

Aggregation of Climate-Related Risk Exposure in Employer-Sponsored 401(k) Plans

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1. Executive Summary

This report evaluates the climate-related financial risks embedded within the investment options of a large employer-sponsored 401(k) plan. Using Morningstar/Sustainalytics, Bloomberg, PACTA, Reuters, and fund-level financial data, the analysis identifies significant exposure to high-emitting sectors, limited sustainability alignment, and substantial transparency gaps. While the portfolio is diversified, its concentration in carbon-intensive industries exposes plan participants to elevated transition, regulatory, and stranded-asset risks. Importantly, scenario testing shows that reducing these exposures can be achieved without compromising long-term returns.

Across the funds, **exposure to fossil fuels and heavy-emitting sectors remains widespread**. Bloomberg emissions data show that a **majority of financed emissions stem from value-chain (Scope 3) activities**, confirming deep structural ties to high-carbon business models. Several core funds—particularly global and broad-market index offerings—generate extremely high absolute emissions and carbon intensities, far exceeding industry benchmarks.

More than half the plan's assets (nearly 70%) are invested in funds categorized as unattractive for sustainability-focused investors. Only a small number of options exhibit strong ESG characteristics, and one-fifth of the lineup lacks any ESG disclosure. T. Rowe Price, representing over half of all fund offerings, shows consistent underperformance in ESG metrics across most funds. This absence of transparency constrains participants' ability to assess climate-risk exposure and limits fiduciaries' oversight capabilities.

The PACTA sector analysis reveals pronounced **misalignment between the portfolio's sector exposures and Paris-aligned decarbonization trajectories**. Aviation, cement, steel, oil & gas, and internal-combustion automotive production all exceed science-based climate benchmarks. The **portfolio is also underexposed to low-carbon and climate-solution technologies**, reinforcing long-term transition vulnerability.

Ten-year back-testing shows that **removing the top 1%–10% of carbon emitters has a negligible impact on risk-adjusted performance and, in several cases, enhances returns**.

Furthermore, **Index Funds are most affected by removing large parts of the high emitters**, while **Small- and Mid-Cap and Other funds even increase their returns on average**. However, the impacts vary and appear to differ across fund issuers.

These results demonstrate that climate-risk mitigation—through selective divestment or portfolio tilting—is financially viable and compatible with fiduciary obligations.

The analysis confirms a material, unmanaged climate risk burden within the plan's current fund menu.

Key fiduciary implications include:

- High transition risk due to exposure to carbon-intensive companies and sectors.
- Inadequate disclosure of nearly 20% of funds, limiting oversight and informed participant choice.
- Over-reliance on fund families with weak ESG performance, particularly T. Rowe Price.
- Clear evidence that decarbonization strategies can be implemented without sacrificing financial returns.

Hence, plan sponsors should:

1. Require complete sustainability disclosure from all fund providers.
2. Incorporate climate-risk metrics into manager selection and ongoing monitoring.
3. Expand the menu to include credible low-carbon and transition-aligned investment options.
4. Conduct scenario-based climate-risk modelling and periodic stress tests.
5. Develop a standardized climate-risk index for evaluating and comparing 401(k) plan options.

Enhancing transparency, reducing exposure to high-carbon sectors, and providing sustainable alternatives will strengthen fiduciary resilience, protect long-term participant outcomes, and align the plan with emerging best practices in climate-aware retirement governance.

2. Background and Rationale

Climate change introduces material financial risks to investment portfolios through both physical risks and transition risks. 401(k) plans aggregate these risks across millions of participants. Employees depend on employers and plan fiduciaries to ensure investment choices are prudently diversified and resilient to climate-related financial risks. Many 401(k) offerings remain heavily exposed to fossil fuels and carbon-intensive industries, amplifying potential long-term portfolio volatility.

2.1. Literature Review

A growing body of literature addresses how pension funds can assess their exposure to climate risks, with a focus on both regulatory requirements and methodological innovations. The analytical approaches address climate scenario modeling, regulatory compliance strategies, and ESG integration frameworks.

The paper by van Dijk (2020) provides an overview of how Dutch pension funds approach both physical and transition climate risks. It emphasizes the importance of aligning with regulations that mandate integrating climate risk into risk management processes. The study presents various analytical tools, including carbon footprinting, sectoral stress testing, and scenario analysis, that pension funds can use to assess their climate-related risks.

Zain Ul Abedin (2021) adopts a “just transition risk lens” to evaluate how pension funds incorporate socio-economic factors when facing climate transition risks. The study argues for more inclusive scenario modeling that considers both environmental and social impacts, reflecting the multi-dimensional nature of climate risk.

In the UK context, Klumpes et al. (2019) analyze climate risk reporting practices among pension schemes. While not focused on the mechanics of risk assessment itself, their study identifies inconsistencies and gaps in how climate exposures are disclosed. They recommend standardization in reporting frameworks to improve comparability and decision-making. However, standardized climate risk reporting of pension funds cannot be expected yet.

Further, Medeiros et al. (2025) propose a novel methodology for analyzing annual reports from pension funds using sustainability indicators. Their model includes assessing governance practices and investment portfolios to determine sustainability alignment. This method complements climate risk models by embedding ESG performance metrics, including climate-related strategies, into fund evaluation.

Finally, case-specific analyses provide insight into how large-scale institutional investors have adapted their climate change strategies over time, highlighting challenges in implementation and communication, such as standardized assessment and reporting.

In summary, pension funds now use a variety of tools—ranging from scenario-based stress tests to ESG metrics and regulatory compliance audits—to measure and manage climate exposure. However, the field continues to evolve, particularly the need for standardized

disclosures. Hence, standardized climate-related reporting cannot be expected from pension funds or from the funds in which they invest.

2.2. Climate Exposure Analysis of Investment Portfolios

A growing body of empirical and theoretical research examines the relationship between carbon exposure in investment portfolios and portfolio performance, highlighting both risks and opportunities in carbon-conscious investing.

Foundational frameworks, such as the one proposed by Thomas et al. (2007) introduce integrated environmental and financial performance metrics, such as GHG emissions, emission intensity, and ESG ratings, allowing portfolio managers to evaluate the carbon intensity of assets alongside traditional financial indicators. This lens is essential for assessing sustainability-adjusted returns across portfolios with varying fossil fuel and climate risk exposures.

Studies like Zonta et al. (2023) provide strong empirical evidence from U.S. equity markets, demonstrating that portfolios with lower carbon intensity tend to outperform over time, especially under increasing regulatory and societal pressure for decarbonization. These findings reinforce the thesis that low-carbon investment strategies may offer superior risk-adjusted returns.

Further diversification benefits have been demonstrated by Zhang et al. (2017), who analyze carbon market instruments as alternative assets. Their study reveals that including carbon assets can reduce portfolio volatility, as they are only partially decoupled from traditional financial markets.

From a corporate governance angle, Benz et al. (2021) explore how carbon performance at the firm level affects investor engagement strategies. Improved carbon metrics are associated with both reduced short-term risk and enhanced shareholder advocacy potential, highlighting the role of carbon exposure as a proxy for governance and operational resilience.

In the domain of socially responsible investing (SRI), Muñoz (2021) investigates how carbon-intensive sectors are represented in SRI mutual funds. The paper shows that exposure to “black industries” can erode the financial performance of these portfolios unless effectively managed, reinforcing the importance of sectoral screening.

Lastly, studies like Gianfrate (2018) and Fang et al. (2019) provide actionable guidance on designing carbon-neutral portfolios. Their research supports strategic allocation methods that simultaneously target emissions reductions and financial robustness.

Overall, the literature reveals a consistent trend: managing carbon exposure not only supports climate goals but also enhances portfolio performance by improving risk management, enhancing reputation, and aligning with macroeconomic transition pathways.

2.3. Analyzing the Climate Exposure of Pension Funds

Pension funds, as major institutional investors, face increasing scrutiny regarding their exposure to climate-related risks. With shifting investor and stakeholder preferences, and growing empirical evidence, funds must strike a balance between fulfilling fiduciary duties and achieving climate objectives that some see as a part of fiduciary duty (Waitzer & Sarro, 2012). This literature review synthesizes existing studies—including regulatory compliance frameworks, scenario modeling, empirical backtesting, and ESG integration.

2.4. Regulatory Compliance and Risk Management Frameworks

van Dijk (2020) highlights how pension funds integrate both physical and transition risks into risk management processes, emphasizing the EU's IORP II directive as a driver for incorporating climate risks into governance frameworks (e.g., carbon footprinting, scenario analysis). Klumpes et al. (2019) emphasize the need for standardized climate risk disclosures, highlighting inconsistencies that impede comparability across pension schemes. Medeiros et al. (2025) expand on these findings by proposing a five-stage model that evaluates sustainability performance in annual reports, blending ESG indicators with financial assessments. These studies, however, mainly focus on the European context, which is more regulated with regard to sustainable finance. This is not the case in the US.

2.5. Divestment vs. Tilting Strategies

Edmans et al. (2022) critically assess the effectiveness of blanket divestment from high-carbon assets, proposing instead a tilting strategy—holding brown firms that take credible decarbonization actions. This approach balances externality reduction and financial performance, particularly when decarbonization pathways are uncertain. Zonta et al. (2023) empirically demonstrate that divesting from energy stocks between 2013 and 2022 would have improved pension fund returns by an average of 13 percentage points while reducing the carbon footprint by 16.6%, equivalent to the energy use of 35 million homes. Hence, reducing carbon exposure is possible without reduced risk-adjusted returns.

2.6. Portfolio Construction and Net-Zero Alignment

Bolton et al. (2022) propose a carbon budget-based approach for portfolio alignment with net-zero targets. Their methodology involves annual carbon budget allocations, dynamic rebalancing to minimize tracking error, and active engagement incentives for companies to decarbonize. This approach complements traditional carbon footprinting by integrating scenario-based alignment with science-based targets.

2.7. Financial Performance and Carbon Exposure

As mentioned above, carbon exposure is often connected with lower risk-adjusted returns (Hunt & Weber, 2019). However, Pástor et al. (2022) find that green assets may have lower expected returns but serve as hedges against climate risk shocks—suggesting a trade-off that pension funds must consider.

2.8. Conclusion

Analyzing the climate exposure of pension funds requires a multidimensional approach that combines regulatory frameworks, carbon footprinting, empirical backtesting, and ESG indicators.

Overall, pension funds stand at the intersection of financial performance, regulatory compliance, and climate stewardship. The literature supports a shift toward nuanced strategies that integrate climate goals with fiduciary duties, ensuring resilience and sustainability in a rapidly changing investment landscape. However, this approach is applied by all pension funds.

Among the indicators that can be used to assess carbon exposure and to simulate financial returns across different divestment scenarios are total GHG emissions, GHG intensity of investments, ESG ratings, and indirect climate exposure across sectors.

3. Methods

The analysis integrates multiple climate-risk assessment frameworks, portfolio analytics tools, and fund-level financial datasets to evaluate the employer-sponsored 401(k) plan's climate-related exposures. The methodological approach combines (1) third-party ESG and emissions datasets, (2) sector-level climate-alignment modelling, and (3) empirical back-testing of divestment scenarios. Together, these methods enable a comprehensive assessment of both the sustainability characteristics and financial implications of climate-risk mitigation strategies within the plan's investment lineup.

- Analytical Procedure:
 - Calculated fund performance under different exclusion scenarios by sequentially removing the top 10%, 5%, and 1% of the highest CO₂ emitters.
 - Redistributed excluded weights proportionally among remaining holdings to maintain portfolio neutrality.
 - Computed the resulting 10-year HPR (Holding Period Return) and performance deltas for each decarbonization scenario.

3.1. Data Sources and Fund Universe

The analysis covers the equity funds offered within the plan. Data were collected from the following sources:

- Morningstar/Sustainalytics: ESG risk ratings, sustainability labels, issue-level controversies, and fund-level sustainability verdicts.
- Bloomberg Finance L.P.: Fund-level greenhouse gas (GHG) emissions (Scopes 1, 2, and 3), carbon intensities, fossil-fuel revenue exposure, value-chain risk metrics, and sustainability opportunity indicators.
- PACTA (Paris Agreement Capital Transition Assessment): Sector-level production trajectory analysis for climate-relevant industries (e.g., oil & gas, power, automotive, aviation, cement, and steel).
- Reuters Refinitiv Eikon/LSEG Database and Company Reports: Additional fund-level emissions and ESG indicators for triangulation of results.
- Historical Fund Performance Data: Ten-year financial returns for all funds, used to model risk-adjusted return outcomes under different divestment strategies.

3.2. Morningstar/Sustainalytics Evaluation

Each fund was evaluated using:

- ESG Risk Rating
- Overall Morningstar sustainability “ratings”
- Share of holdings flagged for material ESG concerns
- Presence or absence of ESG disclosure

Funds were categorized according to their appeal to sustainability-conscious investors and assessed for consistency with basic climate-risk management expectations.

3.3. Bloomberg Emissions and Revenue-Risk Analysis

Bloomberg data were used to quantify:

- Total financed emissions (Scopes 1–3)
- Emission sources (operational vs. value-chain)
- Carbon-intensity metrics (t CO₂e per USD million revenue)
- Fossil-fuel revenue shares, including coal, oil, gas, and related energy subsectors
- Exposure to sustainability opportunities, such as climate-solution revenue and emissions-reduction initiatives

These metrics enabled comparison across funds and identification of outliers such as highly carbon-intensive index strategies.

3.4. Climate-Alignment Modelling (PACTA)

The PACTA model was applied to evaluate the alignment of each fund’s sectoral exposures with Paris-aligned decarbonization pathways. Sector-by-sector trajectories were compared with 1.5–2°C pathways to determine:

- Degree of positive or negative alignment
- Whether production capacities exceed climate-aligned benchmarks
- Relative positioning versus fund benchmarks

Particular attention was given to high-emitting, hard-to-abate sectors.

3.5. Fund-Level Emissions Analysis

Absolute financed emissions and carbon-intensity values were aggregated across all funds. Comparisons were made by:

- Fund type (index, small/mid-cap, other active)
- Sector exposure
- Geographic and market-cap characteristics

This enabled the identification of structural drivers of emissions (e.g., exposure to global large-cap industrial companies).

3.6. Divestment Scenario Modelling

Six divestment scenarios were constructed, each removing different proportions of the highest-emitting holdings within each fund:

1. Retaining all holdings (baseline)
2. Removing the top 1% highest emitters
3. Removing the top 5% highest emitters
4. Removing the top 10% highest emitters

For each scenario, the following were recalculated:

- Ten-year holding period returns (HPR)
- Relative return (percentage of baseline)

The methodology assumes proportional reallocation of the remaining holdings within each fund, maintaining the original weighting structures after top emitters are removed. This approach isolates the financial significance of the excluded assets without the confounding influence of manager discretion.

Furthermore, results were analyzed by fund type:

- Index funds
- Small- and mid-cap funds
- Other active funds

This classification allowed detection of structural differences across investment styles, such as the heavy dependence of global index funds on high-emitting sectors versus the relatively low exposure of small- and mid-cap growth funds.

3.7. Limitations

The analysis is subject to several limitations:

- Not all funds disclose complete emissions or ESG data. For firms without ESG or CO₂ emissions data, industry-level averages were imputed using AI-based retrieval and aggregation from comparable peer groups.
- Scope 3 emissions estimates are model-based and may vary across data providers.
- Divestment scenario modelling assumes proportional reinvestment rather than active portfolio redesign.

- Some international index funds include holdings from markets with limited ESG reporting.

Despite these constraints, triangulation across multiple datasets and robustness checks ensure that the analysis provides a reliable representation of the plan's climate-risk profile.

4. Results of the Morningstar/Sustainalytics Analysis

The Morningstar/Sustainalytics analysis reveals that the plan's investment options show limited alignment with sustainable investment principles. Over half of the funds are managed by T. Rowe Price, yet only one demonstrates even partial consistency with ESG-oriented expectations. Approximately 70% of total invested assets remain allocated to funds that are considered unattractive to sustainability-conscious investors. Furthermore, almost one-fifth of the funds still lack ESG or emissions disclosures. The absence of consistent disclosure in this portion of the portfolio represents a substantial transparency gap and hinders participants' ability to assess climate-related exposure accurately.

In detail, we found that:

- 53% of the 32 funds (17 in total) are from T. Rowe Price, yet only one of them—T. Rowe Price Growth Stock—has any appeal to sustainability-conscious investors — and even that fund is flagged with issues worth attention.
- A total of \$5.28 billion (or nearly 70% of total assets reviewed) is invested in funds classified as “may not appeal to sustainability-conscious investors”, raising concerns about ESG alignment.
- Only five funds in the entire set demonstrate positive sustainability characteristics, and just one of those is managed by T. Rowe Price—indicating limited sustainable options among the plan's core fund providers.
- AB Global Core Equity, one of the few ESG-aligned options, accounts for just 6.9% of the total invested amount, reflecting significant underexposure to high-quality sustainable investments.
- 6 funds (19%) provide no ESG data or sustainability verdict, which presents transparency risks and complicates decision-making for investors prioritizing climate or social impact.

5. Morningstar/Sustainalytics and Bloomberg Ratings

The following Figure 1 presents the Morningstar/Sustainalytics ratings of the funds. The results suggest that AB Global Core and AMG Times Square have the highest Morningstar ratings. However, six funds have a rating of 2, indicating poor sustainability performance.

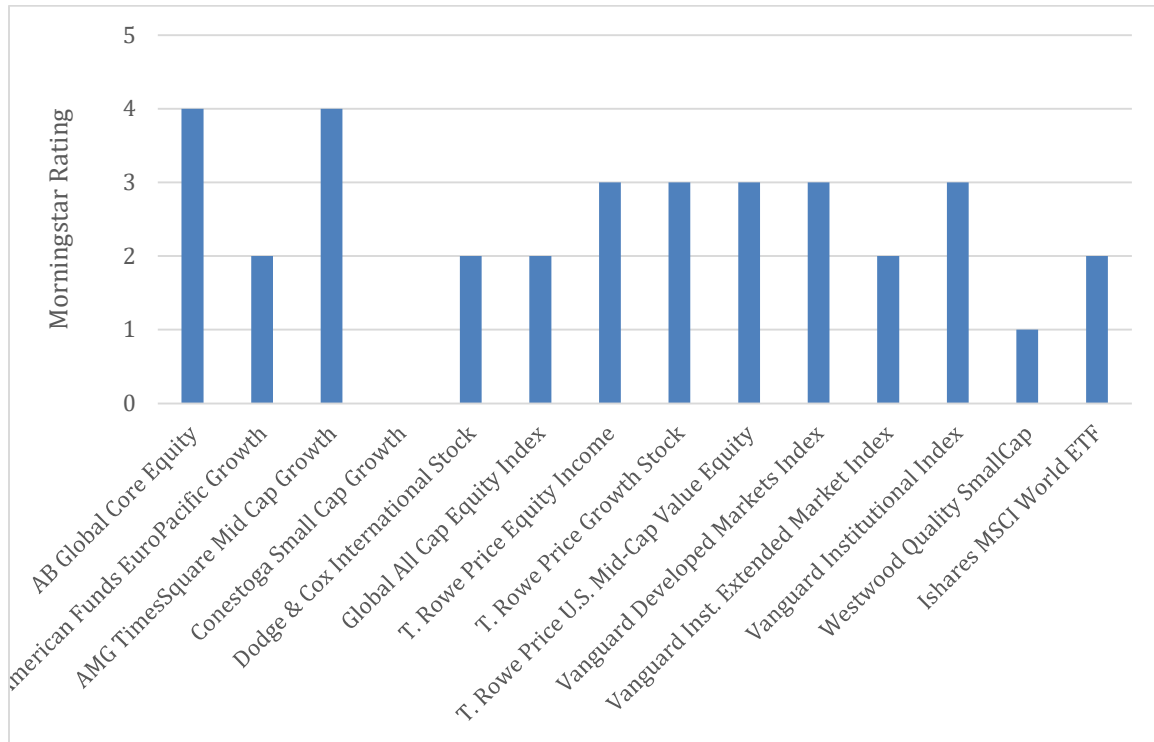


Figure 1: Morningstar/Sustainalytics Ratings

The Bloomberg ratings of the funds are presented in Figure 2



Figure 2: Radar graph for Bloomberg ratings

Across almost all funds, the ESG sub-scores tend to cluster closely, usually between 60 and 90, while the overall Bloomberg ESG score (blue line) sometimes dips lower than the individual components. This reflects that Bloomberg ESG is not a simple average; it is often weighted or adjusted for controversies and sectoral risks, and that funds with a low overall ESG score may have underlying concerns that are not reflected in individual E/S/G sub-metrics.

A few funds show consistently high ratings across all metrics:

- AB Global Core Equity
- American Funds EuroPacific Growth
- Ishares MSCI World ETF

These funds score in the 80–95 range across environmental, social, and governance factors. They seem to be strong performers on sustainability metrics and may have fewer ESG concerns than peers.

Mid-Range Performers are:

- Westwood Quality SmallCap
- Conestoga Small Cap Growth
- Dodge & Cox International Stock
- Global All Cap Equity Index

The scores for these funds typically are between 50 and 70 on most metrics. These funds have mixed ESG performance. They may have solid governance structures but weaker environmental scores, or moderate environmental and social scores but governance concerns.

Several funds consistently show lower Bloomberg ESG scores, particularly:

- T. Rowe Price Growth Stock
- T. Rowe Price U.S. Mid-Cap Value Equity
- Vanguard Developed Markets Index

These funds often appear near the lower ring of the chart, especially for Environmental and Social scores. These funds lag in key ESG factors, especially environmental performance, often due to higher exposure to carbon-intensive sectors, less stringent ESG integration, and holdings with weak governance frameworks or social risk exposure.

The Global All Cap Equity Index appears mid-range (around 60–70). Hence, this index fund's benchmark does not perform strongly on ESG metrics. Consequently, some actively managed funds exceed their benchmarks, while several score below the global index, indicating underperformance from an ESG standpoint. However, as shown below, the Index has a very high exposure to carbon-intensive investments.

To conclude, T. Rowe Price funds frequently underperform across ESG dimensions, highlighting a structural weakness in the current fund lineup. The disparity between total ESG scores and ESG sub-scores suggests hidden risk factors—such as exposure to high-emission sectors or governance controversies. Funds with the highest ratings (e.g., AB Global Core Equity) are more aligned with sustainability-conscious investing. Funds at the lower end pose greater transition risk and are likely to contribute disproportionately to the portfolio's financed emissions.

5.1. Bloomberg Fund Emissions

Figure 3 presents the fund's total emissions, split by direct, indirect, and value-chain emissions, sourced from Bloomberg.

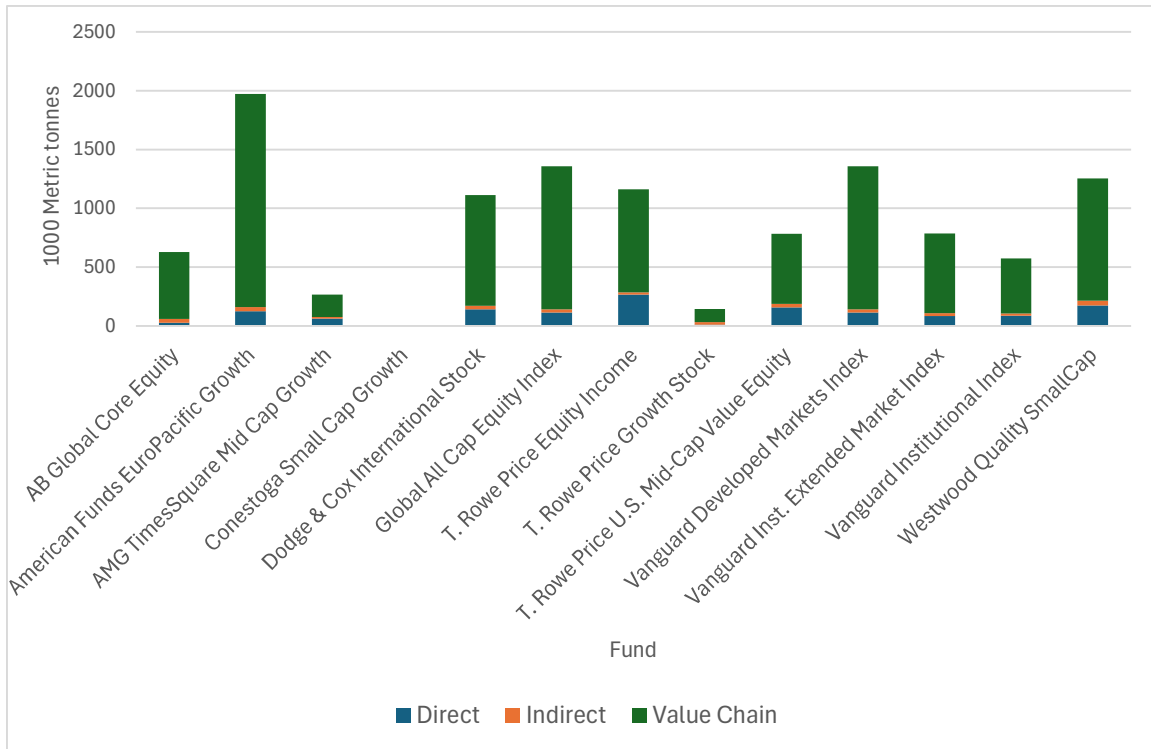


Figure 3: Fund total emissions

Across the funds, Scope 3 value-chain emissions represent the largest source of total financed emissions. Consequently, most financed emissions stem from the underlying companies' full value-chain activities, not their direct operations. This indicates deep structural exposure to carbon-intensive economic systems.

The funds with the highest total emissions are:

- American Funds EuroPacific Growth
- Global All Cap Equity Index
- Vanguard Developed Markets Index
- T. Rowe Price Equity Income
- Westwood Quality SmallCap

These funds are likely to invest heavily in sectors or regions with high carbon intensities, such as heavy industry, power generation, or global diversified equities. This reinforces the above findings that the portfolio is heavily exposed to transition risks and carbon-intensive industries, despite several funds having moderate ESG ratings.

The revenue-risk exposure of the funds, based on the Bloomberg analysis, is presented in Figure 4.

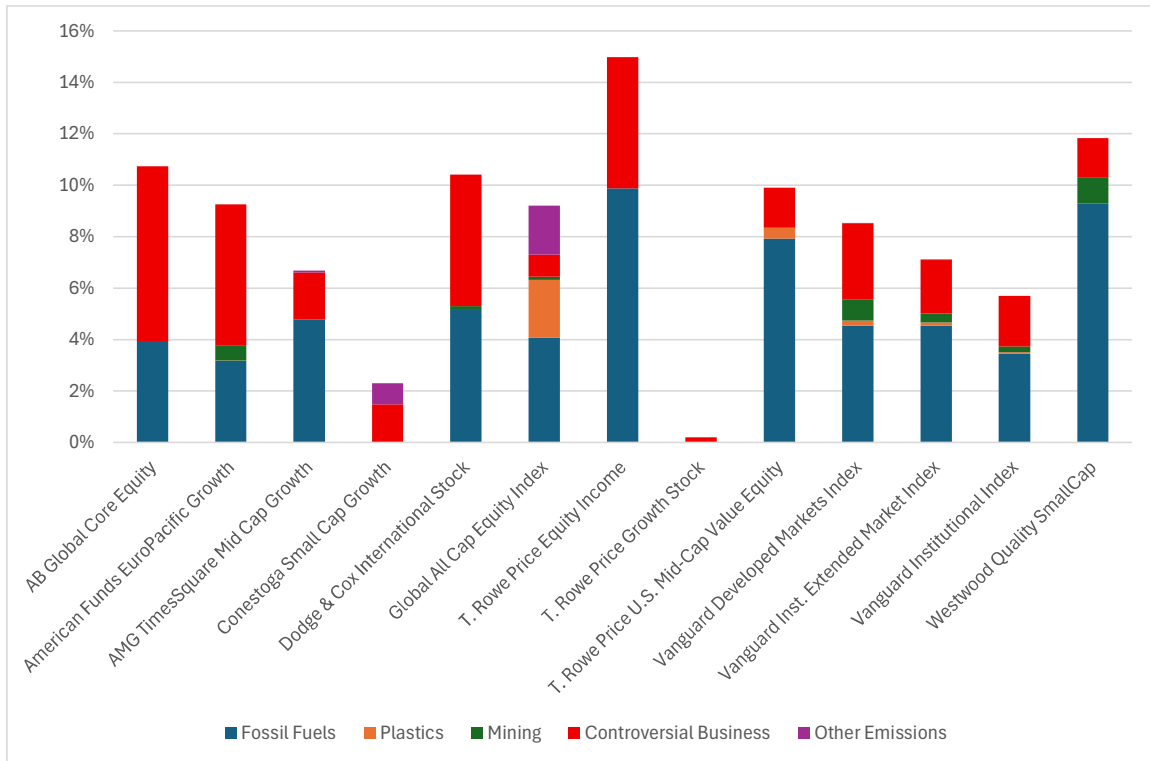


Figure 4: Bloomberg Revenue-Risk Exposure

Figure 4 shows that fossil fuel revenue exposure is the largest component across the funds. Fossil fuel exposure dominates most bars, indicating that many underlying companies in these funds still generate a significant share of income from oil, gas, coal, and related energy sectors. This makes fossil-fuel dependency the primary source of transition risk across the portfolio.

Funds with particularly high fossil-fuel exposure include:

- T. Rowe Price Equity Income
- Global All Cap Equity Index
- Vanguard Institutional Index
- Westwood Quality SmallCap

These funds may face meaningful risks from future carbon pricing, regulation, or declining demand for fossil fuels.

Some funds, such as Global All Caps Equity Index Fund, Global Core Equity and American Funds Euro Pacific Growth are exposed to carbon emissions from non-oil & gas industries, such as the cement industry.

The following analysis focuses on both risks and opportunities of the funds regarding sustainability (see Figure 5).

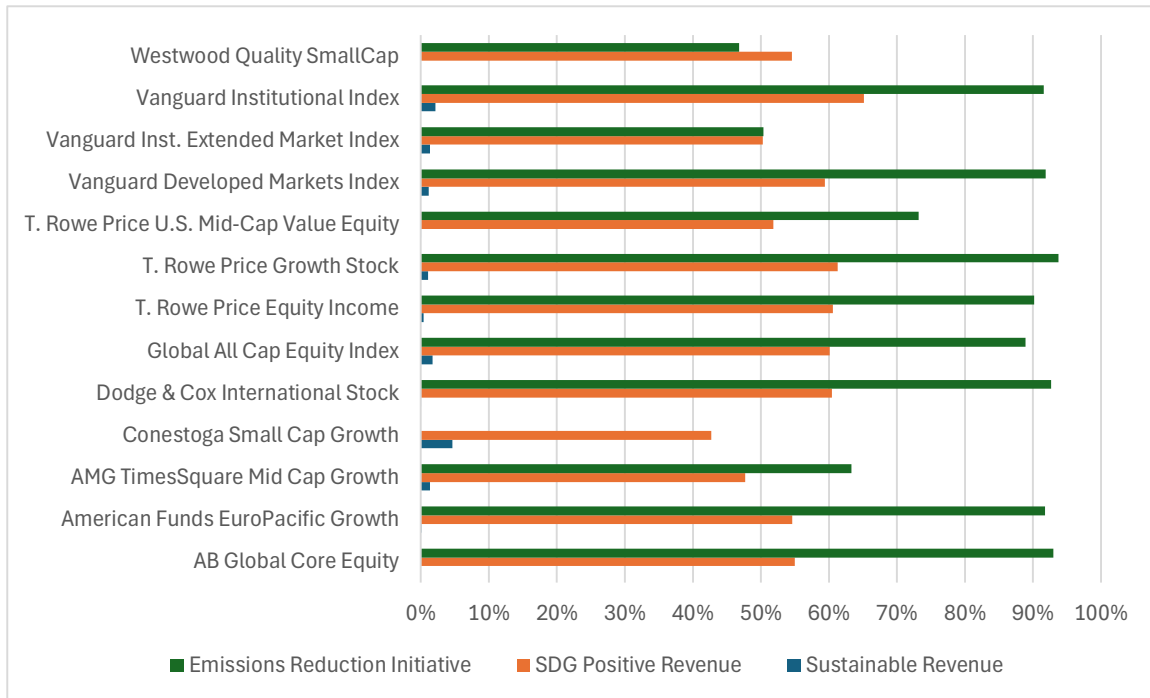


Figure 5: Sustainability risks and opportunities

Most funds show very high exposure (80–95%) to companies with emissions-reduction initiatives. This does *not* necessarily mean the revenues are sustainable. It might be that many underlying companies have announced climate strategies or emissions reduction targets, reflecting sector-wide pressure to decarbonize. This suggests that transition planning is underway across industries, even in carbon-intensive sectors, and that results, such as reduced emissions, are evident. Hence, the opportunities indicate that most funds are exposed to companies preparing for transition but not yet delivering sustainable revenue or rapid decarbonization.

SDG-aligned revenue ranges widely, from about 10% to nearly 60% depending on the fund. SDG-positive revenue indicates more realistic, sustainability-aligned activities within companies. Funds with high orange bars have better long-term transition opportunities, while those with low orange bars remain tied to traditional, non-SDG sectors.

The blue segments (explicitly sustainable revenue) are small (often near zero) for almost all funds. This confirms that although many companies may have reduction initiatives and generate SDG-positive revenue, very few derive significant revenue directly from sustainable products/services, indicating limited exposure to sustainability opportunities, suggesting that the portfolio is not strongly aligned with the emerging green economy.

6. PACTA Analysis

The extended PACTA analysis provides a more granular perspective on the level of misalignment across various climate-relevant sectors. The evidence suggests that industries such as aviation, automotive manufacturing, cement production, oil and gas extraction, steelmaking, and power generation continue to follow production trajectories that diverge significantly from those required to achieve a Paris-aligned transition. This misalignment underscores a systemic exposure to transition risks within the portfolio and highlights the vulnerability of these sectors to policy tightening, technological disruption, and investor-driven decarbonization pressures. However, the analysis demonstrates that the portfolio is significantly more exposed to carbon-intensive sectors than the benchmark in nearly every category, often by a wide margin (see Figure 6). This indicates elevated transition risk, stranded-asset risk, and regulatory vulnerability.

The portfolio holds more high-carbon power, is heavily exposed to internal combustion engines (ICE), has higher oil & gas exposure than the benchmark, still invests in coal, has higher exposure to the cement and heavy-emitting steel industries, and to aviation. Furthermore, it has a lower exposure to low-carbon technologies than the benchmark.

Consequently, the portfolio has significantly elevated transition risk relative to the benchmark because it is more heavily invested in the highest-emitting, hardest-to-abate sectors, and shows weaker alignment with low-carbon technologies. The detailed production trajectories of the funds and the alignment with climate scenarios compared to their benchmarks are presented in

Annex 1.

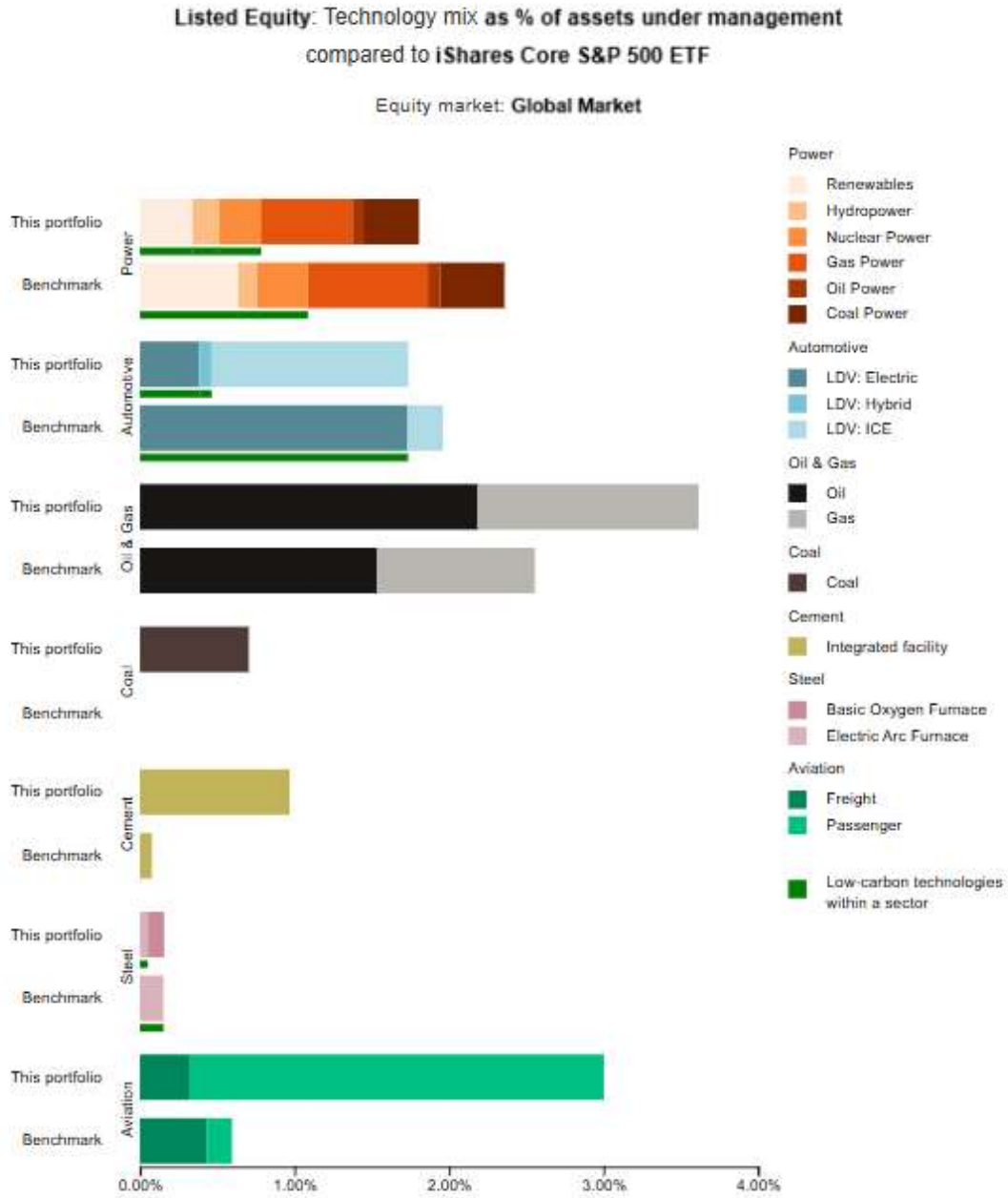


Figure 6: PACTA analysis results

7. Funds Emission and ESG Analysis based on Reuters and Company Analyses

The absolute emission exposure of the funds, also called financed emissions, is presented in Figure 7.

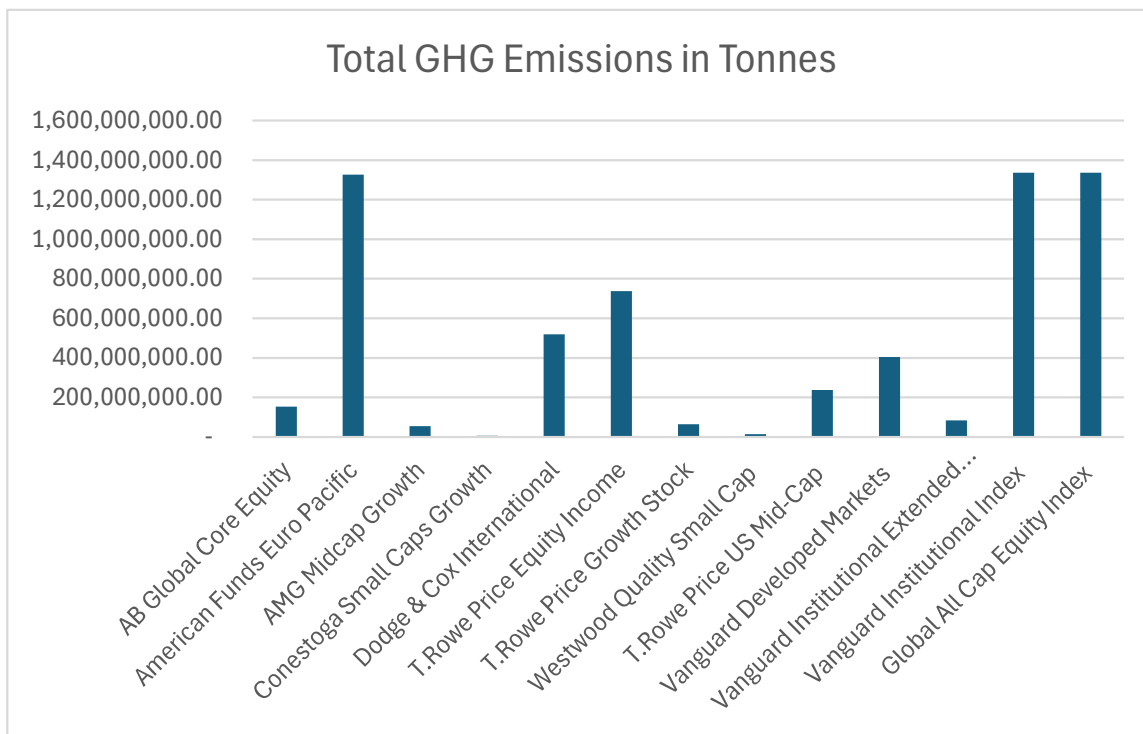


Figure 7: Total GHG emissions by fund

According to Figure 7 and Three funds stand out with exceptionally high total GHG emissions, each over 1.2–1.3 billion tons:

- Global All Cap Equity Index
- Vanguard Institutional Index
- Vanguard Inst. Extended Market Index

These funds have broad, diversified exposure to global markets, including fossil fuel extractors, heavy industry, utilities, manufacturing, and transportation. Their high absolute emissions indicate they hold large-cap, highly emitting companies that are driving elevated climate and transition risk.

Table 1 some funds have extremely high financed emissions, while others are orders of magnitude lower. This indicates dramatically different climate-risk exposures across the funds.

Three funds stand out with exceptionally high total GHG emissions, each over 1.2–1.3 billion tons:

- Global All Cap Equity Index
- Vanguard Institutional Index
- Vanguard Inst. Extended Market Index

These funds have broad, diversified exposure to global markets, including fossil fuel extractors, heavy industry, utilities, manufacturing, and transportation. Their high absolute emissions indicate they hold large-cap, highly emitting companies that are driving elevated climate and transition risk.

Table 1: Total GHG emissions by fund

Fund	Total Emissions in Tons
AB Global Core Equity	153,125,322.19
American Funds Euro Pacific	1,327,581,529.33
AMG Midcap Growth	54,818,586.74
Conestoga Small Caps Growth	6,246,493.26
Dodge & Cox International	519,345,099.31
T.Rowe Price Equity Income	736,793,163.26
T.Rowe Price Growth Stock	64,544,741.06
Westwood Quality Small Cap	13,058,476.21
T.Rowe Price US Mid-Cap	238,227,137.45
Vanguard Developed Markets	403,731,413.74
Vanguard Institutional Extended Markets	83,853,344.00
Vanguard Institutional Index	1,336,062,434.68
Global All Cap Equity Index	1,336,062,434.68

Several funds exhibit very low absolute emissions, often close to zero. They are:

- Conestoga Small Cap Growth
- T. Rowe Price U.S. Mid-Cap Value Equity
- AMG Midcap Growth

These portfolios likely invest in service-sector firms, tech companies, and non-industrial small and mid-cap equities with lower carbon footprints.

The difference in the emissions might be caused by the size of companies in the fund (large industrial companies vs. small tech firms), the sector composition (energy, utilities, industrials = high emissions), the geographic footprint, and supply chain emissions (Scope 3). Consequently, funds focused on global large caps have higher emissions, while small-cap and mid-cap growth funds have much smaller carbon footprints, hence much lower emissions.

Another way to assess carbon exposure is to measure carbon intensity, which refers to GHG emissions per dollar of income. This measure standardizes the size of the investment. The results of the analysis for the funds are presented in Figure 8.

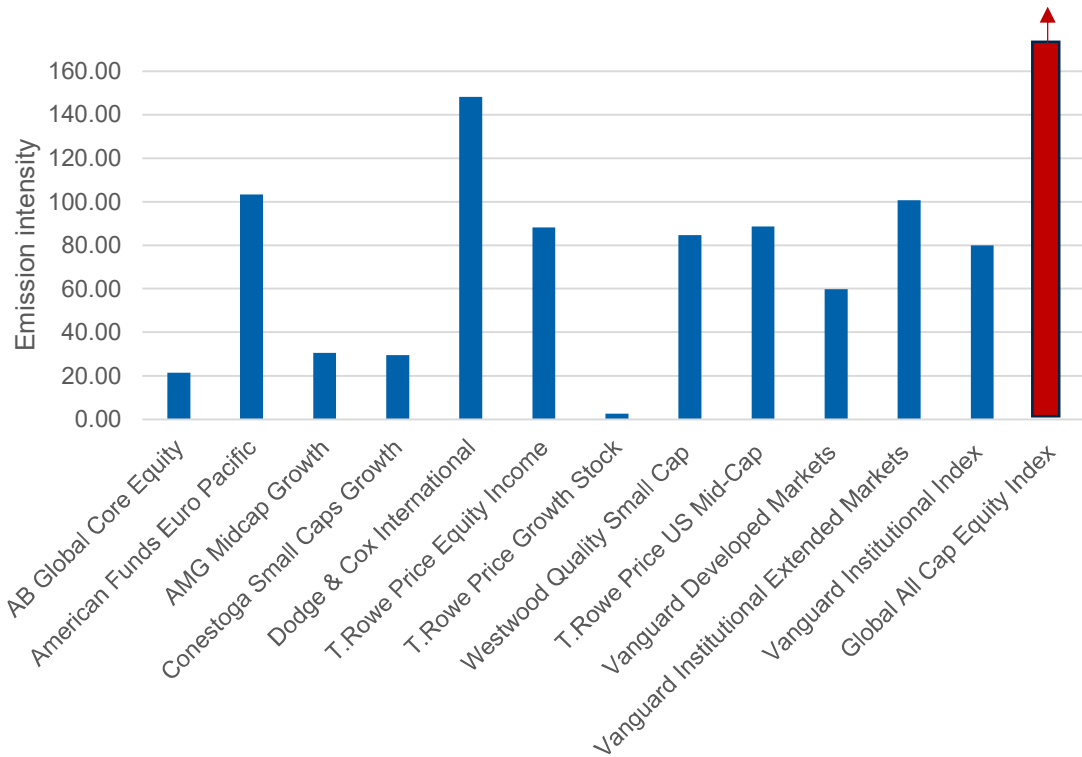


Figure 8: Fund emission intensities

Again, we see a significant difference between the funds. The Global All Cap Equity emission intensity is so high that it is not presented in Figure 8 to avoid the fact that differences between other funds cannot be recognized anymore (see Table 2).

Table 2: Fund emission intensity

Fund	Emission intensity
Global All Cap Equity Index	584859.09
Dodge & Cox International	148.17
American Funds Euro Pacific	103.45
Vanguard Institutional Extended Markets	100.69
T.Rowe Price US Mid-Cap	88.73
T.Rowe Price Equity Income	88.24
Westwood Quality Small Cap	84.72
Vanguard Institutional Index	79.93
Vanguard Developed Markets	59.72
AMG Midcap Growth	30.47
Conestoga Small Caps Growth	29.54
AB Global Core Equity	21.37
T.Rowe Price Growth Stock	2.58

Hence, the carbon intensity of the Global All Cap Equity Index Fund is presented in Figure 9.

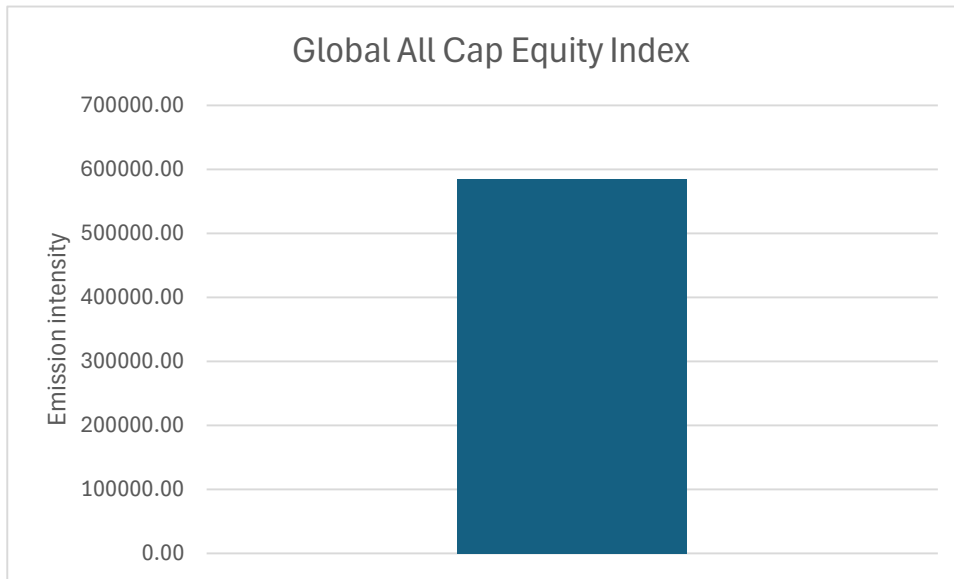


Figure 9: Emission intensity of the Global All Cap Equity Index

The Global All Cap Equity Index Fund is an outlier among all these funds. The carbon intensity is much larger than that of every other fund in the dataset. The fund has exposure to carbon-intensive investments. Examples of these investments include Tokuyama Corporation, Indocement, Hokkaido Electric Power, Yunnan Aluminium, and CSN Steel. These entities operate in inherently carbon-intensive sectors such as chemicals, cement, power generation, aluminum production, and steelmaking. In addition, they have high carbon intensities even compared to their industry group. Their inclusion within portfolio holdings significantly elevates long-term transition risk because these industries face substantial decarbonization challenges and may be adversely affected by future regulatory changes or shifts in market demand.

Other funds with high carbon intensity (80-150) are:

- Dodge & Cox International
- American Funds Euro Pacific
- Vanguard Institutional Extended Markets
- T. Rowe Price US Mid-Cap
- T. Rowe Price Equity Income
- Westwood Quality Small Cap

These funds hold a significant share of carbon-intensive industries, such as international heavy industry, materials and chemicals, traditional energy, manufacturing, and transportation. They represent high transition risks and may be vulnerable to carbon taxes, fossil fuel phase-outs, regulations targeting high-emission value chains, and stranded-asset risk.

Low-emission-intensity funds, such as AMG Midcap Growth, Conestoga Small Cap Growth, AB Global Core Equity, and T. Rowe Price Growth Stock, have lower exposure to heavy industry and greater exposure to service, healthcare, consumer, and technology sectors, as well as to smaller companies with less carbon-intensive supply chains. They represent lower transition risk and are more aligned with sustainability goals.

The emission intensity data show that the portfolio contains funds with vastly different levels of carbon risk, ranging from ultra-low-emission growth funds to extremely carbon-intensive global index funds. The Global All Cap Equity Index represents a massive concentration of transition risk, while small-cap and growth-oriented funds represent cleaner, lower-risk alternatives.

8. 10-Year Investment Return for Different Divestment Scenarios

The following Figure 10 presents financial returns over 10 years under different divestment scenarios. The scenarios are non-divestment and divestment of the highest 1%, 5%, and 10% of emitters.

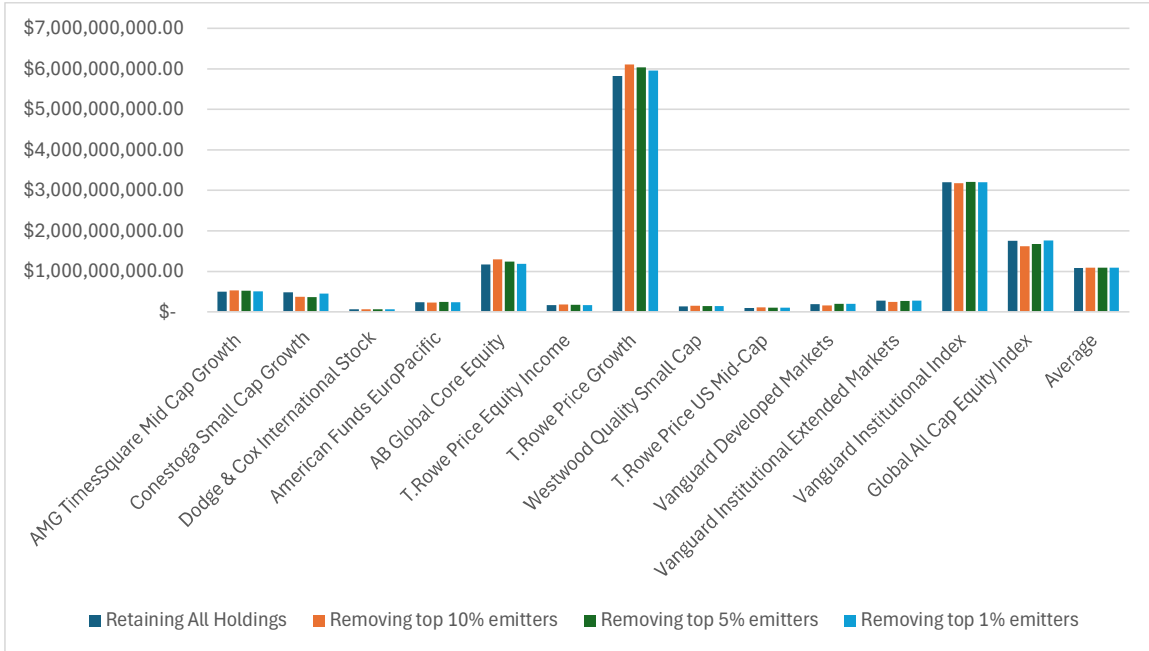


Figure 10: Financial returns for ten years based on different divestment scenarios

Table 3 Presents the financial returns for ten years based on the same divestment options.

Table 3: Financial returns for ten years based on different divestment scenarios

Fund	Retaining All Holdings	Removing top 10% emitters	Removing top 5% emitters	Removing top 1% emitters
AMG TimesSquare Mid Cap Growth	\$501,838,744	\$525,974,044	\$519,051,194	\$506,332,339
Conestoga Small Cap Growth	\$480,087,922	\$368,199,192	\$364,573,868	\$454,902,913
Dodge & Cox International Stock	\$63,117,465	\$66,413,833	\$64,481,543	\$62,743,931
American Funds EuroPacific	\$236,895,663	\$230,286,218	\$243,384,689	\$238,250,119
AB Global Core Equity	\$1,172,245,400	\$1,300,363,739	\$1,236,603,359	\$1,190,704,949
T.Rowe Price Equity Income	\$166,478,918	\$186,518,616	\$178,369,548	\$171,466,538
T.Rowe Price Growth	\$5,831,226,546	\$6,111,494,869	\$6,045,556,506	\$5,956,747,702
Westwood Quality Small Cap	\$136,148,787	\$151,428,833	\$143,899,977	\$139,023,561
T.Rowe Price US Mid-Cap	\$91,909,561	\$104,437,538	\$99,231,989	\$97,781,889
Vanguard Developed Markets	\$191,923,366	\$158,525,302	\$194,628,647	\$194,525,500
Vanguard Institutional Extended Markets	\$277,819,588	\$241,979,246	\$269,938,000	\$277,175,138
Vanguard Institutional Index	\$3,200,105,522	\$3,177,881,589	\$3,210,033,943	\$3,205,159,474
Global All Cap Equity Index	\$1,757,262,196	\$1,619,769,664	\$1,673,490,951	\$1,759,792,110
Average	\$1,085,158,437	\$1,095,636,360	\$1,095,634,170	\$1,096,508,166

Figure 11 presents the ten-year financial returns as percentages under different divestment scenarios.

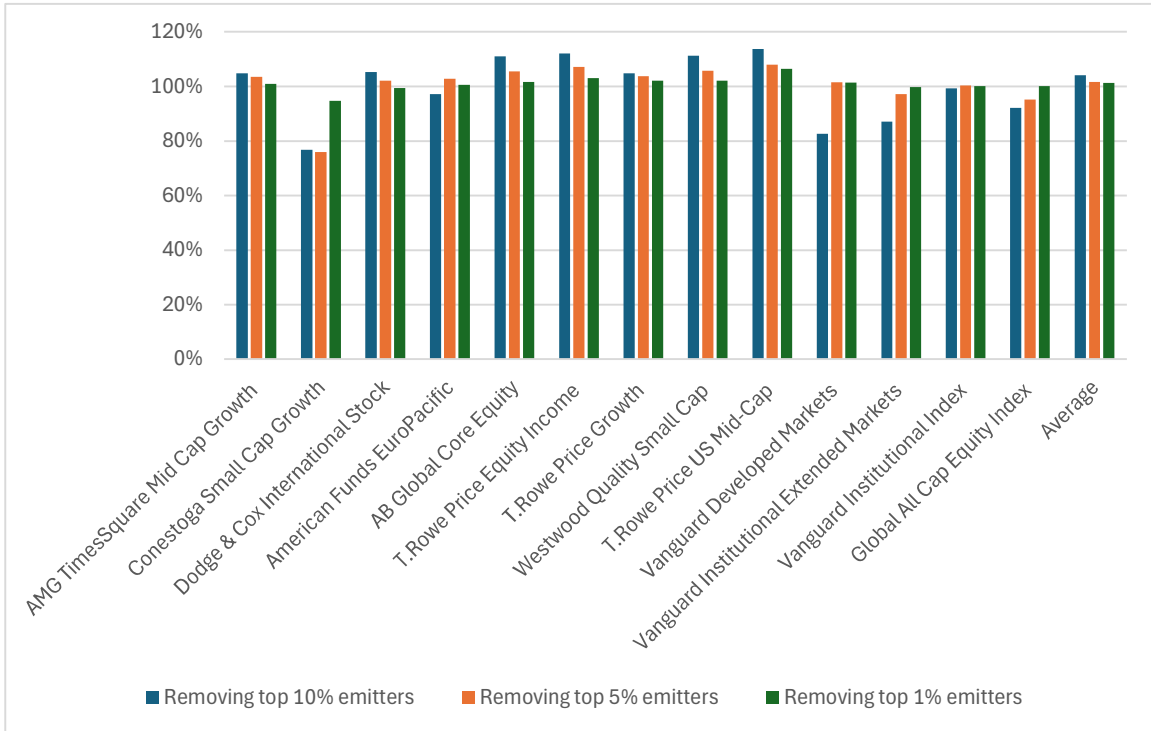


Figure 11: Ten-year returns on a percentage basis

Table 4 presents the ten-year financial returns as percentages under different divestment scenarios.

Table 4: Ten-year returns on a percentage basis

Fund	Removing top 10% emitters	Removing top 5% emitters	Removing top 1% emitters
AMG TimesSquare Mid Cap Growth	105%	103%	101%
Conestoga Small Cap Growth	77%	76%	95%
Dodge & Cox International Stock	105%	102%	99%
American Funds EuroPacific	97%	103%	101%
AB Global Core Equity	111%	105%	102%
T.Rowe Price Equity Income	112%	107%	103%
T.Rowe Price Growth	105%	104%	102%
Westwood Quality Small Cap	111%	106%	102%
T.Rowe Price US Mid-Cap	114%	108%	106%
Vanguard Developed Markets	83%	101%	101%
Vanguard Institutional Extended Markets	87%	97%	100%
Vanguard Institutional Index	99%	100%	100%
Global All Cap Equity Index	92%	95%	100%
Average	104%	102%	101%

Across all funds, removing the highest emitters has only a small impact on financial returns, and in some cases even increases them. In most cases, the difference between full retention and even aggressive divestment is minimal. This means funds can lower emissions exposure without sacrificing returns. The average returns before and after the divestment options are presented in Table 5.

Table 5: Returns and percentage returns of different divestment strategies

Divestment Strategy	Returns	Percentage Returns
Retaining All Holdings	\$ 1,085,158,436.79	100%
Removing top 10% emitters	\$ 1,095,636,360.28	104%
Removing top 5% emitters	\$ 1,095,634,170.33	102%
Removing top 1% emitters	\$ 1,096,508,166.37	101%

The result indicates that the most carbon-intensive holdings are not necessarily the primary drivers of financial performance. This is because many of the high emitters are in declining industries (oil & gas, coal, heavy industry), are structurally risky (volatility, stranded-asset risk), and face long-term regulatory pressure. Thus, eliminating them has a limited impact on the fund's ability to generate returns.

A small number of funds, especially the large index-based funds, show slight dips in financial returns when top emitters are removed. These funds are:

- Vanguard Institutional Index

- Vanguard Institutional Extended Markets
- Global All Cap Equity Index
- T. Rowe Price Equity Income

These declines, however, are modest, do not alter the overall trend, and remain within a narrow range. These funds are broadly diversified. Hence, removing large parts of emitters slightly reshuffles sector weights but does not fundamentally harm performance.

In some cases (e.g., AB Global Core Equity, Dodge & Cox International, small-cap funds), removing the top emitters slightly increases returns. This might occur because high-emission companies can perform poorly in volatile markets, removing them eliminates downside risk from fossil fuel price swings, and smaller, low-emission companies often outperform over time. Consequently, divesting from high emitters can be return-neutral or even return-positive for certain portfolios.

Finally, bigger funds, such as Vanguard Institutional Index, Vanguard Inst. Extended Market Index, and Global All Cap Equity Index show almost no variation across divestment strategies. Highly diversified funds are resilient to divestment because removing top emitters affects only a small portion of total holdings.

The main results of the divestment analysis are:

- Divestment does not significantly reduce returns
- High-emitting companies are not critical for financial performance
- Some funds perform better when top emitters are removed

Overall, climate-conscious investing is financially viable, can be achieved without financial losses, and can even increase financial returns. A correlation analysis between emission intensity and financial returns across different investment scenarios shows that even high-emitting portfolios (such as the Global All Cap Equity Index) are not financially sensitive to climate-related divestment. From Figure 11, we can see that removing the top 10% of emitters creates the largest variation.

Hence, it seems that the top emitters contribute either disproportionately positively or negatively, depending on the fund. Excluding them reshapes portfolios dramatically, amplifying differences in return drivers.

Most funds' performance is not highly sensitive to excluding a small number of the largest emitters, suggesting that the highest-emitting companies are not the primary drivers of performance and that moderate decarbonization activities incur minimal performance penalties or even positive financial effects. For instance, AB Global Core Equity, T. Rowe Price Equity Income, and T. Rowe Price US Mid-Cap improve their financial performance after high-emitting companies are removed. Hence, the results suggest that broad index funds depend on large emitters (e.g., energy, materials, industrials) for long-term performance. Significant exclusions disrupt diversification and impact returns more severely than for an actively managed fund. Consequently, investors could significantly reduce financed emissions

without major return penalties and possibly achieve small performance gains if exclusions are applied moderately ($\leq 10\%$).

8.2. Analysis by Fund Type

In this section, we analyze the financial consequences of the different divestment strategies by fund type. Therefore, we split the funds into three groups:

1. Index funds
2. Small- and mid-cap funds
3. Other funds

The percentage returns for index funds are presented in Figure 12. Removing 5% or 10% of high emitters causes significant declines in the performance of two index funds, except the S&P 500 fund (Vanguard Institutional Index Fund). However, the Vanguard Institutional Index (S&P 500) shows almost no performance loss (99–100% of the original return). In contrast, Vanguard Extended Markets experiences a severe drop, especially in aggressive scenarios that exclude 10% of the highest emitters. The Global All Cap Equity Index is extremely sensitive at high removal levels (e.g., 10% removal), but less sensitive at lower cutoffs (e.g., 1%). None of the funds reduced its financial returns significantly if 1% of the highest emitters are removed.

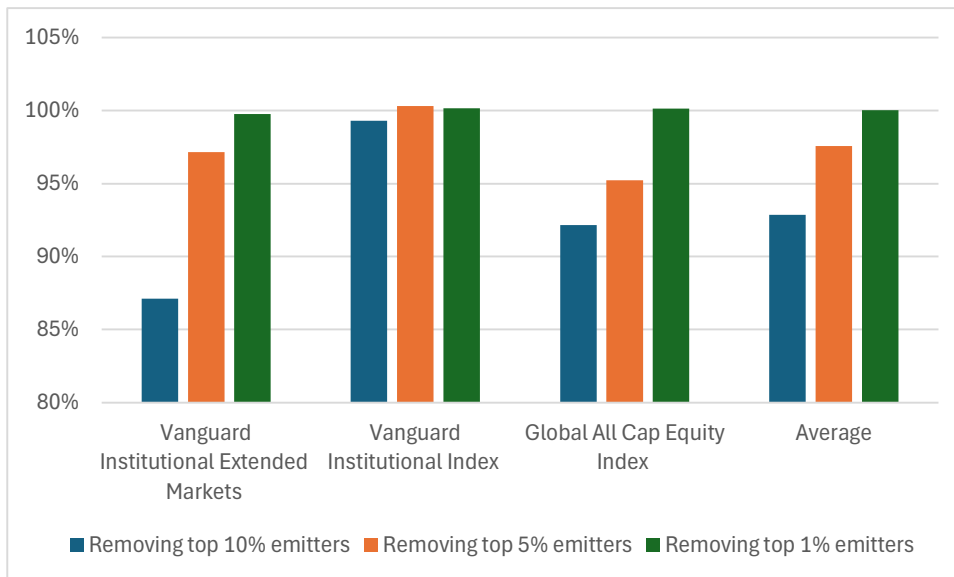


Figure 12: 10 Year percentage returns for index funds under different divestment options

Overall, we conclude that excluding high emitters reduces returns in diversified global index strategies but has little effect on returns in large-cap U.S. index funds such as the S&P 500. A review of the literature shows that broader market conditions heavily influence both fossil-fuel-free and conventional energy ETFs. However, conventional energy ETFs do not have a better performance than fossil fuel-free ETFs (D’Ecclesia et al., 2024). This is also valid for other global funds (Plantinga & Scholtens, 2021). Some of the fossil fuel-free funds perform even better than their conventional counterparts (Henriques & Sadorsky, 2017).

The returns for small- and mid-cap funds are presented in Figure 13. The results suggest that removing high emitters does not hurt. They may even improve returns by actively managed small- and mid-cap strategies, because these managers already avoid carbon-intensive underperformers. High-emitting firms in small- and mid-cap universes might often be lower-quality or cyclical stocks (e.g., energy, materials, industrials). Growth-oriented small- and mid-cap funds tend to hold low-emission tech or healthcare, so excluding emitters removes weaker positions. Finally, many active managers are already underweighting in high-emission sectors, so the impact is mild or even positive. This can also be seen in the emission intensity of the funds, which is relatively low (see, for instance, Figure 8).

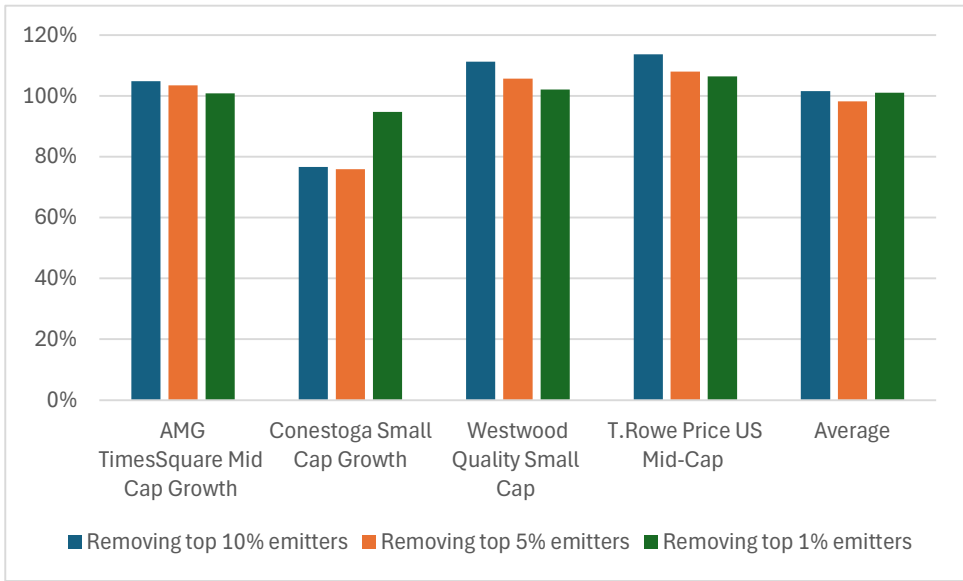


Figure 13: 10 Year percentage returns for small- and mid-cap funds under different divestment options

The results of other actively managed funds are presented in Figure 14.

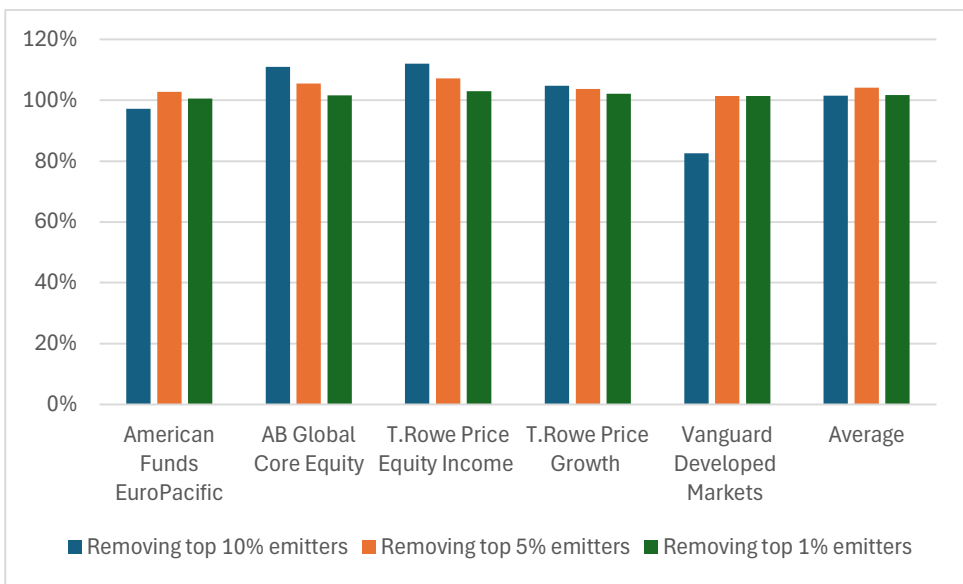


Figure 14: 10 Year percentage returns for other funds under different divestment options

The performance changes under different divestment scenarios vary. Removing the top emitters often shows moderate declines or moderate increases (some funds do worse, some slightly better). An exception is the Vanguard fund, which shows a significant decrease when 10% of the high emitters are removed. Overall, Global and value-oriented funds experience mixed returns from excluding high emitters. However, changes in financial returns are minimal if 15 or 5% of the highest emitters are removed.

Overall, Index Funds are most affected by removing large parts of the high emitters, while Small- and Mid-Cap and Other funds even increase their returns on average. However, the impacts vary and appear to differ across fund issuers. Overall, removing 15 or 5% of the highest emitters does not have a significant negative impact on the funds' financial performance.

9. Conclusions

The report's findings confirm that the portfolio continues to exhibit substantial exposure to climate-related risks. The dominance of high-carbon sectors, the presence of major emissions-intensive companies, and the continued lack of transparency for nearly one-fifth of the funds all contribute to heightened long-term risk. Particularly, Index Funds are exposed to these risks. Moreover, sector-level production trajectories remain widely misaligned with Paris-aligned decarbonization pathways, further amplifying vulnerability. These conclusions underscore the importance of enhancing transparency, integrating sustainability into fund selection, and supporting regulatory efforts to standardize climate-related disclosures.

Consequently, plan sponsors should incorporate climate-risk considerations into their fiduciary oversight processes by ensuring that investment options are evaluated not only on financial performance but also on their exposure to transition and emissions-related risks. Sponsors should request complete sustainability reporting from fund managers and expand the availability of investment options that credibly align with decarbonization pathways. This approach would better support long-term retirement security and align plan governance with emerging best practices.

10. Next Steps

Future research should focus on scenario-based risk modeling to clarify the extent to which various decarbonization pathways may affect portfolio performance. Additionally, developing a dedicated climate-risk index for retirement plans would help standardize comparisons across different employers and plan providers. Expanding the analysis to include more 401(k) plans would enable the identification of systemic patterns in climate-risk exposure.

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Annex 1: PACTA Results

