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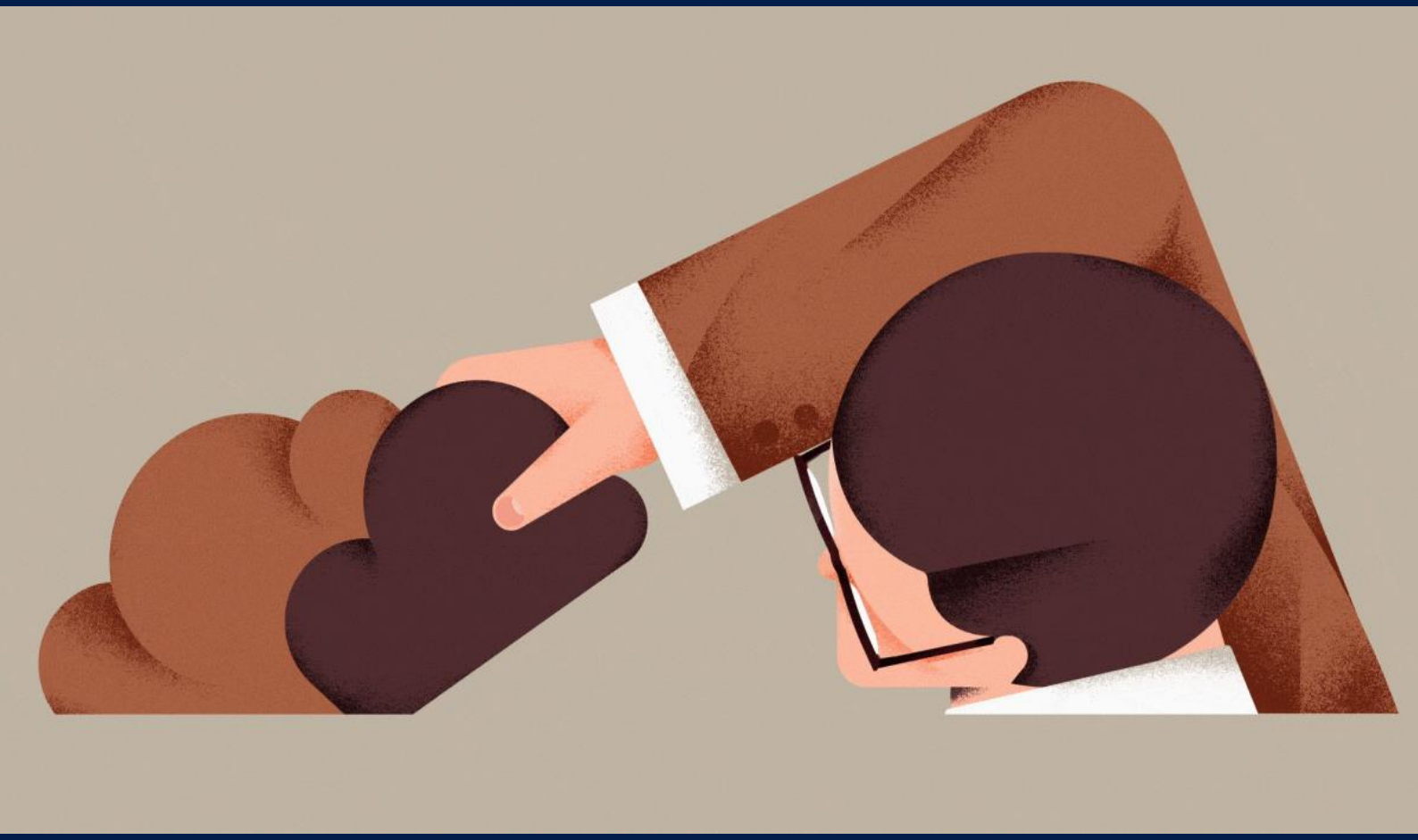

Beyond Financing Gaps: Sizing the Decarbonisation Investment Opportunity

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Executive summary

- A large amount of investment is required to accelerate the low-carbon transition – estimated at US$126 trillion[1] from now until mid-century to meet the International Energy Agency (IEA)'s net-zero scenario.
- To size the resulting investment potential, GIC has evaluated the decarbonisation opportunity based on total addressable market (TAM)[2] for mitigation technologies, revenue growth, and technological maturity. The study zooms in on revenue and value rather than financing gaps, which have been the focus of the industry so far.
- Existing research that assesses revenue opportunities typically covers only climate solution providers, such as renewable energy companies or electric vehicle (EV) manufacturers, thereby missing the huge potential presented by capital goods providers, as well as raw materials and low-emission fuel producers. GIC's methodology instead accounts for the whole value chain and hence produces a more comprehensive view of opportunities.
- Using a high-dimensional dataset and statistical techniques, we estimate the total incremental investment value[3] of the climate solutions supply chain in 2030 to range between US$5-11 trillion, between the IEA's Stated Policies (STEPS) Scenario[4] and Net Zero Emissions by 2050 (NZE) Scenario.[5]
- In the NZE Scenario, electricity networks, sustainable vehicles, electric vehicle (EV) charging infrastructure, solar, wind, lithium, hydrogen, and building heating are among the solutions with the greatest incremental enterprise value. Except for hydrogen and EV charging infrastructure, these are mature solutions that represent investible opportunities today.

[1] Based on GIC analysis of Vivid Economics estimates, using data from the IEA, the Food and Land Use Coalition (FOLU), the Food and Agriculture Organization of the United Nations (FAO) and the Network of Central Banks and Supervisors for Greening the Financial System (NGFS). Sourced from the Institutional Investors Group on Climate Change (IIGCC) (2022). *Climate Investment Roadmap*; excludes fossil fuel investments.
[2] The overall available revenue opportunity for a particular product or service.
[3] Represented by firm enterprise value.
[4] IEA (2023). *Stated Policies Scenario (STEPS)*.
[5] IEA (2023). *Net Zero Emissions by 2050 Scenario (NZE)*.

- The fastest growing among larger opportunities include hydrogen, biofuels, lithium, and electricity storage. Biofuels, in particular, offer a currently underappreciated area of growth given their potential to decarbonise a range of sectors, from power generation to aviation.
- Nascent technologies such as direct air capture as well as hydrogen-powered and electric aviation present interesting opportunities for early-stage venture and growth capital, but technology risks and paths to commercialisation must be managed for these solutions to mature and scale.
- The majority of climate solutions are expected to see the fastest growth within this decade, while the Asia-Pacific region represents the largest total addressable market due to rapid economic and emissions growth.
- In our 2030 forecasts, equity and debt account for ~86% and ~14% respectively of the capital structure for the climate solutions value chain. We estimate that within equity, ~83% of value will be in listed equities and the remaining ~17% in private equity, which is significantly higher than the value of private equity compared to listed equity in the broader market.
- Our research offers a holistic view of the decarbonisation opportunity set, across different technologies, time periods, regions, and asset classes, which can then inform investors' portfolio management decisions.

Introduction

To meet the International Energy Agency (IEA)'s Net Zero Emissions by 2050 Scenario (NZE), over US$126 trillion of capital expenditure (capex) investment is needed from now until 2050. Private actors could provide 70% of this financing,[6] which is expected to offer significant opportunities for investors.

However, not all investments have the appropriate risk-return profiles to meet the fiduciary mandates of investors and calls to mobilise private capital have not addressed this challenge. To size the investment opportunity and the subsequent need to scale up capital, GIC has developed a climate scenario-agnostic framework for the incremental investment value expected from decarbonisation revenues. We believe that the market has yet to appreciate the vast value generation potential and industrial growth cycle of capital goods[7] to support the global energy transition.

Emissions are fundamental demand drivers for decarbonisation revenues

To understand the demand drivers for decarbonisation solutions, it is critical to first identify the main sources of global greenhouse gas (GHG) emissions that these solutions aim to mitigate. 73% of GHG emissions result from the production of energy for industry (manufacturing), buildings (electricity and heat), and transport (fuel).[8] An additional 18% of GHG emissions arise from agriculture, forestry, and land use (AFOLU), while 5% are a by-product of industrial processes, and 3% originate from waste.

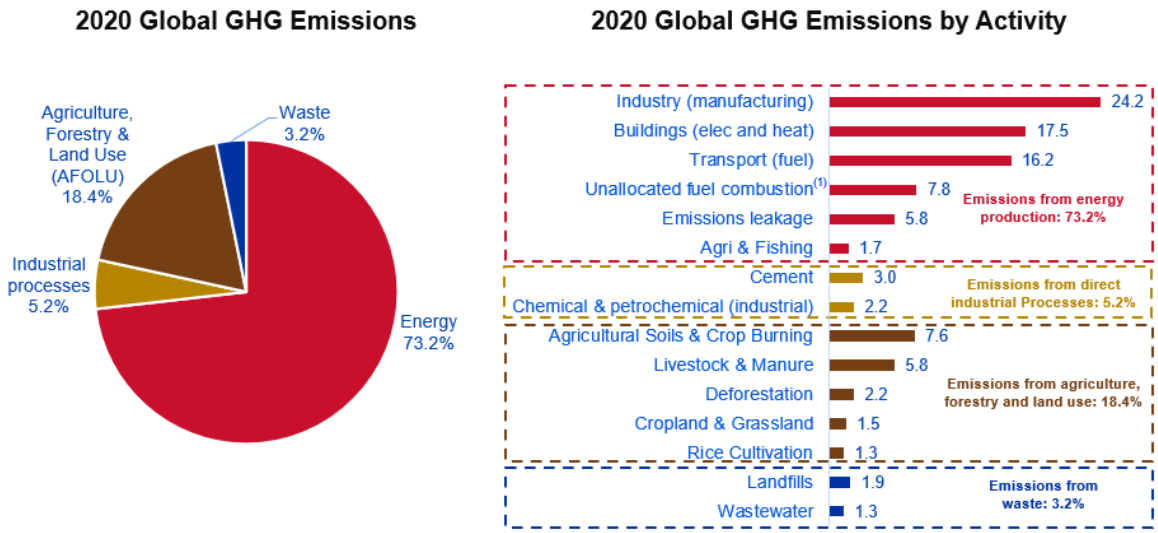
To reduce emissions from the various underlying economic activities, the Institutional Investors Group on Climate Change (IIGCC) defined a taxonomy of over 30 climate mitigation solutions across six major sectors: electricity,

[6] Glasgow Financial Alliance for Net Zero (2023). *Race to Zero Financing Roadmaps*.
[7] Capital goods are any tangible asset used by a business to produce goods or services for consumer goods or for use by other businesses, e.g. machinery, equipment, buildings and facilities.
[8] OurWorldInData.org, Climate Watch, The World Resources Institute, as of 2020.

transport, buildings, industry, low emission fuels, and AFOLU.[9] Our study builds on this analysis to broaden the opportunity set to include raw materials, low-emission fuels, and capital goods providers, and applies a financial valuation lens to frame the opportunity in the language of investors.

Figure 1: Global Greenhouse Gas Emissions Accounting

Decarbonisation and emissions reductions will increase demand for transition and green solutions



Source: GIC Sustainability Office, OurWorldinData.org, Climate Watch, The World Resources Institute (2020), IIGCC.

Note: Emissions from the production of energy from other fuels including electricity and heat from biomass; on-site heat sources; combined heat and power (CHP); nuclear industry; and pumped hydroelectric storage

In 2022, capex investments for climate mitigation solutions were estimated at US$1.7 trillion by the IEA[10] and US$1.1 trillion by BloombergNEF.[11] Capex investments into fixed assets, such as renewable energy or sustainable vehicles, have long been the bedrock of energy systems modelling and economic activity assumptions in climate scenarios.

A high proportion of these investments represents revenues for the value chain, comprising sellers of components, equipment, and raw materials, while decarbonised fuel combustion processes will generate revenues for low-

[9] IIGCC (2022). *Climate Investment Roadmap*.
[10] IEA (2023). *World Energy Investment 2023*.
[11] BloombergNEF (2023). *Energy Transition Investment Trends*.

emission fuels. Incremental revenue growth for these companies has the potential to increase their future value and returns for investors. Through a systematic and data-driven approach, we have developed a signpost for investors to evaluate their portfolio exposure to the energy transition theme and the potential investment opportunity.

Climate solutions supply chain could add US$5-11 trillion in value by 2030

Using historical valuation multiples, forecasted revenues and revenue growth, we estimate that **the total incremental enterprise value of the climate solutions supply chain in 2030 will reach US$5-11 trillion**[12] between the IEA Stated Policies Scenario (STEPS) and the NZE Scenario.

The STEPS Scenario reflects current policy settings based on a sector-by-sector and country-by-country assessment of not only existing policies, but those that are under development by governments globally. Conversely, the NZE Scenario sets out a pathway for the global energy sector to achieve net-zero carbon emissions by 2050. The two scenarios provide bookends for an investment opportunity-sizing exercise, but our approach and framework can be applied to any desired climate scenario.

Taking the upside NZE Scenario, each major mitigation solution is assessed across three dimensions to identify the most relevant investment areas to prioritise for different asset classes or risk-return requirements. These criteria include the technological maturity of the solution based on its IEA Technology Readiness Level score, its revenue compound annual growth rate (CAGR) between 2022 - 2030, and the enterprise value of its supply chain.

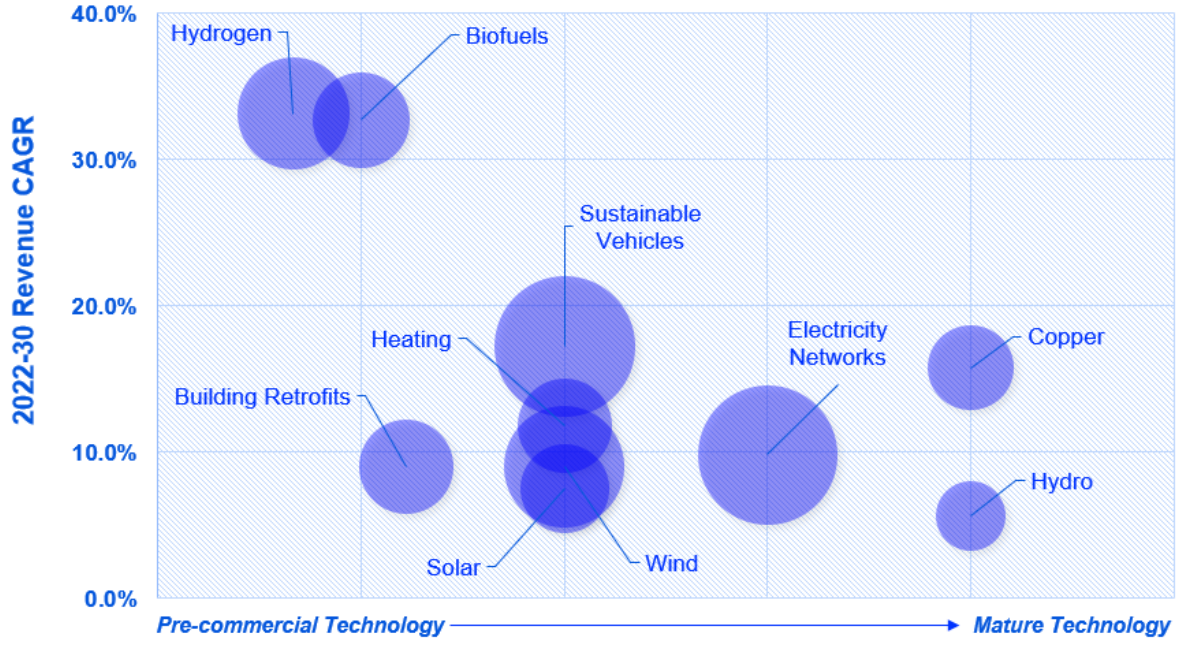
[12] 2022 real figures. Please see the Appendix for an overview of the sizing methodology.

Mature solutions among the most promising opportunities

Under the NZE Scenario, the analysis shows that **the largest opportunities by incremental enterprise value, each constituting over US$400 billion by 2030, include electricity networks, sustainable vehicles, electric vehicle (EV) charging infrastructure, wind, solar, copper, lithium, hydrogen (low-emission fuel and equipment), and building heating solutions**. Except for hydrogen and EV charging infrastructure, products and technologies in the supply chain for these categories are mature and commercialised, thereby representing available and investible opportunities today.

Figure 2: 2030 Decarbonisation Value Chain Revenue Opportunity in the IEA NZE Scenario

Select climate mitigation solutions
Bubble size represents 2030 addressable revenues (indicative representation, not to scale)



Source: GIC Sustainability Office analysis, Vivid Economics, IEA

Since energy production contributes 73%[13] of global GHG emissions, the key driver of the energy transition is clearly the buildout of renewable energy capacity. The last decade has seen a considerable drop in the cost curves for renewables,[14] making them the most economic option in most major markets. The significant levels of investment needed to scale up renewable electricity generation in turn translate into increased spending, particularly on wind and solar components and equipment.

Meanwhile, as renewable power generation increases, so does the need for more resilient energy infrastructure to address intermittency and connectivity issues. Aside from transmission and distribution upgrades in developed markets, population growth and urbanisation in developing economies would also require vast amounts of investments in electricity networks and storage.

Tapping into the EV boom

In addition, regulators and auto manufacturers around the world are setting ambitious targets to phase out internal combustion engine (ICE) vehicles in the coming decades.[15] EV sales rose by 60% globally in 2022, which is significant against a backdrop of a flat global auto market, with an overall annual sales growth of 2%.[16] EVs are projected to comprise close to one-fifth of the entire auto market by the end of 2023, up from only 4% in 2020.[17] This signals both exponential growth in recent years as well as continued investment opportunities, especially as electrification expands from passenger vehicles to electric buses and trucks. With the majority of EV charging currently done at home,[18] building out public charging infrastructure will be likewise key to enabling widespread EV adoption.

Increased electrification in transport and other sectors requires more upstream raw materials, including critical

[13] Our World in Data (2020). *Sector by sector: where do global greenhouse gas emissions come from?*
[14] International Renewable Energy Agency (2023). *Renewable Power Generation Costs in 2022*.
[15] IEA (2023). *Global EV Policy Explorer*.
[16] BloombergNEF (2023). *Electric Vehicle Outlook 2023*.
[17] IEA (2023). *Global EV Outlook 2023*.
[18] IEA (2023). *Trends in charging infrastructure*.

minerals and metals such as copper and lithium. From 2017 to 2022, the market size of major transition minerals (copper, lithium, nickel, cobalt, and graphite) doubled to US$320 billion.[19] However, volatile prices, extraction and refining concentration, as well as geopolitical concerns have led to a range of regulatory developments to ensure security of supply. These policies are disrupting existing mining and refining businesses, while simultaneously creating opportunities for new or previously less competitive suppliers, as well as innovation in materials and recycling solutions.

Can green hydrogen scale?

Hydrogen, one of the only emerging technologies among the most promising opportunities by 2030, has the potential to reduce global carbon emissions by more than 20%, according to McKinsey.[20] When used alongside other solutions, including renewables and biofuels, hydrogen could help decarbonise some of the most hard-to-abate sectors, including steel, petrochemicals, fertilisers, heavy-duty mobility, shipping, and aviation. However, scaling low-emission or green hydrogen – hydrogen that's produced by splitting water into hydrogen and oxygen using renewable electricity – remains challenging due to limited offtake demand, supply chain issues, and high production costs. Almost half of all announced projects are at the early stages of development and only 4% have taken a final investment decision.[21] Greater regulatory support and incentives such as those offered by the Inflation Reduction Act (IRA) in the US will play a vital role in crowding in more capital to scale production, infrastructure, and end-use applications.

[19] IEA (2023). *Critical Minerals Market Review 2023*.
[20] McKinsey Sustainability (2022). *Five charts on hydrogen's role in a net-zero future*.
[21] IEA (2023). *Global Hydrogen Review 2023*.

Earlier-stage technologies to see higher growth due to smaller base

The fastest growing opportunities,[22] with over US$100 billion in projected enterprise value growth by 2030 in the NZE Scenario, include hydrogen (low-emission fuel and equipment), biofuels, lithium, and electricity storage. Our research highlights biofuels as an underappreciated growth theme due to their potential to decarbonise a range of economic activities, including power generation and many hard-to-abate sectors. A noteworthy example is aviation where sustainable aviation fuels are starting to see strong regulatory and end-demand momentum.

Below the US$100 billion enterprise value mark, nascent technologies such as direct air capture, as well as hydrogen-powered and electric aviation represent interesting opportunities for venture and growth capital. These technologies are in the prototyping phase with limited revenue and cash flow generation currently, and require technology risks to decline and paths to commercialisation to be developed in order to mature and scale.

Largest increase in investment values expected this decade

In the NZE Scenario, **most climate solutions experience the fastest growth this decade** and see revenues peaking by the early 2030s. Transport, including sustainable vehicles and charging infrastructure, and industry, comprising solutions such as electrification, energy efficiency and carbon capture, utilisation, and storage (CCUS), offer a longer runway for growth into the 2040s, driven by asset replacement and increased adoption rates over time.

Across all major technologies, **the Asia-Pacific region represents the largest addressable market** due to rapid

[22] >20% revenue CAGR from 2022-2030.

population and economic growth. Such a development trajectory translates into an upward emissions path and a subsequent increase in demand for decarbonisation solutions, assuming a policy environment aligned to net zero. A notable exception is the buildings sector, where a significant stock of existing assets in Europe and North America requires retrofits, heating, and appliance upgrades.

Broadly speaking, the STEPS Scenario sees lower revenue and enterprise value figures by roughly 50-60%, although variations remain depending on the technology and region.

Investment implications and asset class-specific insights

Understanding the decarbonisation investment opportunity in terms of revenues and value, rather than financing gaps, has served multiple purposes for GIC:

- First, as a top-down research tool, it provides a holistic and granular view of the decarbonisation investment opportunity across technologies and value chain segments, time periods, regions, and asset classes.
- Second, it helps our bottom-up investment teams to assess the relative attractiveness of opportunities and compare the results to other market sizing approaches and estimates.
- Third, it provides a backdrop for idea generation and thematic research for our climate alpha investment strategies, particularly in areas less covered by the market.

To inform an asset class-relevant approach, we extended the technology- and region-based analysis to evaluate the historical capital structure of companies and the evolution of listed versus private equity values based on technology readiness levels. We estimate that **by 2030, equity and debt represent ~86% and ~14%** respectively of the capital structure for the climate solutions and value chain segments covered. **Within equity, ~83% of value is estimated to be in listed equities, while the remaining ~17% will be in private equity**, which is significantly higher than the value

of private equity compared to listed equities in the broader market.

FTSE Russell has also sized the green economy with a focus on listed equities and estimated its market capitalisation today to be ~US$6 trillion.[23] Based on GIC calculations, this figure would grow at ~7-11% per annum to reach ~US$10-15 trillion by 2030. Assuming equity markets grow in line with global GDP,[24] **the green economy would represent ~12-17% of global listed market capitalisation in 2030, compared to ~8%[25] today**.

Conclusion

The energy transition is a complex and dynamic process, with numerous technologies, pathways, geopolitical and macroeconomic factors at play. Investor-minded frameworks can help to focus capital where it would be most effective. As with any other investment approach, determining the best opportunities will require more detailed top-down research and bottom-up due diligence to assess the regulatory environment, competitive moats, and the financial profiles of companies, among other factors.

For GIC, the analysis has enabled us to build conviction in there being significant room for institutional investors to grow their exposure across the cone of potential climate outcomes, based on the expected value and returns implications. However, the trajectories and opportunities will differ significantly across underlying technologies, regions, and time periods.

Additionally, investors must remain mindful of the headwinds ahead, including a potential higher-for-longer interest rate environment, supply chain constraints, regulatory challenges, and geopolitical uncertainty. It is therefore more critical than ever for investors to thoughtfully integrate climate risks and opportunities into their portfolio management decisions.

[23] As of 30 June 2023, excluding energy generation. FTSE Russell (2023). *Investing in the green economy 2023*.
[24] Based on GIC internal global GDP forecasts as of 4 December 2023.
[25] FTSE Russell (2023). *Investing in the green economy 2023*.

Appendix: Overview of the investment sizing methodology

In its 2022 Climate Investment Roadmap report, the IIGCC defined a taxonomy of over 30 climate mitigation solutions across six major sectors, with capex investment estimates from now until 2050 in the NZE Scenario.

For each sector, we reviewed the capex components of representative projects to identify revenue opportunities for the relevant supply chain segments. Additionally, we evaluated the key transition metal and mineral inputs required to build these climate solutions and forecasted volumes and prices to determine the total addressable market for miners and refiners. Given the activity-level assumptions, we also forecasted volumes and prices for low-emission fuels to compute the revenue opportunity for hydrogen and biofuels. Using assumptions under the STEPS Scenario, we repeated these steps to derive the total addressable market for each value chain segment.

As the IEA's definition of capex is based on incremental capacity needs for supply-side sectors (power generation, grids, storage, and low-emission fuels) and additional consumer spend for demand-side sectors (industry, buildings, transportation, and others), we focused on incremental revenue opportunities above a baseline activity level or baseline spending.

Based on the list of value chain segments across technologies, we built comparable company baskets of listed companies with over 50% revenue exposure[26] to the value chain product or activity. For each basket, we conducted statistical analysis on historical financials and used the results to estimate future enterprise values and the respective investment opportunity size in debt, listed equities, and unlisted equities.

[26] The threshold was lowered in certain cases due to data availability or quality issues. Solutions that were too nascent to have listed company comparables or that could not be custom built were grouped with the most similar baskets with data.

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