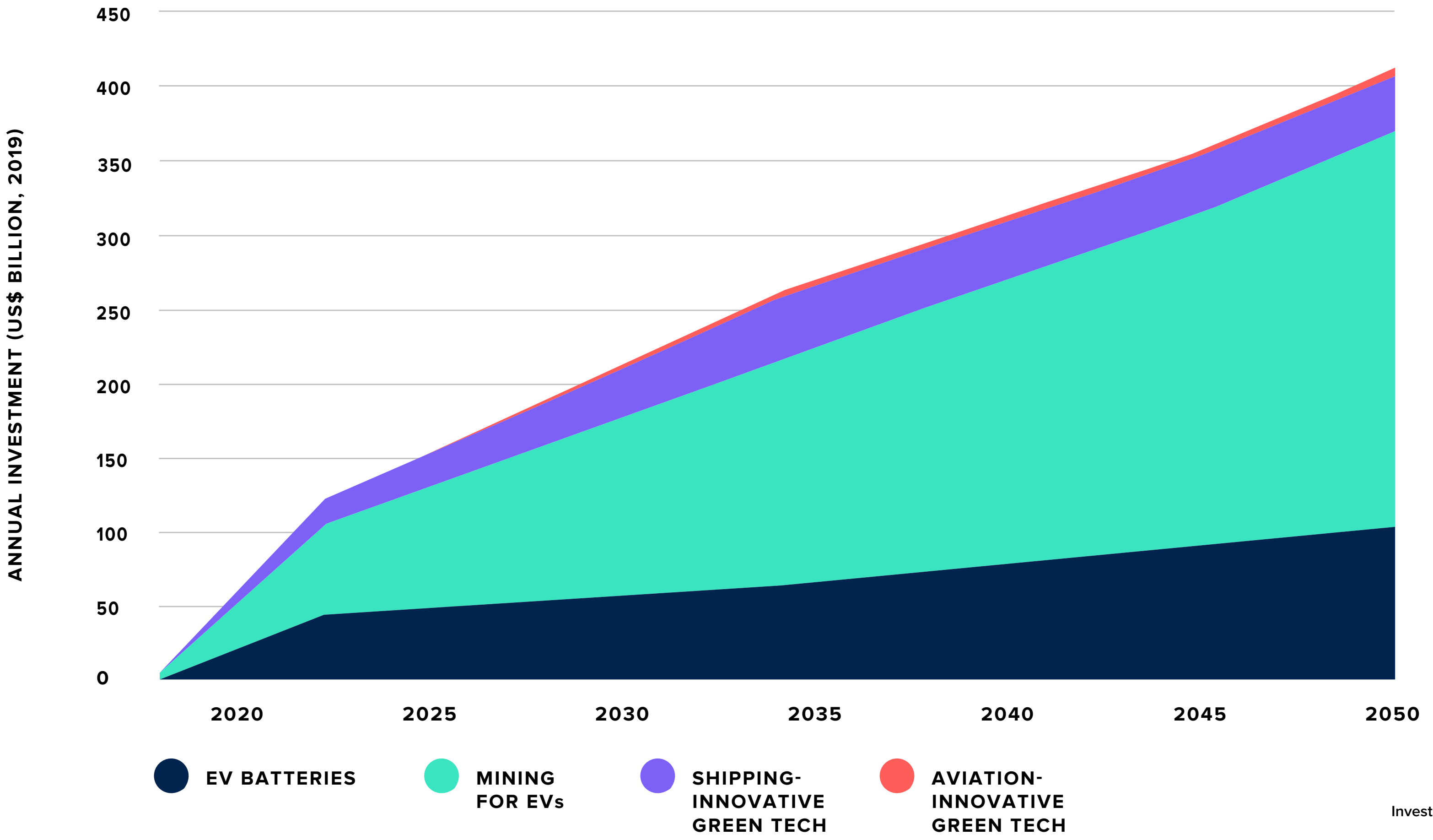


Figure 21 - The decarbonisation of transport is likely to provide investment opportunities across the EV value chain

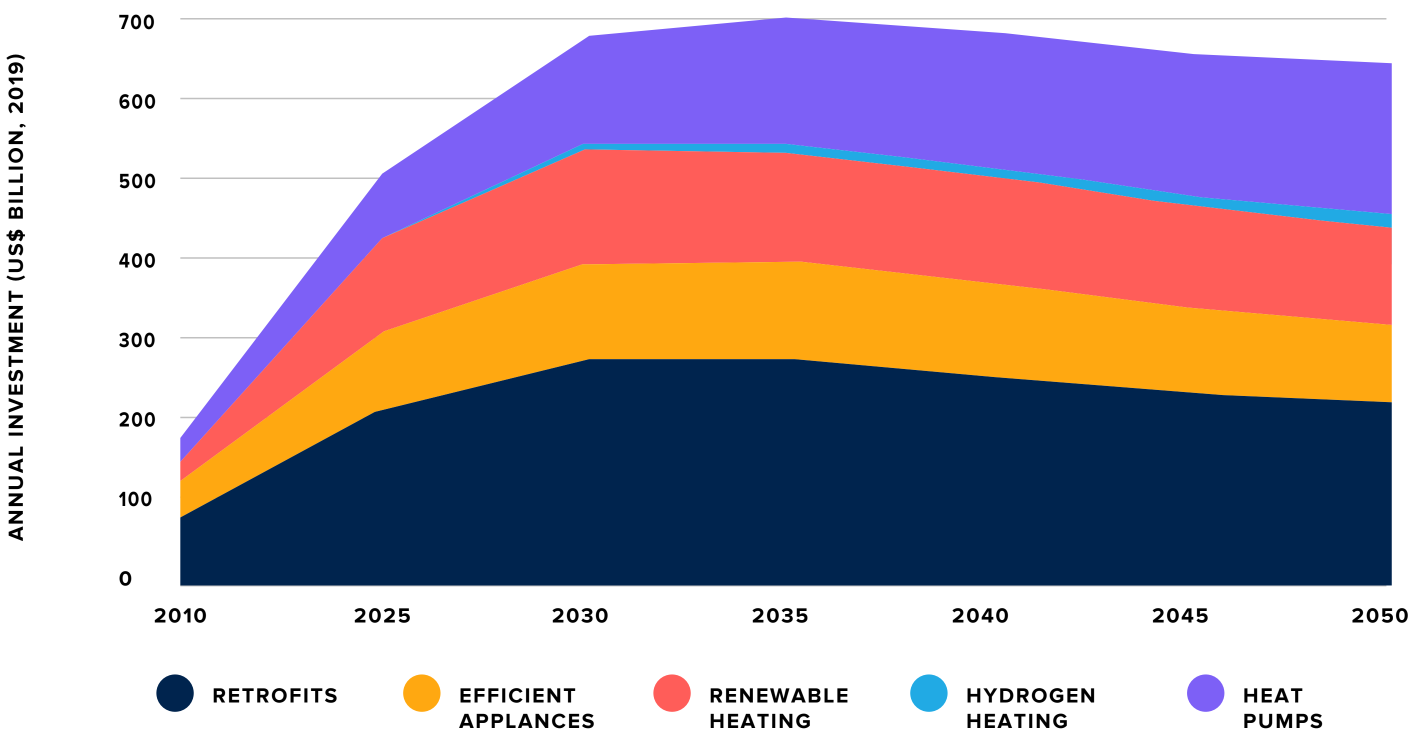


2.3.3 Buildings

Energy efficiency spending, including retrofits and efficient appliances, accounts for 56% of investment in building sector: $19 trillion to 2050. To achieve net zero, the IEA estimates that 85% of residential and commercial properties must be zero carbon-ready by 2050. This implies that almost all existing buildings not already net zero-compliant need to be retrofitted by 2050.[70] The yearly rate of retrofit must increase rapidly, from less than 1% today to 2.5% in developed economies and to 2% in emerging markets.[71,72] As is the case for EVs used in transportation, buildings investments are borne directly by consumers who own or use residential and commercial properties.

Heating is the second-largest driver of investment in buildings, requiring $3.8 trillion of investment to 2050, shown in Figure 22. Within heating, heat pumps are expected to have the fastest development, with an estimated 55% of houses across the world adopting this technology by 2050.[73] Traditional renewable heating will be another valuable investment opportunity, comprising a variety of technologies, such as boilers and stoves relying on 'modern' solid biomass (e.g. pellets), or solar thermal water heating.[74] Spending on biomass- and solar-based heating is estimated amount to around $4.3 trillion over the next three decades, a larger amount than spending on heat pumps, and their maturity implies a small technological risk.

Figure 22 - Retrofits and heat pumps drive investments needs in buildings in the IEA NZE 2050 scenario



Source: Vivid Economics analysis based on IEA data

Figure 23 - Building retrofits require the most spending in the transition to net zero, with Europe, North America and Asia Pacific playing the largest role

REGION	RETROFITS	EFFICIENT APPLIANCES	HEAT PUMPS	OTHER GREEN HEATING
Investment Gap (2021-30 Compared to Historical; $ Billion)				
North America	431	217	120	249
Central & South America	27	15	8	13
Europe	359	143	260	403
Africa	34	24	19	30
Middle East	75	24	17	26
Eurasia	33	12	8	13
Asia Pacific	359	151	142	219
Annual Scale-up Needed - Investment CAGR (2020-30)				
North America	11%	10%	12%	19%
Central & South America	19%	15%	22%	24%
Europe	10%	12%	18%	20%
Africa	21%	11%	18%	20%
Middle East	18%	18%	25%	28%
Eurasia	22%	20%	26%	30%
Asia Pacific	13%	14%	19%	22%

Note: 'Other Green Heating' refers to heating relying on hydrogen, biomass, or solar thermal energy. 'Investment gap' corresponds to the additional investment effort needed in the years 2021–30 over and above historical levels. 'Investment CAGR' is the average annual growth rate needed over 2021–30 for investment projections. Light and dark shades correspond to lower or higher investment gaps respectively.

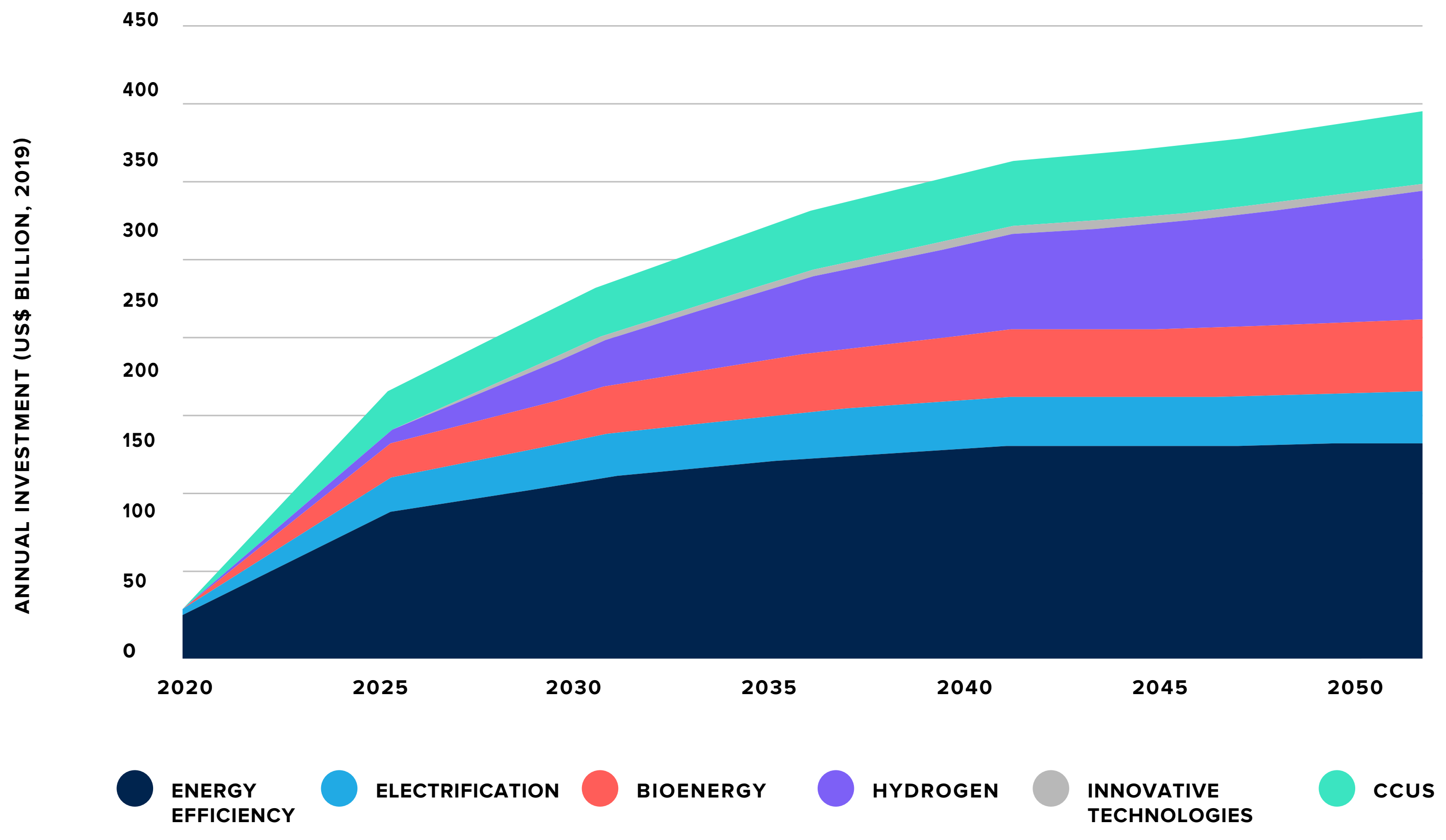
Source: Vivid Economics analysis based on IEA data

2.3.4 Industry

Improvements in energy efficiency account for around $4 trillion (45 %) of the investment needed in heavy industries (steel, chemicals, and cement). Technologies and practices that can help deliver these energy savings include heat pumps, innovations improving electric and fuel efficiency, and industrial energy management systems that improve system-wide efficiencies.[75]

CCUS and hydrogen are expected to face investment needs of around $1.2 trillion (14%) and $1.4 trillion (16%) respectively, most of which is expected to occur after 2030. CCUS development is required due to the hard-to-abate nature of heavy-industry emissions. Hydrogen is likely to be key for the steel sector in particular, where production can benefit both from blue hydrogen (i.e., hydrogen produced via fossil fuels and CCUS-equipped) and from electrolytic or green hydrogen.[76] While hydrogen is particularly apt at providing the required amounts of high-temperature heat, bioenergy and electrification are likely to also play a role in industrial decarbonisation, as shown in Figure 24.[77]

Figure 24 - Spending on energy efficiency is the main driver of investment in heavy industry, but the role of CCUS and hydrogen is growing rapidly



Note: Spending on 'Innovative technologies' refers to investment in clean, speculative production routes such as iron ore electrolysis, innovative use of solar power, and bioenergy to produce heat for industrial processes.
Source: Vivid Economics analysis based on IEA data

Figure 25 - Investment in the industry sector is likely to be concentrated in the Asia Pacific region

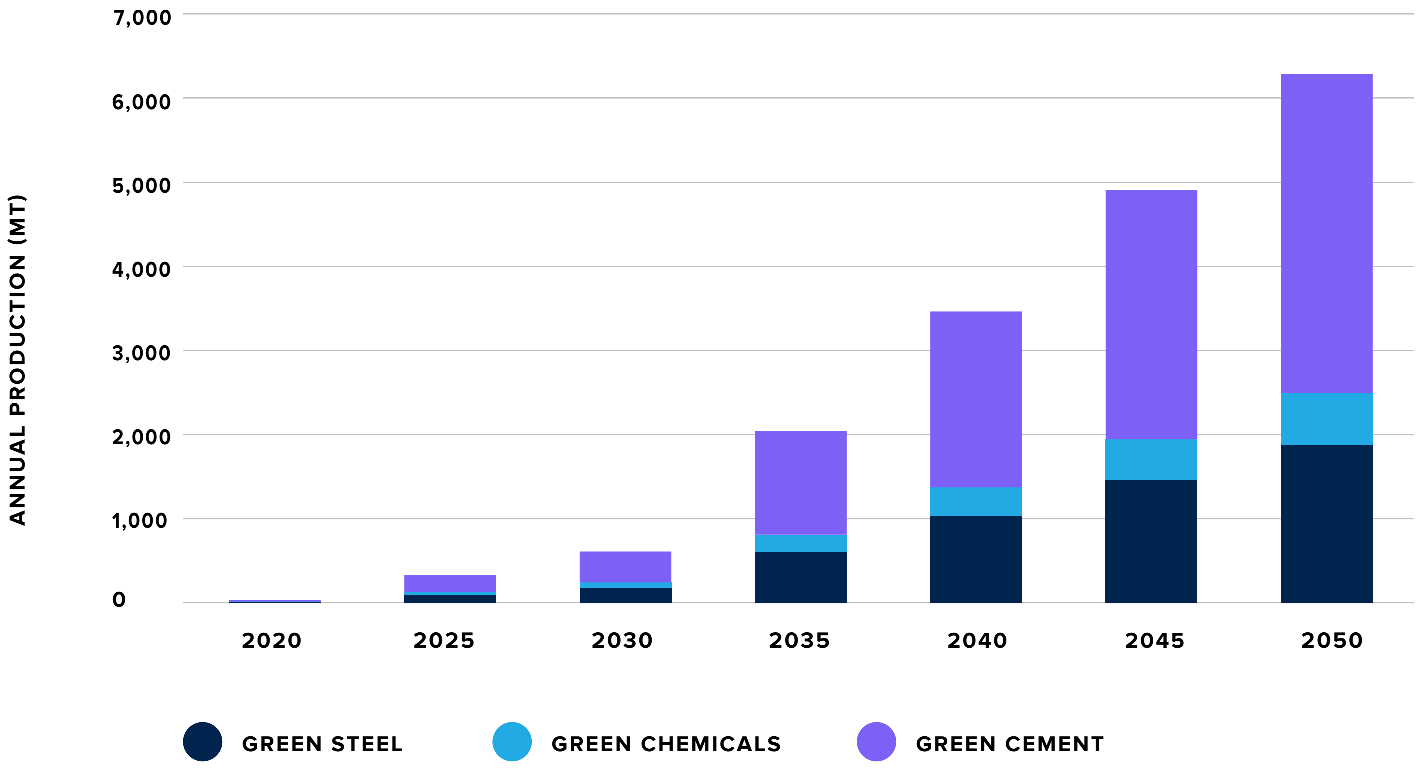
REGION	ENERGY EFFICIENCY	ELECTRIFICATION	CONVENTIONAL BIOENERGY	CCUS	HYDROGEN
Investment Gap (2021-30 Compared to Historical; $ Billion)					
North America	67	42	42	35	23
Central & South America	19	5	5	8	2
Europe	89	41	30	34	15
Africa	12	3	3	6	1
Middle East	21	13	15	13	8
Eurasia	1	5	4	4	3
Asia Pacific	510	141	111	176	47
Annual Scale-up Needed - Investment CAGR (2020-30)					
North America	16%	61%	29%	42%	N/A
Central & South America	13%	55%	26%	46%	N/A
Europe	15%	58%	30%	43%	N/A
Africa	12%	56%	25%	47%	N/A
Middle East	14%	58%	26%	41%	N/A
Eurasia	8%	50%	21%	34%	N/A
Asia Pacific	15%	57%	30%	47%	N/A

Note: A meaningful CAGR for hydrogen cannot be computed over 2020–30 due to the negligible current levels of investment in this technology. 'Investment gap' corresponds to the additional investment effort needed in the years 2021–30 over and above historical levels. 'Investment CAGR' is the average annual growth rate needed over 2021–30 for investment projections. Light and dark shades correspond to lower or higher investment gaps respectively.

Source: Vivid Economics analysis based in IEA data

Due to the technological challenges associated with decarbonising heavy industry, the volumes of steel, cement and primary chemicals produced via low-emissions technologies is expected to remain low for the next decade. The volumes of low-carbon output are expected to ramp up after 2030, as shown in Figure 26.

Figure 26 - The decarbonisation of heavy industry is expected to require time and may be limited in the 2020s

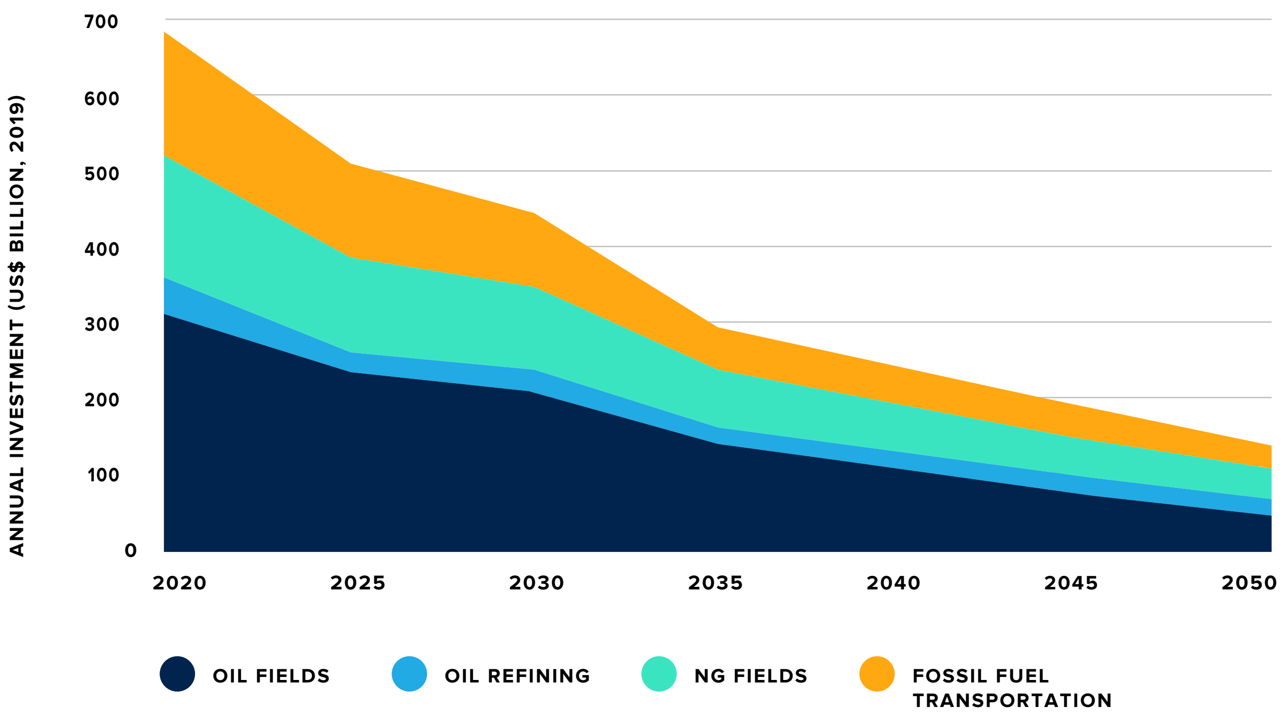


Source: Vivid Economics analysis based on IEA data

2.3.5 Fossil-fuel Supply

Investment in fossil fuels decreases rapidly in IEA's NZE scenario, but continues to account for $10 trillion, or 7.1%, of total investment to 2050. No new oil or natural gas fields are developed (except for those already approved), as the decrease in fossil-fuel prices would risk stranding these assets. However, large investments are still needed to support production from existing fields, shown in Figure 27, implying that the average volume of investments in 2021–30 are likely to be comparable to that in 2001–10.[78]

Figure 27 - Investment needs for fossil fuels decrease considerably in the IEA NZE 2050 scenario, but remain significant



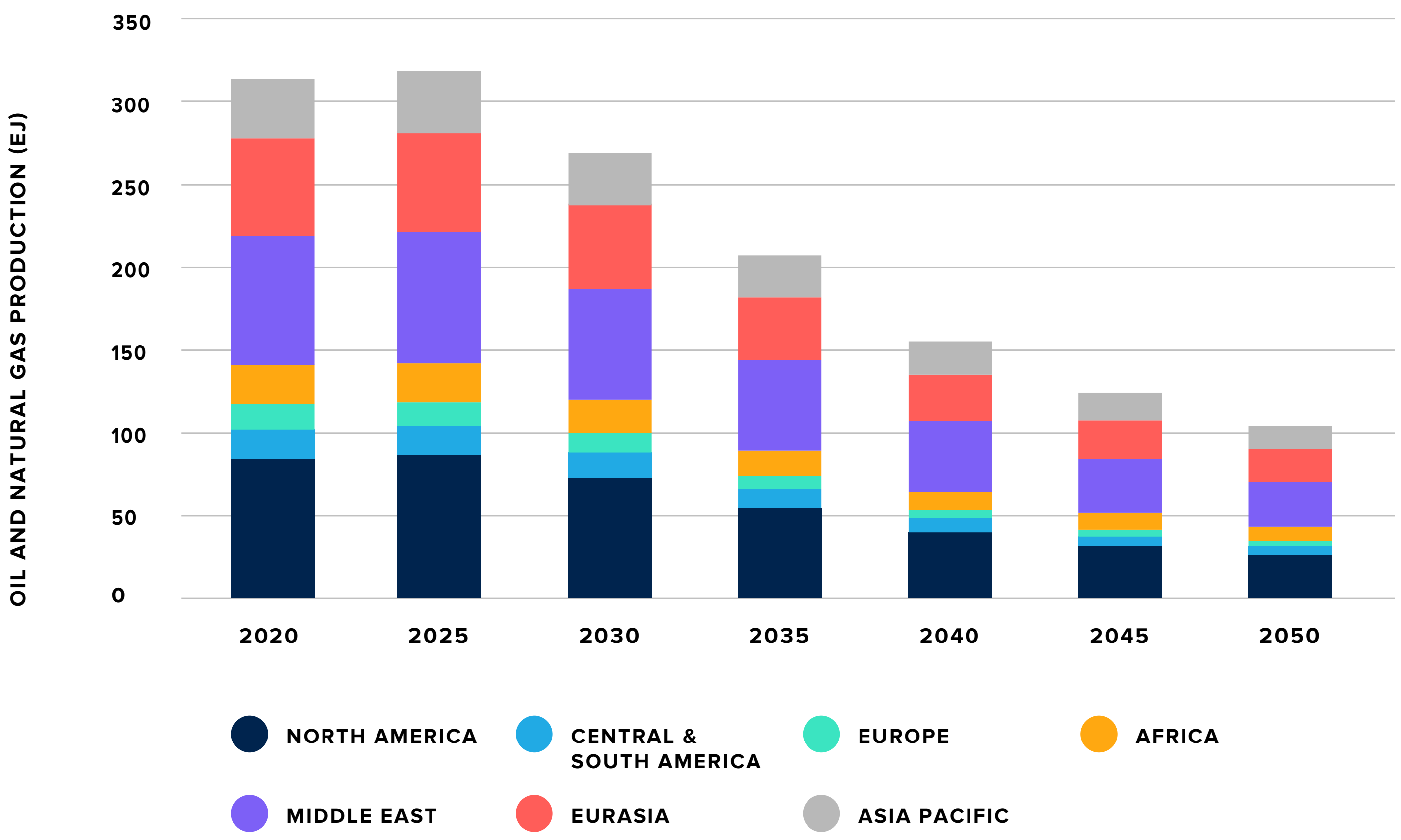
Source: Vivid Economics analysis based on IEA data

Due to continued production from existing fields, fossil-fuel production does not decrease as rapidly as investments. As shown in Figure 28, global output starts to decrease only after 2030.

The continued role played by fossil fuels is an important driver for CCUS development. In the NZE, the use of CCUS to limit emissions from fossil fuels, across the fuel supply, electricity and industry sectors, accounts for 70% of the use of this technology. While deployment is surrounded by significant uncertainty, plans for more than 30 integrated CCUS facilities have been announced in the last four years. These plans are concentrated in the USA and Europe, but some are also planned in China, the Middle East, Korea and Australia. If all are completed, the global CO_2 capture capacity will more than triple from current levels.[79] Despite the positive trends, this amount falls short of the IEA projections in its NZE scenario. While, historically, the IEA has projected high levels of CCUS deployment in its scenarios, in the past decade CCUS development has been only 13% of the target set by the IEA in its 2009 Roadmap.[80]

Considering projections for 2021–50, the IEA projects higher levels of CCUS deployment in its scenario than McKinsey, is in line with IPR, NGFS and IRENA, and has lower levels of deployment than IPCC. If CCUS development is lower than the IEA forecasts, shown in Table 5, fossil-fuel demand is expected to need to fall more rapidly to reach net zero by 2050, as shown in the IPR and McKinsey scenarios. This would increase the risk of asset stranding and depress future investments in fossil-fuel supply.

Figure 28 - Fossil-fuel production is projected to remain high in the next decade



Source: Vivid Economics analysis based on IEA data

Table 5 - IEA projections regarding CCUS are in line with the NGFS and IRENA estimates

	IEA NZE	MCKINSEY 1.5 PATHWAY	NGFS NET ZERO 2050 (ORDERLY)	IPR 1.5 REQUIRED POLICY SCENARIO	IPCC 1.5˚C (MEDIAN SCENARIO)	IRENA
Total fossil-fuel primary demand (EJ)	120	87	121	107	155	112
CCUS (Gt CO_2 captured)	7.6	4.3	8.5	6.9	15.0	8.1

Source: Vivid Economics analysis based on IEA, McKinsey, NGFS and IPCC data

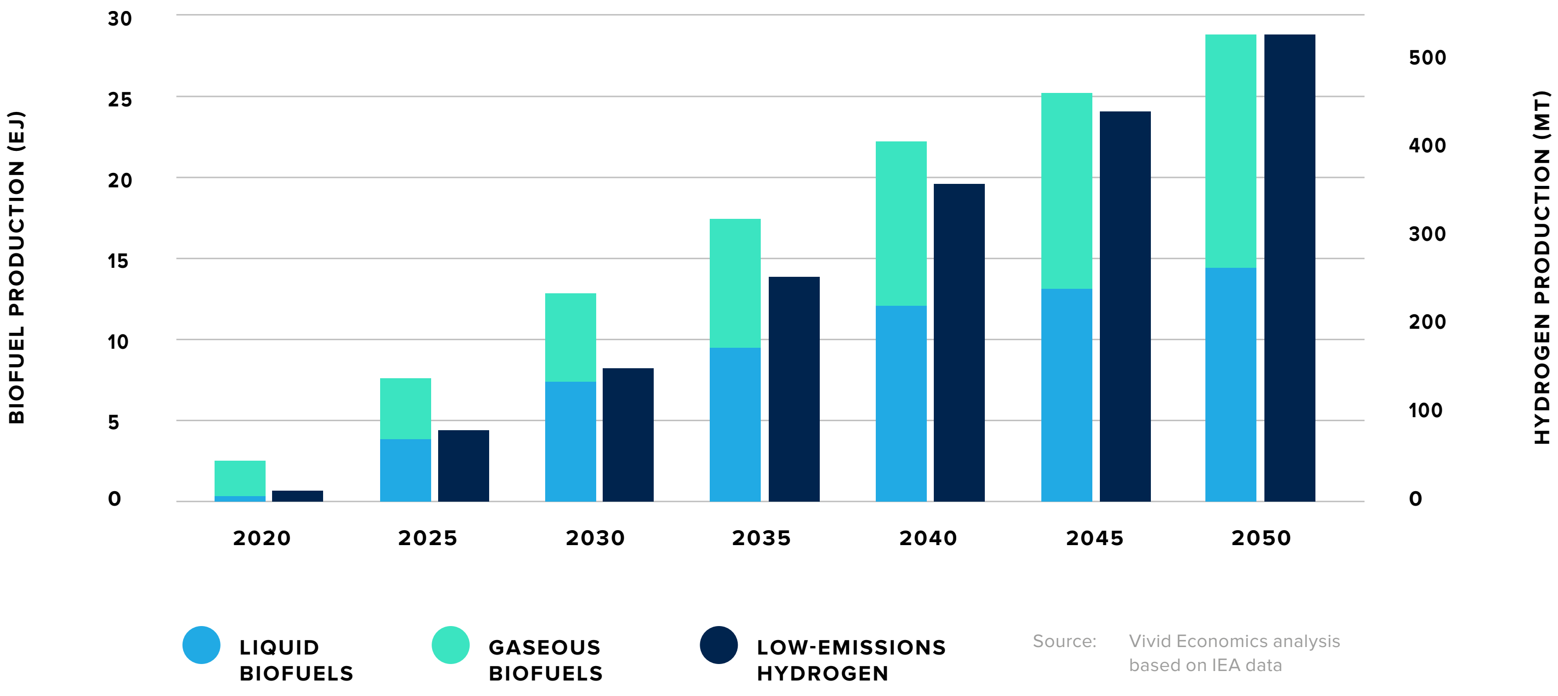
2.3.6
Low-Emissions Fuels and Carbon Capture

The production of low-emissions fuel is driven by biofuels in the 2020s, shown in Figure 29, due to their higher technological maturity relative to hydrogen-based fuels. While biofuels are currently more established than hydrogen-based fuels, significant technological development is needed in this field too: currently, more than 90% of biofuels are produced from conventional crops (corn, soybeans), and therefore compete with food production. In the NZE, biofuels are expected to be derived from other sources, such as wastes and 'woody' energy crops grown on marginal lands, unsuitable for conventional agriculture.[81] These 'advanced biofuels', in addition to mitigating land use concerns, offer higher emissions reductions relative to conventional biofuels.[82]

To ensure that fuel supply is low-carbon across the economy can also require investment in CCUS, estimated to be around $6.7 trillion to 2050. Carbon capture is employed across multiple sectors, with the key uses being in electricity generation (69%, to limit emissions from bioenergy and fossil fuels), in heavy industry (18%), and in direct air capture installations (13%). Carbon capture plays an increasingly key role after 2030.

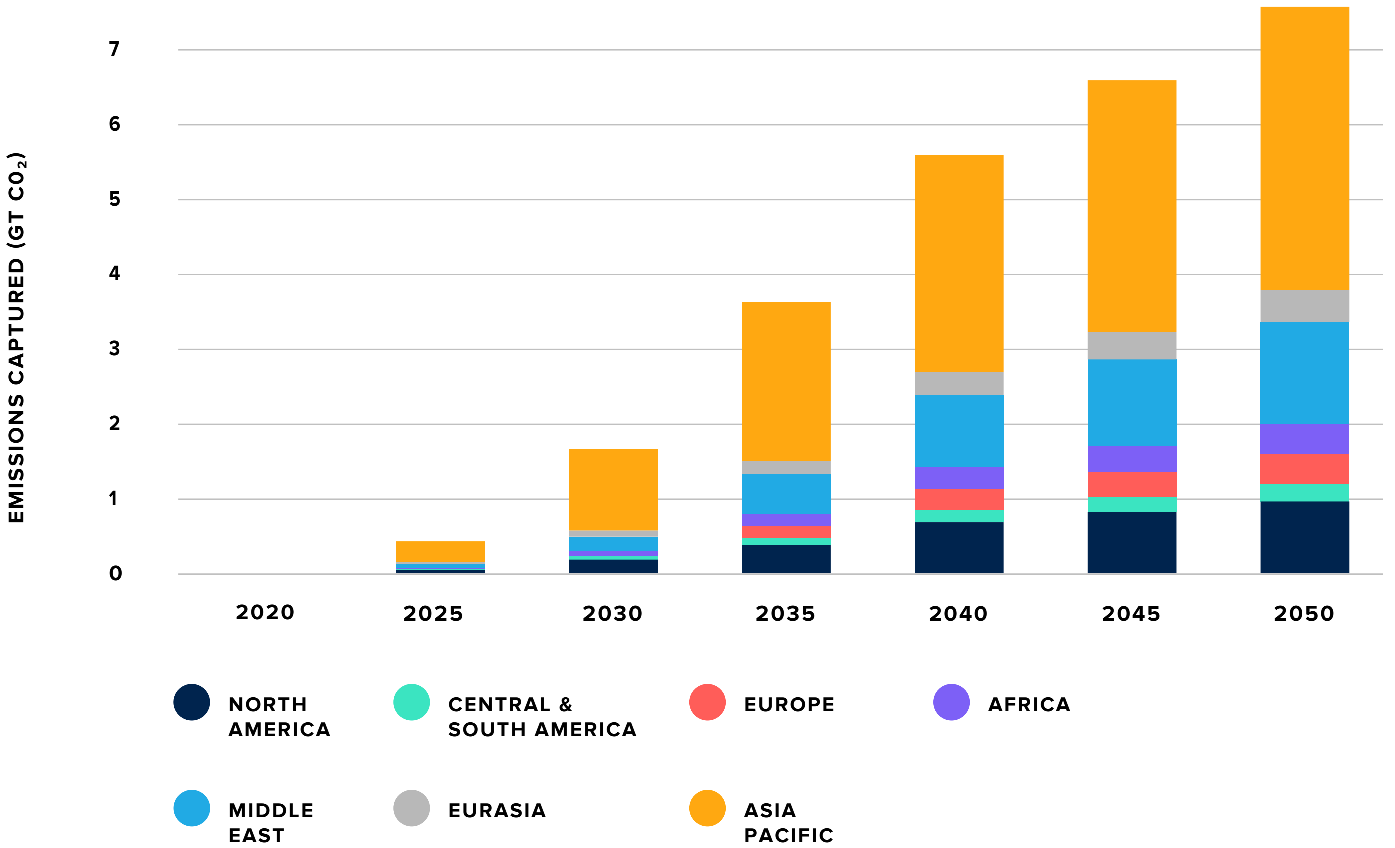
Investment in biofuels, hydrogen-based fuels and direct carbon capture follows the same patterns as the production volumes. Biofuels, for example, play the largest role in the 2020s, accounting for 76 % of investment to 2030.

Figure 29 - Low-emissions hydrogen production ramps up only in the 2030s



Source: Vivid Economics analysis based on IEA data

Figure 30 - Reliance on carbon capture technologies increases significantly after 2030



Source: Vivid Economics analysis based on IEA data

Investment in hydrogen and hydrogen-based fuels (ammonia and synfuels) is relatively small in the 2020s, $25 billion per year, but grows to $75 billion per year in the 2030s. During the 2020s production facilities are scaled up but production increases sharply only afterwards, when demand for hydrogen in transport increases.[83] Furthermore, production from naphtha (CNR) is phased out, electrolysis reaches a mature stage, and production from fossil fuels overwhelmingly relies on carbon capture.

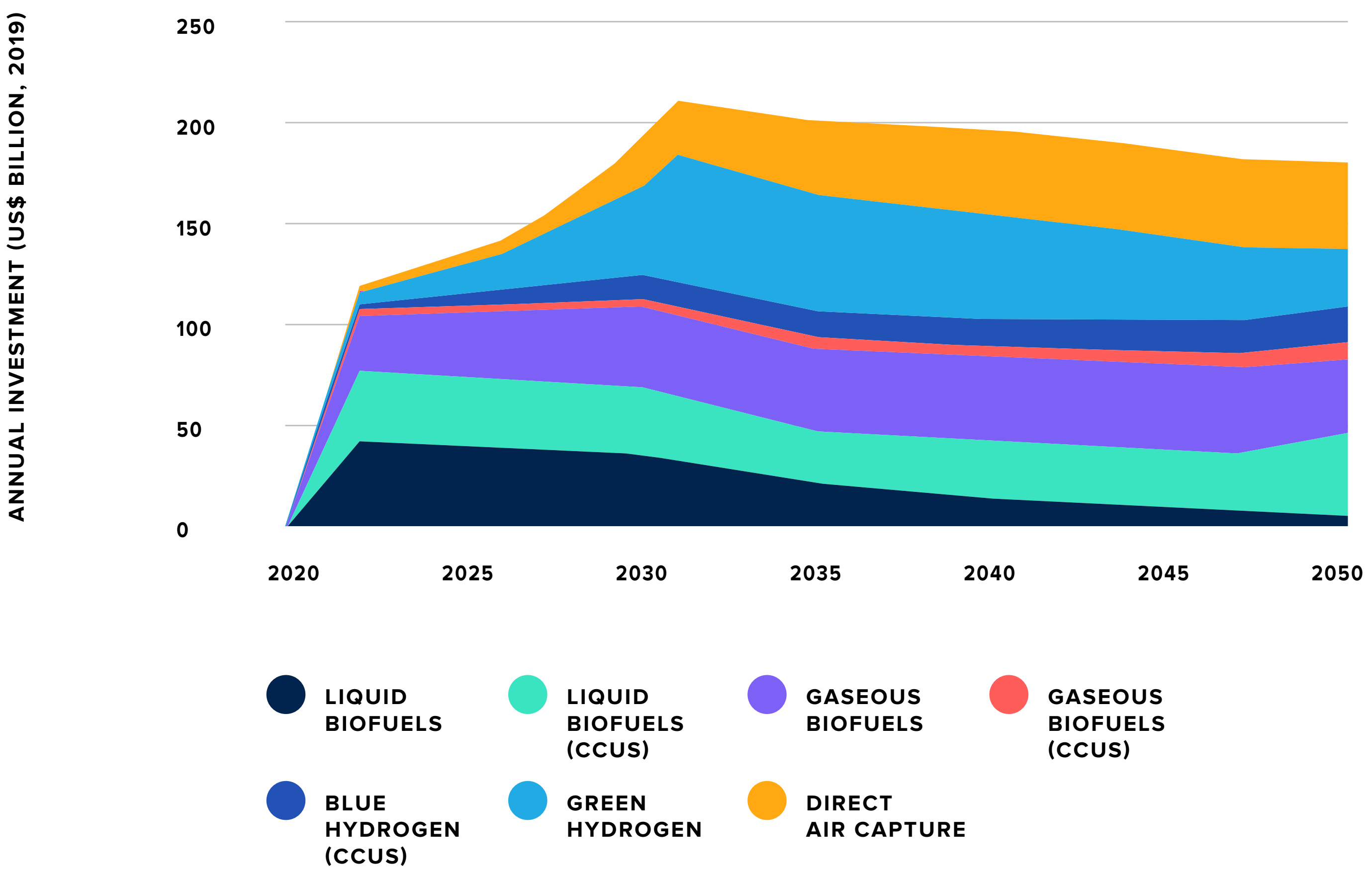
Bioenergy provides less risky investment opportunities compared to hydrogen, due to relatively higher technology readiness. However, because low-emissions fuels technologies are not commercially mature, all investment in the sector will be affected by significant uncertainties.

Notably, deployment of hydrogen diverges significantly across net zero scenarios. IEA projections are in line with the NGFS estimates, below IPR, McKinsey and IRENA projections, and above the conservative estimates by IPCC. There is also uncertainty regarding the development of specific technologies for hydrogen production: while the IEA sees CCUS-equipped production from natural gas playing a significant role even in 2050, IPR and McKinsey estimates that by 2050 almost all hydrogen will be produced via electrolysis.

Note: Total hydrogen demand includes hydrogen which is produced via electricity and natural gas then and used as a feedstock in industry; and, hydrogen use in electricity generation. These categories of hydrogen demand are not always captured in final energy demand balances.

Source: Vivid Economics analysis based on IEA, McKinsey, NGFS, IPR, IPCC and IRENA data

Figure 31 - To deliver low-carbon fuel supply, biofuels attract the most investment in the 2020s



Source: Vivid Economics analysis based on IEA data

Table 6 - There is great uncertainty regarding the role of hydrogen production in the net zero transition

	IEA NZE	MCKINSEY 1.5 PATHWAY	NGFS NET ZERO 2050 (ORDERLY)	IPR 1.5 REQUIRED POLICY SCENARIO	IPCC 1.5˚C (MEDIAN SCENARIO)	IRENA
Total Hydrogen Demand (Ej)	58	71		110		
Hydrogen And Hydrogen-Based Fuels Final Energy Demand (Ej)	33	53			18	42
Hydrogen Final Energy Demand (Ej)	20		18			
Share Of Green Hydrogen	61%	95%		83%		
Share Of Blue Hydrogen	38%	4%		17%		
Share Of Grey Hydrogen	1%	1%		1%		

Figure 32 - Across low-emissions fuels, investment needs for electrolytic hydrogen are projected to grow at the fastest rate

REGION	GREEN HYDROGEN	BLUE HYDROGEN (CCUS)	LIQUID BIOFUELS	GASEOUS BIOFUELS	DAC
Investment Gap (2021-30 Compared to Historical; $ Billion)					
North America	41	18	306	45	9
Central & South America	10	4	189	30	2
Europe	23	10	95	78	0
Africa	8	4	11	14	3
Middle East	13	6	9	8	9
Eurasia	7	3	9	6	4
Asia Pacific	68	30	111	72	53
Annual Scale-up Needed - Investment CAGR (2020-30)					
North America	83%	33%	36%	23%	N/A
Central & South America	83%	34%	37%	40%	N/A
Europe	82%	33%	36%	14%	N/A
Africa	84%	34%	36%	35%	N/A
Middle East	83%	33%	36%	32%	N/A
Eurasia	83%	33%	36%	32%	N/A
Asia Pacific	85%	35%	41%	19%	N/A

Note: A meaningful CAGR for Direct Air Capture cannot be computed over 2020–30 due to the negligible current levels of investment in this technology. 'Investment gap' corresponds to the additional investment effort needed in the years 2021–30 over and above historical levels. 'Investment CAGR' is the average annual growth rate needed over 2021–30 for investment projections. Light and dark shades correspond to lower or higher investment gaps respectively.

Source: Vivid Economics analysis based on IEA data

2.3.7 Agriculture, Forestry and Other Land Use

AFOLU estimates are based on investments on 'critical interventions' identified by FOLU's 2019 'Growing Better' report. FOLU has estimated the additional investment required not only to achieve net zero emissions, but also to tackle core climate, biodiversity, health and poverty challenges. In the present analysis, only climate-related spending in considered. See Technical Annex Section 7.1 for further details.

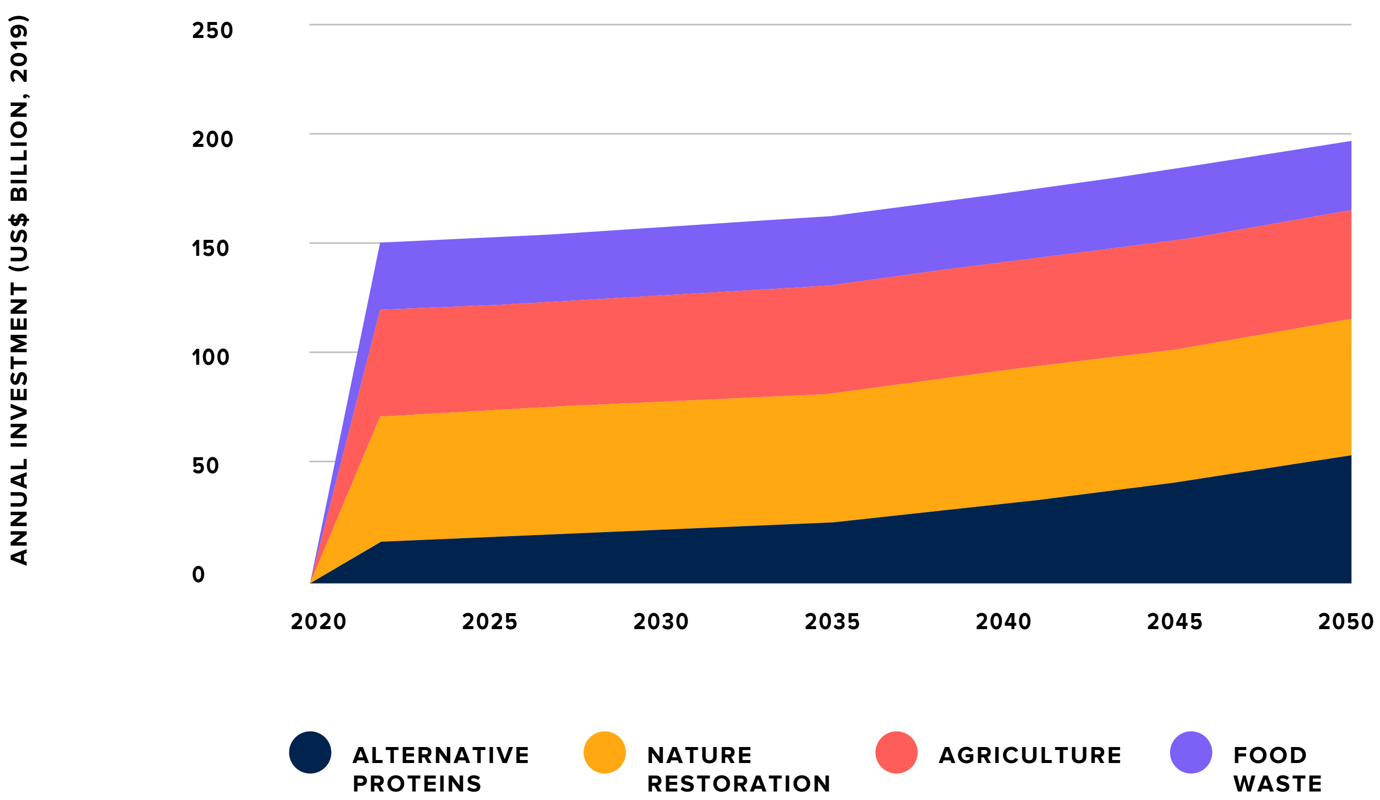
The largest investment opportunity exists in nature restoration and management, including forests, peatlands and mangroves. Over $1.1 trillion of investment is needed in forest restoration, with $0.5 trillion in forest management and the extension of REDD+. Investments in peatland and mangrove restoration are much smaller due to there being more limited potential habitats to be restored, but these ecosystems have high carbon abatement potential, and also provide benefits such as flood control and preventing sea level rise. Overall, restoration is a relatively inexpensive mitigation option. However, for these investments to become attractive to the private sector, enabling policies such as carbon pricing and market creation are likely to be important.

There are substantial food and agriculture investments which focus on improving efficiency and reducing waste, largely in developing economies. Opportunities include basic training, acquisition of capital equipment, and improving food storage and transportation infrastructure to reduce spoilage. For many agriculture investments, a key challenge is expected to be in finding ways to bundle small-scale financing for individual farmers in a way which is attractive to larger investors. If this can be achieved, it could unlock around $170 billion of investment opportunities in Africa, and $130 billion in Asia Pacific.

In developed economies, agriculture investments focus more on high-tech solutions such as precision agriculture, software and robotics. Agtech innovations cover the length of the food supply chain, from upstream farm robotics and drones to downstream grocery companies. The scale-up of investments in urban farming, which uses vertical or greenhouse farming techniques, also helps to reduce land use pressures in urban areas. Additional investments of $165 billion in urban farming and $275 billion in agtech are needed between now and 2050.

While investments in innovative alternative protein sources are initially modest, these grow rapidly to reach $43 billion per year as the market expands. Alternative proteins currently capture a small market share relative to 'traditional' meat products, but the sector is growing rapidly in response to environmental and health concerns shown in Figure 33. This is expected to increase as growing populations and rising living standards drive overall protein demand, especially in regions such as Asia Pacific. Rapid development of innovative products, such as lab-grown cultivated meat, could supplement the already established plant-based meat market.

Figure 33 - AFOLU investment requires a rapid build-up to achieve the FOLU targets



Note: The investment estimates by FOLU refer to the additional spending required to achieve climate sustainability. Therefore, the 2020 investment level is set to 0.

Source: Vivid Economics analysis based on FOLU, FAO and NGFS

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2.4 Investment Needs by Region

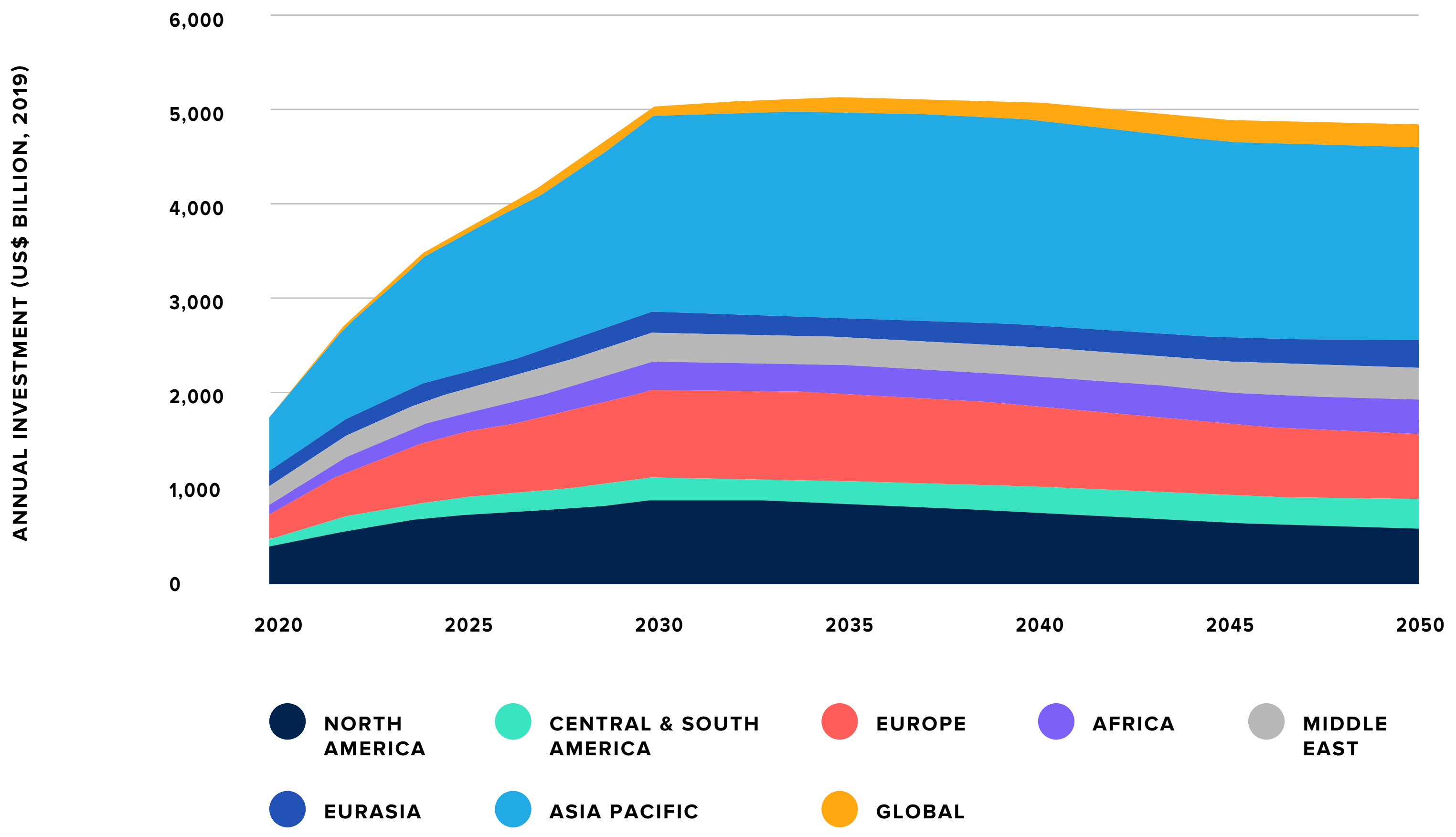
Across seven global regions, Asia Pacific requires the most investment (43% to 2050), followed by Europe and North America.

Africa, Central & South America, Eurasia and the Middle East also require significant investment, especially relative to current investment levels.[84] Figure 34 shows the overall investment level in each region, while Table 7 provides a breakdown of regional investments across each sector. The IPR's 1.5°C scenario projects a similar geographical split in low-carbon investments, with Asia Pacific accounting for 51% of total investment in electricity, transport, buildings, and industry to 2050.

Note: The IEA NZE report does not provide regional investment breakdowns. Investment is allocated to world regions based on the IEA SDS projections published in the 2020 World Energy Outlook, as well as on other IEA publications (such as the World Energy Balances and the 2017 Energy Technology Perspectives report). When no IEA sources are available, third-party publications are used.

Source: Vivid Economics analysis based on IEA, FOLU, FAO and NGFS data

Figure 34 - Breakdown of investment needs in NZE scenario across world regions



Source: Vivid Economics analysis based on IEA data

Table 7 - Breakdown of investment across each macro-region and sector (2019 $ billion; aggregate for 2021–50)

	ELECTRICITY	TRANSPORT	BUILDINGS	FOSSIL FUELS	INDUSTRY	LOW-EMISSION FUELS	AFOLU	TOTAL
North America	8,068	4,227	4,929	2,612	1,155	1,413	661	**23,065**
Central & South America	2,551	1,339	510	548	338	797	856	**6,939**
Europe	11,446	4,613	5,671	466	1,255	712	393	**24,556**
Africa	4,254	1,217	915	712	228	255	863	**8,444**
Middle East	2,965	1,028	1,136	2,462	503	356	124	**8,573**
Eurasia	1,965	914	879	1,760	408	176	555	**6,657**
Asia Pacific	27,284	14,514	4,985	1,393	6,047	1,887	1,540	**57,650**
World	**58,532**	**27,852**	**19,026**	**9,952**	**9,934**	**5,596**	**4,992**	**135,884**

2.4.1
North America: USA, Mexico and Canada

Fossil-fuel investment remains high in North America, particularly in 2021–30, when it accounts for nearly 20% of energy investment. While coal is in a structural decline, further accelerated by the COVID-19 pandemic, oil and gas remain important.[85] To ensure the achievement of net zero emissions by 2050, investment in carbon capture technologies is therefore necessary. Within this region, the largest opportunities for CCUS are at gas-fired plants in the USA, which are young, large facilities with the capacity to accommodate capture equipment.[86] CCUS has also large potential in bioenergy.[87]

The building sector also attracts significant investments. North America is one of the regions with the greatest heating needs, which increases demand for zero-emission heating solutions and retrofits.[88]

2.4.2
Central & South America: Brazil, Caribbean, and rest of Latin America

Nature restoration and energy generation opportunities are particularly important in Central & South America. $346 billion is needed for investments in forest restoration and management, of which almost $200 billion is in Brazil. There are also modest investments in restoring peatland and mangrove ecosystems.

A serious challenge for energy generation in the region is the reliance on hydropower for countries at high risk of extreme weather events. Hydropower attracts the most investment out of all generation technologies in the region. However, Central & South American countries with high hydroelectric potential are also at risk of floods and droughts, which could negatively affect hydro generation.[89]

2.4.3
Europe: EU, UK, Turkey, Israel, and other European countries

Investment needs in Europe are highest in the electricity and transport sectors. Wind power has a dominant role, attracting more than 40% of total investment in power generation, which reflect Europe's favourable wind conditions.[90] In the transport sector, the EU (together with the USA, China and Japan) is a leader in the transition to zero-emission cars.[91]

The buildings sector also shows important investments in Europe. The EU has expressed the desire to increase its renovation efforts to ensure that all buildings are net zero by 2050. This leads to large retrofit investments in the region.[92]

2.4.4
Asia Pacific: China, India, Japan, Korea, Central and SE Asia, Australia and New Zealand

The Asia Pacific region is the main recipient of investments in the NZE scenario. Due to the size and dynamism of its economies, this region receives more than half of the total global investment in the electricity, transport, industry and AFOLU sectors.

The region attracts more than 70% of global energy investment in the industry sector in the NZE scenario. This is driven by the dominant position of China in the heavy industries, where it is projected to produce more than half of the global supply of steel and cement. Due to the concentration of heavy industries in Asia Pacific, global investment aimed at abating emissions needs to be focused on this region.

The least important investment areas are the fossil fuels and buildings sectors. In the former, investment opportunities are limited by natural resource endowments: Asia Pacific countries have limited natural gas and oil deposits. While this region provides more than 70% of the global coal supply,[93] coal use needs to be rapidly reduced to reach net zero in 2050. In the buildings sector, investment demand is relatively low due to the lesser need of retrofits compared to regions such as Europe or North America.

2.4.5
Eurasia: Russia and the Caspian Region

Investment in energy generation in Eurasia focuses on nuclear and hydropower generation, which attract more than 40% of investment in power generation.[94] While wind and solar PV generation are the focus of investment for most world regions, these technologies play a lesser role in Eurasia, with solar generation being especially marginal.

Nonetheless, investment in fossil fuels remains high during the transition. While no new fields are developed, significant investments are made to support the existing fields and infrastructure. The natural gas sector receives particular support in Russia due to strategic industrial consideration.[95] Russian fossil fuel producers are expanding into downstream petrochemical processes (such as plastic production), to hedge against falling oil prices.[96]

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2.4.6
Africa: North Africa and Sub-Saharan Africa

Africa sees a strong shift of investment towards energy generation. This is driven by rapid population growth and by infrastructural catch-up needs: currently, around 600 million people across the region do not have access to electricity. Therefore, large investments are needed to remedy the current unreliability of energy supply, as well as to satisfy future demand. Excluding AFOLU, more than half of the investment in this region is projected to take place in power-related projects, the largest share among the regions considered.[97]

The region is also the main recipient of investments in AFOLU sectors after Asia Pacific. Investments of $173 billion focus on bridging the productivity gap with developed economies through basic extension services and capital equipment. There are also sizable investments in regenerative farming practices, biofertilisers and biopesticides. Currently, almost one quarter of all agricultural land is located in Africa, making these investments critical for the emissions reductions from the food system.

2.4.7
Middle East

In the Middle East, the decline in fossil fuel prices presents major challenges. While investment in fossil fuels remains high compared to other world regions, the reduction in their price poses significant risks to GDP and public revenues, which could affect the provision of public services such as healthcare and education.[98]

Investment in low-emissions fuels are expected to play a key role in the transition. While the oil price in the NZE scenario would, in theory, allow for the development of new fields for the lowest-cost producers, this would put additional downward pressure on fossil fuel prices. Therefore, the IEA assumes that no new fields will be developed.[99] Investment in alternative fuels, such as hydrogen-based ones, are instead likely to be key to satisfying energy demand up to 2050.[100]

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2.5 The Role Of Private and Public Investors

Collaboration between private and public entities is likely to be necessary to mobilise the resources required for the transition to net zero.

The IEA expects that the majority of funding will be privately sourced, with public institutions providing the appropriate set of incentives and regulatory frameworks to foster private activity.[101] However, the respective roles of private and public investment will depend on the investors' perceived risk and/or expected returns associated with each technology and region under consideration, which is determined by a variety of technological, market and economic risks as well as the maturity of supporting regulations and policies. The shares of private investment are expected to increase in each sector and country as the respective markets and technologies mature over time.

Public investment is associated with network infrastructure and mitigation levers facing greater technological and regulatory uncertainty. Market failures such as network externalities or unpriced environmental externalities limit private activity. Governments and multilateral institutions are therefore needed to support the development of the infrastructure required for the transition, such as electricity networks and road infrastructure for EVs. Public investment is also initially needed in sectors affected by high technology risk. This is the case for heavy industry, which is characterised by multiple 'green' technologies at the demonstration or prototype stage facing high upfront implementation costs. Public support may also be needed to catalyse private investment in cases of high perceived country and market risk, which can be the product of political instability or of weak regulatory frameworks. In these cases, activity by multilateral development institutions can be most beneficial. Based on these factors, Table 8 provides estimates for the public share of energy investment in the net zero transition, considering global average values.

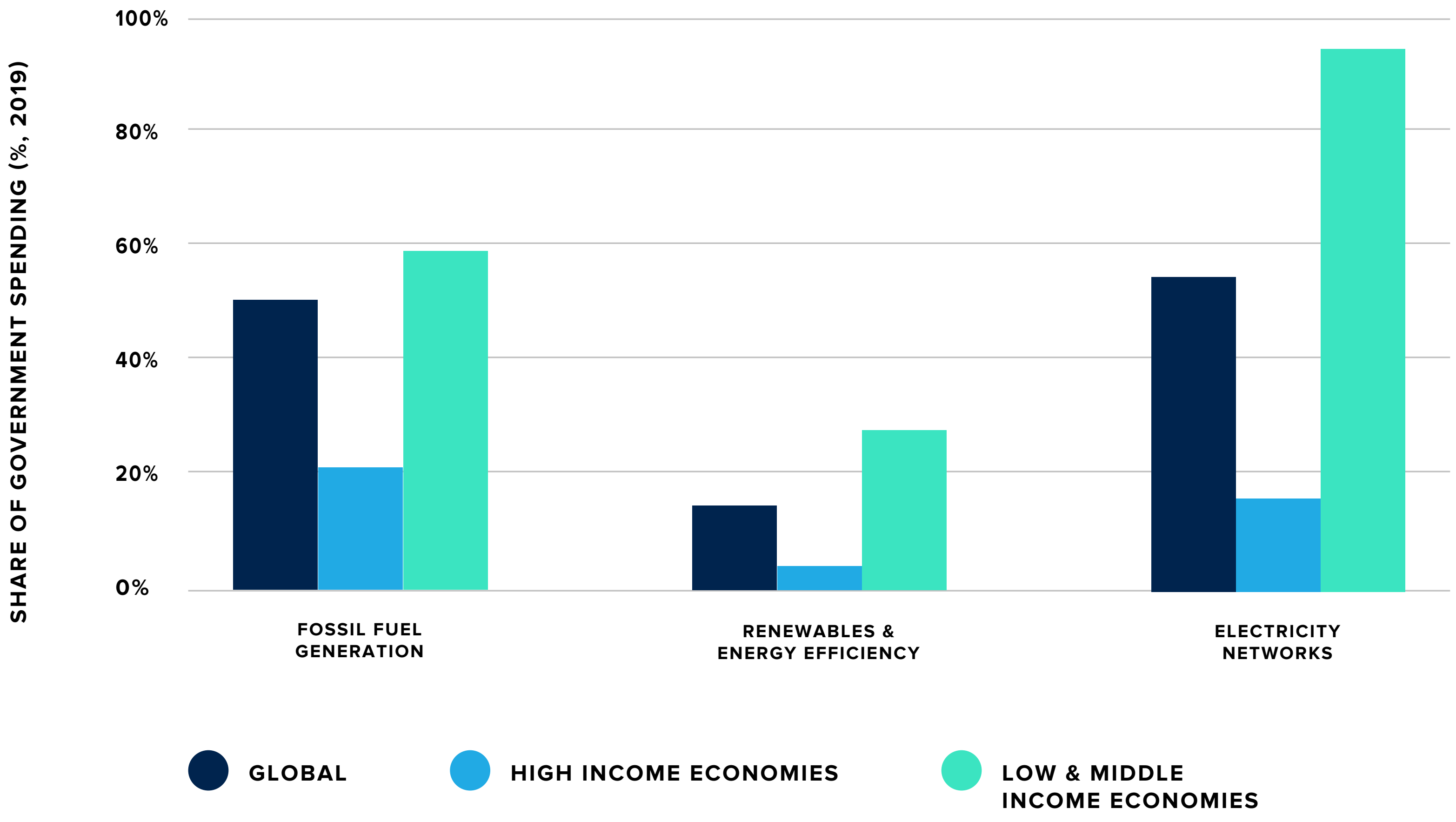
Table 8 - In the NZE scenario, public resources are expected to be predominantly used to develop infrastructure

SECTOR	SHARE OF PUBLIC INVESTMENT
Electricity generation	10–14%
Electricity networks	~70%
Road transport	~20%
EV road infrastructure	~70%
Shipping and aviation	~30%
Buildings	10–20%
Heavy industry	~30%
Low-emissions fuel supply	~20%
AFOLU	30–50%

Source: Vivid Economics analysis

The net zero transition will, in the next decade alone, require a dramatic shift towards private provision of capital for energy investment in emerging economies. Currently, energy investment in developing countries is overwhelmingly provided by public entities, in particular state-owned enterprises, as shown in Figure 35. To reach net zero, this will need to change: according to the IEA, private investors could finance around 60% of total energy investment and around 70% of clean energy investment in emerging economies. State-owned enterprises are likely to maintain a primary role in enabling infrastructure, such as electricity networks.[102]

Figure 35 - Developing countries currently depend on government funding to support energy investment



Source: Vivid Economics based on 2020 World Energy Investment report

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Technology Prioritisation Framework

3.0

3.0 Technology Prioritisation Framework

This chapter sets out suggestions for investors on technologies to prioritise in their investment decisions and engagement activities.

Section 3.1 discusses the range of actions that institutional investors can take to integrate climate into their activities, with particular reference to holistic integration into their existing investment processes. Section 3.2 sets out a framework for prioritising which technology areas to focus on. Section 3.3 and 3.4 deploy this framework to identify ten priority technologies for investment and ten for engagement and policy advocacy. Section 3.5 summarises the key findings on how investors can support technology development and deployment.

The chapter's technology prioritisation is not exhaustive but represents a set of high potential opportunities where investors can consider rapidly scaling up investment and engagement efforts, while also considering their fiduciary duties. There is very little room to manoeuvre in the effort to achieve net zero. Consequently, all technologies considered in this report are likely require a rapid and large scale up in capital in the next decade. The opportunities set out in this chapter indicate priority technologies, based on a consideration of each technology's relative abatement potential and investment need. Individual investors will need to, however, consider how these opportunities fit their own investment strategy.

3.1 Integrating Climate into the Institutional Investment Process

A wide range of climate solutions are available for investors seeking to align with the Paris Agreement.

Section 2 sets out over 100 technologies required for decarbonisation, covering the energy-related sectors and AFOLU. This range of technologies is not expected to be represented equally across each investor portfolio, however. It is also not the case that all investors can contribute to the scale up of finance through the same range of implementation activities. Instead, the diversity of technology options are likely to be reflected in a diversity of net zero aligned investment strategies.

To scale up investment in climate solutions investors have multiple levers at their disposal, including target setting, engagement and investment with assets, and policy advocacy. The PAII's Net Zero Investment Framework (NZIF) Implementation Guide classifies investor actions into three categories: portfolio direction-setting, asset alignment, and external engagement to facilitate alignment.[103] Direction-setting involves aligning the portfolio's governance and strategy with net zero ambitions, primarily by establishing targets which can help to achieve this strategy. Asset class alignment is used to implement this strategy across each of the four asset classes. This involves assessing an asset's current and projected future alignment and investing or engaging to align assets (and portfolios) over time. External engagement includes participation in international, regional and national policy advocacy to ensure their outputs are net zero consistent and to encourage the uptake of net zero aligned strategies and products.

Climate solutions metrics identified in Section 4 can help inform each of these investor actions, by assessing an asset or portfolio's Paris alignment. Section 4 highlights a range of climate solutions metrics that can be implemented by investors to track and set targets against their Paris-aligned investment exposure. They include the portfolio-level green investment ratio, priority net zero technologies investment ratio, and sectoral green capex intensity. Despite their usefulness these metrics provide no strict blueprint for exactly which technologies investors ought to incorporate into their investment strategy. Even the priority net zero technologies investment ratio leaves multiple technology options for investors (see Annex Table 21 for further detail). Each investor will therefore need to consider which technologies they aim to support.

To adapt these investment trajectories into a portfolio alignment strategy, investors will also need to consider the compatibility of each technology with their unique investment strategy. Investment opportunities identified in this report have different risk and return profiles, affecting the forms of financing and the investors they attract. Less mature technologies and business models, for example, typically relying more heavily on private equity. To date, many institutional investors have 'tested the waters' through lower-risk, indirect investments in funds; as investment needs increase and internal capacity is built up, direct investments might become a more popular option.[104] In addition, technologies require different forms of support from an investor to scale up deployment, from engagement to investment. There are the three technology specific considerations which characterise their compatibility with an investment strategy.

1

Technology commercial maturity which can affect both the risk profile of investment and the financing required, making them more or less suitable for an investor depending on their risk preferences and asset class allocation.

2

Geographic spread of investment needs which, similar to a technology's commercial maturity, can affect both the risk-return of an investment and the type of financing required.

3

Market and policy barriers, which in combination with a technology's commercial maturity can affect the type of investor support required to scale up deployment and investment.

While both investment and engagement are likely to be crucial to scaling up institutional investor finance in climate solutions, investors may differ in the types of actions they choose to prioritise. In many sectors, such as road transport, low carbon technologies are mature and require an immediate scale up in financing. Many other technologies face barriers to institutional investment which prevent this immediate scale up in financing, including the lack of clear regulation and supportive policy environments, the structure of financial products, or technology immaturity. In such cases, investors' broader engagement to reduce these barriers can have the most catalytic impact in scaling up finance over the longer term. The study considers the full range of investment and engagement activities in our technology prioritisation (see section 4.2 below).

3.2
Technology Prioritisation

Analysis by Vivid Economics provides a technology framework to assist investors with prioritisation, that could be used by investors alongside their existing due diligence processes. Additional efforts are needed to assess the suitability of each technology, which will depend on regional context and investor risk appetite.

The framework can help investors classify opportunities according to the type of support they require, and can help investors prioritise technologies - in addition to their own investment criteria - based on the emissions impact of scaling up finance in each technology. All technologies identified in Section 2 are important, and many can be critical for achieving the net zero transition – particularly given the narrowing path to reduce emissions sufficiently to limit warming to 1.5 degrees. Nonetheless, prioritising within this broader set of opportunities is essential to ensure that capital is allocated towards the sectors, regions and technologies where it can have the highest impact in achieving decarbonisation.

The framework classifies technologies for investment or broader engagement, based on their stage of technological maturity and the barriers to investment. The framework divides the universe of investable climate technologies is first divided into two archetypes: 'Deploy at Scale' and 'Technology and Market Development' based upon their Technology Readiness Level (TRL) and the accessibility of the technology to institutional investors. Accessibility is assessed by qualitative analysis of 'blockers' which may prevent immediate, large-scale investments – for example, technologies such as buildings appliances and electric vehicles are typically purchased by end users, and so innovative financing mechanisms may be required to make these accessible to institutional capital. Technologies with a lower TRL, which require primarily consumer investments, or which have additional blockers identified (such as the need for market creation) are sorted into 'Technology and Market Development', with the remainder selected into 'Deploy at Scale'.

In each archetype, the framework prioritises potential technologies based on the size of the investment gap and their emissions abatement potential. [105, 106] The highest priority technologies are those estimated to have a global investment gap of over $5 billion per year, and substantive emissions abatement potential. See for detailed criteria and Box 1 for application of the prioritisation framework to Solar PV and Building retrofits.

The framework analyses five potential priority technologies from each of the 'Deploy at Scale' and 'Technology and Market Development' archetypes. All technologies discussed below have an annual financing gap of at least $20 billion, calculated by comparing historic investment levels over the last five years and the average annual investment needs in the 2020s or 2030s. They are all key to mitigate emissions in highly emitting sectors today, or are one of only a few technologies associated with a particular sector's emissions. To assess their contribution to achieving Paris alignment, it is necessary to qualitatively assess the emissions reductions a technology indirectly enables. For example, clean electricity generation, storage and distribution are critical to enable decarbonisation of end use sectors.

Table 9 - Archetype and Technology Prioritisation Criteria

	PARIS ALIGNED TECHNOLOGY ARCHETYPE	
	DEPLOY AT SCALE	TECHNOLOGY AND MARKET DEVELOPMENT
Definition	Commercially mature technologies in sectors where no substantial technology or market barriers have been identified	Technologies that face barriers to institutional investment in the 2020s, including technological immaturity, unsupportive policy environment or lack of financial instruments accessible to institutional investors
Investor action	Rapid large-scale deployment in the 2020s	– Engagement to help support market creation and technology deployment. – Investments in technology demonstration.
Examples	Solar PV, onshore wind	Green steel, forest restoration, hydrogen
Archetype criteria	**Must meet all the following criteria:** – Commercial demonstration or more mature technology (TRL ≥ 8) – Producer investment: capital is required by corporates to acquire production or transmission equipment – Enables emissions reductions across a wide range of sectors – No additional blockers identified	**Must meet at least one of the criteria:** – Pre-commercial demonstration or less mature technology (TRL < 8) – Consumer investment: capital is required by end users – Regulatory or market blocker, such as lack of active markets or financial instruments to channel investment
Technology prioritisation criteria	**Prioritised based on one of the criteria:** – 2020s annual financing gap greater than $20bn – Large technology / sector emissions abatement potential	**Prioritised based on one of the criteria:** – 2030s annual financing gap greater than $20bn – Large technology / sector emissions abatement potential

Source: Vivid Economics

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Box 1 Worked Examples of the Technology Prioritisation Framework

1. Deploy at Scale: Solar PV

- Initial screening sorted solar PV into the 'deploy at scale' archetype: these are producer-side investments, sub-technologies have an average TRL of 8 (first of a kind commercial), and 'additional' blockers such as lack of market development are not identified. Additionally, as a key technology for increasing renewables capacity, and hence supporting electrification of end-use sectors, solar PV was identified as an enabling technology.
- With additional annual investment needs of $260 billion in the 2020s, solar PV easily surpassed the $20 billion requirement for prioritisation.
- For considering emissions abatement potential, the report constructed a proxy indicator which combined current sectoral emissions with a technology's overall importance for decarbonising that sector (with importance determined by its share of total investment between 2020 and 2050). Solar PV accounted for 14% of investments required to decarbonise energy, which itself accounted for 73% of overall emissions.

2. Technology and Market Development: Building retrofits

- Retrofits to improve the efficiency of the building envelope are a mature technology (TRL 11), with no clear 'blockers' (such as the need for market creation) identified. However, building retrofits are generally consumer-side investments undertaken by the owners of building assets, which are not expected to be directly accessible by institutional investors in the immediate term. This led to building retrofits being classified under the 'technology and market development' archetype, as it requires additional financial product development before it can be deployed en masse.
- In the 2030s, building retrofits are estimated to require additional $145 billion in global investments per year. This indicates the significant scale of investments which could be unlocked by ensuring sufficient groundwork over the 2020s.
- Current emissions from buildings are 18% of total emissions, and retrofits account for 35% of total buildings investments between 2020 and 2050. Consequently, this technology has a high emissions abatement potential, leading to its selection for prioritisation.

3.3 Deploy at Scale Technologies

3.3.1 Solar PV

1 Context:

Renewable energy technologies underly the vast majority of decarbonisation investments by enabling electrification and providing a clean power supply. Solar PV in particular is a mature and scalable technology area, with opportunities for substantial investments in the coming decade.

2 Archetype allocation:

Key applications include on-grid solar PV, mini-grids, and standalone systems such as PV units attached to commercial or residential property. With the exception of a few innovative sub-technologies, such as perovskite solar cells and organic thin-film solar cells, almost all technologies have demonstrated commercial operation (TRL 8+) and are accessible to institutional investors. Solar PV is expected to account for 54% of renewable capacity and 43% of electricity capacity by 2050, and can be critical to reducing downstream emissions from the energy sector.

3 Technology prioritisation factors:

Over the next decade, an additional $260 billion in annual solar PV investments is likely to be needed globally. $197 billion annually are projected to be in Asia Pacific. However, there are also substantial opportunities in North America ($75 billion), Europe ($38 billion) and Africa ($18 billion). Africa in particular is expected to need to see a 20x increase in investments relative to the past five years. Solar PV investments account for 14% of clean energy investments (comprising electricity generation, distribution and storage and low emission fuels), giving them a high emissions reduction potential.

4 Potential investor actions:

Immediate actions could focus on rolling out investments on a large scale. As the typical operating lifetime of solar panels is below 25 years, from 2030 investments are likely to include replacement of existing capacity as well as new additions. Mass deployment will be facilitated by the fact that PV cells require very limited adaptation to local conditions.

3.3.2 Wind

1

Context:

Combined with solar PV, wind power is expected to provide 40% of global energy needs by 2030 and almost 70% by 2050. Onshore wind investments are particularly attractive because the technologies are easily scalable. Costs are already low, but have the potential to fall further through innovation, for example using hybrid materials.

2

Archetype allocation:

Around 80% of new wind capacity is estimated to be in onshore wind developments, for which technologies are already market-ready (TRL 9-10). As technology uncertainty is low, investments can focus on rapid deployment, which will be necessary to meet emissions reduction targets over the next decade. Offshore wind investments (including floating and seabed fixed turbines, TRLs 8 and 9) are also attractive prospects, albeit these are generally riskier investments due to higher ticket sizes. Similar to solar PV, wind's role in electricity generation gives it a high enabling potential for other decarbonisation investments related to electrification.

3

Technology prioritisation factors:

There are sizable annual investment needs over the coming decade in Asia Pacific ($170 billion), Europe ($86 billion) and North America ($59 billion). The key technologies require minimal modifications to the local environment, which creates investment opportunities across a range of geographies. Overall, wind investments to 2050 are estimated to be around 16% of energy investments, providing high emissions abatement potential.

4

Potential investor actions:

Investor efforts could focus on scaling up deployment over the coming decade. Institutional investors are already prominent investors in developed markets such as Europe. Requirements for local power generation imply that other regions may also need to build out their capacity, creating new opportunities for 'tried-and-tested' decarbonisation investments. Institutional investors could be major financers, particularly through providing debt to project financing.

3.3.3
Grid-Scale Electricity Storage

1

Context:

Alongside clean energy sources, investments in electricity storage technologies are critical to enabling electrification of end-use sectors. Electric vehicles have already helped to drive cost reductions in battery technologies over the past decade, particularly within lithium-ion, the dominant technology. As electrification becomes more widespread, deployments of grid-scale storage and behind-the-meter (BTM) batteries are expected to also need to increase.

2

Archetype allocation:

Future investments in electricity storage are required to fulfil higher technological requirements and deploy these technologies at scale. Many applications are highly mature, including pumped storage (TRL 11) and lithium-ion, liquid air energy, and flywheel storage (TRL 9). For grid-scale applications, storage technologies can be accessible to institutional investors.

3

Technology prioritisation factors:

Total investments rise from almost $30 billion per year in 2021-30 to over $75 billion from the 2030s. Investment needs in Asia Pacific dominate, and India and China's $8 billion annual investment requirements in the 2020s outstrip those of any other macro-region. In tandem with increasing renewables capacity, investments in electricity storage is expected to be necessary to integrate dispatchable energy into the grid, enabling end-use sector decarbonisation.

4

Potential investor actions:

For institutional investors, the immediate opportunity lies in rapid scaling up of deployment. However, there are also areas where policy engagement is required. In the short term, policy objectives include the introduction of incentives to increase the economic viability of projects, widening the universe of potential investments. For future prospects, engagement could consider pushing governments to plan for longer-term capacity expansion.

3.3.4
New Electricity Lines

1
Context:

Electricity networks are another critical enabling technology for the integration of decentralised renewable energy generation. Infrastructure investments in electricity lines are expected to increase, including network expansion and upgrading and digitalising systems.

2
Archetype allocation:

Electricity transmission technologies needed for achieving net zero are relatively mature (TRL 8 – commercial demonstration). Superconducting high-voltage and ultra-high voltage lines are more efficient than conventional AC lines, and could minimise losses while also achieving lower construction and operating costs. Similar to electricity storage, investments in distribution are likely to be critical to enabling the integration of dispatchable renewable energy.

3
Technology prioritisation factors:

Investments are projected to reach an annual average of $345 billion in the 2020s, almost double current levels. Investment needs are highest in Asia Pacific ($187 billion), but are also sizable in Europe ($77 billion) and Africa ($31 billion). Globally, investments between now and 2050 are expected to total $13.9 trillion. Investments in new electricity lines total 22% of energy generation, storage and distribution investments.

4
Potential investor actions:

Given the substantial financing needs, investors could focus on immediate deployment of investments. This might include through direct investment, but also secondary financing of corporations involved in the sector.

3.3.5 EV Batteries

1 Context:

Electric vehicles are among the most mature technologies for decarbonisation of end-use sectors. Investments in batteries (especially lithium-ion batteries) can enable rapid deployment to abate emissions in the transport sector over the next decade.

2 Archetype allocation:

Li-ion batteries (TRLs 9-11) are currently the dominant technology for EV applications. While alternatives such as Na-ion, Li-air, and multivalent ion batteries are under development, none of these has yet passed the prototype stage. Within Li-ions, nickel-manganese-cobalt is the most prominent technology, covering around 70% of sales in 2021. EV battery investments are likely to be critical to enabling downstream deployment of EVs across the world.

3 Technology prioritisation factors:

In the 2020s, annual investment needs in EV batteries is expected to increase over twentyfold, from $2 billion today to $42 billion. $28 billion of this investment is projected to occur in China. This is around six times the scale of the investment requirement in North America, the next most significant market. Road transport accounted for almost 12% of global emissions in 2016, and car ownership is likely to increase given rising incomes and living standards in developing countries, making this a pressing area for deployment.

4 Potential investor actions:

Over the next decade, most investments are expected to focus on lithium-ion batteries. However, institutional investors with higher risk appetites may consider supporting the development of alternative technologies which are currently less mature (TRLs 1-5).

3.4 Technology and Market Development Technologies

3.4.1 Building Retrofits

1 Context:

Despite substantial additions to the building stock, particularly in developing countries, half of the world's existing building stock will still be standing in 2050. This could necessitate sizable investments in retrofits to improve the energy efficiency of the built environment. Retrofits are likely to also need to address buildings constructed today, which do not meet zero-carbon standards.

2 Archetype allocation:

For retrofits, many technologies focus on upgrades to the building envelope. These include initiatives such as improved sealing of air leakages, increased window insulation through improved materials and additional glass coating, and use of high reflectivity paint for temperature controls. Although many technologies are relatively mature, distributed building asset ownership suggests that many investments will not be directly accessible to institutional investors, requiring the development of innovative securities before large-scale investments can occur.

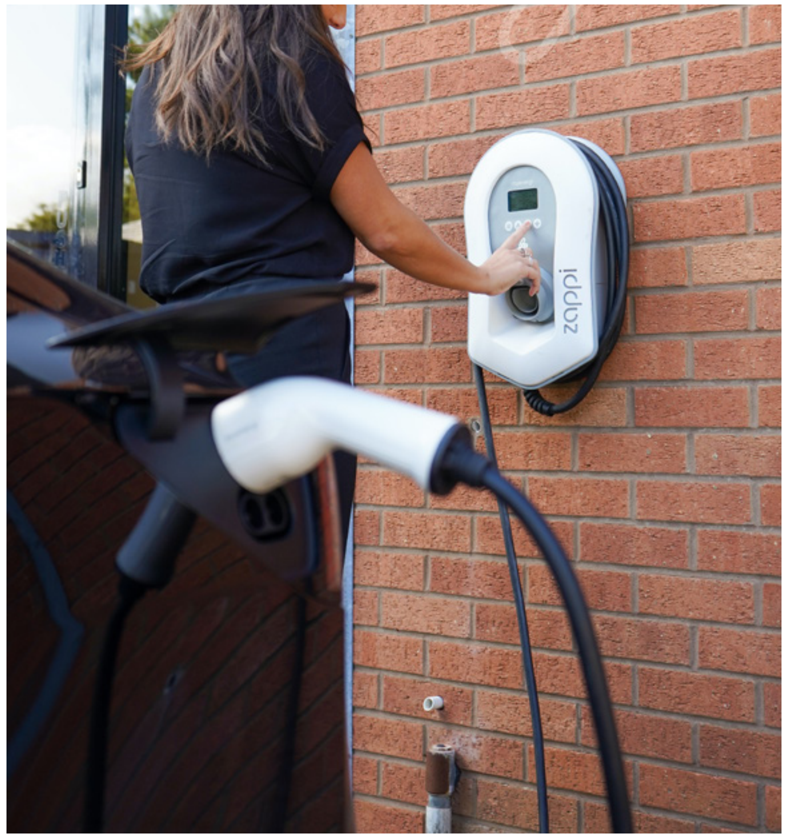
3 Technology prioritisation factors:

Regional investment needs reflect the distribution of the current building stock, as well as its expected growth over the coming decade. In the 2030s, annual investment requirements are estimated to be highest in Asia Pacific ($75 billion), North America ($69 billion), and Europe ($56 billion). Investments are estimated to be lower in absolute terms in Eurasia and Africa, but still are estimated to require a more than fivefold increase over current investments by the 2030s. Globally, retrofits account for over one third of investments in buildings, which were responsible for 18% of emissions in recent years.

4 Potential investor actions:

Investors could prioritise the development of innovative financial products which allow them to access these consumer-financed investments. Key actions may include engagement with financial regulators and real estate investors. Engagement with governments could also help accelerate public policy development, which are likely to be required to incentivise retrofits at a sufficient pace and scale to meet decarbonisation needs.

3.4.2
EV Chargers



1
Context:

As EVs begin to be rolled out, slow chargers are already mature and are being deployed across residential properties and workplaces. However, as EVs become the dominant mode of transport, the supportive infrastructure is expected to need to expand dramatically.

2
Archetype allocation:

Technologies currently under development include fast charging, smart charging, and dynamic charging or electric road systems (ERS). Fast chargers have reached the demonstration phase (TRL 8), but are likely to need to double in speed to increase EV range. Smart charging systems to avoid grid congestion are at the prototype stage (TRL 5), and will need to scale up in step with EV deployment. Dynamic charging of EVs while driving is also being demonstrated in real-life conditions in Germany and Sweden, with alternative, more immature technologies being developed concurrently (TRLs range from 4 to 8).

3
Technology prioritisation factors:

Investment needs in the 2020s are estimated to be $38 billion per year. By the 2030s, this is expected to jump to $138 billion. Investments are projected to be highest in Asia Pacific, at $84 billion annually, but they are also expected to exceed $26 billion in Europe and $9 billion in North America and Central and South America. The emissions abatement potential for EV chargers is moderately high, as road transport accounts for around 12% of emissions in recent years.

4
Potential investor actions:

Investments in deployment is likely to be required over the coming decade. However, there is also a need for substantial policy engagement regarding land use and infrastructure planning, to ensure that chargers are well integrated into the urban environment. Investors might also engage with industry to encourage technology development, or invest directly in earlier-stage technologies.

3.4.3 Hydrogen-Based Electricity Generation

1

Context:

Hydrogen currently provides less than 1% of electricity generation, but technologies such as gas turbines and fuel cells create a huge potential to scale up production of hydrogen-based fuels (including ammonia and synthetic natural gas). If combined with low-carbon production techniques such as electrolysis (green hydrogen) or CCUS (blue hydrogen), this has the potential to decarbonise electricity generation while also providing additional electricity storage options.

2

Archetype allocation:

Hydrogen-based electricity has a wide range of applications, and technological maturity varies by end-use. Applications in buildings and road transport – such as CHP fuel cells and hydrogen fuel cell EVs (both TRL 9) – are beginning to be deployed commercially, while applications in industry (TRLs 3-8) and heavy-duty transport such as shipping (TRLs 4-7) remain in their infancy. In addition to generation technologies, investments in large-scale storage (such as in salt caverns or depleted oil and gas fields) are likely to be required (TRLs 2-11).

3

Technology prioritisation factors:

Geographically, hydrogen-based electricity generation is expected to be driven by the abundance of cheap hydrogen, which in turn will be influenced by the availability of cheap local renewable energy to fuel the electrolysis process. Consequently, investments are expected to be highest in Asia Pacific and North America, at $31 billion and $28 billion per year respectively in the 2030s. The USA alone is expected to require over $25 billion annually over this period. Under the NZE, hydrogen-based fuels will meet 13% of final energy demand by 2030, indicating a high emissions abatement potential.

4

Potential investor actions:

Over the coming decade, investors could engage across industry and governments to encourage rapid market development. Important aims might be the development of financial instruments to incentivise upfront infrastructure investments, the setting of public targets and policies to reduce demand uncertainty, and implementation of carbon prices to increase hydrogen's competitiveness relative to natural gas. This would pave the way for more substantial increases in investment in the 2030s.

3.4.4 Forest Restoration

1 Context:

Nature-based solutions, including the restoration and maintenance of forestry and other natural habitats, can make important decarbonisation contributions through acting as both a source and a sink of GHG emissions. While investors could be mindful of the limitations of carbon offset markets, at the same time it is likely to be essential to provide adequate funding to prevent further deforestation and to increase the scale of restoration activities.

2 Archetype allocation:

Currently, market development is blocked by lack of measurement, recording and verification (MRV) mechanisms, and lack of comprehensive carbon pricing schemes. In their absence, the opportunity cost of land conversion – for example, into agricultural land – is very high, while maintaining valuable habitats and ecosystems is difficult to monetise.

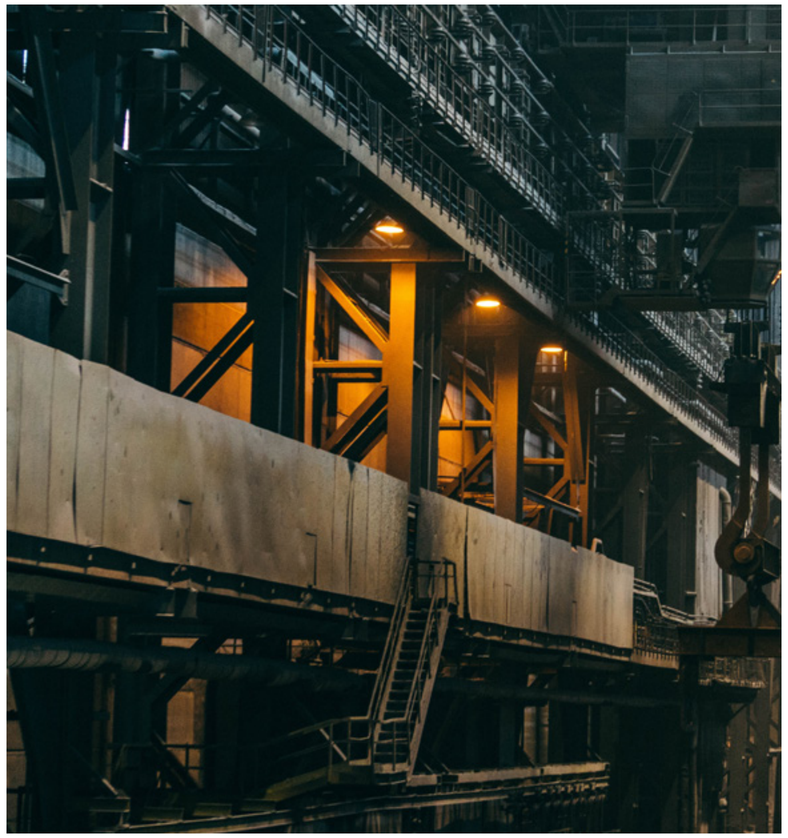
3 Technology prioritisation factors:

Nonetheless, there are substantial opportunities. Globally, investments in forest restoration averaging over $37 billion per year are likely to be needed every year between now and 2050. Additional investments may be required for forest management and mangrove and peatland restoration. The highest investment needs are expected to be in Central and South America and in Eurasia ($8 billion per year each in the 2030s), but there are also sizable opportunities across Asia Pacific, North America and Africa. Net AFOLU-related emissions were estimated at 18% of global GHG emissions in 2016; forest restoration has the potential to substantially reduce emissions from agriculture, and to act as an emissions sink through carbon sequestration.

4 Potential investor actions:

Actions could prioritise policy engagement to encourage regulation and market creation. Given the wide geographical spread of opportunities, it is likely that this will require engagement with multiple governments and market participants.

3.4.5 Green Steel



1 Context:

Steel is an energy-intensive and emissions-intensive sector. Its long-lived capital assets and high temperature requirements make decarbonisation challenging. However, steel is an essential input for constructing much of the infrastructure required for the net zero transition.

2 Archetype allocation:

A range of 'green steel' technologies are currently in development. These include replacing natural gas with hydrogen in Direct Reduced Iron Electric Arc Furnace (DRI-EAF) manufacturing; increasing use of scrap metals in production; and using CCUS to reduce net carbon emissions. Several of these technologies are already at the demonstration (TRLs 7-8) and early adoption (TRLs 9-10) stages, creating investment opportunities over the coming decades.

3 Technology prioritisation factors:

Asia is home to over half of steel manufacturing today, and makes up around two thirds of the total investment opportunity. Overall, investment needs in steel are estimated to increase by nearly $80 billion to reach $119 billion per year in the 2030s (of which $80 billion is in Asia Pacific). In 2016, iron and steel production accounted for 7% of global GHG emissions, indicating substantial emissions abatement potential.

4 Potential investor actions:

To support market development, investors could engage with governments on key 'blockers' within the sector. These include reforming trade laws to increase the liquidity of scrap steel trade, and encouraging companies to commit to cleaner technologies such as hydrogen and CCUS. As new emerging markets build out their steel capacity, engagement is likely to be useful to ensure that they 'lock in' greener production technologies to reduce emissions.

Box 2 IEA's extended Technology Readiness Level (TRL) scale

The technology readiness level (TRL) scale was originally developed by the US National Aeronautics and Space Administration (NASA) in the 1970s. It has since been widely adopted beyond the aerospace industry, and is deployed by a range of research institutes and technology developers worldwide.

NASA's original TRL runs from TRL 1 (basic principles defined) to TRL 9 (full commercial operation). In the Energy Technology Perspectives (ETP) 2020, the IEA extended this to TRL 11, in order to capture the full journey of integration into existing systems and predictable market growth. The IEA's extended TRL scale is set out below:[107]

TRL 1: Initial idea – basic principles have been defined

TRL 2: Application formulated – concept and application of solution have been formulated

TRL 3: Concept needs validation – solution needs to be prototyped and applied

TRL 4: Early prototype – prototype proven in test conditions

TRL 5: Large prototype – components proven in conditions to be deployed

TRL 6: Full prototype at scale – prototype proven at scale in conditions to be deployed

TRL 7: Pre-commercial demonstration – solution working in expected conditions

TRL 8: First of a kind commercial – commercial demonstration, full scale deployment in final form

TRL 9: Commercial operation in relevant environment
– solution is commercially available, needs evolutionary improvement to stay competitive

TRL 10: Integration needed at scale
– solution is commercial and competitive but needs further integration efforts

TRL 11: Proof of stability reached – predictable growth

3.5 How Investors Can Support Technology Development and Deployment

This framework helps to identify which technologies to support, recognising that the type of support required will vary by technology and region.

As discussed above, some mature technologies such as renewables or electric vehicles primarily require large-scale investments in deployment. Where 'support' will be given primarily in the form of investment, then which investors are the most appropriate source of this finance will vary significantly in accordance with the technology's characteristics, corresponding financing structures and financial instruments, and with investor risk appetites. For other technologies, the more immediate need is for engagement with policymakers and other critical stakeholders.

Increasing allocation of capital to climate solutions is recognised as one principal way that institutional investors can support Paris alignment. Section 4 sets out climate solutions metrics to help measure and track the extent to which a portfolio is supporting climate solutions consistent with a Paris aligned investment trajectory. However, as highlighted in 3.1, investment is not the only channel through which institutional investors can scale up climate solutions finance over the long term.

There are several opportunities to support technological innovation beyond direct and large-scale financing:

1

Engagement and non-financial support and: investors could undertake active shareholder engagement, creating an ongoing dialogue with companies on the rate at which investments in these technologies are being scaled up to achieve decarbonisation goals. For earlier-stage investments, some investors may be able to provide non-financial resources, such as key areas of climate expertise, and assistance with governance or management structures.

2

Feasibility studies and demonstrators: for immature technologies (e.g. TRL 6), investors could directly fund (or incentivise companies to fund) small-scale demonstrations and pilots, helping to move technologies up the TRL scale and unlock further financing.

3

Project development: for mature but currently under-commercialised technologies, a key barrier can be unlocking finance through ensuring that commercial and project arrangements are appropriately designed. Provision of funding for project development and preparation facilities – such as the Renewable Energy Scale-Up Facility – may help to address this bottleneck.[108]

4

Policy engagement: for technologies where market failures are preventing rapid scaling up of investment, investors could also actively engage with relevant governments – for example, encouraging greater public investment in goods with positive externalities, such as grid infrastructure, to facilitate increased private investment opportunities in renewables. Engagement could also include pushing for the application of high standards in government contracts, such as adhering to "green steel" standards in all public procurement.[109]

5

Industry engagement: across all technologies (but particularly those which are less mature), investors could engage with the relevant industries to facilitate standard setting and partnership formation. In addition to end use sectors, this includes engagement relating to building out supply chains and supporting infrastructure – for example, through encouraging companies to make public commitments regarding the carbon content of their input materials.

Climate Solutions Metrics & Benchmarks

4.0

4.0 Climate Solutions Metrics and Benchmarks

This chapter sets out metrics and benchmarks to help investors track the alignment of their portfolio to the net zero investment trajectories set out in Chapter 2.

An overview of options for investors is set out in Section 4.1. An introduction to Paris-aligned benchmark setting is set out in Section 4.2. Climate solutions metrics, their applications and measurement methods are detailed in Section 4.3. Finally, the chapter's findings are mapped to the EU's Taxonomy Regulation in Section 4.4

4.1 An Overview Of Climate Solutions Metrics and Benchmarks

To scale up climate finance to the levels required, approximately $130 trillion to 2050, requires better tools to track and set targets for investment in climate solutions.

Investors currently lack tools and sufficient data to measure their current investments in the full range of climate solutions and set Paris-aligned targets for allocation to climate solutions. This partially stems from the limitations of available investment trajectories, sustainable taxonomies and corporate disclosures, which are often not sufficiently granular or comprehensive enough to guide investment decisions or engagement with portfolio companies.

A roadmap of metrics can help investors increase their allocation to climate solutions.

From today, investors could measure and report a:

1

Green investment ratio measuring a portfolio's investments in all climate solutions (see Box 3) relative to total investments. This metric provides a comprehensive picture of investor exposure to net zero activities and will soon be mandatory for investors subject to the EU Taxonomy Regulation. While this ratio can be calculated using capex or revenues (see Box 4), the latter is most feasible today due to more granular corporate disclosures of revenues relative to capex.

2

Priority net zero investment ratio measuring each portfolio's investments in priority technologies or regions relative to its total investments. For ambitious investors seeking to maximise their positive impact on emissions reductions, this metric helps capture their portfolio's exposure to the most critical investment needs. In the absence of corporate disclosures on all climate solutions and the existence of regionally specific priority investment needs, it is possible for investors calculate their exposure to all investments in Section 3 that can be deployed at scale today, set out in Table 21.

As capex disclosures increase, investors may also seek to apply a:

3

Green capex intensity alignment metric, measuring the alignment of a sector's green capex intensity relative to a Paris-aligned benchmark. The shift and scale-up in capital will be essential to the net zero transition, providing a forward-looking indicator of emissions reductions and revenues. While corporate capex disclosures are not widely available today, they will soon become mandatory for all large, public corporates subject to the EU Taxonomy Regulation. Governments and investors can continue to push for capex disclosures to guide investment and engagement.

4

Portfolio carbon return metric could add value in the future if methodological concerns, set out below, are addressed. This metric measures the emissions abated relative to total investments, helping to quantify the relative impact of investment decisions.

Paris-aligned Climate Solutions Benchmarks

To help investors' allocation to climate solutions increasingly align with our Paris-aligned investment trajectories, in Section 5.2 the report provides preliminary benchmarks for three sectors. The report also highlights the challenges associated with the construction of robust Paris-aligned investment benchmarks useful to investors. Given the constraints of revenues and capex projections, the study provides benchmarks, and associated GICS classifications for electricity generation, fuel supply and road mobility.

The work considers these benchmarks to be a first step to providing Paris-aligned portfolio benchmarks, which would allow investors to set Paris-aligned targets for their green investment ratio.

Electricity Generation. Estimate 85% of global capex could be green by 2030, from 59% today.

Fuel Supply. Estimate 29% of global capex could be green in 2030, from 1% today.

Road Mobility. Estimate 53% of global revenues could be green by 2030, from 14% today.

Box 3 What is a climate solution?

A climate solution is an investment in an economic activity, good or service that contributes substantially to emissions reductions required by a 1.5˚C pathway. A climate solution can be classified as a:

- **'Low-carbon' climate solution,** which refers to activities with close to zero emissions that already make a substantial contribution to achieving net zero, e.g. the leasing of passenger vehicles with zero tailpipe CO_2 emissions.
- **'Transitional' climate solution,** which refers to activities that make a substantial contribution to the transition to net zero by reducing their own emissions, even if they are not yet low-carbon, e.g. the manufacture of cement with CO_2 emissions intensity below a specific threshold, and the leasing of vessels with a large % of energy from zero-carbon fuels.
- **'Enabling' climate solution,** which refers to activities that are enabling emissions reductions in the wider economy, e.g. the manufacture of energy-efficient equipment for buildings, and infrastructure for low-carbon road transport such as EV charging points.

Climate solutions may vary by region and over time. Decarbonisation pathways will vary across regions, each of which may rely on a different set of technologies and mitigation levers to achieve a 1.5˚C consistent world. Further, the interaction of policies and technologies is likely to give rise to new climate solutions (or make others redundant in certain contexts), resulting in uncertainty over which technologies will be best placed to deliver future emissions reductions. This uncertainty in technology development highlights the need to have a dynamic and iterative approach to classifying and communicating climate solutions, which uses best available evidence at any time.

Though climate solutions can include both climate mitigation and adaptation activities, this work and the definition used in this report focuses on mitigation solutions. As highlighted by the Net Zero Investment Framework, climate solutions include both mitigation activities that reduce GHGs and adaptation activities that enhance adaptive capacity and strengthen resilience.[110] Despite this work's focus on investment in mitigation activities, it recognises that there is an equally urgent challenge in scaling up finance towards adaptation activities. Notably guidance on investment in adaptation activities is emerging, including the Adaptation SME Accelerator Project (ASAP) adaptation solutions taxonomy and the European Commission's technical screening criteria for adaptation activities.[111, 112]

Climate solutions metrics and targets are a vital tool to help investors measure and increase allocation to the net zero investment needs outlined in Section 3, enabling both real-world and portfolio decarbonisation. Climate solutions metrics aim to assess which assets, technologies or sectors are actively contributing to the net zero transition, either because they are reducing emissions (e.g. a steel manufacturer investing in electrification) or enabling decarbonisation (e.g. a battery manufacturer enabling integration of variable renewables on the grid). In a similar way to portfolio decarbonisation metrics, climate solutions metrics are a tool to guide engagement with assets, inform asset allocation decisions and portfolio construction activities, as well as to guide 1.5˚C-aligned targets for investment in climate solutions.

These metrics intend to complement, not replace, existing guides for portfolio decarbonisation. The suggested metrics value and build on the guidance provided by initiatives such as the Paris Aligned Investment Initiatives and it's Net Zero Investment Framework (NZIF), and NZAO on the best practices for institutional investors aiming to set a net zero investment strategy. As highlighted by the NZIF, a credible net zero investment strategy could focus on both portfolio decarbonisation consistent with global net zero emissions by 2050 and investment in the range of climate solutions needed to decarbonise investment portfolios.[113] Initiatives such as the SBTi and PAT focus only on portfolio-financed emissions, however. They do not track investment in climate solutions and therefore do not provide strong incentives to address the investment needs of a net zero transition, highlighted in Section 3.

4.2
Investor Guide to Setting Paris-Aligned Climate Solutions Targets

4.2.1
Preliminary Paris-aligned Benchmarks

Paris-aligned benchmarks can help investors assess the alignment of their current portfolio with a net zero investment trajectory (Section 3) and set targets for scaling up climate solutions finance. To scale up finance in line with the investment needs set out in Section 3 requires information on where and how much to invest at a portfolio level. To date, however, there has been limited data on how net zero investment needs translate to a portfolio's level of green investment, thereby impairing investors' ability to set credible, science-based investment targets. While this report's Paris-aligned investment trajectories help to fill this gap by quantifying real-world investment needs, they do not translate to a Paris-aligned investment portfolio.

IEA-based net zero investment trajectories are not able to provide comprehensive Paris-aligned benchmarks because of the heterogeneity of these trajectories and their focus on energy-intensive sectors. To calculate benchmarks aligned with our suggested metrics requires information on either future green and total revenues, or green and total capex in a Paris-aligned investment trajectory. However, there are important limitations or nuances of net zero scenarios and investment trajectories available today which imply the following three conclusions.

1

It is not possible to calculate an economy-wide green investment ratio from existing investment trajectories. Scenarios typically capture energy-intensive sectors only, providing no information on how green investment and revenues evolve in the rest of the economy, even though sectors not considered by the investment trajectories are around 95% of global revenues.[114, 115, 116, 117] The IEA scenarios used as a starting point for the report's analysis share this limitation.

2

Paris-aligned sectoral benchmarks will often vary according to the nature of each sector's transition. While some sectors (such as power or industry) transition via capital turnover, others will rely on shifts in demand and consumer investments (such as road mobility and buildings). Investment projections can also vary accordingly between capex projections and demand expenditure, implying that our investment trajectories provide a combination of capex or revenues benchmarks.[118]

3

Paris-aligned sectoral benchmarks can provide only a minimum guide to scaling up finance in these sectors, as current investment trajectories only reflect investment and revenues associated with the final good sold, excluding revenues from the supply chain.[119, 120]

The IEA-based investment trajectories show a guide to Paris-aligned investment in electricity generation, fuel supply and road mobility. In these sectors, investors can already see what portion of real-world activity could be green in these sectors according to a Paris-aligned world.

Electricity generation. The study estimates that around 84% of capex could be green by 2030 and 80% by 2050, rising from an estimated 59% green capex in 2020. This is calculated based on the investment trajectories for the electricity sector, presented in Section 3.3.1. Investment in unabated fossil fuel generation is classified as 'dirty', investment in nuclear and biomass generation without CCUS is classified as 'grey', while all the other investment categories are classified as 'green' (including storage and T&D investment).

Fuel supply. The study estimates that around 29% of capex could be green by 2030 and 52% by 2050, rising from an estimated 1% green capex in 2020. This is calculated based on the investment trajectories for fossil fuels and low-emissions fuels, presented in Section 3.3.5 and Section 3.3.6. Investment in fossil fuel production and infrastructure is classified as 'dirty', while investment in low-emission fuel production and infrastructure is classified as 'green'.

Road mobility. The study estimates that above 60% of revenues could be green by 2030 and 100% by 2050, when the road mobility sector could fully rely on electricity and hydrogen, rising from an estimated 14% green revenues in 2020. This is calculated by:

- Assessing the size of the global automotive market from 2020 to 2050, based on the IEA Global EV data explorer and the OECD ITF Transport Outlook 2017.[121]
- Determining the size of the EV market in each world region from 2020 to 2050, based on EV penetration estimates from the IEA 'Net Zero by 2050' report.[122]
- Deriving the total revenues associated with the sale of each category of vehicle, based on unit vehicle costs from the 2021 IEA World Economic Outlook or proprietary Vivid Economics data.[123]
- Sales of ICE vehicles are classified as 'dirty' revenues, while sales of EVs are classified as 'green' revenues.

For each sector there is a mapping to relevant GICS. Notably, there is not a perfect mapping between sectors discussed in the IEA NZE scenario and the GICS sectors, noted in Table 10 and Table 11.

The share of green revenues and capex in a Paris-aligned pathway is expected to vary significantly by time and region, leading to several notable conclusions by sector:

Electricity generation green capex intensity is relatively high today in nearly all regions, reflecting the maturity of many renewable technologies required in a Paris-aligned investment trajectory. Green capex intensity also falls globally in the 2040s, relative to the 2030s, reflecting the concentrated build-out of renewables in earlier decades. It is important to recognise that not all non-green capex is 'dirty', with a fall in 'green' capex partially compensated by a rise in 'grey' capex.

Fuel supply green capex intensity is, on the other hand, relatively low due to the immaturity of low-carbon fuels such as hydrogen. Large spikes in green capex intensity are expected in regions where current fuel supply is low. For instance, in Asia Pacific, green capex intensity rises from 2% in 2020 to 32% in 2035 due to the relatively small market for fuels supply today.

Road mobility green revenues intensity benchmarks show a global convergence in benchmarks across regions in the 2040s, reflecting the assumption in the IEA NZE scenario that there will be no more ICE sales for passenger cars globally by 2035. In the 2020s and 2030s, non-OECD economies also typically have higher green revenues shares than Europe and North America, reflecting the higher penetration and earlier decarbonisation of 2 and 3 wheelers in these markets.

As preliminary benchmarks, it is important to note that there are additional nuances that need to be interrogated by industry and policymakers in each region going forward.

Moreover, the share of green revenues and capex provides only a partial view of the transition, which needs to be complemented by dirty capex and revenues benchmarks. A focus on green revenues or capex does not help investors allocate investment between non-green activities that can either be emissions-intensive (‘dirty’) or have a neutral impact on emissions (‘grey’). The allocation of investment between these activities could have a significant impact on total emissions. It can therefore be useful for investors to consider the split in investment between emissions-intensive (‘dirty’) activities or have a neutral impact on emissions (‘grey’). Using the study’s net zero investment trajectories, it is possible to calculate net zero benchmarks for dirty revenues and capex for electricity generation, road mobility and fuel supply in Table 14 in the Annex.

Table 10 - Green capex intensity (green capex/total capex) in a Paris-aligned trajectory for electricity and fuel supply

SECTOR	GICS	REGION	2020	2025	2030	2035	2040	2045	2050
Electricity generation	551010, 551030,* 551050	North America	66%	88%	88%	89%	89%	87%	87%
		Central & South America	70%	88%	89%	89%	88%	88%	87%
		Europe	66%	80%	82%	84%	83%	82%	81%
		Africa	48%	84%	86%	88%	86%	85%	84%
		Middle East	17%	85%	87%	89%	87%	86%	85%
		Eurasia	16%	57%	60%	62%	58%	55%	52%
		Asia Pacific	60%	83%	83%	84%	83%	82%	81%
Fuel supply	101020, 10102050**	North America	1%	24%	30%	37%	41%	46%	54%
		Central & South America	2%	47%	54%	63%	66%	72%	79%
		Europe	8%	48%	56%	64%	67%	70%	75%
		Africa	0%	10%	18%	30%	33%	37%	43%
		Middle East	0%	3%	6%	10%	12%	14%	17%
		Eurasia	0%	3%	5%	9%	10%	12%	14%
		Asia Pacific	2%	32%	46%	58%	60%	62%	64%

Note: The ratio reflects the % of total capex in each sector that is associated with low-carbon or ‘green’ activities, defined in the Annex. * GICS 551030 includes all multi-utilities, which in some cases include utilities operating outside of the electricity sector. ** GICS 101020 and 10102050 include consumable fuels such as uranium that are not included in the sector scope.

Source: Vivid Economics based on IEA NZE scenario

Table 11 - Green revenues intensity (green revenues/ total revenues) in a Paris-aligned trajectory for road mobility

SECTOR	GICS	REGION	2020	2025	2030	2035	2040	2045	2050
Road mobility	251020*	North America	3%	37%	65%	74%	80%	90%	100%
		Central & South America	3%	40%	60%	77%	86%	93%	100%
		Europe	13%	43%	68%	75%	80%	90%	100%
		Africa	3%	40%	60%	77%	86%	93%	100%
		Middle East	3%	40%	60%	77%	86%	93%	100%
		Eurasia	3%	40%	60%	77%	86%	93%	100%
		Asia Pacific	22%	46%	63%	77%	86%	92%	100%

Note: The ratio reflects the % of total revenues in each sector that are associated with low-carbon or 'green' activities, defined in the Annex. * GICS 251020 does not include heavy duty vehicles.
Source: Vivid Economics based on IEA NZE scenario

4.2.2
Translating to Paris-Aligned Portfolio Benchmarks

Investment trajectories provide benchmarks for activity in the real economy. Decarbonisation scenarios require changes in the real economy, with investment needs reflecting the activity required across a range of publicly listed corporate entities, private corporate entities and non-corporate entities, such as project finance for electricity generation. Institutional investors, however, often make investment decisions and set Paris-alignment targets by asset class.

As a next step, benchmarks could need to be translated to an investor portfolio or asset class. Investors can understandably benefit from understanding how Paris-aligned green revenues and capex evolve within each asset class, such as in listed equities, and how benchmarks can be translated to a Paris-aligned investor portfolio. As discussed in 5.2.1, it was not possible to calculate portfolio or asset class benchmarks based upon the report's investment trajectories and the underlying IEA scenarios, as these pathways reflect investments in only a subset of energy-intensive sectors in any portfolio or asset class.

In some sectors, such as automobiles, investors can apply our real-economy figures as benchmarks for publicly listed equities. In sectors and regions with a high share of publicly listed equities, it is plausible to assume that Paris-aligned real-economy benchmarks can be translated to benchmarks for the stock market in the relevant sector and region. Examples include automobile manufacturing in North America and Europe.

In many emerging markets, however, benchmarks for listed equities are likely not to be sufficient to support a scale-up in climate finance due to the high share of activity and investment outside of public corporates. As highlighted in Section 3.4, over 70% of investment needs are expected in non-OECD regions over the next three decades, with over 40% required in Asia Pacific. In many of these regions, a large share of corporate activity is in private companies and state-owned enterprises. For instance, in Southeast Asia, some of the largest utilities such as China State Grid Corporation or Singapore Power are state-owned and do not issue equity on public markets. For some sectors such as building retrofits, most of the market is captured by small companies that are not listed on public equity markets and access funds through other channels. An investor benchmark for publicly listed equities is therefore misleading to assess an investor's Paris alignment. It fails to capture the large extent to which investors must support investment in climate solutions outside of traditional asset classes.

4.3 Investor Guide to Tracking Investment In Climate Solutions

Investors seeking to track their portfolio's exposure to climate solutions can begin by measuring their green investment ratio and priority net zero investment ratio using more granular corporate revenues disclosures.

This section highlights the advantages and limitations of some of the most promising financial metrics that investors can use to track their portfolio's exposure to climate solutions, set out in Figure 36. These metrics aim to help investors track their investments portfolio's contribution to climate mitigation efforts, assess their portfolio's Paris alignment, and inform capital reallocation or engagement with portfolio companies. No single metric is a silver bullet to achieve all these objectives, with some metrics particularly constrained by limited availability of data and methodological issues. Given this, investors can consider applying a combination of metrics in the future to track their exposure in a meaningful way.

As corporate capex disclosures improve, investors can also apply sectoral green capital alignment, while seeking to resolve the methodological challenges of a carbon return metric. Application of a sectoral green capital alignment metric and portfolio carbon return metric are inhibited today due to data limitations and methodological challenges, respectively. Both these metrics can add value, however. A sectoral green capital alignment metric is core to aligning corporate activities to the Paris-aligned investment trajectories in Section 3 and setting Paris-aligned investment targets.

Figure 36 - A roadmap of metrics to measure investment in climate solutions

At the portfolio level, investors can measure their exposure to climate solutions via:

GREEN INVESTMENT RATIO

+ Measure % of a portfolio financing climate solutions, aligned with a green taxonomy
+ Aligned with the EU taxonomy reporting requirements
+ Measured using asset-level revenues from today

− Requires more granular revenues disclosures
− Requires regional taxonomies with high interoperability
− Does not capture the varied impact that climate solutions have on emissions reductions

PRIORITY NET-ZERO INVESTMENT RATIO

+ Measure % of a portfolio financing climate solutions in regions critical for achieving net zero by 2050
+ Helps identify solutions facing financing gaps, which require policy support
+ Measured using asset-level revenues from today

− Requires regional taxonomies with clear investment priorities
− Requires more granular revenue disclosures

As data & methods improve, investors can seek to track their exposure via:

SECTORAL GREEN CAPITAL ALIGNMENT

+ Measures alignment to Paris-aligned green capex intensity by region and sector
+ Forward Looking indicator of emissions and green revenues

− Requires better corporate disclosures on capex, which lag behind revenue disclosures

PORTFOLIO CARBON RETURN

+ Quantifies impact of investment on emissions reductions
+ Recognises avoided emissions from products or services sold

− Multiple methodological challenges, complex to solve

Source: Vivid Economics

Green Investment Ratio

A green investment ratio measures the share of a portfolio's total investments that is financing climate solutions, where climate solutions are defined in line with a sustainable investment taxonomy.

Total climate solutions financed can be measured by assessing the amount of a company's business activities (its revenues, capex or opex) that align with a predefined list of climate solutions activities, such as from a sustainable taxonomy. Investors can use company revenues to assess an asset's alignment to a sustainable taxonomy due to the more granular disclosures of corporate revenues relative to capex or opex.

This metric is useful to institutional investors because it:

01

Aligns with the latest EU Taxonomy Regulation, which will mandate that all asset managers subject to the EU's NFRD report a green investment ratio.

The European Commission recently set out the reporting guidelines for financial institutions relating to its Taxonomy Regulation.[124] This guidance implies that asset managers subject to the regulation will need to report a green investment ratio, on the share of taxonomy-aligned investment relative to total investments in their portfolio. See section 5.4. Notably, given the current absence of EU taxonomy-aligned revenue data, investors can rely on other sources of green revenue data, such as those provided by.

02

Provides the most comprehensive snapshot of a portfolio's exposure to climate solutions.

Corporate revenues provide a simple and comparable measure of the degree to which an asset, and a portfolio as a whole, is supporting mitigation activities necessary for the net zero transition. When underpinned by a sustainable investment taxonomy that is comprehensive and science-based, the metric can provide a robust guide of where and where not to invest in climate mitigation goals.[125] While no sustainable investment taxonomy is likely to capture the full universe of mitigation activities or the latest technological developments, regular updates and collaboration with industry can help ensure a taxonomy that guides a scale-up in a wide range of climate solutions.

03

Helps investors to set targets, measure performance over time, and identify growth opportunities.

The metric is particularly helpful in supporting investors to understand their current exposure to mitigation activities, informing target setting for allocation to climate solutions and informing corporate engagement that underperform relative to peers. The metric can also help to track performance over time and identify opportunities that reduce real-world emissions or improve risk-adjusted returns (by identifying assets with growth potential).

Box 4 Measurement of green investment ratio

Institutional investors can use the following approach to calculate a portfolio's green investment ratio.

This measures the quantity of assets under management financing taxonomy-aligned climate solutions (or 'green') relative to total assets under management.

$$\text{Green Investment Ratio} = \frac{\sum_i \left[\text{Gross carrying amount of debt securities / equity holdings}_i \times \dfrac{\text{Revenues in climate solutions}_i}{\text{Total revenues}_i} \right]}{\sum_i \text{Gross carrying amount of debt securities or equity holdings}_i}$$

i = borrower or investee

The calculation method above provides a general principle that should be complemented with asset class specific considerations. The European Banking Authority sets out detailed calculation methods which should be considered by investors seeking to calculate their GIR.[126] The denominator for equity holdings should, for example, exclude assets held for trading, but include "financial assets at fair value through other comprehensive income, financial assets not held for trading at fair value through profit or loss and investments in subsidiaries, joint ventures and associates." They specify the denominator for debt securities should include "the gross carrying amount of debt securities at amortised cost and at fair value through other comprehensive income, and debt securities not held for trading at fair value through profit or loss". Finally, they provide additional recommendations on how to report the GIR, including that the investment ratio should be measured in terms of the stock of debt securities and equity holdings up to a specific date, as well as the flow of new securities and holdings during the disclosure date.

Investors can exclude investments from the calculation if there are no available to methods to calculate the borrower's (or investee's) activity in climate solutions. Methods do not yet exist to assess a sovereign's revenues or activities in relation to climate solutions, for example. Until these methods develop, investors do not need to include their exposure to sovereign debt in the numerator or denominator of the priority net zero investment ratio.

To improve the value of a green investment ratio (and all taxonomy-associated metrics), policymakers and industry can focus on three next steps for taxonomy development.

- **Develop regionally granular taxonomies,** to identify climate solutions specific to each country or region, reflecting the differences between regions in the rate at which they achieve net zero and how they do this.
- **Develop a tiered assessment of priority 'green' activities,** to show the differing impact that investments can have on emissions reductions, and therefore better track the impact that allocation to different solutions has on Paris alignment. Activities could be classified as low, medium and high impact depending on the relative emissions reductions they support.
- **Establish bottom-up mechanisms and coordination with industry,** to better capture supply chain innovation. For example, companies could submit claims of an activity being 'green', showing that it is delivering a substantial contribution to climate mitigation. These claims could be reviewed annually for regular inclusion in the taxonomy.

Data providers and international organisations can also help by developing scenarios to show green revenues ratios expected in a net zero world, to help guide investor target setting. A drawback of existing scenarios is that they often do not provide information necessary to calculate green revenues for all Paris-aligned activities. Though some scenarios show production volumes for specific technologies and sectors, these typically capture the revenues only from the sale of a good (e.g. the sales of EVs) rather than all revenues associated with that good's supply chain (e.g. revenues from maintenance or leasing). Lack of information on green revenues in a net zero world leads to difficulty in setting a credible Paris-aligned targets for allocation to climate solutions across asset classes. The report sets out an approximate benchmark for green investment in some sectors until more information is available (see Section 5.2).

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Priority Net Zero Investment Ratio

A priority net zero investment ratio measures the share of a portfolio's total investments that is financing technologies that are a priority for achieving net zero emissions by 2050 or sooner.

Though there is no predefined taxonomy of priority technologies, the net zero investment trajectories set out in Section 3 help to identify a subset of technologies which are likely to be a priority for climate mitigation. This subset of technologies is ready to be deployed and underpin emissions reductions in the IEA 1.5˚C pathway, including low-carbon power, EVs and grid storage. Table 21 lists all the technologies that meet these criteria and that can be used by investors to prioritise investment today in addition to their existing investment due diligence processes. Further research is necessary to refine this priority technology list and ensure that it is relevant to regional investment roadmaps.

This metric is useful to institutional investors because it:

Prioritises investment in the technologies that are most important for an orderly transition, helping identify opportunities for investors to have a greater impact on emissions reductions. The net zero transition will inevitably require a scale-up in finance across numerous technologies, activities and supply chains. Sustainable investment taxonomies, such as the EU taxonomy, seek to capture the entire universe of net zero climate solutions. It is essential to recognise, however, that these solutions will not have an equal impact on reducing emissions or require equal levels of investment.

Is applicable in the absence of detailed corporate data or regional sustainable investment taxonomies. Though taxonomy development and mandatory corporate reporting are under development, these are unlikely to provide a detailed measure of exposure to all climate solutions in the next year. The EU Taxonomy Regulation will come into force in 2023 for corporates, but even then, it will mandate disclosures on sustainable activities only from large, public EU corporates (see Section 5.4). Though there are also no mandatory corporate disclosures associated with revenues in priority technologies, these are less complex to calculate, for two reasons: they require less granular disclosures and can be more easily proxied.[127]

Helps investors to set science-based and Paris-aligned targets, measure performance over time, identify growth opportunities, and guide policy advocacy. Measures of priority net zero investment ratio provides a good gauge of how close, or far, investors are from having a tangible impact on emissions reductions. This information is valuable beyond the level of an individual investor. It can be useful to guide how investment strategies or policies develop to meet net zero investment needs. Widespread reporting of this metric could, for example, show where investment needs remain systematically underfinanced, thereby informing policy advocacy.

Box 5 Measurement of priority net zero investment ratio

Institutional investors can use the following approach to calculate a portfolio's priority net zero investment ratio.

This measures the quantity of assets under management financing priority technology relative to the total assets under management.

$$\text{Priority net zero investment ratio} = \frac{\sum_i \left[\text{Gross carrying amount of debt securities / equity holdings}_i \times \dfrac{\text{Revenues in priority technologies}_i}{\text{Total revenues}_i} \right]}{\sum_i \text{Gross carrying amount of debt securities or equity holdings}_i}$$

i = borrower or investee

The calculation method above provides a general principle that should be complemented with asset class specific considerations, detailed in Box 4 and EBA guidance.[128]

Investors can exclude investments from the calculation if there are no available methods to calculate the borrower's (or investee's) activity in relation to priority technologies, see Box 4.

Regional priority technology lists and granular corporate disclosures can improve the usefulness of the metric going forward. Decarbonisation pathways will vary across regions depending on a variety of factors, including natural endowments, availability of capital, and policy efforts. Our analysis shows that the technologies required to achieve a 1.5˚C consistent world are largely consistent across regions, such as solar and wind. This similarity could not overlook the fact that the relative importance of technologies will often differ depending on the regional context, leading to different priority investment needs for investors to target. Though data availability is not a key limiting factor for applying this metric, the ease of calculation and robustness of the result would still benefit from granular revenues disclosures by corporates globally, particularly in emerging markets where corporate disclosures are limited. Approximations are possible to estimate corporate revenues, but as these often use industry benchmarks they fail to reflect in full the differences between assets in a portfolio.[129, 130]

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Sectoral Green Capital Alignment

A green capex intensity metric measures the alignment of an asset or a sector to a sectoral net zero capex intensity benchmark, defined as the sectoral green capex intensity consistent with a net zero pathway.

The net zero transition will require large shifts from dirty to low-carbon (or 'green') capital across the economy, and particularly in several material sectors, such as industry, transport and power.[131] In the power sector alone, capital spending on low-carbon generation is expected to increase by $755 million from today's levels to the level required in the 2020s.[132] As a result, investors committed to understanding their future risks and opportunities and willing to engage actively with their portfolio companies will benefit from closely tracking their exposure in these sectors at a more granular level. Despite the limited corporate disclosure on capex today, there are benefits of using green capex rather than revenues as a measure of a company's Paris alignment once data is more widely available, discussed below. Corporate disclosures of capex are likely to improve going forward, with the EU Taxonomy Regulation mandating disclosure of taxonomy-aligned capex and opex from large, publicly listed corporates as of January 2023. See Section 5.4 for further information.

This metric is useful to investors, and additional to metrics that rely on revenues, because it can:

- Provide a forward-looking indicator of future emissions reductions in material sectors. A company's capex plans provide a forward-looking indicator of future emissions reductions or green revenues and can help to substantiate the credibility of corporate net zero transition plans. Looking at capex therefore provides a window of opportunity for investors to act and engage with companies before capital and emissions lock-in. The importance of assessing capex plans is recognised by both the NZIF and the CA100+ net zero benchmarks.[133, 134] The latter found that none of the 159 largest corporate emitters currently commits to aligning future capex with the goal of limiting temperature rise to 1.5˚C benchmarks.
- Show strong links between a company's activities and a net zero pathway. Alignment of an individual asset's green capex intensity from a sectoral (and regional) benchmark provides a forward-looking indicator of whether an asset is investing in mitigation activities at sufficient pace and scale to meet a net zero pathway.[135] Net zero scenarios already provide information that can help to calculate each sector's net zero capex intensity benchmark, while this information would need to be calculated for a green revenues benchmark. As companies in a sector are likely to need different levels of green capex, benchmarks could develop for each type of company within a sector.
- Provides additional actionable insights to guide engagement and within-sector capital reallocations. Measures of an asset's alignment to a sectoral benchmark helps to show both which portfolio companies are under- or over-performing and the drivers of their underperformance, helping investors identify companies to engage with to ensure future emissions reductions increase and to identify best-in-sector assets for future capital reallocations.

Box 6 Measurement of sectoral green capex intensity alignment

Institutional investors can use the following approach to calculate each sector's green capex intensity alignment.

Given differences in green capex needs by sector, and region, the largest benefit of applying this metric is at the sectoral and regional level – either to understand how an asset is performing relative to a sectoral and regional benchmark, or how all sectoral investments are performing as a whole.

$$\text{Sectoral Green Capex Intensity Alignment}_{s,r} = \sum_i \left[\text{Attribution factor}_i \times \text{Asset Green Capex Intensity Alignment}_{i,s,r} \right]$$

$$\text{Asset Green Capex Intensity Alignment}_{i,s,r} = \left[\frac{\text{Green capex}_{i,s,r}}{\text{Dirty + Green capex}_{i,s,r}} - \frac{\text{Green Capex in 1.5 degrees scenario}_{s,r}}{\text{Dirty + Green capex in 1.5 degrees scenario}_{s,r}} \right]$$

$$\text{Attribution Factor}_i = \frac{\text{Outstanding amount}_i}{\text{Total Equity}_i + \text{Total Debt}_i}$$

i, s, r = borrower or investee in sector s and region r

s, r = sector s in region r

The attribution factor is defined as the share of a borrower or investee's annual revenues that is allocated to the institutional investor's investments, with the calculation varying by asset class. In line with the Partnership for Carbon Accounting Financials (PCAF) GHG accounting and reporting principles, an investor's share of emissions can be measured as proportional to its exposure to the borrower or investee's total (company or project) value. As a general principle, PCAF calculates the attribution factor as the share of the outstanding amount of loans and investments of an investor relative to the total equity and debt of the company, project, and property that the investor is invested in. The underlying financial data sources and equations will, however, vary by the type of financing provided. In the case of listed equities, for example, the attribution factor is calculated based on the value of outstanding listed equity and corporate bonds over the company's EVIC (enterprise value including cash).[136, 137]

To ensure industry comparability investors use PCAF's detailed guidance on calculating attribution factors by asset class, available for the following asset classes: listed equity and corporate bonds, business loans and unlisted equity, project finance, commercial real estate, mortgages and motor vehicle loans.

If there is no clear classification of dirty activities within a sector, investors can calculate intensity using green capex over total capex. Currently there is no economy-wide taxonomy of 'dirty activities', though the possibility of developing such a taxonomy is being discussed by the EU Platform on Sustainable Finance. As investors wait for these taxonomies to develop, they can use our classification of 'dirty' capex in energy-intensive sectors (see Table 18 in Annex). Notably, this does not comprehensively assess 'dirty' activities in all sectors of the economy (e.g. manufacturing) and does not consider 'dirty' activities across the supply chain. In many cases today investors may therefore need to work out green capex intensity using total capex, despite the limitations of this approach, discussed in the text below.

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To ensure that green capex intensity better reflects an asset's green transition, it is necessary to have taxonomies and scenarios that define and assess emissions-intensive (or 'dirty') capex respectively. Current calculations for green capex intensity measure green versus total capex. The latter includes capex in 'green' activities that contribute to climate mitigation (are aligned to a net zero taxonomy), 'dirty' activities that are emissions-intensive, and 'grey' activities that have little impact on net zero emissions. This is because there is currently no systematic taxonomy for 'dirty' activities, and therefore it is not easy to compute which activities are harmful to Paris alignment versus those that have little impact. Similarly, scenarios do not always provide information necessary to calculate dirty capex in each sector. Measures of green to dirty capex are, however, a better indicator of an asset's transition to net zero because they:

– Provide a leading indicator of future emissions reductions, by more closely tracking how much capital is being invested in Paris-aligned assets compared to assets that are not aligned.
– Do not disadvantage assets that have already transitioned, which may have low green capex relative to total capex (as most green capex has already been invested in) but high green to dirty capex (because there is near zero emissions-intensive or 'dirty' capex).

Box 7 Case study: green capex intensity in the utility sector

An investor wants to allocate between two utility companies with similar current emissions intensity and emissions reduction targets.

To distinguish between the two companies, the investor is interested in understanding whether the two companies are investing sufficiently in the net zero transition to ensure they achieve their emissions targets. For context, the companies are utility E operating in the EU and utility I operating in India. See Table 12 for comparison of the companies' capex plans.

Table 12 - Asset capex over time

COMPANY NAME	REGION	DIRTY CAPEX ($ MILLION)		
		2021–30	2031–40	2041–50
E	EU	25	17	10
I	India	30	15	5
		GREEN CAPEX ($ MILLION)		
E	EU	100	110	150
I	India	75	100	150
		GREEN CAPEX INTENSITY (0 = no green capex, 1 = green capex only)		
E	EU	0.80	0.87	0.94
I	India	0.71	0.87	0.97
		DEVIATION FROM NET ZERO BENCHMARK (%)		
E	EU	-5%	-2%	8%
I	India	-16%	-4%	9%

Note: All numbers in this table are hypothetical. Green capex reflects all capex aligned to activities in a green (net zero-aligned) taxonomy. Dirty capex reflects all capex in activities that increase emissions levels. Green capex intensity = green capex / (green capex + dirty capex).
Source: Vivid Economics

To determine the utility company's net zero alignment, the investor needs information on the net zero capital intensity benchmark in the electricity generation sector in each relevant region. Table 13 shows the green capital intensity benchmark for the electricity generation sector in Europe and India based on investment calculations in Section 3. Notably, in both regions there is a small decrease in green capex intensity in 2041–50, underpinned by a fall in both green and dirty capex relative to 2031–40. The slightly larger fall in green capex (from $116 to $85 million in the EU) relative to the fall in dirty capex ($16 to $14 million in the EU) between the 2030s and 2040s reflects that: a) most green infrastructure is established in the 2020s and 2030s; and b) the costs of low-carbon capital fall at a higher rate than more mature emissions-intensive alternatives. Overall, cost declines imply a fall in green capex investment need that do not wholly represent falling demand for green capital items.

Table 13 - Net zero green capex intensity benchmark over time

COMPANY NAME	REGION	SECTORAL NET ZERO CAPEX INTENSITY BENCHMARK		
		2021–30	2031–40	2041–50
E	EU	0.85	0.88	0.86
I	India	0.87	0.91	0.88

Source: Vivid Economics

Portfolio Carbon Return Metric

A portfolio carbon return metric measures the emissions abatement for each dollar invested.

The definition of emissions abated used in this report includes both the emissions reduced in a company or other asset's own activities and the emissions avoided in the economy due to the company's sale of goods or services. To date, requirements to report GHGs mandate the reporting of emissions produced from a company's own activities or supply chain only (scope 1, 2 and 3 emissions). To capture the full impact that companies are having on achieving net zero, this report also considers how to include 'avoided emissions', or scope 4 emissions (see Box 8). These avoided emissions are included only if the activities associated with emissions avoidance align with the activities required in a 1.5˚C pathway, and could not be used to offset produced emissions.[138]

This metric can help investors capture the relative contribution of an investment towards decarbonisation goals and is less constrained by a predefined list of mitigation activities. Emissions abatement metrics can add value by overcoming some of the challenges of taxonomy-based metric. For instance, they can:

- Quantify the degree to which an asset is contributing to necessary emissions reductions.
- Capture the contribution of multiple supply chain actors enabling emissions reductions, which is difficult to capture fully from any top-down system-wide perspective.
- Reflect innovative mitigation activities, which a mitigation taxonomy may not be as agile to capture.

Emissions abatement calculations can, when taken in isolation, lead to investments inconsistent with a 1.5˚C world, however, and are hindered by a lack of methodology standardisation. A first challenge to emissions abatement metrics is that an asset may reduce emissions relative to business-as-usual (BAU) while not necessarily contributing to net zero-consistent investment. For instance, an investment in a gas turbine can lead to high avoided emissions in a coal-powered country but disincentivise investment in low-carbon power in the next decade. A second challenge relates to the methodological challenges of calculating avoided emissions, which inhibits credible reporting and comparison of the metric. This includes difficulty of attributing emissions reductions across actors in a supply chain and determining a plausible baseline scenario. See the Annex for further discussion of these challenges.

The widespread use of these metrics is not likely to be useful until methodologies to calculate scope 4 avoided emissions are improved. Mission Innovation's Avoided Emissions Framework provides the most robust guidance to date on avoided emissions methods.[139] However, if this metric is to be credibly reported and compared across portfolios, methodological challenges still need to be resolved. In particular, methods need to show how to overcome double-counting, and to calculate emissions reductions associated with net zero enabling technologies, such as a utility-scale battery. If calculations remain too difficult or time consuming for priority net zero technologies, the metric is expected to inevitably be skewed to easier-to-calculate but less important products and services.

Box 8 Introducing avoided emissions as scope 4

The GHG Protocol defines three 'scopes' of emissions (scope 1, scope 2 and scope 3) to help delineate direct and indirect emission sources.[140]

However, scope 1, 2 and 3 emissions do not account for positive impacts of products that may not have emissions in the use phase, but contribute to decarbonisation relative to other conventional products. An example would be the production of polysilicon for the manufacture of solar panels. A company's scope 1, 2, and 3 emissions might increase when it starts to manufacture or scale up the manufacture of polysilicon, which has no emissions in the use phase but nonetheless enables electricity generation via solar energy, and thereby contributes to displacing non-renewable power generation.

In this report, scope 4 is used to refer to the emissions impact of a product (good or service) relative to the situation where that product does not exist. Positive differences, where emissions are reduced, are also known as 'avoided emissions'.[141]

The broader picture of emissions can help investors better identify companies that are enabling emissions reduction outside their own supply chain. There is widespread recognition that scope 3 emissions ought to be more widely reported, particularly in sectors where upstream and downstream emissions are significant (e.g. automotive, oil & gas). Without information on scope 3 emissions for a car company, for example, it is impossible to estimate which companies are enabling the real-world decarbonisation of transport through sales of zero-emissions vehicles. Inclusion of scope 4 emissions is arguably just as essential to capture the impact that companies have on Paris alignment through their sale of goods and services. Scope 4 reporting is in many cases additional to scope 3 because it reflects the difference in emissions relative to an economic baseline rather than the company's pre-existing emissions.[142] While scope 1–3 reporting rewards companies that are transitioning to net zero, scope 4 rewards innovative players who provide the solutions that enable a company to transition.

There are six next steps to ensure the comparability and quality of a carbon return metric.

- Science-based, up-to-date business-as-usual emissions trajectories.
- Robust and transparent calculation methods, which take into account life-cycle emissions of a climate solution (solution effects), emissions avoided by implementation of the solution (enabling effects) and changes in baseline emissions due to implementation of the solution (rebound effects).[143, 144]
- Standardised methods to avoid double-counting, such as allocation according to each actor's value add.[145] Though the method could vary, it is essential that a standard approach is applied to allow for aggregation of avoided emissions across assets in a portfolio and comparability across portfolios.
- Standardised avoided emissions factors associated with the implementation of climate solutions in each region, which provide robust estimates of avoided emissions from each unit of product sold or unit of activity. These factors are key to ensuring greater uniformity across estimates.
- Impact measurement frameworks to guide calculation of avoided emissions for innovative technologies (or technologies which by their nature may not have standardised avoided emissions factors). This framework could set out the types of evidence required and calculation methods.
- A technical working group to verify company estimates and help drive standardised approaches, for instance providing advice on baseline emissions trajectories and avoided emissions factors.

Given the many challenges discussed and the potential cost to resolve them, efforts can instead focus on improvements in taxonomy-based metrics (such as the green investment ratio, priority net zero investment ratio, and sectoral green capital alignment). The challenges of other metrics discussed in this report can be overcome through improvements in taxonomy creation and data reporting, which are likely to be quicker to implement than efforts to resolve the methodological problems around avoided emissions.

Box 9 Measurement of portfolio carbon return metric

The method to calculate a portfolio carbon return metric suffers from methodological challenges which hinders credible application and reporting efforts today

Notable challenges of calculating scope 4 emissions are highlighted in the chapter, related to the difficulty in identifying a credible BAU emissions trajectory and the lack of standard methods to avoid double-counting of emissions reductions. The method discussed below does not solve all these challenges and could not be considered as guidance on the comprehensive steps that investors need to take. It is intended to provide guiding principles on how the metric can be calculated if the aforementioned challenges are resolved.

If methodological challenges are resolved, institutional investors can use the following approach as a guiding principle for how to calculate a portfolio's carbon return metric. This measures the scope 1, 2, 3 and 4 emissions abated by a portfolio relative to its total AUM. Due to the challenges of assessing scope 4 emissions, the return on scope 1 to 3 emissions is calculated separately to that on scope 4 emissions.

$$\text{Annual portfolio carbon return (scope 1 – 3)}_y = \sum \frac{\text{Attribution factor}_i \times \text{Annual abatement from scope 1, 2, 3 emissions}_{i,y}}{\text{Annual AUM}_y}$$

$$\text{Annual portfolio carbon return (scope 4)}_y = \sum \frac{\text{Attribution factor}_i \times \text{Annual abatement from scope 4 emissions}_{i,y}}{\text{Annual AUM}_y}$$

$$\text{Attribution Factor}_i = \frac{\text{Outstanding amount}_i}{\text{Total Equity}_i + \text{Total Debt}_i}$$

i = borrower or investee

y = calendar year

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Similar to guidance on the sectoral green capital alignment metric, investors can use PCAF guidance on calculating attribution factor.[146] These factors are defined as the share of a borrower or investee's capex alignment that is allocated to the institutional investor's investments, based on the proportion of the investor's exposure to the borrower or investee's total (company or project) value. PCAF guidance varies by asset class, however the general principles of the calculation are shown above and set out in Box 6.

Abatement of scope 1, 2, 3 compares a company's emissions to the industry average emissions in a BAU scenario. It is calculated by comparing how a company's corporate emissions profile compares to a BAU scenario specific to the industry in which the company operates.

$$\text{Annual abatement from scope 1, 2, 3 emissions} = \text{Scope 1+2+3 emissions}_{i,y} - \text{Industry average scope Scope 1+2+3 emissions}_{y,bau}$$

bau = BAU scenario

i = borrower or investee

y = calendar year

Abatement of scope 4 emissions compares emissions reductions associated with a product or service sold by a company relative to a world. The abatement associated with a company is likely to reflect:

1. **The annual net avoided emissions from the relevant climate solutions** to which a company contributes through its sale of goods and services. Each climate solution, such as an EV battery, avoids emissions relative to a BAU scenario where the solution was not available. To calculate net avoided emissions, however, the calculation must subtract the solution's direct emissions (emissions created during production, use or end of life). Where applicable, it must also subtract rebound emissions (which occur if consumption and emissions increase despite lower emissions intensity).
2. **The attribution factor for the good or service sold by a company**, which aims to reflect the proportion of total emissions reductions associated with a climate solution that result from a specific good or service in the value chain. In the example of an EV battery, the attribution factor is calculated for each value chain actor, from raw material supplier to cathode manufacturer. This attribution across the value chain is necessary to avoid double-counting of emissions abated at a portfolio level. To measure relative contribution, one approach is to measure the relative value added of a good or service sold relative to the final climate solution (suggested below).

$$\text{Annual abatement from scope 4 emissions}_{i,y} = \sum \left[\text{Value chain attribution factor}_{i,x,cs} \times \text{Net avoided emissions from climate solution}_{cs,y} \right]$$

x= good or service sold by company

cs = climate solution

i = borrower or investee

y = calendar year

$$\text{Net avoided emissions from climate solution}_{cs,y} = \text{Avoided emissions relative to BAU}_{cs,y} - \text{Direct emissions}_{cs,y} - \text{Rebound emissions}_{cs,y}$$

$$\text{Value chain attribution factor}_{i,x,cs} = \frac{\text{Value added of good or service}_{i,x,}}{\text{Value added of climate solution}_{cs}}$$

4.4
Impact of EU Taxonomy Regulation

As of 2023, EU regulation will mandate that all companies report on revenues, capex and opex aligned to the European Commission's definition of mitigation activities.

The discussion above highlights the importance of greater transparency on the environmental performance of companies and investors. In recognition of this need to 'increase market transparency, mitigate risks of greenwashing and subsequent reputational risks for financial institutions', in 2020 the European Parliament introduced a framework to facilitate sustainable investment, known as the EU Taxonomy Regulation. The regulation specifies that corporates and financial institutions disclose how and to what extent their activities are aligned with environmentally sustainable economic activities.[147] In 2021, the Commission released technical screening criteria on exactly which activities make a sufficiently large contribution to climate mitigation objectives, to be reported as 'green'.[148]

The upcoming regulation will mandate investment firms (including asset managers and insurers) to report a green investment ratio as of 1 January 2024, in line with the suggested metrics set out in Section 4.3.[149] Recent guidance by the Commission has set out the reporting guidelines for financial institutions, including credit institutions, asset managers and insurers.[150] Asset managers, for example, will need to report on the share of taxonomy-aligned investment managed relative to total AUM in their portfolio. The EU's reporting requirements can help to improve data availability necessary to calculate green revenues and green capex, helping in the calculation of a corporate green capex intensity as well as a green investment ratio.

Investment ratios are expected to consider only a portion of an investor's portfolio in the near term. The Commission advises that all financial institutions exclude sovereign exposures as there is no agreed methodology to assess a sovereign's environmental performance.[151] Exposures to companies not subject to EU reporting regulation could also be excluded from the calculation of taxonomy-aligned investment during the transitional period to 2025, although exposures to these companies could still be included in the denominator of the investment ratio. This implies excluding private companies, small or medium EU companies and all non-EU companies from the numerator, even if they report on their alignment with EU mitigation objectives.

Additional work is required to build on the EU regulation and improve applications of climate solutions metrics at the global level. As of 2021, the Taxonomy's technical screening criteria do not yet provide consistently clear thresholds to classify an activity as sustainable, and often exclude supply chain activities that contribute significantly to mitigation efforts. Reporting at company and investor level captures only large EU companies, with data on non-EU companies or SMEs still unavailable for investors. Strengthened reporting and the standardisation of sustainability criteria are nevertheless a step in the right direction. The next step could be a proliferation of regional sustainable investment taxonomies (or a globally agreed taxonomy) that can better guide investment and reporting globally.

Summary of Caveats and Next Steps

5.0

5.1
Limitations of the Report

To summarise previous discussion in the report, there are four main caveats investors could consider when applying the work's findings, often relating to the scenarios and data available today.

Investment trajectories in Section 2 are only one projection of future investment needed and face several uncertainties. Any net zero scenario relies on a series of assumptions which influence how technology deployment and investment will evolve. The investment trajectories are based upon the IEA Net Zero scenario, and similar to any forward-looking projection face a series of uncertainties, including technological uncertainty, regulatory uncertainty, supply chain and infrastructure uncertainty, and behavioural uncertainty.

Paris-aligned investment benchmarks are only available for a sub-set of sectors, and do not translate to investor asset classes. The investment trajectories discussed in Section 2, and more generally the net zero scenarios available today, do not provide sufficient information to calculate Paris-aligned investment benchmarks for the whole economy, or even all energy intensive sectors. This is due to the fact that scenarios only consider a subset of the economy and, even for sectors they cover, do not provide comprehensive projections of all low-carbon or emissions intensive investment needed.

Corporate data to calculate climate solutions metrics is not widely available today. This challenge faces all climate solutions metrics discussed in the report and will only be partially alleviated by upcoming EU Taxonomy regulation (See Section 6.4). It is critical to recognise that without granular disclosure of corporate revenues and capital expenditure, it will be challenging for any investor to identify and scale up their portfolio's allocation to climate solutions.

Identification of priority technologies is constrained by data limitations, particularly around the emissions reductions associated with a technology. It is possible to qualitatively assess a technology's abatement potential based upon a sector's current mitigation need (e.g. size of emissions today) and each technology's importance within sectoral emissions reductions. However, there are limitations to this approach. Notably some sectors will see a growth in emissions, and technologies in these sectors may be disadvantaged within our prioritisation.

5.2 Next Steps

While the analysis above highlights many potential next steps, the following actions are a priority.

1

Investors apply the report's findings, by measuring their portfolio's exposure to climate solutions; benchmarking and setting targets to align investments with the Paris agreement; and, identifying opportunities to scale up investment or engagement in climate solutions. In doing so, investors can also identify areas for improvement and learnings for the industry.

2

Investors, scenario providers and international organisations collaborate to create investment trajectories and Paris aligned investment benchmarks that better reflect the scale up of green revenues and capex required in a Paris-aligned investment trajectory.

3

Investors, development banks and green finance institutions develop financial products that channel investor finance to emerging markets, recognising that benchmarks and metrics are unable to incentivise Paris aligned investment if the majority of finance continues to be allocated to listed equities in advanced economies.

4

Policy advocacy by investors to push for granular corporate disclosure of revenues and capex amongst all companies, through both government regulation and requests upon investees.

5

Policy advocacy by investors to encourage governments and transnational organisations to create regionally specific investment roadmaps and sustainable investment taxonomies, that provide a tiered framework for classifying climate solutions based on their impact on the net zero transition.

Technical Annex

6.0

6.1
Net Zero Investment Trajectories

This section sets out the methodology used to calculate the investment needs associated with the net zero transition presented in Section 2.

Investment projections are based on the global estimates provided by IEA's 'Road to Net Zero by 2050'. These estimates are downscaled to more granular projections across sub-sectors, technologies, regions, and countries. The data series used to perform the downscaling include technology-specific installed capacities, production volumes, and unit capex estimates.

Table 14 - Investment Trajectories Taxonomy

SECTOR	TECHNOLOGIES	COMMENTS
Electricity sector	**Generation by technology:** solar PV, wind, hydro, bioenergy, CSP, geothermal, marine, nuclear, hydrogen-based, coal w/ and w/o CCUS, natural gas w/o and w/o CCUS, oil	
	Storage: behind-the-meter, grid-scale	
	Networks: new lines, replacement and digitalization (includes smart meters)	
Fossil fuel supply	**Oil:** refining, transport, existing fields, new fields	
	Natural gas: transport, existing fields, new fields	
Transport	**Road Mobility:** BEVs/PHEVs/FCEVs, energy efficiency	Road mobility spending refers to the expenditure required to purchase vehicles. Expenditure on BEVs and PHEVs only considers the value of the battery within the vehicles Expenditure on FCEVs only considers the value of battery, fuel cell and hydrogen tank. Energy efficiency expenditure is the additional price of each energy-efficient vehicle sold compared to average vehicle prices.
	EV charging infrastructure	
	EV batteries factories	
	Mining for EV-required minerals	Minerals considered are copper, lithium, nickel
	Shipping: bioenergy, hydrogen, ammonia, synthetic fuels, electricity	Refers to the aggregate spending on vehicles optimised for low- or zero-emission fuels. Only the value of the engine is considered.
	Aviation: hydrogen, electricity	Refers to the aggregate spending on vehicles optimised for low- or zero-emission fuels. Only the value of the engine is considered.

Source: Vivid Economics

Furthermore, investment needs are also projected for some sub-sectors not considered by IEA. In the transport sector, the investment trajectories include aviation, shipping, EV battery factories, and mining for minerals used in EV batteries. In the AFOLU sector, the investment trajectories provide climate-related spending based on 'critical interventions' identified by FOLU's 2019 'Growing Better' report.[152]

SECTOR	TECHNOLOGIES	COMMENTS
Buildings	**Buildings retrofitting:** insulation	Expenditure on building insulation
	Heating unit investments: biomass, solar thermal, hydrogen, heat pumps	Expenditure on heating units
	Energy-efficient appliances	Refers to expenditure on energy-efficient heating, ventilation, air conditioning, appliances and lighting. This category measures the incremental spending on energy-efficient products compared to the spending needed to achieve the minimum required energy performance
Industry	**Steel by route:** hydrogen-based, CCUS-based, conventional bioenergy, energy efficiency, electrification, innovative production routes	Energy efficiency spending refers to investment in industrial energy management systems, fuel efficiency, electrical efficiency, heat pumps
	Chemicals by route: hydrogen-based, CCUS-based, conventional bioenergy, energy efficiency, electrification, innovative production routes	
	Cement by route: hydrogen-based, CCUS-based, conventional bioenergy, energy efficiency, electrification, innovative production routes	
	Non-heavy Industry	
Low emission fuel supply (includes CCUS not covered in previous sectors)	**Hydrogen by route:** from NG with CCUS, from biomass, electrolysis	Refers to investment in hydrogen production
	Hydrogen infrastructure **Biofuels**: biogas, biomethane, biomethane with CCUS, conventional ethanol with CCUS, advanced ethanol, advanced ethanol with CCUS, advanced biodiesel and biokerosene, advanced biodiesel and biokerosene with CCUS	Refers to investment in biofuels production
	Direct Air Capture	

The regional groupings considered are the seven macro-regions considered in the World Energy Outlook reports. They are North America, Central & South America, Europe, Africa, Middle East, Eurasia, Asia Pacific. Furthermore, projections are also provided for 6 countries: USA, Brazil, the EU, China, India and Japan.

Table 14 provides the investment taxonomy and Table 15 summarises the methodology used to estimate investments across each sub-sector.

SECTOR	TECHNOLOGIES	COMMENTS
AFOLU	**Diet:** meat substitutes, dairy substitutes	Refers to alternative protein technologies including plant-based meat and dairy and edible insect protein
	Nature restoration: forest restoration, peatland restoration, mangrove restoration, forest management	
	Agriculture: regenerative farming, closing the productivity gap, biofertilisers, biopesticides, urban farming, precision agriculture machinery, agtech software	Agtech refers to investments such as agribusiness marketplaces, farm management software, farm robotics and Internet of Things.
	Food waste: supply chain waste, postharvest waste, demand management	Demand management refers to reduction of consumer food waste in advanced economies. Postharvest waste refers to reduced waste during storage and harvest in developing countries.

Source: Vivid Economics

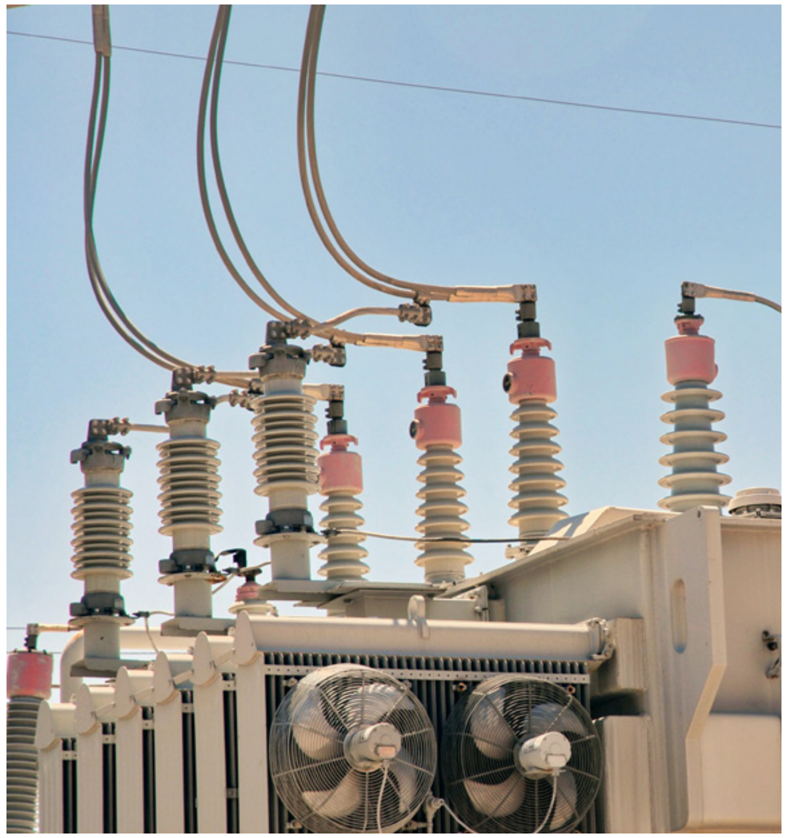

Table 15 - Investment Trajectories Downscaling and Projection Methodologies

SECTOR	DOWNSCALING AND PROJECTION METHODOLOGY	MAIN SOURCES
Electricity: Electricity Generation	**Downscaling by technology:** IEA investment projections downscaled using: 1) change in global installed capacity for each technology and 2) unit capex for each technology. **Regional downscaling:** Technology-specific investments are allocated to each macro-region based on their share of the 2020-40 capacity addition in the SDS. An adjustment based on the 2021 WEO is also applied; it accounts for the greater additional effort needed by emerging economies to reach net zero by 2050, compared to high-income countries. Regional capex differences are accounted for.	IEA (2021a) IEA (2020a) IEA (2020b) IRENA (2020a)
Electricity: Battery Storage	**Downscaling by technology:** Investment in battery storage broken down into investment in utility-scale and behind-the-meter storage based on the 2016-20 investment in each technology. **Regional downscaling:** investment is allocated across regions based on the projected capacity addition of utility-sized battery storage.	IEA (2021c) IEA (2018)
Electricity: Networks	**Downscaling by technology:** Investment in electricity networks is broken down into investment in new lines and in 'replacement and digitalization'. This is done using the investment needs for electricity networks in the Stated Policies scenario. **Regional downscaling:** Investments are allocated to regions based on the cumulative investments in electricity networks in 2020-40 in the SDS	IEA (2020b)
Fossil Fuel Supply	**Downscaling by technology:** Investment by technology already provided by IEA NZE **Regional downscaling:** performed based on projected share of global oil production, oil refining, and NG production capacity in the SDS.	BP (2020) IEA (2020b)
Transport: BEVs and PHEVs	**Downscaling by technology:** Investment is computed based on the total investment in electrification in end-use sectors. Industry investment in electrification is subtracted from the end-use total, and the remaining investment is allocated between the transport and building sectors based on their estimated investment needs. The share allocated to road transport is based on the projected sales of vehicles and the unit cost of batteries. **Regional downscaling:** Investment is allocated to each region based on the projected market size for low- and zero-emission vehicles. Regional differences in prices are accounted for.	IEA (2021b) IEA (2021d) IEA (2020c) OECD (2017) OICA

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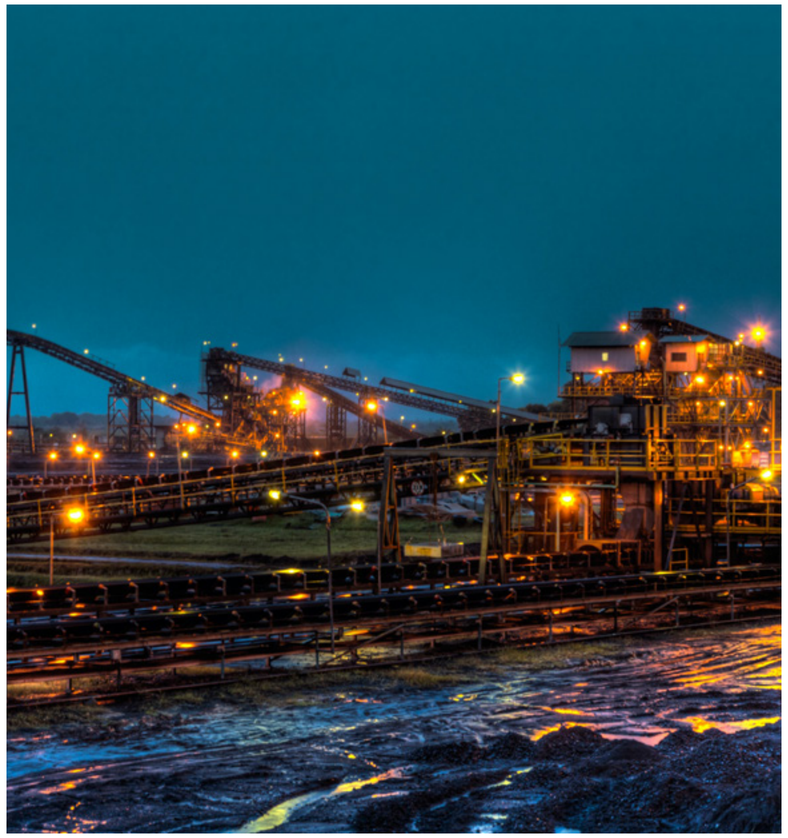
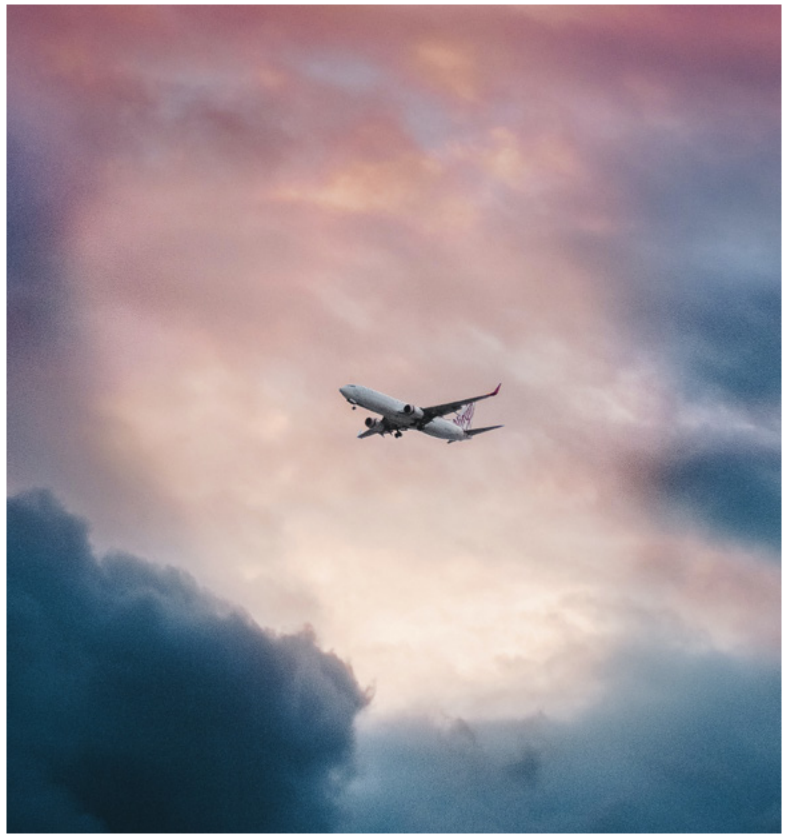


SECTOR	DOWNSCALING AND PROJECTION METHODOLOGY	MAIN SOURCES
Transport: FCEVs	**Downscaling by technology:** Investment is computed based on the total investment in hydrogen in end-use sectors, which is allocated to the transport, buildings and industry sectors based on their estimated investment needs. The share allocated to road transport is based on the projected sales of vehicles and the unit cost of fuel cells. **Regional downscaling**: Investment is allocated to each region based on the projected market size for low- and zero-emission vehicles. Regional differences in prices are accounted for.	IEA (2021b) IEA (2020c) OECD (2017) OICA
Transport: Energy Efficiency	**Downscaling by technology:** Total investment in energy efficiency is computed by subtracting the hydrogen and electrification investment from the total investment in transport. **Regional downscaling:** Investment is allocated to each region based on the projected size of the automotive sector. Regional differences in prices are accounted for.	IEA (2021b) IEA (2021d) IEA (2020c) OECD (2017) OICA
Transport: EV Chargers	**Downscaling by technology:** Investment directly provided by IEA NZE report **Regional downscaling:** Investment allocated to each region based on the projected sales of EVs	IEA (2021b) IEA (2020c) OECD (2017) OICA
Transport: EV Batteries Factories	**Investment by technology:** Investment is not downscaled from IEA estimates. It is computed based on the projected additions in battery production capacity and on the unit capex of battery manufacturing. **Regional downscaling:** Based on announced lithium-ion battery production capacities.	IEA (2020d) IEA (2020e) Bennet and Munera (2017)
Transport: Mining for EV Minerals	**Investment by technology:** Investment is not downscaled from IEA estimates. It is computed based on the projected volumes of minerals required for EV manufacturing and on the mineral-specific capex intensity of extraction activity. **Regional downscaling:** for this sub-sector only, estimates are global only.	Fraser et al (2021) IEA (2020c) Credit Suisse (2017
Transport: Shipping	**Investment by Technology:** Investment is not downscaled from IEA estimates. It is computed based on the projected size of the global merchant marine, the projected share of each propulsion technology within the fleet, and the engine cost by technology. **Regional downscaling:** Investment is allocated across world regions based on freight final energy consumption in the 'beyond 2 degrees scenario'.	IEA (2021b) UNCTAD (2020) Hansson et al (2019) DNV (2017) IEA (2017a)



SECTOR	DOWNSCALING AND PROJECTION METHODOLOGY	MAIN SOURCES
Transport: Aviation	**Investment by technology:** Investment is not downscaled from IEA estimates. It is computed based on the projected size of the global aircraft fleet, the projected share of each propulsion technology within the fleet, and the engine cost by technology. **Regional downscaling:** Investment is allocated across world regions based on projected size of the aircraft fleet in each area.	IEA (2021b) Mckinsey (2020) Airbus (2019)
Buildings: Renewable Heating	**Investment by technology:** Investment is computed based on the total investment in renewables in end-use sectors. It is allocated to the buildings and industry sectors based on historical investment levels and on the projected growth in renewable energy demand in each sector. **Regional downscaling:** Investment is allocated to each region based on the projected energy demand for heating in the 'beyond 2 degrees scenario'.	IEA (2021a) IEA (2021d) IEA (2021c) IEA (2017a)
Buildings: Hydrogen Heating	**Downscaling by technology:** Investment is computed based on the total investment in hydrogen in end-use sectors, which is allocated to the transport, buildings and industry sectors based on their estimated investment needs. The share allocated to heating is based on the projected units installed and on the unit cost of hydrogen heaters. **Regional downscaling:** Investment is allocated to each region based on the projected energy demand for heating in the 'beyond 2 degrees scenario'.	IEA (2021a) IEA (2017a)
Buildings: Heat Pumps	**Downscaling by technology:** Investment is computed based on the total investment in electrification in end-use sectors. Industry investment in electrification is subtracted from the end-use total, and the remaining investment is allocated between the transport and building sectors based on their estimated investment needs. The share allocated to heat pumps is based on the projected units installed and on their unit cost. **Regional downscaling:** Investment is allocated to each region based on the projected energy demand for heating in the 'beyond 2 degrees scenario'. Regional differences in prices are accounted for.	IEA (2021a) IEA (2021d) IEA (2020b) IEA (2017a)
Buildings: Retrofits and Energy-Efficient Appliances	**Downscaling by technology:** Investment is computed by subtracting heating investment from the total energy investment in buildings. **Regional downscaling:** Spending in retrofits is allocated based on the projected volumes of emissions from buildings in the Sustainable Development Scenario. Spending in energy-efficient appliances is allocated to each region based on the projected energy demand for appliances in the 'beyond 2 degrees scenario'.	IEA (2021a) IEA (2021d) IEA (2020f) IEA (2020b) IEA (2017a)

SECTOR	DOWNSCALING AND PROJECTION METHODOLOGY	MAIN SOURCES
Industry: CCUS	**Downscaling by technology:** Investment in CCUS in industry is directly provided by the IEA NZE report. **Sub-sector downscaling:** Investment is allocated to the Steel, Chemicals and Cement sub-sectors based on the addition of CCUS-equipped production capacity in each sub-sector and on unit capex estimates. **Regional downscaling:** Investment is allocated across world regions and countries based on their historical share of output production.	IEA (2021a) IEA (2017b) Cembureau (2020a)
Industry: Innovative Production Routes	**Downscaling by technology and sub-sector downscaling:** Investment in innovative production routes is computed based on capacity addition and unit capex estimates. **Regional downscaling:** Investment is allocated across world regions and countries based on their historical share of output production.	IEA (2021a) IEA (2017b) Cembureau (2020a) Worldsteel (2020a)
Industry: Conventional Bioenergy	**Downscaling by technology:** Investment is computed based on the total investment in renewables in end-use sectors. It is allocated to the buildings and industry sectors based on historical investment levels and on the projected growth in renewable energy demand in each sector. **Sub-sector downscaling:** Investment is allocated to the Steel, Chemicals and Cement sub-sectors based on their respective projected increase in energy demand from renewables. **Regional downscaling:** Investment is allocated across world regions and countries based on their historical share of output production.	IEA (2021a) IEA (2021d) IEA (2017b) Cembureau (2020a) Worldsteel (2020a) IEA (2020g) IEA (2020h)
Industry: Electrification and Energy Efficiency	**Downscaling by technology:** Aggregate investment in electrification and energy efficiency is found by subtracting the investment in CCUS, hydrogen, renewables and other innovative renewables from the total energy investment in industry. This amount is divided between electrification and energy efficiency based on the projected investments in the 2020s. **Sub-sector downscaling:** Investment in electrification is allocated to the Steel, Chemicals and Cement sub-sectors based on their projected increase in energy demand from electricity. Investment in energy-efficiency investment is allocated based on the projected energy savings over 2020-50. **Regional downscaling:** Investment is allocated across world regions and countries based on their historical share of output production.	IEA (2021a) IEA (2021d) IEA (2017b) IEA (2021c) Cembureau (2020a) Worldsteel (2020a) IEA (2020h)

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Low Emission Fuels: Hydrogen	**Downscaling by technology:** Investment in hydrogen is disaggregated in investment in blue, green and gey hydrogen based on projected capacity addition per production route and unit capex. **Regional downscaling:** Performed based on the current demand for fossil fuels and real GDP projections	IEA (2021a) IEA (2020b) IEA (2019)
Low Emission Fuels: Biofuels	**Downscaling by technology:** Investment in biofuels is disaggregated in investment in different types of biofuels based on projected capacity addition per production route and unit capex. **Regional downscaling:** For liquid biofuels, investments are allocated based as of their production shares in 2024. For gaseous biofuels, investments are allocated based on their production potential for biogas and biomethane.	IEA (2021a) IEA (2020i) IEA (2020j) IEA (2020b) IEA (2020k)
Direct Carbon Capture	**Downscaling by technology:** Investment indirect carbon capture is directly provided by IEA **Regional downscaling:** Allocated based on the projected captured emission in the Sustainable Development Scenario	IEA (2020l)
AFOLU: Diet	**Regional downscaling:** performed using FAO 2018 country-level data on crop production. **Forward projection:** investments are projected forward from 2030 values using BCG projections on alternative protein market growth.	FOLU (2019) FAO BCG
AFOLU: Nature restoration	**Downscaling by technology:** forest and peatland restoration investments are separated out using the investment ratios from UNEP State of Financing for Nature. **Regional downscaling:** performed using FAO 2018 country-level data on forest land use and mangrove land cover. Peatland investments are downscaled using Wetlands International data. **Forward projection:** investments are projected forward using NGFS variables for forest cover, and historic data from FAO and Wetlands International on mangrove and peatland land cover.	FOLU (2019) FAO NGFS Wetlands International (2009) UNEP (2021)
AFOLU: Agriculture	**Regional downscaling:** performed using FAO 2018 country-level data on agricultural land cover. For urban farming, urban land cover data is used. **Forward projection:** investments are projected forward using NGFS variables for non-energy cropland cover. Crop yields variables are used for projecting productivity gap investments.	FOLU (2019) FAO NGFS

AFOLU: Food waste	**Regional downscaling:** performed using FAO 2018 country-level data on: food losses from storage and transportation (for supply chain waste); agricultural land cover in developing countries only (for postharvest waste); and food consumption in advanced economies only (for demand management). **Forward projection:** investments are projected forward using NGFS variables on crops and livestock production (for supply chain waste); agricultural land cover (for postharvest waste); and food demand (for demand management).	**FOLU (2019)** **FAO** **NGFS**

Source: Vivid Economics; IEA (2021a). “Net Zero by 2050: A Roadmap for the Global Energy Sector”; IEA (2021b) “Global EV Data Explorer”; IEA (2020a) “Energy Technology Perspectives 2020”; IEA (2020b) “World Energy Outlook 2020”; IRENA (2020a) “Mobilising Institutional Capital for Renewable Energy”; IEA (2021c) “World Energy Investment 2021”; IEA (2018) “World Energy Outlook 2018”; BP (2020) “Statistical Review of World Energy 2020”; IEA (2021d) “World Energy Outlook 2021; IEA (2020c) “The Role of Critical Minerals in Clean Energy Transitions: World Energy Outlook Special Report”; OECD (2017) “ITF Transport Outlook 2017”; IEA (2020d) “Announced Capital Costs per Unit of New EV and Energy Storage Battery Manufacturing Capacity, 2010-2019”; IEA (2020e) Commissioned EV and Energy Storage Lithium-Ion Battery Cell Production Capacity by Region, and Associated Annual Investment, 2010-2022”; Bennet and Munera (2017) “Who Wants to Be in Charge?”; Fraser et al (2021) “Study on Future Demand and Supply Security of Nickel for Electric Vehicle Batteries”; Credit Suisse. 2017. “Global Mining 2020 Capex”; UNCTAD (2020) “2020 E-Handbook of Statistics: Merchant Fleet”; Hansson et al (2019) “Alternative Marine Fuels: Prospects Based on Multi-Criteria Decision Analysis Involving Swedish Stakeholders”; DNV (2017) “Energy Transition Outlook 2017: Maritime Forecast to 2050”; IEA (2017a) “Energy Technology Perspectives 2017”; Mckinsey (2020) “Hydrogen Powered Aviation: A Fact-Based Study of Hydrogen Technology, Economics, and Climate Impact by 2050”; Airbus (2019) “Global Market Forecast: 2019-2038”; IEA (2017b) “World Energy Balances”; Cembureau (2020a) “2020 Activity Report”; Worldsteel (2020a) “Steel Statistical Yearbook 2020”; IEA (2020f) “Sustainable Recovery: World Energy Outlook Special Report”; IEA (2020g) “Sustainable Recovery: World Energy Outlook Special Report”; IEA (2020h) World Energy Investment 2020; IEA (2019) “The Future of Hydrogen”; IEA (2020i) “Production Potential for Biogas or Biomethane by Feedstock Source”; IEA (2020j) Global Biofuel Production in 2019 and Forecast to 2025”; IEA (2020k) “Advanced Biofuels – Potential for Cost Reduction”; IEA (2020l) “CCUS in Clean Energy Transitions”; ”FOLU. 2019. “Growing Better: Ten Critical Transitions to Transform Food and Land Use”onal Capital for Renewable Energy”; IEA (2021c) “World Energy Investment 2021”; IEA (2018) “World Energy Outlook 2018”; BP (2020) “Statistical Review of World Energy 2020”; IEA (2021d) “World Energy Outlook 2021; IEA (2020c) “The Role of Critical Minerals in Clean Energy Transitions: World Energy Outlook Special Report”; OECD (2017) “ITF Transport Outlook 2017”; IEA (2020d) “Announced Capital Costs per Unit of New EV and Energy Storage Battery Manufacturing Capacity, 2010-2019”; IEA (2020e) Commissioned EV and Energy Storage Lithium-Ion Battery Cell Production Capacity by Region, and Associated Annual Investment, 2010-2022”; Bennet and Munera (2017) “Who Wants to Be in Charge?”; Fraser et al (2021) “Study on Future Demand and Supply Security of Nickel for Electric Vehicle Batteries”; Credit Suisse. 2017. “Global Mining 2020 Capex”; UNCTAD (2020) “2020 E-Handbook of Statistics: Merchant Fleet”; Hansson et al (2019) “Alternative Marine Fuels: Prospects Based on Multi-Criteria Decision Analysis Involving Swedish Stakeholders”; DNV (2017) “Energy Transition Outlook 2017: Maritime Forecast to 2050”; IEA (2017a) “Energy Technology Perspectives 2017”; Mckinsey (2020) “Hydrogen Powered Aviation: A Fact-Based Study of Hydrogen Technology, Economics, and Climate Impact by 2050”; Airbus (2019) “Global Market Forecast: 2019-2038”; IEA (2017b) “World Energy Balances”; Cembureau (2020a) “2020 Activity Report”; Worldsteel (2020a) “Steel Statistical Yearbook 2020”; IEA (2020f) “Sustainable Recovery: World Energy Outlook Special Report”; IEA (2020g) “Sustainable Recovery: World Energy Outlook Special Report”; IEA (2020h) World Energy Investment 2020; IEA (2019) “The Future of Hydrogen”; IEA (2020i) “Production Potential for Biogas or Biomethane by Feedstock Source”; IEA (2020j) Global Biofuel Production in 2019 and Forecast to 2025”; IEA (2020k) “Advanced Biofuels – Potential for Cost Reduction”; IEA (2020l) “CCUS in Clean Energy Transitions”; ”FOLU. 2019. “Growing Better: Ten Critical Transitions to Transform Food and Land Use”Vivid Economics; IEA (2021a). “Net Zero by 2050: A Roadmap for the Global Energy Sector”; IEA (2021b) “Global EV Data Explorer”; IEA (2020a) “Energy Technology Perspectives 2020”; IEA (2020b) “World Energy Outlook 2020”; IRENA (2020a) “Mobilising Instituti

6.2 Net Zero Investment Trajectories

This section sets out the methodology to calculate net zero investment benchmarks in Section 5.2.

There are two main types of net zero benchmarks discussed in the report:

- **Sector-specific green revenues and dirty revenues benchmarks,** which measure green or dirty revenues over total revenues in each sector in the IEA Net zero Scenario.
- **Sector-specific green capex and dirty capex benchmarks,** which measure green or dirty revenues over total revenues in each sector in the IEA Net zero Scenario.

Table 16 and Table 17 present the dirty capex and revenues benchmarks for road mobility, electricity generation and fuel supply.

Table 16 - Dirty revenues intensity (dirty revenues/ total revenues) benchmark in a Paris aligned trajectory

SECTOR	GICS	REGION	2020	2025	2030	2035	2040	2045	2050
Road mobility	251020*	North America	3%	37%	65%	74%	80%	90%	100%
		Central & South America	3%	40%	60%	77%	86%	93%	100%
		Europe	13%	43%	68%	75%	80%	90%	100%
		Africa	3%	40%	60%	77%	86%	93%	100%
		Middle East	3%	40%	60%	77%	86%	93%	100%
		Eurasia	3%	40%	60%	77%	86%	93%	100%
		Asia Pacific	22%	46%	63%	77%	86%	92%	100%

Source: Vivid Economics

Table 17 - Dirty capex intensity (dirty capex/ total capex) benchmark in a Paris aligned trajectory

SECTOR	GICS	REGION	2020	2025	2030	2035	2040	2045	2050
Electricity generation	551010, 551030,* 551050	North America	20%	4%	3%	2%	2%	3%	3%
		Central & South America	20%	3%	2%	1%	2%	2%	2%
		Europe	14%	6%	4%	3%	3%	4%	5%
		Africa	51%	8%	6%	4%	4%	5%	6%
		Middle East	63%	7%	5%	3%	3%	4%	5%
		Eurasia	65%	7%	5%	3%	4%	5%	6%
		Asia Pacific	26%	4%	3%	2%	3%	4%	5%
Fuel supply	101020, 10102050**	North America	99%	76%	70%	63%	59%	54%	46%
		Central & South America	98%	53%	46%	37%	34%	28%	21%
		Europe	92%	52%	44%	36%	33%	30%	25%
		Africa	100%	90%	82%	70%	67%	63%	57%
		Middle East	100%	97%	94%	90%	88%	86%	83%
		Eurasia	100%	97%	95%	91%	90%	88%	86%
		Asia Pacific	98%	68%	54%	42%	40%	38%	36%

Source: Vivid Economics

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Table 18 sets out the activities classified as 'green' or 'dirty', and the methodology followed to compute revenue- and capex-based metrics. As the IEA does not include all value chain activities, it is necessary to understand the specific activities within each sector that are included in our net zero benchmark. Investors seeking to compare their portfolio's performance relative to this benchmark could apply the same classification approach for comparability.

Table 18 - Net zero benchmarks: classification of activities, methods, data sources

SECTOR	BENCHMARK TYPE	GREEN ACTIVITIES	DIRTY ACTIVITIES	METHOD USED	MAIN DATA SOURCES
Electricity generation	Green capex intensity	Investment in power generation from renewable energy sources: Solar PV, Wind, Hydro, Bioenergy w/ BECCS,CSP, Geothermal, Hydrogen-based, Coal w/ CCUS, Natural Gas w/CCUS; investment in electricity transmission, distribution and storage.	Investment in power generation from coal w/o CCUS, natural Gas w/o CCUS, oil.	Green, Dirty and Total capex computed based on the electricity sector investment trajectories, presented in Section [XX].	IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector" IEA. 2021. "World Energy Outlook 2021" IEA. 2020. "Projected Costs of Generating Electricity 2020" IEA. 2020. "World Energy Outlook 2020"
Fuel supply	Green capex intensity	Investment in low-emission fuels. Including hydrogen(blue hydrogen with CCUS) green hydrogen, hydrogen from biomass), liquid biofuels (advanced ethanol with and w/o CCUS, conventional ethanol with CCUS, advanced biodiesel and biokerosene w or w/o CCUS), and gaseous biofuels (Biogas, Biomethane w or w/o CCUS).	Investment in fossil fuels (oil and natural gas)	Green, Dirty and Total capex computed based on the electricity sector investment trajectories, presented in Section [XX].	IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector" IEA. 2019. "The Future of Hydrogen" IRENA. 2016. "Innovation Outlook: Advanced Liquid Biofuels" Statistica. 2021. "Returns of S&P 500 Index in the United States from 2010 to 2020, by Sector"
Road Mobility	Green revenues intensity	Sale of green vehicles: BEVs, PHEVs, and FCVEs. Vehicle categories include: light duty, heavy duty and 2/3 wheelers.	Sale of internal combustion engine vehicles. Vehicle categories include: light duty, heavy duty and 2/3 wheelers.	Green revenues and dirty revenues by combining the vehicle sales estimates underlying the investment trajectories model, the EV penetration estimates provided by IEA, and projected unit vehicle prices from IEA or from internal Vivid Economics model.	IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector" IEA. 2021. "Global EV Data Explorer".

Source: Vivid Economics

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6.3 Overview of Climate Solutions metrics

6.3.1 How Climate Solution Metrics Differ

Investors can rely on metrics that originate from top-down systems change scenarios and taxonomies, or on metrics that result from an assessment of the extent to which an individual asset contributes to achieving net zero. The metrics that investors use at present can be grouped in these two categories:

Taxonomy based metrics: which measure the proportion of a company's activities that can be classified as a climate solution using a taxonomy of 1.5 degrees consistent investments. The taxonomy can be applied to different measures of business activity. Examples include:

Sales – a green revenues metric;

Costs – a green operating costs metric;

Investments – a green capital expenditure metric;

Research and development – a green R&D investment or patents metric.

Emissions abated metrics: which measure the marginal impact of a company's activities on achieving net zero, including its direct emissions, emissions from purchase of electricity, heat and steam, its supply chain emissions and emissions from the products or services the company sells. These metrics are classified as 'emissions abated metrics' - See section 3.2.4. They are broader than past definitions of abatement because they also consider 'avoided emissions' in the economy from products and services sold.

6.3.2 Criteria for Assessing Climate Solution Metrics

To determine the potential added value of current and future metrics, the study assesses them against seven criteria. Any request for a new metric ought to consider the extent to which a metric is meeting its intended aim, therefore justifying additional reporting efforts. The study looks at seven criteria to assess each metrics' performance, which builds upon the criteria used by the Portfolio Alignment Team:[153]

Additional: delivers an additive effect in terms of directing financing to meet climate goals, in a way that is not achievable through current portfolio alignment metrics alone.

Easy to understand: is simple to understand and communicate.

Science based: is built upon the latest peer-reviewed science and is logically and analytically sound.

Incentive-optimal: directs investment to assets that either deliver, will deliver, or enable the delivery of climate solutions in proportion to their overall contribution to net zero. Equally does not create unintended negative consequences if widely applied. For example, metrics could recognize differences between sectors and regions in classifying a 'climate solution'.

Decision-useful: can be implemented in the near term to guide investor decisions.

Aggregable: provides individual company-level scores that can be seamlessly aggregated upwards into a portfolio-level answer.

Measurable: is based on data that is measurable, even if data is not available today.

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6.3.3 Assessment of Climate Solution Metrics

No one metric is a silver bullet to track and improve financing of net zero activities. Table 19 shows our assessment of these metrics against each of the criteria, setting out the unique challenges and solutions for each metric. Note that the assessment of each metric's value-add and challenges reflects a world where data is disclosed, and scenarios are fit for purpose. As discussed below, this is not a given, and currently impedes application of all metrics to some extent.

Metrics that measure alignment with a taxonomy of mitigation activities provide a partial guide for where to invest but they fail to show the relative impact of an asset or portfolio on achieving net zero. Where taxonomy-based metrics are underpinned by credible and granular 1.5 degrees pathways or otherwise aligned with net zero goals, they provide a useful measure of investment in climate mitigation.[154,155] However, if used alone, these measures may offer a partial assessment of the degree to which an investment or portfolio contributes to net zero, due to three reasons:

- Whether an asset is classified as a mitigation activity does not give full indication to the scale of emissions reductions achieved by an asset or the associated investment.
- No scenario or green taxonomy is likely to capture the full universe of mitigation activities.
- A pre-defined taxonomy is likely to always lag behind the latest technological developments. A current example of this is that existing taxonomies exclude the manufacture of parts used in carbon capture equipment.

Emissions abated metrics, in contrast, capture the relative contribution of an investment towards decarbonization goals, and may not be limited by pre-defined categorizations of climate mitigation activities. Emissions abatement metrics aim to overcome some of the gaps resulting from system-wide metrics by:

- showing the degree to which, an asset is contributing to necessary emissions reductions;
- capturing the contribution of multiple supply chain actors enabling emissions reductions, which is difficult to capture fully by any top-down system-wide perspective;
- capturing innovative mitigation activities, which a mitigation taxonomy may not capture.

Table 19 - An overview of existing climate solutions metrics

ARCHETYPE	TYPE OF METRIC	VALUE-ADD	CHALLENGE	NEXT STEPS
System-wide metric	Green revenues	Directs investment to assets already delivering climate solutions.	Does not track the relative impact of investments on net zero, as 'green' activities need only meet a minimum net zero aligned threshold despite resulting in different contributions to net zero.	Use alongside a metric to assess the relative impact of different assets (e.g. exposure to high impact net zero financing needs).
	Green operating costs	Directs investment to assets already delivering climate solutions.		
	Green capital expenditure	Directs investment to assets which will deliver climate solutions in future.		
	Green patents	Directs investment to assets delivering innovative climate solutions in future.	Patents can be a misleading proxy of climate mitigation activities due to large biases in patenting between regions, sectors and companies.	Apply with caution.
Investment level metrics	Abated emissions	Directs investment to assets helping to reduce emissions, differentiating impact between climate solutions.	Some assets 'avoid emissions' relative to BAU but are not necessarily 1.5C aligned.	Measure the avoided emissions of an asset relative to the avoided emissions required in a 1.5 degrees pathway to ensure investment flows to net zero aligned assets.

Note: System-wide metrics assume that the measurement of what is 'green' is aligned with a specific 1.5 degrees pathway or to a net zero goal, and is set out in a sustainable taxonomy (e.g. the EU taxonomy).
Source: Vivid Economics

However, emissions abatement calculations can lead to investments inconsistent with a 1.5 degrees world when taken in isolation and are hindered by a lack of methodology standardisation. A first challenge to emissions abatement metrics is that an asset may reduce emissions relative to business-as-usual while not necessarily contributing to net zero consistent investment. For instance, an investment in a gas turbine can lead to high avoided emissions in a coal-powered country but disincentivise low-carbon power finance in the next decade. A second challenge relates to the lack of a best-practice method for calculating avoided emissions, sometimes also known as Scope 4 emissions (see Box 2), which inhibits credible reporting and comparison of the metric. There is no standardised approach, for instance, on how to determine a consistent baseline trajectory against which to calculate avoidance or how to attribute avoided emissions between multiple actors (see Section 4.2.4).

6.3.4 Discussion of Emission Abatement Metrics

The definition of emissions abated used in this report includes both the emissions reduced in a company or other asset's own activities and the emissions avoided in the economy due to the company's sale of goods or services. Greenhouse gas reporting requirements to date only mandate reporting of emissions produced from a company's own activities or supply chain (scope 1, 2 and 3 emissions). The definition of emissions abated used in this report also includes 'avoided emissions', to fully capture the impact that companies are having on achieving net zero. These 'avoided emissions' capture when a company's sale of a good or service enables an activity to be performed in the wider economy with less GHG emissions than under a business-as-usual scenario. For instance, a company's sale of solar home systems avoids emissions due to a consumer's reduced consumption of emissions-intensive electricity sources (e.g. diesel generators).

To report total emissions abated at a portfolio level requires methods to avoid double counting, however. If all companies were to report their scope 1 - 4 emissions abated, estimates would far exceed real-world emissions reductions. For example, a taxi fleet that switches to zero-emissions and a company that switches to using a low-carbon taxi company for business travel could both report abated emissions (scope 1 and 3 respectively) for the same real-world impact. Similarly, an ice cream manufacturer which switches to plant-based dairy substitutes and the manufacturer of plant-based dairy substitutes could both report abated emissions (scope 3 and 4 respectively). A lack of industry wide guidance on how to attribute emissions reduction across these actors hinders the accuracy and comparability of any portfolio emissions abated calculation today.

Inclusion of scope 4 emissions also requires more robust and well-evidenced methods for estimating ex-post emissions reductions. The gold standard for identifying the marginal contribution of products or services sold would be a comparative trial with two identical economies, one acting as a treatment economy in which a company introduces a low-emissions product or service. By comparing the emissions in the 'treatment economy' with the control (or baseline) economy, it would be possible to robustly estimate scope 4 emissions. This method, however, is impossible to apply in practice. Scope 4 emissions can therefore only be measured in approximation. Minimum requirements for an approximation to be reliable include use of real-world evidence and independent verification.[156] In the case of a manufacturer of plant-based dairy substitutes, for example, evidence needs to show a) how much of its sales replace dairy products, b) the emissions of each product substitute, c) the % of sales which reflect growth in the consumer market for dairy-substitutes, which ought to be excluded. These are only some of the considerations that make scope 4 calculations complex and difficult to compare.

Until current methodological issues are fully resolved, investors can separately report on scope 4 abatement. Despite the benefit of reporting a total 'emissions abatement' metric, this is only possible after resolving the methodological challenges of double counting and scope 4 calculations.

Table 20 - Emissions abatement scope and examples

SCOPE	DESCRIPTION OF EMISSIONS AVOIDED	EXAMPLES OF ACTIVITIES THAT AVOID EMISSIONS
1	Direct GHG emissions from sources owned or controlled by a company	– A steel manufacturer that switches to electric arc furnaces, powered by low-carbon electricity – A taxi company that switches to an electric vehicle fleet
2	GHG emissions from the generation of purchased electricity, heat or steam	– A steel manufacturer that purchases low-carbon electricity to use in its production process – A plastics manufacturer that recycles heat and steam
3	GHG emissions that occur in the value chain of the reporting company (including upstream and downstream emissions) 1 but which do not occur from sources owned or controlled by a company. There are 15 categories of scope 3 emissions.	– An ice-cream manufacturer that uses plant-based dairy substitutes (reduces upstream emissions) – A car company that converts its production units to electric vehicles (reduces downstream emissions)
4	Emissions avoided though the goods or services a company sells	– A wind turbine manufacturer that reduces the carbon intensity of electricity generation relative to the average intensity of the grid.

Note: Upstream emissions are indirect GHG emissions related to purchased or acquired goods and services. Downstream emissions are indirect GHG emissions related to sold goods and services, downstream leased assets, franchises, investments.

Source: Vivid Economics; GHG Protocol. A Corporate Accounting and Reporting Standard; GHG Protocol. Corporate Value Chain (Scope 3) Accounting and Reporting Standard

6.4
Priority Technologies

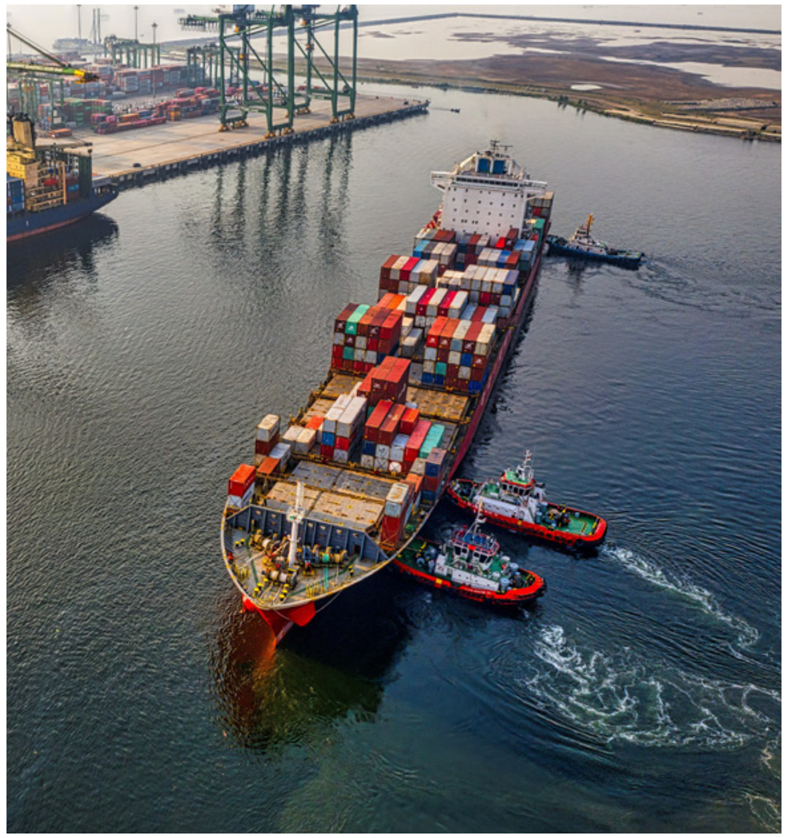
Table 21 and Table 22 set out the archetypes discussed in Chapter 4; within each archetype, these technologies are prioritised into three tiers.

This prioritisation is based on technologies' reduction potential, and the size of the gap between historic investments and investment needs in the 2020s and 2030s.

All technologies considered in this report will be required to some extent, and many may be considered 'critical' within their particular region or sector. Consequently, tiers could be seen as an indication of the scale of contribution that a technology has the potential to make, rather than an indication that some technologies are unimportant or could be deprioritised.

Table 21 - Deploy at Scale Archetype

TIER	SECTOR	SUB-SECTOR	TECHNOLOGY/FUEL
1	Electricity	Electricity Generation	Wind
	Electricity	Electricity Generation	Solar PV
	Electricity	Electricity Networks	New Lines
	Electricity	Electricity Networks	Replacement and Digitalisation
	Electricity	Electricity Generation	Nuclear
	Electricity	Electricity Generation	Hydro
	Transport	EV Batteries	EV Batteries
	Electricity	Electricity Generation	CSP
	Electricity	Electricity Storage	Grid-Scale Storage
	Electricity	Electricity Generation	Bioenergy w/ BECCS
	Industry	Non-heavy Industry	Non-heavy Industry
	AFOLU	Agriculture	Productivity gap
	AFOLU	Diet	Dairy substitutes
	Electricity	Electricity Storage	Behind-the-Meter Storage
2	Transport	Mineral Mining for EVs	Nickel
	Low Emission Fuels	Biofuels	Advanced ethanol



TIER	SECTOR	SUB-SECTOR	TECHNOLOGY/FUEL
	Low Emission Fuels	Biofuels	Conventional ethanol with CCUS
	Transport	Mineral Mining for EVs	Copper
	Low Emission Fuels	Hydrogen	From Electricity
	Transport	Heavy Duty Vehicles	Efficiency Expenditure
	Transport	Heavy Duty Vehicles	Battery electric
	Electricity	Electricity Generation	Geothermal
	Low Emission Fuels	Hydrogen	Infrastructure
	Transport	Mineral Mining for EVs	Lithium
3	Transport	Heavy Duty Vehicles	Plug-in hybrid electric
	Transport	Shipping	Bioenergy
	AFOLU	Food waste	Demand management
	Transport	Shipping	Electricity
	Transport	Shipping	Synthetic fuel

Note: Opportunities in bold are priority investments which are discussed in more detail in Chapter 4.
Source: Vivid Economics

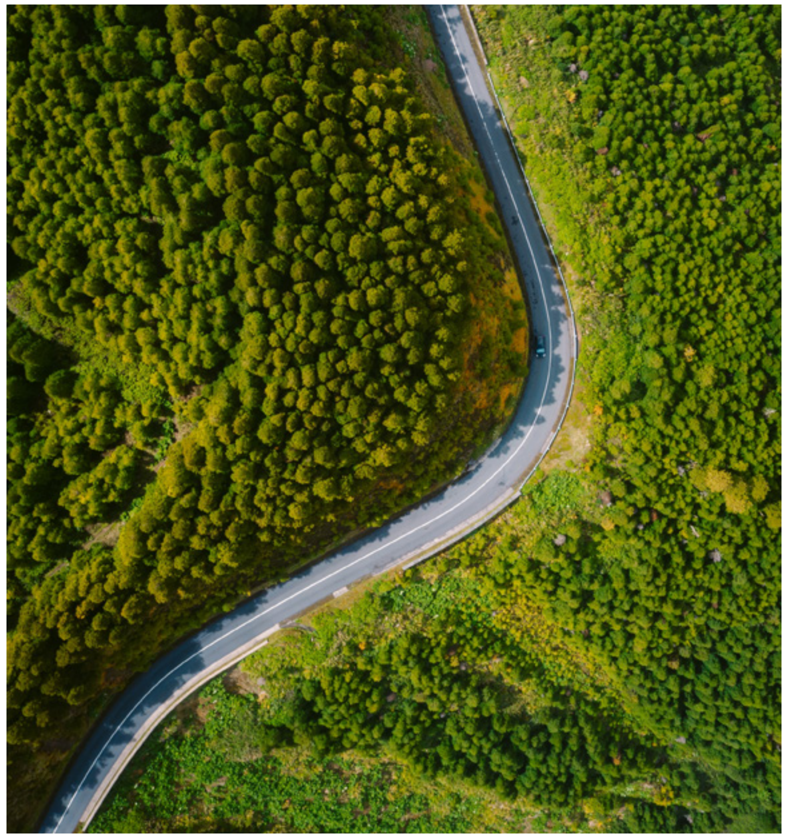


Table 22 - Technology and Market Development Archetype

TIER	SECTOR	SUB-SECTOR	TECHNOLOGY/FUEL
1	Transport	Light Duty Vehicles	Battery electric
	Buildings	Retrofits	Retrofits
	Transport	Road Infrastructure	EV Chargers
	Transport	2/3 Wheelers	Battery electric
	Buildings	Heating	Heat pumps
	Transport	Light Duty Vehicles	Fuel cell electric
	Industry	Steel	Green steel
	Industry	Chemicals	Green chemicals
	Electricity	Electricity Generation	Hydrogen-based
	Buildings	Efficient Appliances	Efficient Appliances
	Industry	Cement	Green cement
	AFOLU	Food waste	Supply chain waste
	AFOLU	Agriculture	Agtech investment
	Transport	Light Duty Vehicles	Efficiency Expenditure
	Buildings	Heating	Solar thermal
	Buildings	Heating	Biomass

TIER	SECTOR	SUB-SECTOR	TECHNOLOGY/FUEL
	AFOLU	Nature restoration	Forest restoration
	Low Emission Fuels	Biofuels	Biomethane
	Low Emission Fuels	Direct Air Capture	Direct Air Capture
	Transport	Shipping	Ammonia
2	Electricity	Electricity Generation	Bioenergy with BECCS
	Transport	Heavy Duty Vehicles	Fuel cell electric
	Transport	Light Duty Vehicles	Plug-in hybrid electric
	Electricity	Electricity Generation	Coal with CCUS
	AFOLU	Nature restoration	Forest management
	Transport	2/3 Wheelers	Efficiency Expenditure
	Low Emission Fuels	Biofuels	Advanced biodiesel and biokerosene with CCUS
	Electricity	Electricity Generation	Natural gas with CCUS
	Low Emission Fuels	Hydrogen	with CCUS
	Transport	Shipping	Hydrogen
	Buildings	Heating	Hydrogen
	Electricity	Electricity Generation	Marine
	Low Emission Fuels	Biofuels	Advanced biodiesel and biokerosene

TIER	SECTOR	SUB-SECTOR	TECHNOLOGY/FUEL
	AFOLU	Food waste	Postharvest waste
	AFOLU	Diet	Meat substitutes
	AFOLU	Agriculture	Biofertilisers
	AFOLU	Agriculture	Urban farming
	AFOLU	Agriculture	Regenerative farming
	Transport	Aviation	Electricity
3	Low Emission Fuels	Biofuels	Biomethane with CCUS
	AFOLU	Nature restoration	Peatland restoration
	AFOLU	Agriculture	Biopesticides
	AFOLU	Agriculture	Precision agriculture machinery
	Low Emission Fuels	Biofuels	Advanced ethanol with CCUS
	Transport	Aviation	Hydrogen
	AFOLU	Nature restoration	Mangrove restoration
	Low Emission Fuels	Hydrogen	From Biomass
	Low Emission Fuels	Biofuels	Biogas

Note: Opportunities in bold are priority investments which are discussed in more detail in Chapter 4.
Source: Vivid Economics

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Footnotes

1 Paris Aligned Investment Initiative. 2021. “Net Zero Investment Framework 1.0 Implementation Guide” https://wwwparisalignedinvestment.org/media/2021/03/PAII-Net-Zero-Investment-Framework_Implementation-Guide.pdf

2 CERES. 2020. “Addressing Climate as a Systemic Risk” https://www.ceres.org/resources/reports/addressing-climate-systemic-risk

3 Climate solutions are required in all sectors either to reduce emissions of existing carbon-intensive activities (e.g. low carbon industrial processes), displace emissions intensive activities with low-carbon alternatives (e.g. supply of low-emissions vehicles), or enable emissions reductions (e.g. utility scale energy storage).

4 The Inevitable Policy Response (IPR)’s 1.5 degrees Required Policy Response (RPS) scenario forecasts that the capital investment needs across power, transport, buildings, industry, and hydrogen production, will amount to $40 trillion additional investment in the 2020s, owing to more decisive action by governments to reduce emissions over the 2020s. The inevitable policy response will be increasingly forceful and abrupt, leaving financial portfolios exposed to significant transition risk, while also increasing the demand for low-carbon technologies.

5 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector.” https://www.iea.org/reports/net-zero-by-2050

6 Food and Land Use Coalition (FOLU). 2019. “Growing Better: Ten Critical Transitions to Transform Food and Land Use” https://www.foodandlandusecoalition.org/global-report/

7 GFANZ. 2021. Race to Zero Financing Roadmaps. https://www.gfanzero.com/netzerofinancing/. Note this assumes a WACC of 4%.

8 See Section 4 for further discussion of the methodology underlying the prioritisation of technologies. See Table 21 and Table 22 in the Annex for a comprehensive classification of technologies.

9 These five technologies are a subset of technologies considered in the priority net zero investment ratio metric in chapter 6.

10 Article 8(1) of the Taxonomy Regulation stipulates that any financial undertaking in the scope of the Non-Financial Reporting Directive (NFRD) is required to report the extent to which its activities are associated with economic activities that qualify as environmentally sustainable under the Taxonomy Regulation as od 1 January 2024. The NFRD applies to listed and large public interest companies with more than 500 employees, which have either a) a balance sheet of more than EUR 20 million or b) a net turnover of more than EUR 40 million. European based banks, insurance companies and asset managers that meet these criteria are in scope. The regulation also mandates corporates in the scope of the NFRD report on their revenues, capex and opex aligned with the EU’s Sustainable Taxonomy as of January 2023.

11 This includes 29 technologies which are classified within the ‘deploy at scale’ archetype in the report (see Section 4.2). Deploy at scale technologies are commercially mature technologies in sectors where no substantial technology or market barriers have been identified.

12 There is work advancing in this area, with the IPR’s 1.5oC Required Policy Scenario (RPS) using detailed country-level policy forecasts to inform energy and land use pathways to 2050.

13 The IFRS recently suggested a consolidated set of climate metrics for all sectors and geographies to include capital deployment and share of business activities aligned with climate-related opportunities.

14 Based upon Vivid Economics’ investment trajectories model, using IEA data.

15 The Thinking Ahead Institute. 2020. “The World’s Largest 500 Asset Managers | Joint Study with Pensions & Investments | October 2020”.

16 This is due both to the increasing frequency and severity of climate-related events (including flooding and droughts) and to the increasing stringency of climate policies (such as carbon pricing).

17 Ceres. 2020. “Addressing Climate as a Systemic Risk”.

18 Universal owners are typically defined as investors with diversified investments across asset classes, sectors and geographies with long time horizons – a definition that applies to all large institutional investors with diversified portfolios. The universal owner hypothesis is based on the evidence that there are clear links between the performance of diversified investment portfolios and the economy overall. As a result, a universal owner investing in a company which creates environmental externalities may face a reduction in overall returns if these externalities affect other investments in their portfolio. UNEPFI. 2011. “Why Environmental Externalities Matter to Universal Owners”.

19 TCFD. 2021. “Measuring Portfolio Alignment: Technical Supplement”. https://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Portfolio_Alignment_Technical_Supplement.pdf

20 For instance, a technology service company and a low-carbon utility may have similar asset-level emissions, despite different impacts on economy-wide emissions reductions. This is because a technology service company is in a low-carbon-emissions sector, whereas a low-carbon utility is in an emissions-intensive sector and may ‘displace’ a carbon-intensive utility. As a result, investing in a technology service company may have a relatively neutral impact on carbon emissions, whereas investing in a low-carbon utility leads to emissions reduction.

21 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector”. Annex A. https://www.iea.org/reports/net-zero-by-2050

22 Our World in Data, based on the Global Carbon Project. https://ourworldindata.org/grapher/cumulative-co2-emissions-region?stackMode=absolute

23 UNEP. 2020. “Emissions Gap Report 2020”. https://www.unenvironment.org/interactive/emissions-gap-report/2019/.

24 IPCC. 2018. “Global Warming of 1.5°C”. An IPCC Special Report on the impacts of global warming of 1.5°C above 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. Chapter 2, Table 2.2. https://www.ipcc.ch/sr15/chapter/chapter-2/

25 Taskforce on Climate-Related Financial Disclosures. 2017. “Technical Supplement: The use of scenario analysis in disclosure of climate-related risks and opportunities”. https://www.fsb.org/wp-content/uploads/Technical-Supplement-1.pdf

26 IPCC. 2001. “TAR Climate Change 2001: The Scientific Basis”. Chapter 13. https://www.ipcc.ch/report/ar3/wg1/chapter-13-climate-scenario-development/

27 Taskforce on Climate-Related Financial Disclosures. 2017. “Technical Supplement: The use of scenario analysis in disclosure of climate-related risks and opportunities”. https://www.fsb.org/wp-content/uploads/Technical-Supplement-1.pdf

28 Carbon Tracker Initiative. 2018. “Carbon Budgets Explainer”. https://carbontransfer.wpengine.com/wp-content/uploads/2018/02/Carbon-Budgets_Eplained_02022018.pdf

29 Carbon Brief. 2018. “Explainer: How ‘Shared Socioeconomic Pathways’ explore future climate change”. https://www.carbonbrief.org/explainer-how-shared-socioeconomic-pathways-explore-future-climate-change; Riahi et al. 2017. “The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview”. https://www.sciencedirect.com/science/article/pii/S0959378016300681

30 IPCC. 2018. “Global Warming of 1.5°C”. An IPCC Special Report on the impacts of global warming of 1.5°C above 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. Chapter 2. https://www.ipcc.ch/sr15/chapter/chapter-2/

31 IPCC. 2018. “Global Warming of 1.5°C”. An IPCC Special Report on the impacts of global warming of 1.5°C above 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. Chapter 2, Table 2.2. https://www.ipcc.ch/sr15/chapter/chapter-2/

32 Matthews et al. 2021. “An integrated approach to quantifying uncertainties in the remaining carbon budget”. https://www.nature.com/articles/s43247-020-00064-9

33 IEA. 2021.”Net Zero by 2050: A Roadmap for the Global Energy Sector”. https://www.iea.org/reports/net-zero-by-2050

34 IIGCC. 2021. “Net Zero Investment Framework Implementation guide”. https://cutt.ly/ZbGhJLH

35 This includes the scenarios underpinning the four illustrative emissions pathways (P1, P2, P3 and P4).

36 IIASA. AR5 Scenario Database. https://iiasa.ac.at/web/home/research/researchPrograms/Energy/IPCC_AR5_Database.html

37 IPCC. “Chapter 11: Agriculture, Forestry and Other Land Use”. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter11.pdf

38 For the purpose of comparisons made in this chapter, ‘hydrogen’ excludes hydrogen-based fuels such as ammonia and synfuels.

39 While the previous section discussed total GHG emissions, including non-CO_2 emissions and emissions from AFOLU, the following two sections rely on IEA data and so focus exclusively on energy sector CO_2 emissions.

40 IEA. 2021. ”Net Zero by 2050: A Roadmap for the Global Energy Sector”. Annex A, figure 2.12. https://www.iea.org/reports/net-zero-by-2050

41 Hydrogen final energy demand does not capture the total demand for hydrogen across the economy, as it excludes the use of hydrogen to produce electricity and the use of hydrogen on-site as a feedstock in industry. Including these categories of hydrogen demand leads to a total hydrogen demand of around 58 EJ in 2050 in the IEA NZE, compared to 110 EJ in the IPR RPS.

42 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector”. Chapter 2. https://www.iea.org/reports/net-zero-by-2050

43 Ibid. Chapter 3, Figure 3.21.

44 Ibid. Chapter 3, Figure 3.21.

45 Ibid. Chapter 3, Figure 3.25.

46 IEA. 2020. “Energy Technology Perspectives 2020”. Chapter 4. https://www.iea.org/reports/energy-technology-perspectives-2020

47 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector”. Chapter 3. https://www.iea.org/reports/net-zero-by-2050

48 Total GHG emissions from AFOLU are estimated at 10–12Gt CO_2e in recent years, of which 5–6Gt are CO_2.

49 FOLU. 2019. “Growing Better: Ten Critical Transitions to Transform Food and Land Use”. https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/FOLU-GrowingBetter-GlobalReport.pdf

50 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector”. Figure 3.11. https://www.iea.org/reports/net-zero-by-2050

51 IEA. 2020. “World Energy Outlook 2020”. Annex A. https://www.iea.org/reports/world-energy-outlook-2020

52 IEA. 2020. “World Energy Outlook 2020”. Annex A. https://www.iea.org/reports/world-energy-outlook-2020

53 Section 7.1 presents a detailed taxonomy of the sectors, sub-sectors and technologies considered in the analysis. FOLU data is used as the starting point of the analysis of the AFOLU sector, while IEA data is used as a basis for the analysis of the other six sectors.

54 IEA. 2021. “World Energy Outlook 2021”. Figure 3.4. IEA projections do not include AFOLU sectors. https://www.iea.org/reports/world-energy-outlook-2021

55 IEA. 2021. “World Energy Outlook 2021”, Annex C. https://www.iea.org/reports/world-energy-outlook-2021

56 A detailed explanation of the investment boundaries for each sector and sub-sector considered in the analysis are provided in Table 14 of the Technical Annex.

57 Food and Land Use Coalition (FOLU). 2019. “Growing Better: Ten Critical Transitions to Transform Food and Land Use”. https://www.foodandlandusecoalition.org/global-report/

58 The IPR 1.5 degrees Required Policy Response (RPS) scenario is IPR’s current assessment of future policy developments needed to accelerate emissions reduction and hold global temperature increase to a 1.5 degree outcome. The McKinsey scenario, ‘1.5 Pathway’, models the economic changes required to limit global warming within 1.5˚C in the current century. The NGFS scenario is called ‘Net Zero 2050’ and its underlying model is REMIND-MAgPIE 2.1-4.2. Considering IPCC, the analysis considers 18 scenarios achieving net zero in 2050, presented in the Special Report on 1.5˚C. The IRENA scenario is the ‘1.5˚C Pathway’ scenario discussed in the 2021 report “World Energy Transitions Outlook”.

59 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector”. Chapter 2.6. https://www.iea.org/reports/net-zero-by-2050

60 Ibid.

61 IEA. 2020. ”World Energy Outlook”. Chapter 1.4. https://www.iea.org/reports/world-energy-outlook-2020

62 The IEA’s forecast expenditure on BEVs and FCEVs only includes expenditure on the battery (or fuel cell) in the vehicle. Total investment required in ZEVs is therefore likely to be far higher than IEA estimates, with IPR’s 1.5oC RPS expecting $85 trillion to 2050 in low-carbon road mobility, 65% of investment occurring in light duty vehicles, 25% in heavy-duty vehicles and 5% in two- and three- wheelers.

63 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector”. Chapter 2.6. https://www.iea.org/reports/net-zero-by-2050

64 Ibid. Chapter 2.7.1.

65 Unlike the IEA, IPR’s 1.5oC RPS provides country by country forecasts of when policymakers will phase out ICEs to account for the fact that not all countries will phase out ICES at the same time.

66 McKinsey. 2019. “Making electric vehicles profitable”. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/making-electric-vehicles-profitable

67 IEA. 2021. Net Zero by 2050: A Roadmap for the Global Energy Sector”. Chapter 3.6. https://www.iea.org/reports/net-zero-by-2050

68 Considering the automotive value chain, investment in EV battery production and in mining for minerals used in EVs is estimated to amount to around $6.5 trillion over 2021–50. The IEA does not model investment upstream in the value chain; the investment estimates are based on extraction volumes from the 2020 IEA report ‘The Role of Critical Minerals in Clean Energy Transitions’ and on unit capex estimates from Credit Suisse and Roskill.

69 IEA. 2020. “Energy Technology Perspectives”. Chapter 5. https://www.iea.org/reports/energy-technology-perspectives-2020

70 IEA. 2021. “Net Zero by 2050: A Roadmap for the Global Energy Sector”. Chapter 3.7. https://www.iea.org/reports/net-zero-by-2050

71 Ibid.

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72 Retrofitting involves a variety of measures such as installing highly insulating windows and improving air sealing.

73 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". Chapter 3.7. https://www.iea.org/reports/net-zero-by-2050

74 Ibid. Chapter 3.7 and Annex C.

75 IEA. 2021. "World Energy Investments". Methodology Annex, p. 11. https://www.iea.org/reports/world-energy-investment-2021

76 IEA. 2020. "Energy Technology Perspectives". Chapter 4. https://www.iea.org/reports/energy-technology-perspectives-2020

77 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". Chapter 3.5. https://www.iea.org/reports/net-zero-by-2050

78 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". Chapter 3.2. https://www.iea.org/reports/net-zero-by-2050

79 IEA. 2020. "Energy Technology Perspectives". https://www.iea.org/reports/ccus-in-clean-energy-transitions/a-new-era-for-ccus

80 Ibid.

81 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". Chapter 2.7.1. https://www.iea.org/reports/net-zero-by-2050

82 IEA. 2021. "Transport Biofuels". https://www.iea.org/reports/transport-biofuels

83 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". Chapter 2.6. https://www.ietasa.org/reports/net zero-by-2050

84 These are the same regions considered in the IEA World Energy Outlook reports. More detailed and granular results are provided in the companion dataset to this report, as well as investment projections for five selected economies: China, India, the EU, USA, Japan and Brazil.

85 IEA (2020), "World Energy Outlook". Chapter 7.4. https://www.iea.org/reports/world-energy-outlook-2020

86 IEA (2021), "Financing Clean Energy Transitions in Emerging and Developing Economies". Chapter 3.4. https://www.iea.org/reports/financing-clean-energy-transitions-in-emerging-and-developing-economies

87 IEA (2020), "Energy Technology Perspectives". Chapter 3. https://www.iea.org/reports/energy-technology-perspectives-2020

88 IEA (2020), "World Energy Outlook". Chapter 3.4. https://www.iea.org/reports/world-energy-outlook-2020

89 IEA (2021), "Financing Clean Energy Transitions in Emerging and Developing Economies", Chapter 3.2. https://www.iea.org/reports/financing-clean-energy-transitions-in-emerging-and-developing-economies

90 IEA (2020), "Energy Technology Perspectives". Chapter 3. https://www.iea.org/reports/energy-technology-perspectives-2020

91 Ibid.

92 Ibid.

93 IEA. 2020. "World Energy Outlook". Annex A. https://www.iea.org/reports/world-energy-outlook-2020

94 IEA. 2021. "Financing Clean Energy Transitions in Emerging and Developing Economies". Chapter 3.2. https://www.iea.org/reports/financing-clean-energy-transitions-in-emerging-and-developing-economies

95 Ibid. Box 2.4.

96 Ibid. Chapter 4.2.

97 Ibid. Chapter 1.2.

98 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". Chapter 4.2. https://www.iea.org/reports/net-zero-by-2050

99 Ibid. Chapter 3.2.

100 Ibid. Chapter 4.2.

101 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". Chapter 2.6. https://www.iea.org/reports/net-zero-by-2050

102 IEA. 2021. "Financing Clean Energy Transitions in Emerging and Developing Economies". Chapter 2.2. https://www.iea.org/reports/financing-clean-energy-transitions-in-emerging-and-developing-economies

103 IIGCC. 2021. "Net Zero Investment Framework Implementation Guide." https://cutt.ly/ZbGhJLH.

104 IRENA. 2020a. "Mobilising Institutional Capital for Renewable Energy." https://www.irena.org/publications/2020/Nov/Mobilising-institutional-capital-for-renewable-energy

105 For 'Deploy at Scale', the gap between current investment and investment needs in the 2020s is used for prioritisation. For 'Technology and Market Development', the gap between current investment and investment needs in the 2030s is used.

106 Emissions abatement potential is measured using an abatement proxy. This is constructed by mapping data on current emissions by sector onto our technologies taxonomy, and calculating each technology's contribution towards its subsector's emissions using the technology's share of subsector investments. A high emissions abatement proxy score can indicate large sectoral emissions, the technology making up a large share of investments within a sector, or some combination of the two.

107 IEA. 2020. "Energy Technology Perspectives 2020." https://www.iea.org/reports/energy-technology-perspectives-2020.

108 ODI, Clean Energy Project Preparation Facilities (2018). https://cdn.odi.org/media/documents/12504.pdf; Climate Finance Lab, https://www.climatefinancelab.org/project/renewable-energy-scale-facility-resf/

109 IIGCC, and Climate Action 100+. 2021. "Global Sector Strategies: Investor Interventions to Accelerate Net Zero Steel." https://www.iigcc.org/download/global-sector-strategy-steel/?wpdmdl=4810&refresh=6155277e9e2c01632970622.

110 IIGCC. 2021. "Net Zero Investment Framework Implementation Guide". https://cutt.ly/ZbGhJLH.

111 EU Technical Expert Group on Sustainable Finance. 2020. "Taxonomy: Final Report of the Technical Expert Group on Sustainable Finance. European Commission - European Commission". https://ec.europa.eu/info/files/200309-sustainable-finance-teg-final-report-taxonomy_en

112 ASAP. 2021. "Adaptation Solutions Taxonomy". https://climateasap.org/the-asap-taxonomy/

113 IIGCC. 2021. "Net Zero Investment Framework Implementation Guide". https://cutt.ly/ZbGhJLH.

114 OECD. 2021. "Value Added by Activity". https://data.oecd.org/natincome/value-added-by-activity.htm

115 UNSTATS. 2021. "Value Added by Economic Activity". https://unstats.un.org/unsd/snaama/limited

116 IEA. 2020. "World Energy Outlook 2020". https://www.iea.org/reports/world-energy-outlook-2020

117 Energy-intensive sectors covered in the IEA NZE scenario include: electricity generation, road mobility, buildings, industry (specifically steel, cement, chemicals), fuel supply and energy infrastructure (grid energy storage, transmissions and distribution infrastructure, EV charging infrastructure, hydrogen infrastructure).

118 Though it is, in theory, possible to compute the revenues associated with capital-intensive transition, any resulting benchmark would include additional assumptions (e.g. prices of green and dirty technologies) which can reduce the benchmark's alignment with a net zero scenario.

119 For instance, revenues associated with EVs reflect revenues from the vehicle sale, but exclude revenues created through the sale of parts or maintenance services.

120 A further limitation, specific to the IEA scenarios, is the very narrow sectoral boundary considered by the IEA when computing investment needs in the end-use sectors (transport, buildings, industry). In these sectors, the IEA often considers only spending directly associated with 'energy use': for instance, for EVs only the value of the battery is considered, rather than the full value of the vehicle. Energy-efficiency spending is computed as the additional spending needed to acquire energy-efficient equipment rather than 'baseline' equipment. This approach allows the IEA to assess clearly the volume of energy investment needed for the net zero transition. However, using these investment estimates as a basis for revenue or capex targets would require managers to acquire extremely granular information about the revenue and investment activity of all their assets.

121 OECD. 2017. "ITF Transport Outlook 2017". https://www.oecd.org/regional/itf-transport-outlook-25202367.htm

122 IEA. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector". https://www.iea.org/reports/net-zero-by-2050

123 IEA. 2021. "World Energy Outlook 2021". https://www.iea.org/reports/world-energy-outlook-2021

124 European Commission. 2021. "Frequently Asked Questions: What Is the EU Taxonomy Article 8 Delegated Act and How Will It Work in Practice?". https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/sustainable-finance-taxonomy-faq_en.pdf

125 A science-based taxonomy would be built on the latest peer-reviewed and credible Paris-aligned net zero pathways.

126 European Banking Authority. 2021. "Advice to the commission on KPIs and methodology for disclosure by credit institutions and investment funds under the NFRD on how and to what extend their activities qualify as environmentally sustainable according to the EU Taxonomy regulation" https://www.eba.europa.eu/sites/default/documents/files/document_library/About%20Us/Missions%20and%20tasks/Call%20for%20Advice/2021/CfA%20on%20KPIs%20and%20methodology%20for%20disclosures%20under%20Article%208%20of%20the%20Taxonomy%20Regulation/963616/Report%20-%20Advice%20to%20COM_Disclosure%20Article%208%20Taxonomy.pdf

127 For instance, sales volumes or market shares within a technology can be used to approximate revenues in each of the considered priority technologies.

128 European Banking Authority. 2021. "Advice to the commission on KPIs and methodology for disclosure by credit institutions and investment funds under the NFRD on how and to what extend their activities qualify as environmentally sustainable according to the EU Taxonomy regulation"

129 The FTSE Green Revenues index estimated that only 30% of publicly listed companies with green revenues provide sufficiently granular data to break down green business activities.

130 FTSE Russell. 2020. "Sizing the Green Economy: Green Revenues and the EU Taxonomy". https://content.ftserussell.com/sites/default/files/sizing_the_green_economy_green_revenues_and_the_eu_taxonomy_final_2.pdf?_ga=2.40875682.1474506896.1600759636-956076349.1598743739.

131 Material sectors are defined in the Net Zero Investment Framework as those in NACE code categories A–H and J–L. Translations of NACE to BICS and GICS are also provided.

132 This value reflects both public and private investment needs. It is calculated based on the gap between spending on low-carbon power generation in 2016–20 relative to spending required in 2021–30, based on the investment trajectories discussed in Section 3. Low-carbon power generation includes solar PV, CSP, wind, hydro, bioenergy, geothermal, marine, nuclear, hydrogen-based, coal with CCUS, natural gas with CCUS.

138 IIGCC. 2021. "Net Zero Investment Framework Implementation Guide". https://cutt.ly/ZbGhJLH.

139 Mission Innovation. 2020. "The Avoided Emissions Framework". https://misolutionframework.net/pdf/Net zero_Innovation_Module_2-The_Avoided_Emissions_Framework_(AEF)-v2.pdf

140 WBCSD and WRI. 2012. "The GHG Protocol. A Corporate Accounting and Reporting Standard". Greenhouse Gas Protocol. https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

141 Russell, Stephen. 2019. "Estimating and Reporting the Comparative Emissions Impacts of Products". World Resources Institute Working Paper, no. January: 26. https://ghgprotocol.org/sites/default/files/standards/18_WP_Comparative-Emissions_final.pdf.

142 Avoided scope 4 emissions are sometimes captured in a company's scope 3 reporting, such as when a company replaces existing product lines with net zero-emitting products.

143 Solution effects include all life-cycle emissions of a climate solution, including emissions associated with the production, use and end of life, e.g. emissions resulting from manufacture and end-of-life recycling of energy-efficient air conditioners; enabling effects include all emissions avoided from a climate solution, e.g. reduced emissions from the improved efficiency of the air conditioning unit; rebound effects include the emissions resulting from increased usage of a solution, e.g. if the efficient air conditioner leads to greater use, and therefore increases emissions.

144 Mission Innovation. 2020. "The Avoided Emissions Framework". https://misolutionframework.net/pdf/Net zero_Innovation_Module_2-The_Avoided_Emissions_Framework_(AEF)-v2.pdf

145 Value add captures the additional value a company adds to its goods and services, which can be measured as the difference between the price to the consumer of a good or service and the cost of producing that good or service.

146 PCAF. 2020. "The Global GHG Accounting & Reporting Standard for the Financial Industry." https://carbonaccountingfinancials.com/standard

147 European Commission. 2021. "Frequently Asked Questions: What Is the EU Taxonomy Article 8 Delegated Act and How Will It Work in Practice?". https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/sustainable-finance-taxonomy-faq_en.pdf

148 Criteria for the EU's other environmental objectives are still under development.

149 Article 8(1) of the Taxonomy Regulation stipulates that any financial undertaking in the scope of the NFRD is required to report the extent to which its activities are associated with economic activities that qualify as environmentally sustainable under the Taxonomy Regulation. The NFRD applies to listed and large public interest companies with more than 500 employees, which have either a) a balance sheet of more than EUR 20 million or b) a net turnover of more than EUR 40 million. EU-based banks, insurance companies and asset managers that meet these criteria are in scope.

150 European Commission. 2021. "Frequently Asked Questions: What Is the EU Taxonomy Article 8 Delegated Act and How Will It Work in Practice?". https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/sustainable-finance-taxonomy-faq_en.pdf

151 European Commission. 2021. "Frequently Asked Questions: What Is the EU Taxonomy Article 8 Delegated Act and How Will It Work in Practice?". https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/sustainable-finance-taxonomy-faq_en.pdf

152 FOLU. 2019. "Growing Better: Ten Critical Transitions to Transform Food and Land Use." https://www.foodandlandusecoalition.org/wp-content/uploads/2019/09/FOLU-GrowingBetter-GlobalReport.pdf.

153 TCFD. 2021. "Measuring Portfolio Alignment: Technical Supplement". Criteria used by the Portfolio Alignment Team intend to show whether an alignment metric is decision-useful include: simplicity of use, transparency, actionability, scientific robustness, broad applicability, aggregability, and incentive optimality. The study include a subset of this most applicable to climate solutions metrics, and includes 'additionality' as part of the criteria.

154 For example, the performance level of the EU taxonomy "is designed to be consistent with a net zero by 2050 goal".

155 EU Technical Expert Group on Sustainable Finance. 2020. "Taxonomy: Final Report of the Technical Expert Group on Sustainable Finance. European Commission - European Commission." https://ec.europa.eu/info/files/200309-sustainable-finance-teg-final-report-taxonomy_en

156 For discussion of additional considerations and guidance on how to answer methodological questions, see Mission Innovation. 2020. "Avoided Emissions Framework"

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About IIGCC

The Institutional Investors Group on Climate Change (IIGCC) is the European membership body for investor collaboration on climate change and the voice of investors taking action for a prosperous, low carbon future. IIGCC has more than 375 members, mainly pension funds and asset managers, across 23 countries, with over €51 trillion in assets under management.

IIGCC's mission is to support and enable the investment community in driving significant and real progress by 2030 towards a net zero and resilient future. This will be achieved through capital allocation decisions, stewardship and successful engagement with companies, policy makers and fellow investors. IIGCC works to support and help define the public policies, investment practices and corporate behaviours that address the long-term risks and opportunities associated with climate change.

IIGCC
The Institutional Investors Group on Climate Change

Contact us

Media Enquires
media@iigcc.org

Recruitment Enquires
vacancy@iigcc.org

General Enquiries
info@iigcc.org

Institutional Investors Group on Climate Change (IIGCC)

@IIGCCnews

Find us

IIGCC
Pennine Place
2a Charing Cross Road
London,
WC2H 0HF

Designed by Jory&Co.