Mind the gaps: Clarifying corporate carbon

John Simmons
Senior Research Lead, SI Research
+1 646 952 7435
john.simmons@ftserussell.com

Jaakko Kooroshy
Global Head of Sustainable Investment Research,
+44 0 7557 782101
jaakko.kooroshy@ftserussell.com

Edmund Bourne
Senior Analyst, SI Research
+44 207 797 3696
edmund.bourne@ftserussell.com

Mallika Jain
Analyst, SI Research
mallika.jain@lseg.com

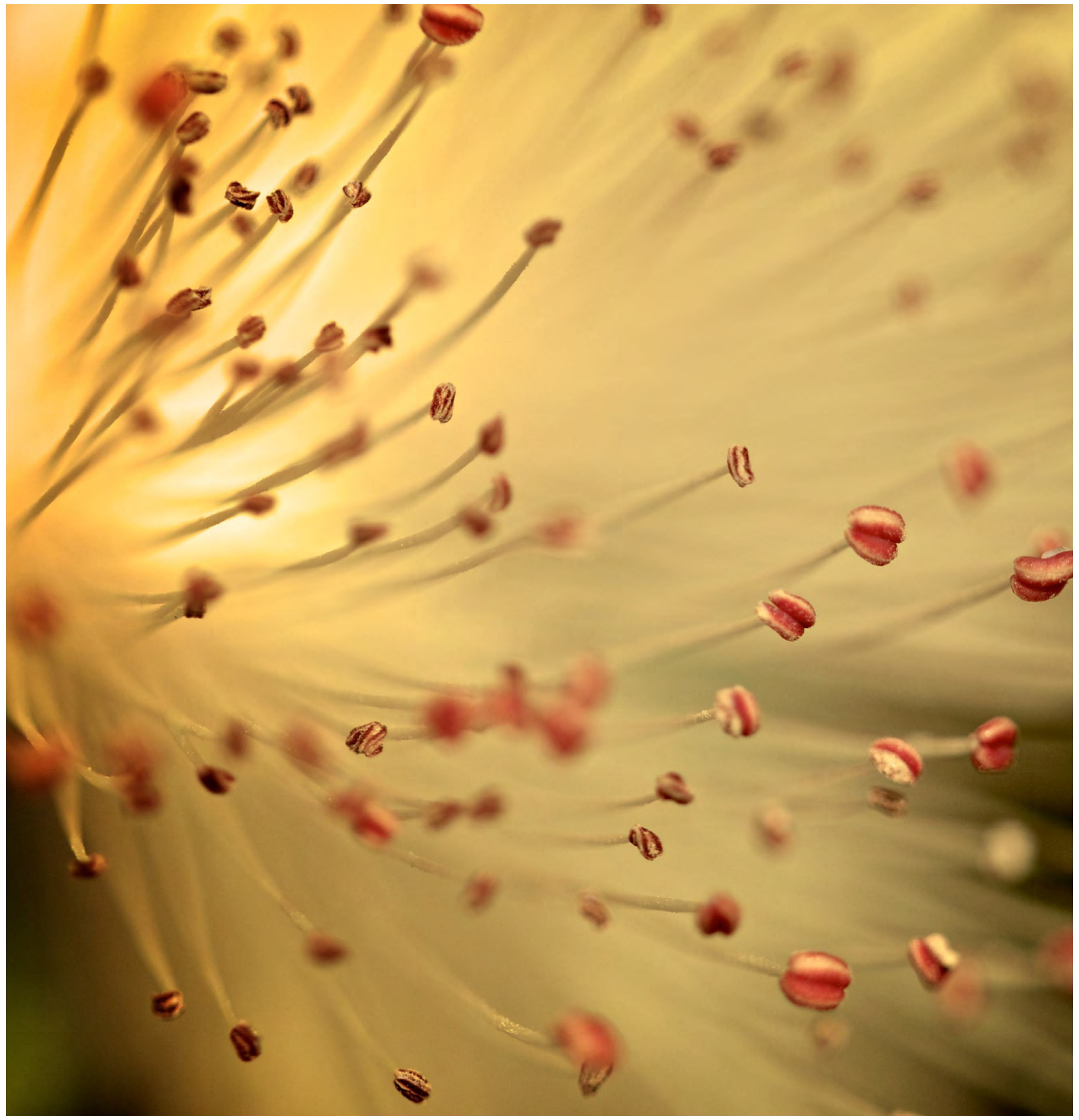
Lee Clements
Head of Sustainable Investment Solutions, SI Research
+44 0 207 797 3812
lee.clements@ftserussell.com

FTSE RUSSELL
An LSEG Business

Overview

Scope 1 and 2 carbon intensity is pervasive in sustainable finance and perhaps the most influential sustainability metric used by investors today. Widely available, science-based, and easily compared or aggregated, emissions data plays a critical role in constructing low-carbon investment products; in portfolio-level climate target setting; in regulatory reporting and compliance; and as a key input to more complex, forward-looking metrics. As pressure continues to mount on investors to decarbonize their portfolios, the importance of this foundational metric will only increase.

In this paper, we survey the current state of corporate carbon disclosure and explore the challenges facing investors in using estimation strategies. We propose an improved estimation strategy, combining the strengths of several existing methodologies, and introduce a new FTSE Russell carbon emission dataset for c. 10,000 companies based on a hierarchical, multi-model approach.



Acknowledgements

The authors would like to thank Professor Timo Busch at the University of Hamburg, Tim Smith and Jennifer Anderson from Lazard Asset Management's Sustainable Investment & ESG Team, and Felix Preston at Climate Arc for their helpful comments and suggestions.

FTSE RUSSELL
An LSEG Business

Contents

Executive summary

Emissions data is increasingly critical for capital allocation—whether for setting portfolio targets, constructing sustainable investment products, regulatory reporting, or net zero alignment tools. In this paper, we re-examine data available on Scope 1 and 2 corporate greenhouse gas emissions across a broad range of investment universes.

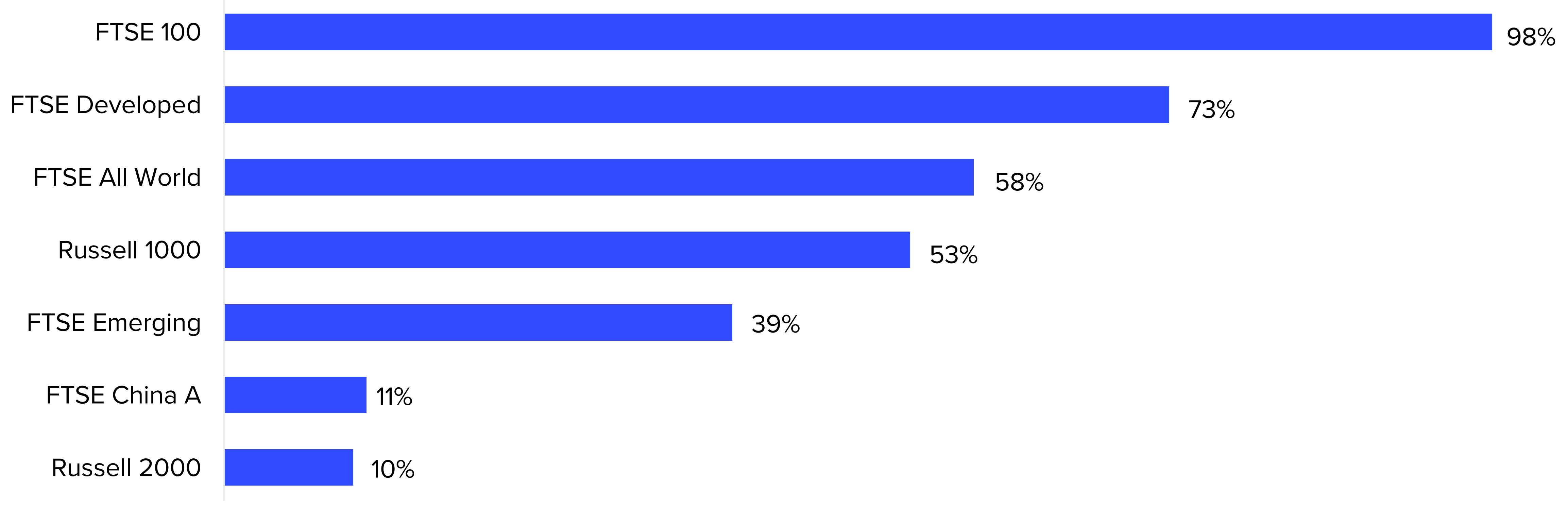
We argue that mandatory disclosure standards—as currently implemented in the UK and proposed by the Securities and Exchange Commission in the United States—are urgently required for emissions data. In the meantime, the choice of estimation methods carries greater significance than is often assumed and requires careful consideration. Markets require transparency on the models used; at a minimum, routine reporting should include details on the ratio of estimated vs reported carbon data, a summary of estimation methods and model specifications, and disclosure of any adjustments or standardization of reported data.

We finally propose an improved estimation strategy, combining the strengths of several existing methodologies, and introduce a new FTSE Russell carbon emission dataset for c. 10,000 companies based on a hierarchical, multi-model approach. We show that this provides improved accuracy and, in particular, reduces the risk of underestimating emissions, which has attracted greater scrutiny as the transition accelerates.

To demonstrate why this matters, we go back to basics and set out two persistent challenges facing investors:

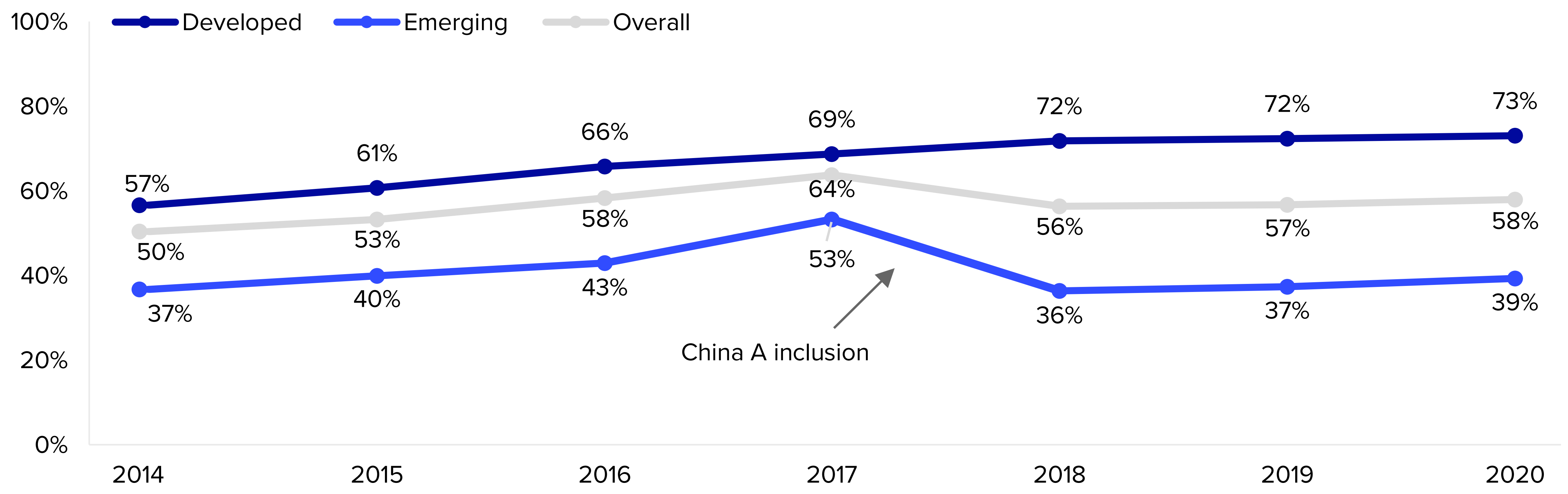
- **The Disclosure Gap:** Even in markets with well-developed sustainability reporting, there is a significant share of companies that are still not disclosing their operational emissions. Although there is a common perception that this disclosure gap is closing rapidly, our research suggests that recent progress has been incremental at most. In some sense this gap is widening, as sustainable investment strategies and reporting are applied ever more broadly across regions and to smaller firms as illustrated by the impact of China A inclusion on disclosure rates in key global benchmarks (see Figures 1 & 2).
- **The Estimation Gap:** In the absence of universal reporting, investors routinely turn to estimates to fill missing values. However, significant challenges remain in effectively estimating carbon data, with no industry or scientific consensus on the best method, despite extensive research over the past two decades. We systematically evaluate the major approaches with sobering results—regardless of the strategy used, almost half of estimated values diverge from reported data by 100%, large enough to sway the weighted average carbon intensity (WACI) for a large, diversified global portfolio by several percentage points.

Figure 1. Share of companies disclosing Scope 1 & 2 emissions across selected FTSE Russell indices[1]



Source: FTSE Russell.

Figure 2. Proportion of companies disclosing both Scope 1 & 2 emissions in the FTSE All World[1]



Source: FTSE Russell.

1 Indices as at 31/12/2020 and using FY2019 emissions data although FTSE All World, Emerging and Developed as at 31/12/2021 using FY2020 emissions data. Firms disclosing in FY2019 assumed to disclose in FY2020. Disclosure requires reporting of both Scope 1 and Scope 2 emissions.

CHAPTER 1.
A critical tool in the sustainable investment toolkit

Climate-related risks are driving changes in asset values, future revenues and cashflows through a combination of transition risks associated with accelerating efforts to decarbonize individual sectors and the global economy, as well as physical risks that arise from global warming and shifting climate patterns. Investors need robust, comparable metrics and data to assess these risks and manage related exposure in their portfolios.

Today, by far the most pervasive climate risk indicator is carbon emissions—or more precisely, current annual operational (Scope 1 and 2) carbon equivalent greenhouse gas (GHG) emissions, typically normalized over revenues.[2] Compared to other climate risk metrics, carbon emissions intensity benefits from being:

- **Widely available**—carbon emissions are among the most disclosed data points by corporates, with more than 15 years of information available in some cases.
- **Consistently measured and methodologically mature**—carbon emissions benefit from standardized and recognized reporting frameworks such as the GHG Protocol[3] and dedicated collection efforts such as CDP (see Box 2).
- **Easy to compare**—intensity metrics enable direct comparison across sector peers, regions, and even asset classes, and can be aggregated across individual holdings to the portfolio level by calculating the weighted average carbon intensity or WACI (see Box 1).

Arguably this has made Scope 1 and 2 carbon emissions intensity the single most influential metric used by investors to measure and shape investment outcomes based on sustainability considerations.[4] Carbon emissions data, either directly, or as a key input into more complex climate risk measures, has become ubiquitous in many sustainable investing products and processes (see Figure 3).

As investors look to decarbonize their portfolios, emissions intensity data is becoming increasingly important to quantify and track asset owners' and asset managers' progress against targets.[5] Leading investor initiatives focused on achieving net zero—for example, the UN-convened Net-Zero Asset Owners Alliance, Net Zero Asset Managers Initiative, and the Institutional Investor Group on Climate Change—have already signalled they will require members to develop, issue, and report on progress against their targeted carbon intensities for their portfolios.[6]

Next to voluntary initiatives, emissions data are also tied to regulatory requirements. Mandatory reporting requirements for listed corporates are in force in the UK[7] and have now been proposed by the Securities and Exchange Commission (SEC) in the US,[8] with Japan considering expanding the scope of its existing reporting requirements to more companies.[9] Regulators are also increasingly outlining emissions-linked reporting requirements for investors, most notably in the EU, where compliance with SFDR and EU BMR regulation, as well as the Climate Transition Benchmark (CTB) and Paris-Aligned Benchmark (PAB) labels, requires disclosure of aggregate emissions profiles for relevant portfolios and indices.[10]

2 Most methods discussed in this paper focus on carbon intensity with respect to Revenues, however, Enterprise Value (including Cash) or EVIC is sometimes used, e.g., as specified by the European Commission for index construction of so-called Paris Aligned Benchmarks (PAB).

3 Greenhouse Gas Protocol, 'A Corporate Accounting and Reporting Standard', accessed 21/04/22.

4 As early as 2015, over 120 investors representing $10 trillion in assets under management had committed to disclose their carbon footprints as signatories of the Montreal Carbon pledge.

5 FTSE Russell, 'Towards investor-oriented carbon targets data', accessed 04/04/22.

6 UN-convened Net-Zero Asset Owners Alliance, 'Target Setting Protocol', accessed 27/04/22.IIGCC, 'Net Zero Investment Framework', accessed 16/12/21.Net Zero Asset Managers Alliance, 'Our Commitment', accessed 16/04/22.

7 The Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013 made it mandatory for publicly listed UK-incorporated firms to report their annual emissions and methodologies used to calculate them.

8 SEC, SEC.gov | SEC Proposes Rules to Enhance and Standardize Climate-Related Disclosures for Investors, accessed 28/03/22.

9 Japan's Mandatory GHG Accounting and Reporting System has required emissions disclosure from specific 'high-emitting' companies since 2006. The FSA is now reported to be considering making TCFD-aligned disclosures mandatory for listed companies on the Tokyo Stock Exchange's Prime Market. See Nikkei, 'Japan to require 4,000 companies to disclose climate risks', accessed 25/04/2022.

10 Benchmarks (europa.eu), accessed 16/03/22. Under EU BMR, benchmark providers are required to disclose emissions profiles for specific types of sustainability-based indices.

Critically, Scope 1 and 2 emissions intensity is also a key component of newer, more sophisticated climate metrics such as Implied Temperature Rise (ITR)[11] or Climate-Adjusted VaR, where they are combined with specific climate, economic, and company assumptions and projections. Such 'forward-looking' metrics typically rely on current or extrapolated emissions to estimate such parameters as the cost of decarbonization (as part of Climate-Adjusted VaR) or the emissions trajectories of portfolio constituents relative to sector decarbonization benchmarks (as in ITR methodologies).

Figure 3. Carbon Emissions data serve a variety of investor needs

Use Case	Examples
Portfolio Analytics	– Compute aggregate portfolio carbon intensity to compare against competitors and the market (see Box 1) – Calculate relative sector or regional performance or active weight against a benchmark – Key input for forward-looking metrics (e.g., Implied Temperature Rise (ITR) or Climate-Adjusted VaR)
Security Selection	– Screen for the best, exclude the worst, particularly in low carbon strategies – Use as a tilting factor alongside other metrics to determine constituent weights in portfolios
Voting & Engagement	– Track progress against specific corporate emissions reduction targets – Prioritize engagement efforts and determine voting practices[12]
Regulatory Compliance	– Disclose climate risks to regulators and investors – Meeting labelling requirements for sustainable funds or investment strategies

Source: FTSE Russell.

11 Portfolio Alignment Technical Supplement, TCFD, accessed 16/03/22.
12 'Fidelity International threatens tough stance on climate and gender', Financial Times, accessed 16/03/22; 'Heavyweight investors demand more disclosure of environmental risks', Financial Times, accessed 16/03/22.

Box 1. Emissions intensity metrics

Carbon Emissions Intensity	Weight Average Carbon Intensity (WACI)
$I_k = \frac{E_k}{S_k}$ – Where I_k is the Carbon Intensity of company k – E_k is the annual carbon emissions of company k – S_k is the annual Net Revenues of company k **Definition** – Normalized rate of carbon emissions per unit of economic activity. Emissions intensity is often calculated relative to Net Revenues. – For specific applications, units of output from industrial processes (e.g., steel, automobiles) are more relevant.	$\text{WACI} = \sum_{k=1}^{n} I_k * W_k$ – Where Ik is the Carbon Intensity of a firm – W_k is the weight of the firm in a portfolio such that $\sum_{k=1}^{n} W_k = 1$ **Definition** – Portfolio-level indicator describing the current emissions intensity, weighting each security by portfolio exposure. – WACI does not capture overall absolute emissions exposure, better illustrated by metrics such as 'Financed Emissions.'

This paper goes back to basics, surveying the current state of carbon emissions disclosures across sectors, regions and over time, and systematically evaluating the major estimation strategies used to fill in missing values. We ultimately present a new FTSE Russell carbon emission dataset for c. 10,000 companies, based on a hierarchical, multi-model approach to produce more consistent and transparent portfolio-wide emissions data.

This analysis focuses on operational emissions (Scope 1 and 2), which are already deeply embedded within the investor use cases outlined earlier in this section. Scope 3 emissions, emitted as part of a company's value chain, have significantly poorer rates of disclosure, are more complex to calculate, and rely on patchy supply chain information. Correspondingly, their use within investment processes is less mature, yet growing as pressure mounts on companies and investors to consider their full emissions profiles, such as the requirement to include material Scope 3 emissions in portfolio carbon reduction targets for Net Zero Asset Managers Initiative members.[13] This paper will be followed by a forthcoming companion paper, which will focus on Scope 3 emissions data and estimation strategies.

13 'Net Zero Asset Managers Commitment', Net Zero Asset Manager Initiative, accessed 17/03/2022.

CHAPTER 02.
The Disclosure Gap

Companies have faced growing pressure to disclose their carbon emissions since the Kyoto Protocol first established national climate commitments in the 1990s and the GHG Protocol began standardizing the measurement of corporate emissions from 2001 onwards. A few large multinational corporations, like Danone and IBM,[14] were early adopters of emissions reporting in 1990s, but widespread disclosure of emissions only slowly permeated corporate behavior[15] before the mid-2000s.[16]

More recently, investors have played a critical role in encouraging companies to disclose emissions data, as they anticipate the impact of future carbon pricing and other climate-related risks on their portfolios.[17] Significant numbers of investors have publicly backed reporting standards and frameworks like CDP, GRI, CDSB, and later TCFD;[18] similarly, investor-backed organizations like TPI and Climate Action 100+ have created pressure for companies to disclose emissions alongside a broad set of consensus climate metrics. In some cases, individual investors have publicly urged all their portfolio companies to disclose emissions, as Norges Bank Investment Management did through the publication of its Expectations of Companies on Climate Change.[19]

Box 2. Carbon Disclosure Project (CDP)

CDP is an influential non-profit organization focused on improving corporate disclosure of carbon emissions, carbon reduction targets, and other environmentally-focused information. In 2003, CDP issued its first questionnaire for corporates, seeking responses around emissions levels and emissions reduction targets.

Since then, CDP's standardized reporting system has become a key mechanism through which corporates disclose GHG emissions data and other climate risk information. In 2021, more than 13,000 companies participated in CDP's annual survey.

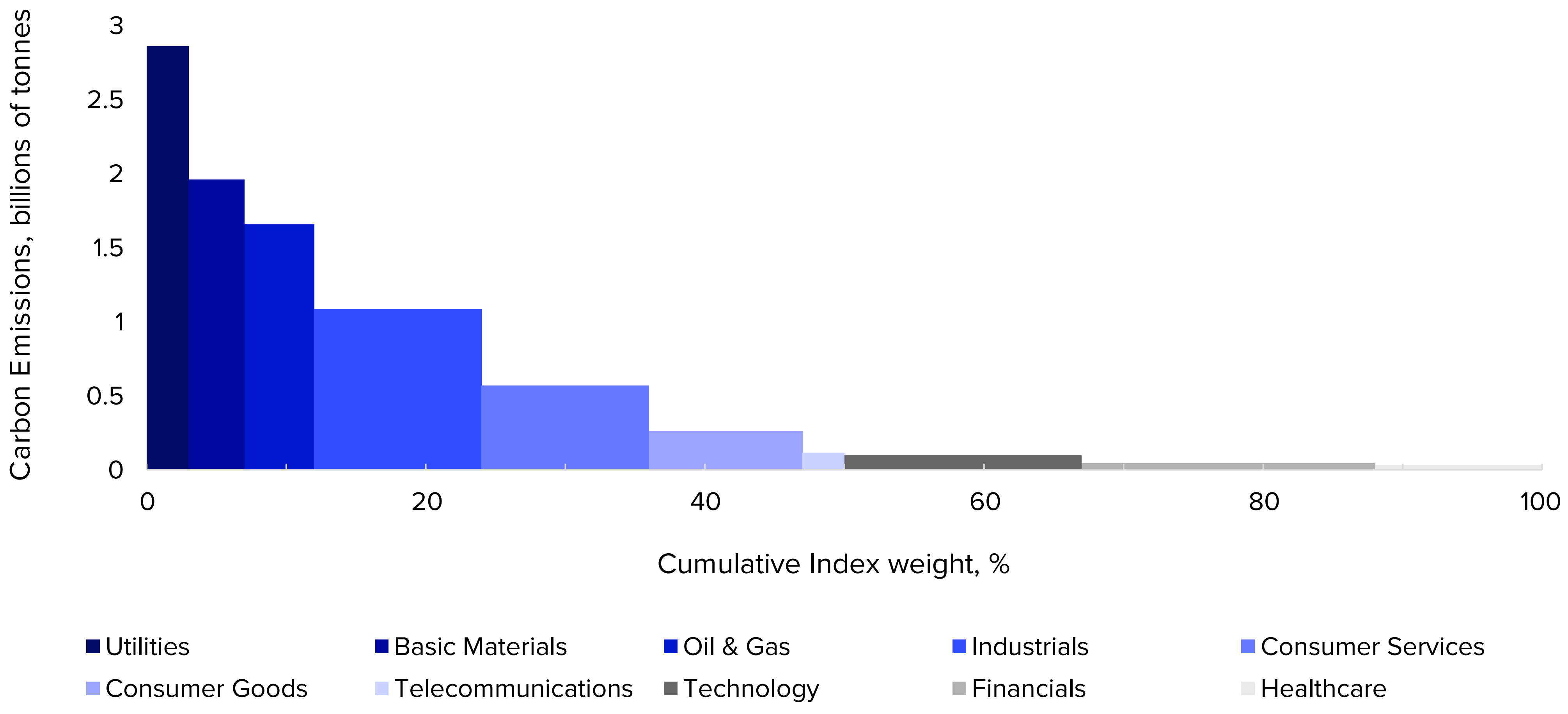
14 Danone Corporation. (2016). Integrated Report; IBM, "IBM and the Environment," accessed 24/02/2022.
15 He, R., Luo, L., Shamsuddin, A. and Tang, Q. (2021), Corporate carbon accounting: a literature review of carbon accounting research from the Kyoto Protocol to the Paris Agreement. Account Finance. https://doi.org/10.1111/acfi.12789.
16 Up to 2005, CDP's annual survey contained less than 500 corporate responses. See Kauffmann, C. et al. Emission reporting corporate greenhouse gas. OECD. accessed 10/04/2021.
17 Sullivan, Rory & Gouldson, Andy. (2012). Does voluntary carbon reporting meet investors' needs?. Journal of Cleaner Production. 36. 60–67.
18 Acronyms can be explained as follows: CDP is the Carbon Disclosure Project, GRI is the Global Reporting Initiative, CDSB is the Climate Disclose Standards Board, and TCFD is the Task Force on Climate-Related Financial Disclosures.
19 NBIM, "Climate Change: Expectations of companies", accessed 16/03/2022.

Nonetheless, there remains a material disclosure gap overall, with considerable variation in reporting levels according to company size, region, and sector:

- Of the c. 4,000 large and mid-sized constituents in the FTSE All World index, more than half currently disclose operational emissions data. But 42% of large and mid-caps globally still do not disclose both Scope 1 and 2 emissions, including high-profile firms like Berkshire Hathaway[20] and Moderna[21] (see Figure 5).
- Larger companies are far more likely to disclose, with more than two thirds reporting their operational emissions versus only half of mid-caps (see Figures 5 & 7).
- Regional and market differences in disclosure are pronounced; 89% of companies in Developed Europe report compared to around 23% of Chinese companies overall, and 11% of China A firms (see Figures 5 & 9). Despite impending mandatory reporting requirements, US firms remain more unlikely to disclose, with only 53% of companies in the Russell 1000 and 10% in the Russell 2000 reporting (see Figure 5).
- Disclosure rates in industries like Technology or Health Care significantly lag sectors such as Telecoms, Utilities or Oil & Gas (see Figure 10).

Figure 4. Accurate emissions can help investors target emissions reductions[22]

Distribution of Scope 1 & 2 emissions & index weight in the FTSE All World Index by sector



Source: FTSE Russell.

20 Berkshire Hathaway has not published emissions data although its subsidiary Berkshire Hathaway Energy has. See Berkshire Hathaway Energy (2020) ESG/Sustainability Quantitative Information, accessed 28/04/2022.

21 Moderna has not disclosed operational carbon emissions, though it has pledged to achieve net-zero globally by 2030. See Moderna Announces Pledge to Achieve Net-Zero Carbon Emissions Globally by 2030, accessed 28/04/2022.

22 Scope 1 & 2 emissions are heavily concentrated. 3 industries—Utilities, Oil & Gas, and Basic Materials—account for 75% of the emissions in the FTSE All World, but only 13% of the index weight. Estimated data is used for non-disclosing constituents based on FTSE Russell's hierarchical estimation mode outlined in Section 4.

Though some contend that this disclosure gap is narrowing, our research suggests that it is persistent, with recent progress incremental at most (see Figure 8).[23] In fact, as sustainable investment strategies are applied ever more broadly across regions and smaller firms with lower disclosure rates, 'non-disclosing' companies are added to portfolios more quickly than the rate at which disclosures first appear. The recent inclusion of China A share firms in mainstream indices illustrates this point; more than 700 China A companies, the majority of which do not disclose, entered the FTSE All World Index in 2018,[24] leading to an 8 percentage point decrease in disclosure levels globally, and 17 percentage points in the Emerging Market overall (see Figure 8). Companies choose not to disclose emissions for a number of reasons, such as a lack of stakeholder focus on climate reporting,[25] perceived reputational risks from poor carbon performance relative to peers,[26] and reticence to incur additional costs and headcount.

One market where the disclosure gap has closed markedly is the UK. Following the implementation of mandatory reporting for large listed UK firms in 2013,[27] the disclosure rate increased significantly with improvements in the quality and completeness of reporting.[28] In our analysis, nearly all companies in the FTSE100 (99 of 101) disclose material carbon emissions[29] and the UK returns the highest disclosure rate for large and mid-cap stocks in aggregate.[30] These findings further underline the case for urgent mandatory economy-wide disclosure to provide investors with the emissions data they require to transition their portfolios.

23 FTSE All World Index, as at 31/12/ 2020.

24 China A inclusion occurred in 2019; however, for this analysis we match this to FY2018 carbon data to control for data availability lag.

25 See: Liesen, A., Hoepner, A.G., Patten, D.M. and Figge, F. (2015), "Does stakeholder pressure influence corporate GHG emissions reporting? Empirical evidence from Europe", Accounting, Auditing & Accountability Journal, Vol. 28 No. 7, pp. 1047-1074

26 Matsumura, Ella Mae and Prakash, Rachna and Vera-Munoz, Sandra C., To Disclose or Not to Disclose Climate-Change Risk in Form 10-K: Does Materiality Lie in the Eyes of the Beholder? (June 8, 2017).

27 Downar, B., Ernstberger, J., Reichelstein, S. *et al*. The impact of carbon disclosure mandates on emissions and financial operating performance. *Rev Account Stud* **26**, 1137–1175 (2021). https://doi.org/10.1007/s11142-021-09611-x.

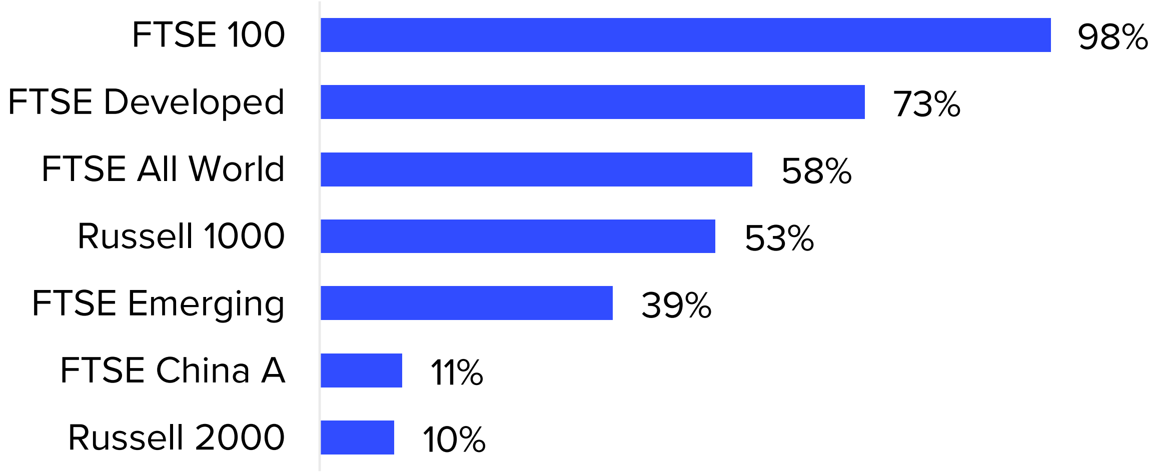
28 Grewal, Jody. (2021). Real Effects of Disclosure Regulation on Voluntary Disclosers. Journal of Accounting and Economics. 101390. 10.1016/j.jacceco.2021.101390.

29 As of FY2019, two financial corporations do not disclose Scope 1 & 2 emissions.

30 Considering all countries with over 15 listed firms within the FTSE All-World Index.

Figure 5. Small caps and emerging indices lag peers on carbon disclosure[31]

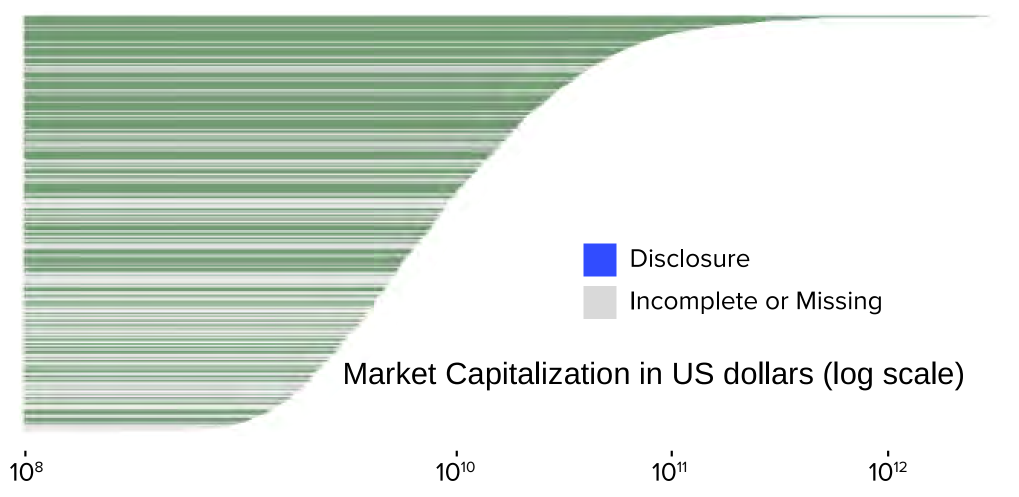
Proportion of companies disclosing both Scope 1 & 2 emissions across selected FTSE Russell indices



Source: FTSE Russell and Refinitiv.

Figure 6. Rate of disclosure drops off as issuer market cap decreases[31]

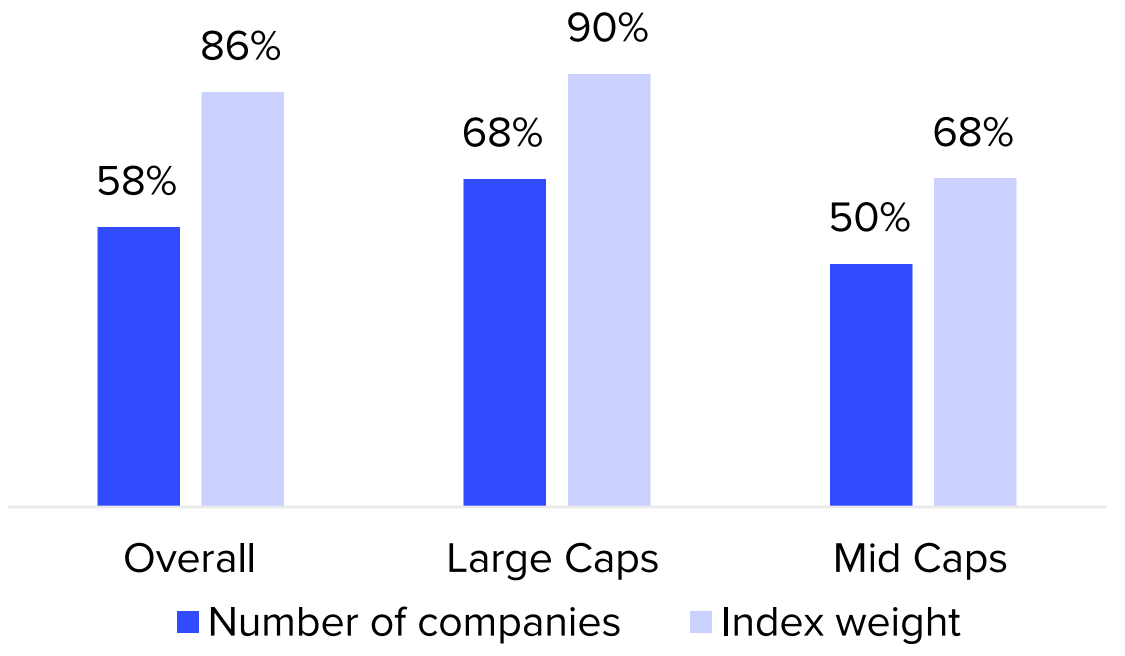
Companies disclosing Scope 1 & 2 in the FTSE All World Index, ranked by market capitalization



Source: FTSE Russell.

Figure 7. Larger companies are significantly more likely to disclose[31]

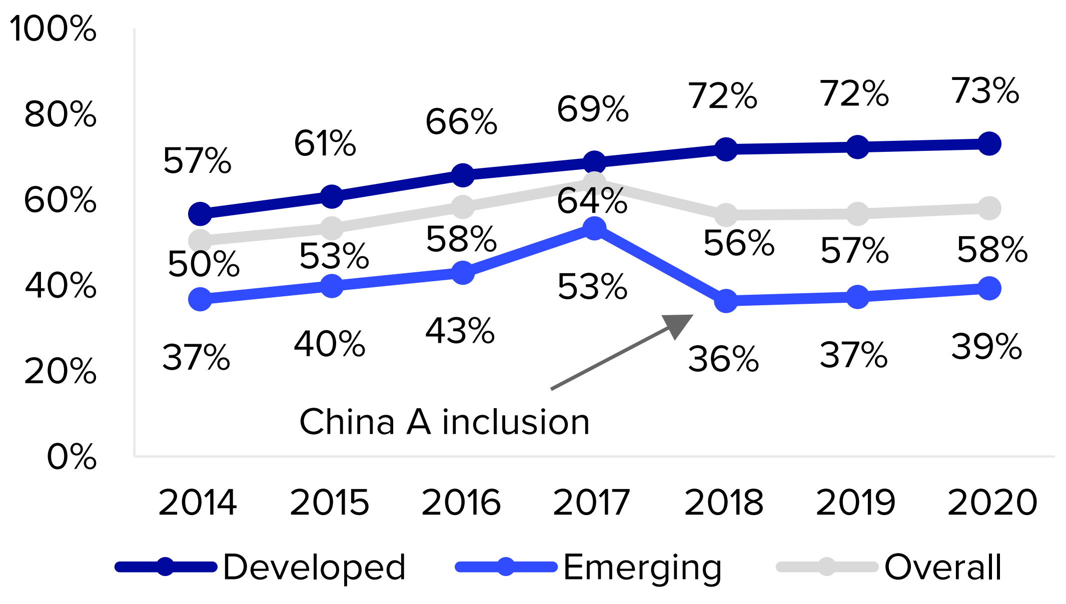
Proportion of companies disclosing both Scope 1 & 2 emissions in the FTSE All World Index, by size



Source: FTSE Russell.

Figure 8. Progress toward closing the disclosure gap has stagnated in recent years[31]

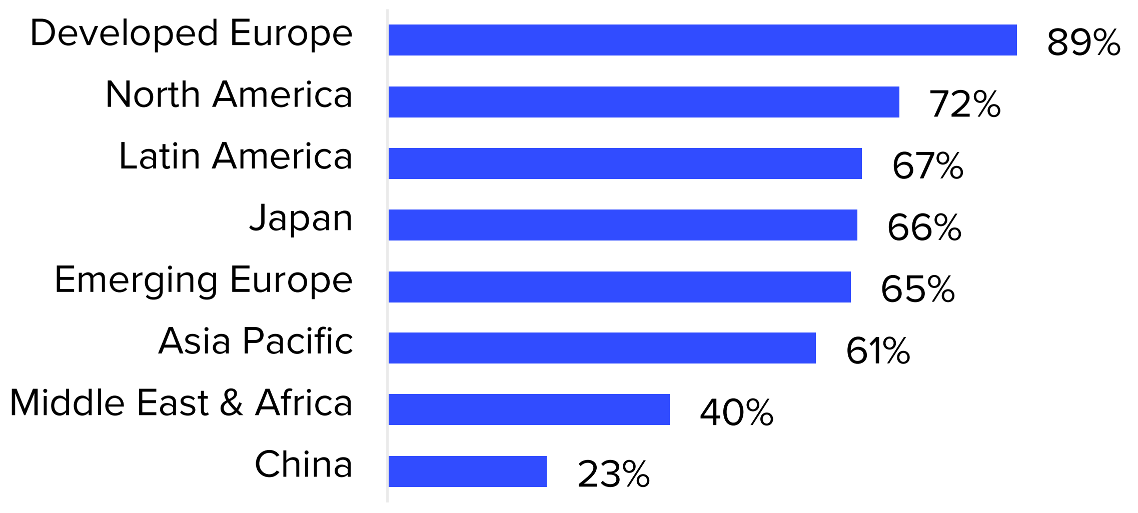
Proportion of companies disclosing both Scope 1 & 2 emissions in the FTSE All World Index, by market



Source: FTSE Russell.

Figure 9. Only Developed Europe shows a disclosure rate greater than 75%[31]

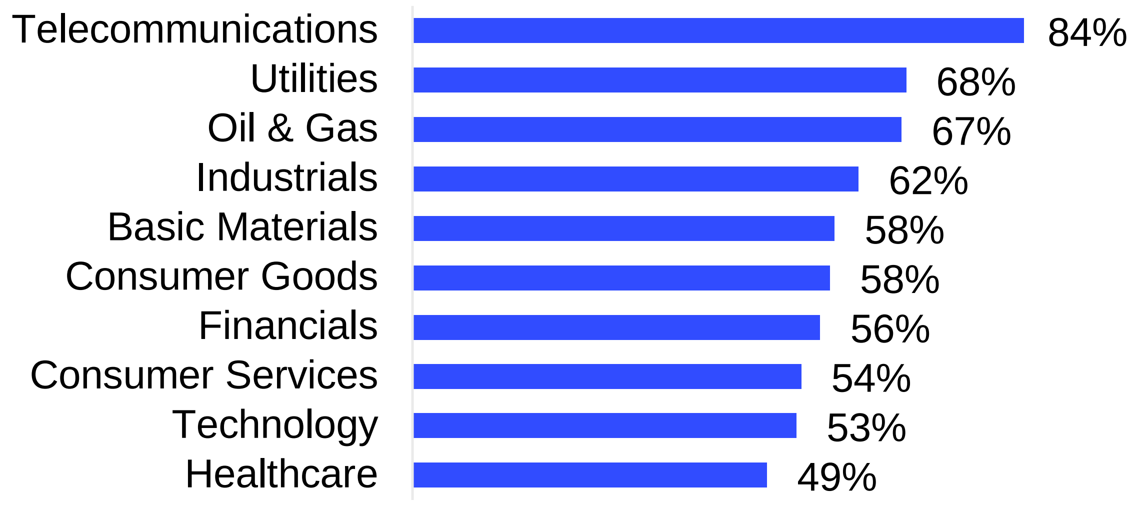
Proportion of companies disclosing both Scope 1 & 2 emissions in the FTSE All World Index, by region



Source: FTSE Russell.

Figure 10. Carbon-intensive sectors and Telecoms show a high rate of disclosure[31]

Proportion of companies disclosing both Scope 1 & 2 emissions in the FTSE All World Index, by sector



Source: FTSE Russell.

31 Indices as at 31/12/2020 and using FY2019 emissions data, although FTSE All World, Emerging and Developed as at 31/12/2021 using FY2020 emissions data. Companies disclosing in FY2019 assumed to disclose in FY2020. Disclosure requires reporting of both Scope 1 and Scope 2 emissions.

Box 3. Marking up corporate emissions exposure

Carbon emissions refer to seven greenhouse gases ("GHGs") emitted from terrestrial sources, which accumulate in the atmosphere and contribute to climate change. As a long-lived, well-mixed gas, each tonne of carbon dioxide in the atmosphere contributes equally to radiative forcing and subsequent temperature rise, regardless of geography or time of emissions,[1] enabling the construction of a simple accounting framework for emissions disclosure. For accounting purposes, emissions of other greenhouse gases such as methane and nitrous oxide are converted to carbon dioxide equivalent emissions (CO2e) through the application of global warming potential (GWP) factors.

Though there are multiple standards for emissions accounting, most companies and disclosure frameworks have adopted the standards set out by the GHG protocol,[2] a partnership between the World Resources Institute and the World Business Council for Sustainable Development. The GHG Protocol recommends that firms report emissions relative to equity stake or either operational or financial control of operations. Emissions are divided into three categories relative to their source and relation to the reporting entity.

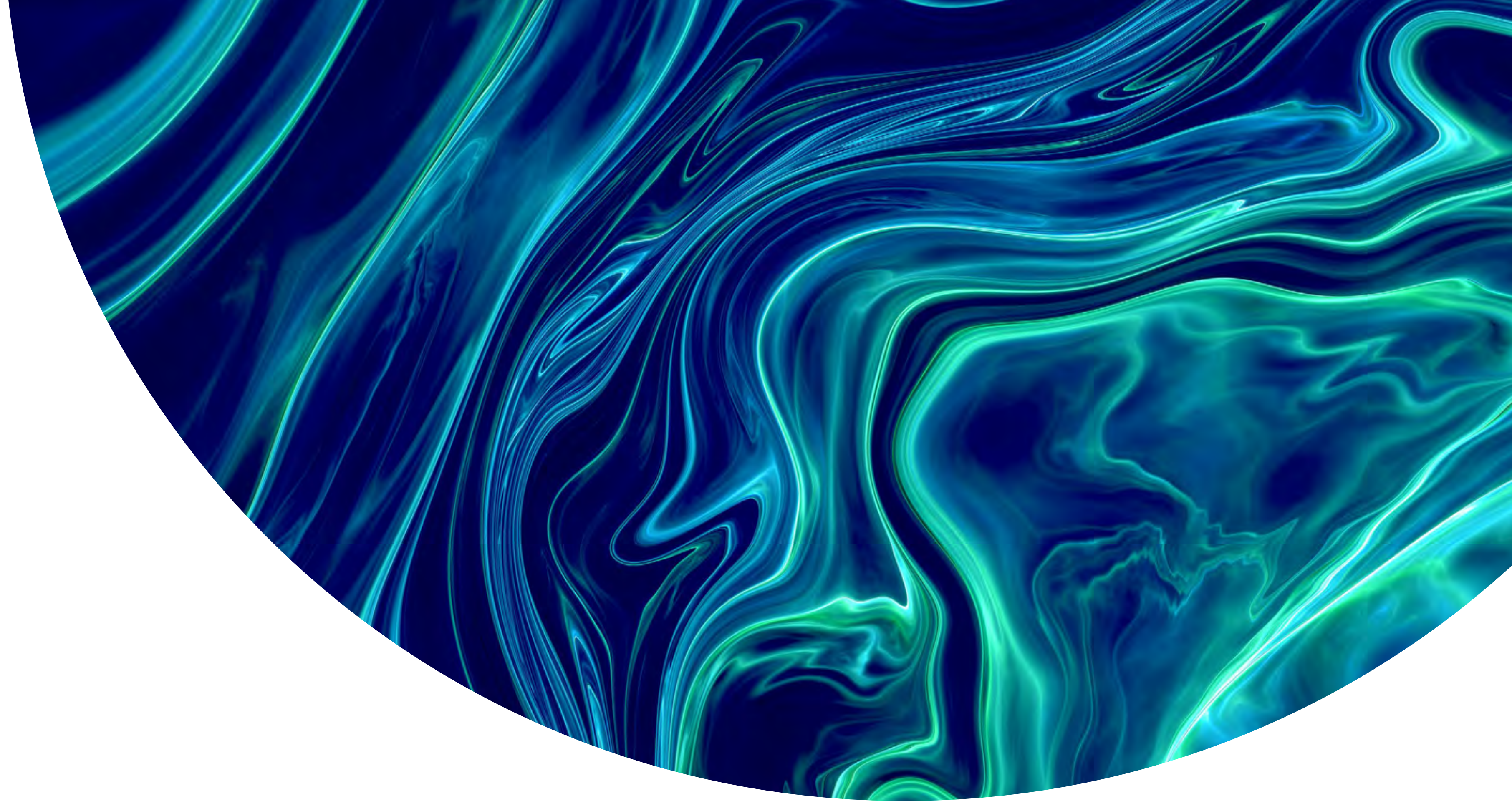
1. Rogelj, J., Forster, P.M., Kriegler, E. et al. Estimating and tracking the remaining carbon budget for stringent climate targets. Nature 571, 335–342 (2019). https://doi.org/10.1038/s41586-019-1368-z.
2. Greenhouse Gas Protocol. Scope 2 Guidance, accessed 10/03/2022.
3. Markwat, T. (2021, September 18). The co$_2$lumnist: Market versus location-based scope 2 emissions. Robeco, accessed 10/03/2022
4. Jerry Patchell, Can the implications of the GHG Protocol's scope 3 standard be realized?, Journal of Cleaner Production, Volume 185, 2018, Pages 941-958, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2018.03.003.

Figure 11. Emissions scopes

Source		Definition	Example
Direct	**Scope 1**	Emissions from sources that are owned or controlled by the reporting company.	**Emissions from:** – A utility's power stations – Company-owned gasoline-powered cars
Indirect	**Scope 2**	Emissions from consumption of electricity, heat, steam, and cooling. This can be calculated via two methods (see Appendix): – **Location-Based** refers to emissions calculated through emission rates of the local power grid. – **Market-Based** refers to emissions calculated based on purchasing agreements with electricity suppliers. For most corporates, this tends to result in lower estimations than Location-Based emissions.[3]	**Emissions associated with:** – Electricity consumption of company-owned EV vehicles – Electricity consumption of company-owned computer servers
	Scope 3	**Upstream:** GHG emissions embedded by processes in the value chain that contribute to a company's products or services.	**For an automaker:** – Emissions produced by suppliers, while manufacturing vehicle components, such as steel or tires
		Downstream: GHG emissions originating from the activities of customers using a company's products and services.	**For an oil & gas firm:** – Emissions from the combustion of oil, gas, and other derived products **For an automaker:** – Emissions from their cars' tailpipes throughout their lifecycle

From an accounting perspective, Scope 1 and 2 or 'operational' emissions are clearly defined and straightforward to calculate. Alternatively, Scope 3 calculation requires complex assumptions involving external counterparties and parts of the value chain, where a company has limited visibility. Downstream Scope 3 emissions are also challenging to assess, often requiring complex lifecycle analysis. Scope 1 and 2 emissions disclosures, though incomplete, have thus far outpaced Scope 3 reporting.[4]

CHAPTER 03.
The Estimation Gap for corporate carbon data



In the absence of universally and consistently reported corporate emissions, investors are routinely forced to revert to estimated emissions data to close the disclosure gap and drive investment decisions. Such estimates are used alongside reported data to assess individual companies and to footprint portfolios, often without distinction or communication of associated uncertainty ranges.[32]

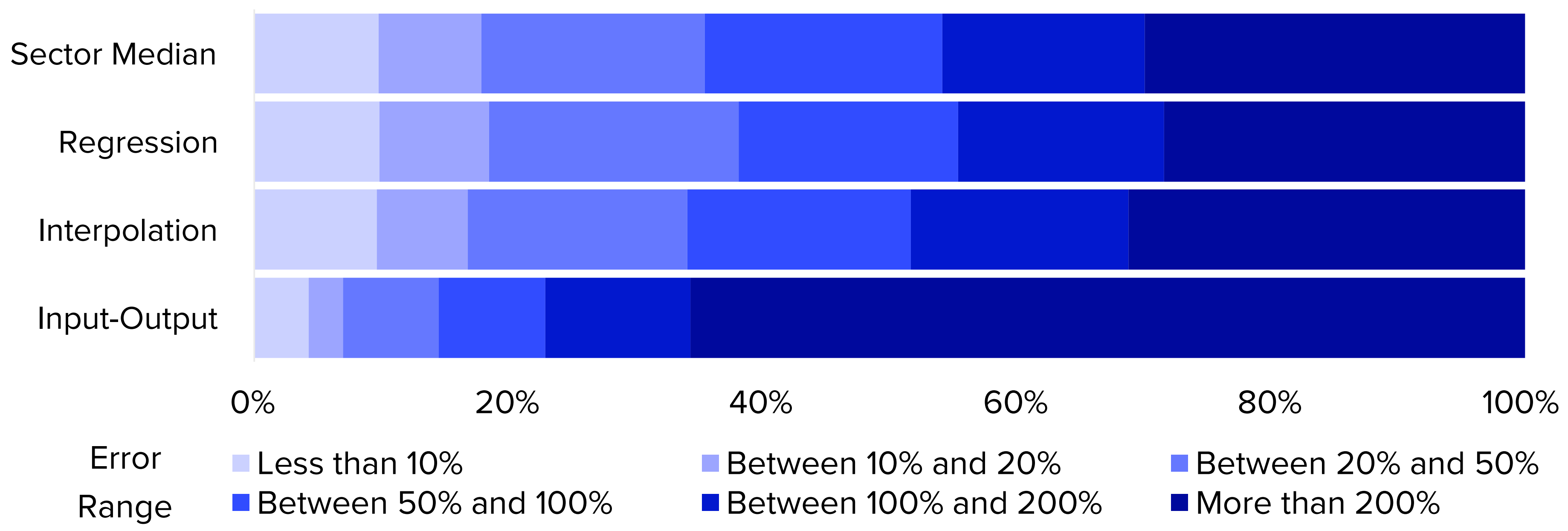
However, despite extensive research efforts by industry and academia over the past two decades, significant challenges remain in effectively estimating carbon emissions data – what we refer to here as the 'estimation gap'. These challenges can be summarized in four parts:

A) **There is no industry or scientific consensus on the best estimation strategy for imputing unreported carbon emissions.** A set of competing estimation methodologies have been proposed (main approaches are summarized in Figure 17, please see Appendix for a detailed discussion of estimation approaches), ranging from simple sector median strategies to complex analysis of company business exposures, often involving so-called 'environmentally extended Input-Output tables' (EEIOs[33]). Commercial providers rely on these strategies to different extents and typically treat model specifications beyond general methodological outlines as closely-guarded trade secrets. Information on model performance and input data is scant, making it difficult for investors to systematically assess and compare competing approaches.[34]

B) **Irrespective of the methodology used, the predictive power of the resulting estimates tends to be low.** To be able to systematically compare the impact of diverging estimation strategies, model specifications, and outputs, FTSE Russell has developed a comprehensive range of carbon emission estimation models, representing each of the major approaches (see Section 4). The results are sobering. We find that almost half of estimated values diverge from reported data by 100%; and over a quarter of values are off by at least 200%;[36] regardless of the estimation strategy or model specifications used (see Figure 12).

Figure 12. All models struggle to generate consistently accurate estimates[35]

Share of estimated observations within error thresholds by model (Scope 1 & 2)



Source: FTSE Russell.

32 Goldhammer, B., Busse, C. and Busch, T. (2017), Estimating Corporate Carbon Footprints with Externally Available Data. Journal of Industrial Ecology, 21: 1165-1179.https://doi.org/10.1111/jiec.12522; Han, You, Achintya Gopal, Liwen Ouyang, and Aaron Key. "Estimation of Corporate Greenhouse Gas Emissions via Machine Learning." arXiv preprint arXiv:2109.04318 (2021).

33 Tukker, A., de Koning, A., Owen, A., Lutter, S., Bruckner, M., Giljum, S., Stadler, K., Wood, R. and Hoekstra, R. (2018), Towards Robust, Authoritative Assessments of Environmental Impacts Embodied in Trade: Current State and Recommendations. Journal of Industrial Ecology, 22.

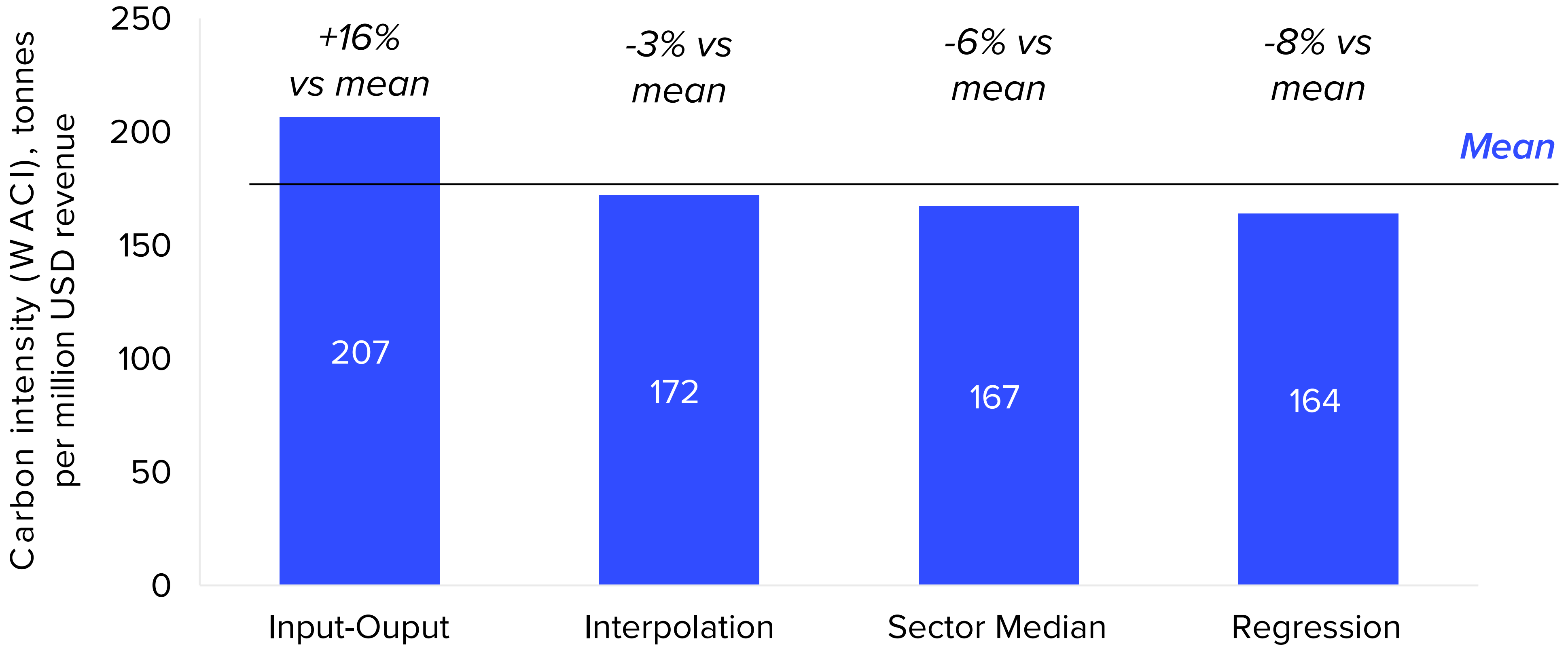
34 Nguyen, Quyen and Diaz-Rainey, Ivan and Kuruppuarachchi, Duminda, Predicting Corporate Carbon Footprints for Climate Finance Risk Analyses: A Machine Learning Approach (June 2, 2020). USAEE Working Paper No. 20-450, Available at SSRN: https://ssrn.com/abstract=3617175.

35 FTSE All World index constituents as at 31/12/2020 and using emissions data disclosed as part of FY2019 reporting where available. Estimated data is generated based on FTSE Russell's estimation models (see Appendix) and outputs compared against reported figures where possible. Thresholds for negative errors adjusted to achieve symmetrical results relative to natural logarithm (e.g., 50% negative error equivalent to 100% positive error).

C) **Not only are estimates imprecise, but they tend to diverge materially from each other, with differences significant enough to sway results for large, diversified portfolios.**[36] On average, the range of the estimates generated by different models is over 60% relative to the median estimate, across each sector. These differences are enough to sway results for a large, diversified global portfolio. The weighted carbon intensity (WACI—see Box 1) for the FTSE All World diverges by several percentage points depending on the estimation strategy used (and up to 16 percentage points for Input-Output model)—even if reported data is used where available (See Figure 13).

Figure 13. Estimation strategies produce material differences in carbon intensity, even for a diversified global portfolio with 55% reported data[37]

Emissions intensity (WACI) for the FTSE All World Index using different estimation strategies



Source: FTSE Russell.

D) **Opportunities to systematically improve the quality of estimates are intrinsically limited by the heterogeneity of firms, the high variability of observed carbon intensities, and sample size restrictions.** Estimation strategies for companies that do not report emissions essentially rely on identifying companies with similar characteristics and using the data reported by peers to infer an emissions estimate. However, even ostensibly similar companies can vary hugely in Scope 1 and 2 emissions footprints, based on largely unobserved company characteristics, such as the precise mix of business activities (see Figure 15), the business model (e.g., vertical integration vs outsourcing[38]), the production technologies used, or companies' geographic exposures.

There is no straightforward approach to overcoming these challenges. Elsewhere we have shown that modelling advancements, including the implementation of cutting-edge data science techniques, can deliver some gains, but that these are relatively marginal.[39] Fundamental improvements would ultimately require additional data such as granular breakdowns of firm activities or production technologies.[40] For utilities, for example, relatively effective estimates can be generated from power generation mix data (see Section 4)—but such data is not readily available in other industries. Similarly, more granular peer groups can increase homogeneity, but also rapidly reduces sample sizes. Moving from ICB Industry to ICB Subsector reduces inter-sample emissions variation by 42% — but this comes at the cost of cutting sample sizes by 95% (see Figure 14 & 16).

36 Busch, T, Johnson, M, Pioch, T.Corporate carbon performance data: Quo vadis? J Ind Ecol. 2020; 1– 14. https://doi.org/10.1111/jiec.13008

37 FTSE All World index constituents as at 31/12/2020 and using emissions data disclosed as part of FY2019 reporting where available. Estimated data is used for non-disclosing constituents based on FTSE Russell's hierarchical estimation mode outlined in Section 4.

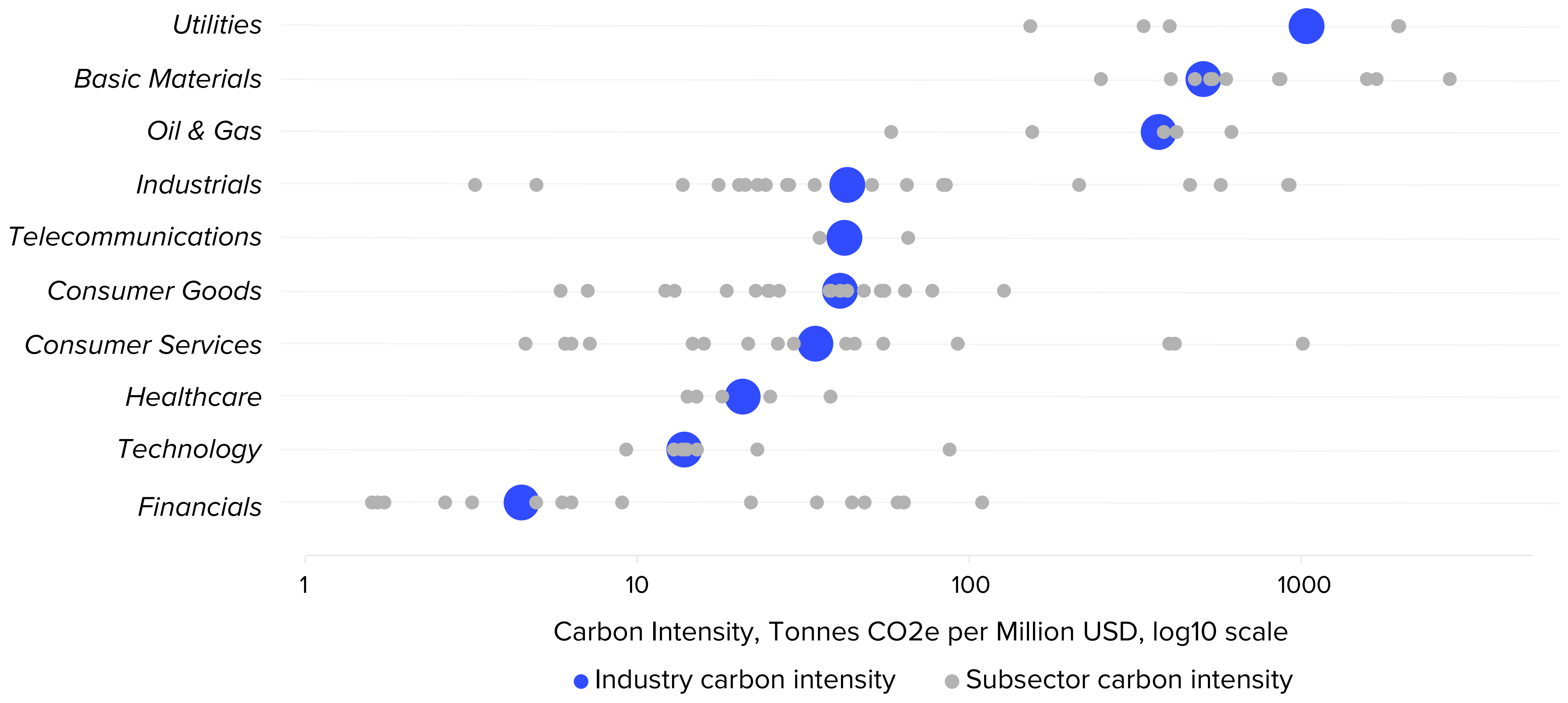
38 Emissions outsourcing can shift emissions from Scope 1 to Scope 2 or even Scope 3: See: Microsoft. (2021). A new approach for Scope 3 emissions transparency. Microsoft.com. Accessed February 4, 2021.

39 Olesiewicz, Malgorzata & Kooroshy, Jaakko & Greven, Sonja. (2021). Navigating the corporate disclosure gap: modelling of Missing Not at Random Carbon Data.

40 Many sectors have techniques available to reduce carbon intensity, such as the use of electric vehicles in transport or Electric Arc Furnaces in steel. See: Hoffman, C., Van Hoey, M., & Zeumer, B. (2020, June 3). Decarbonization challenge for steel. Mckinsey.com, accessed 12/04/2021.

Figure 14. What's in a peer group? Sectors contain business activities with huge variations in carbon intensity[41]

Comparison of median emissions intensity for ICB Industries and their component subsectors



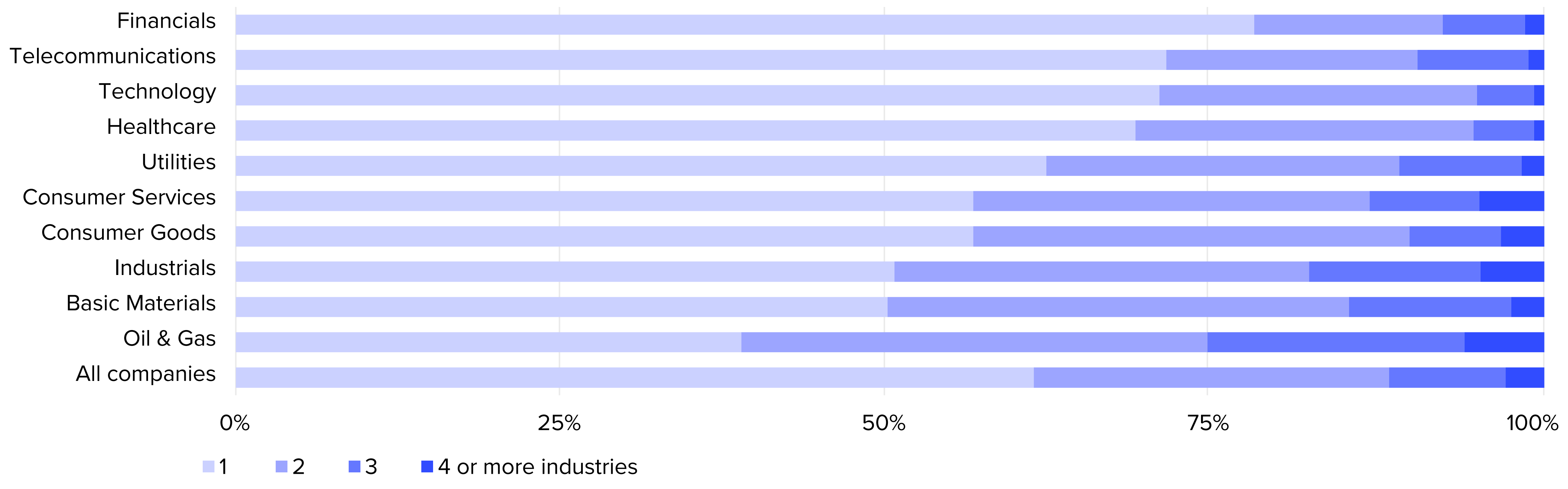
Source: FTSE Russell.

41 FTSE All World index constituents as at 31/12/2020 and using scope 1 & 2 emissions data disclosed as part of FY2019 reporting. A company's "Industry" and "Subsector" is based on its classification within FTSE Russell's Industry Classification Benchmark[41] (ICB) and represents the least and most granular levels of classification, respectively.

42 Companies' reported revenue segments are attributed to a unique single digit SIC code.

Figure 15. Many firms are engaged in multiple industries with vastly different carbon intensities[42]

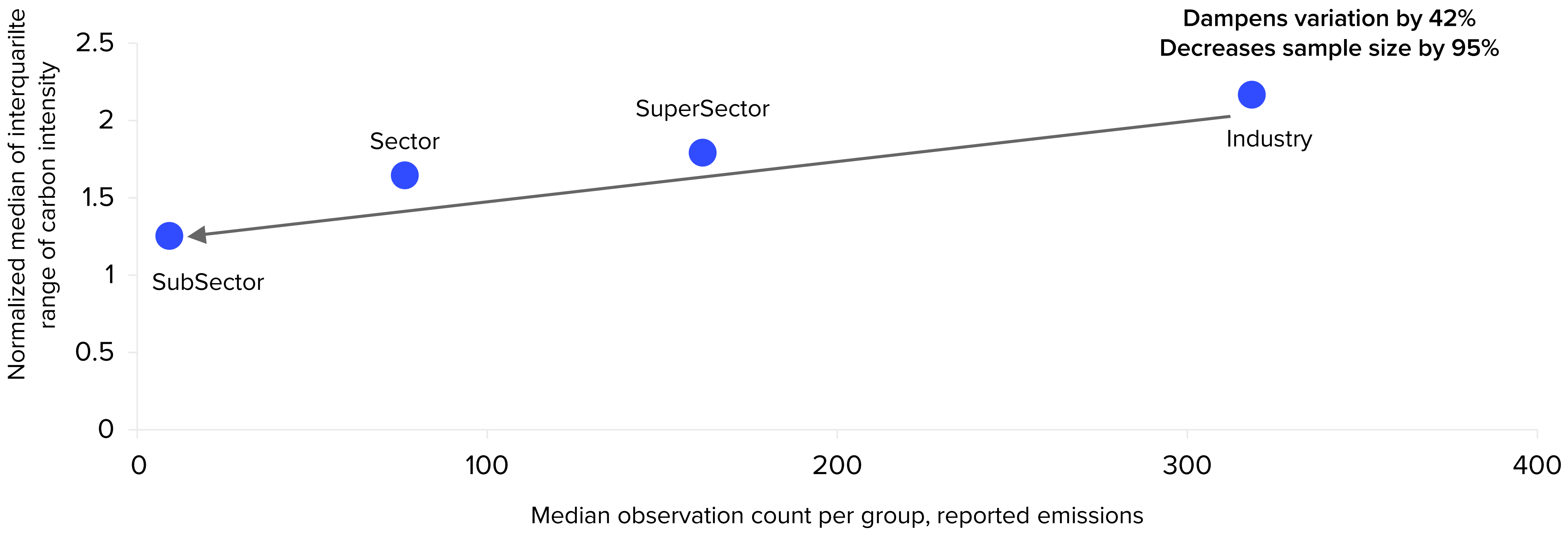
Number of disclosed revenue segments per company in different industries



Source: FTSE Russell.

Figure 16. Greater sector resolution helps estimation accuracy, but rapidly cuts sample size[42]

Median difference of peer group carbon intensity using different levels of granularity in an industry classification



Source: FTSE Russell.

Figure 17. Overview of key emissions estimation strategies

	Overview	Source	Peer Group	Key Strengths	Limitations
Extrapolation	Calculates carbon emissions by assuming carbon intensity is unchanged from a previous year	Reported Emissions	None	– Simplicity and accuracy; typically, a firm's carbon intensity does not dramatically change year-on-year	– Only applicable to small and a shrinking number of companies as disclosure improves year-on-year
Energy Production	Applies emissions intensity relative to a unit of energy generated, specific to a given fuel type	Energy Production data	None	– Highly specialized and accurate method for estimating carbon emissions based on actual energy generation activities	– Limited coverage; only applicable to Energy Utilities
Sector Median	Calculates median carbon intensity for individual sector 'peer groups' as defined by sector and region	Reported Emissions	ICB Sectors (One per company)	– Simple and interpretable – Granularity can be adjusted to focus on specific sectors or regions	– Attributing company to a single sector risks oversimplifying business models – Reliant on accurate and granular industry classification system
Regression	Quantifies relationship between firm attributes (sector, multiple financial variables) and reported carbon intensity	Reported Emissions	ICB Sectors (One per company)	– Highly flexible, allowing users to include or omit predictive variables across peer groups – Based on well-known statistical principles and benefits from set of established techniques to improve output (e.g., variable transformation or regularization)	– More complex implementations hinder contribution analysis of emissions results – Decisions in data preparation have a significant impact on the value of the eventual predictive coefficients – Highly sensitive to the underlying distributions of variables
Interpolation	Estimates carbon emissions intensity for specific business segments based on reported data by assigning a heavier weight to 'pure-play' firms	Reported Emissions	SIC Industrial Segments (Several per company)	– Generates more nuanced estimates for complex, diversified firms with multinational exposures than simpler models – 'Pure-play' or specialized companies have a greater impact on activity carbon intensities than diversified companies	– Complex, with multiple computations that can be difficult to communicate. – Accuracy depends on numerous, specialized firms to generate intensity estimates on each industrial activity – Highly dependent on quality of segment mapping
Input-Output	Derives carbon intensities for individual business segments from Environmentally Extended Input-Output (EEIO) tables	EEIO Tables	SIC Industrial Segments (Several per company)	– Transparent methodology and easily auditable – Generates nuanced estimates for complex, diversified firms with multinational exposures – Consistent boundary conditions for emissions estimates.	– Outputs highly dependent on EEIO table selected and quality of segment mapping, leading to large variation between models – EEIO tables are infrequently updated and do not reflect year-on-year trends in industry emissions levels

CHAPTER 04. Introducing a hierarchical, 'multi-model' approach

The previous chapter has shown that no single estimation strategy can be relied on to deliver outputs of comparable quality or consistency to company-reported data. In this context, markets require greater transparency about the use of estimated carbon emissions data in investment products and reporting. The choice of an estimation model carries greater significance than is often assumed, and requires careful consideration. At a minimum, routine reporting should include details on the ratio of estimated vs reported data, any adjustments or standardization of reported data, and a summary of estimation methods and model specifications, including any implementation of the Precautionary Principle (see Box 4).

To address this challenge, FTSE Russell has developed a hierarchical, multi-model approach to produce more consistent and transparent emissions data for c. 10,000 companies in the FTSE Global All Cap. This approach first prioritizes reported data, and then situational models where outputs are relatively more reliable, before drawing on a combined or 'Ensemble' estimate derived from multiple general estimation strategies (see Appendix I for details).

In model development, each estimation strategy underwent a rigorous statistical analysis to test their predictive power, correlations to one another, and volatility over time. Drawing on the procedure implemented by Kalesnick et al. (2020)[43], we calculated performance metrics for each individual strategy (Sector Median, Regression, IDW Interpolation, and Input-Output). We then systematically compared the first reported emissions of a firm to estimates from the year prior to separate test data from input data used to train the models.[44]

Box 4. The Precautionary Principle

The precautionary principle is a decision-making framework used to address situations where there is an uncertain risk of environmental damages; in such a case, the environment should be prioritized over the interests of any individual firm. For emissions, non-disclosing firms should be presumed to have an above-average carbon intensity due to the risks of systematically underestimating emissions.

Elements of the Precautionary Principle are already considered within emerging regulatory requirements. Index providers offering EU Climate Transition and Paris-Aligned benchmarks must disclose their approach to calculating emissions, the methodology used to estimate missing data, and the precautionary principle used under the EU's Article 13 Commission Delegated Regulation.

43 Kalesnik, Vitali and Wilkens, Marco and Zink, Jonas, Green Data or Greenwashing? Do Corporate Carbon Emissions Data Enable Investors to Mitigate Climate Change? (November 24, 2020). Available at SSRN: https://ssrn.com/abstract=3722973.

44 The test subset, comprising estimated observations the year before companies begin disclosing, comprise 859 observations from FY2014-2019.

We demonstrate that while an ensemble approach does not eliminate the 'estimation gap', it attenuates the idiosyncratic weaknesses of individual strategies (as expressed in volatility, bias, or inconsistent performance), delivering more dependable consensus estimates. We find that the Carbon Ensemble "Best Estimate" produces slightly lower error rates than the best performing individual model (Sector Median strategy), while—more importantly—conferring the benefits of diversifying the peer-group taxonomy and data sources. Specifically, compared to the Sector Median model, the Ensemble:

1) **Delivers significantly more consistent performance across sectors**—it ranks among the three best performing models in all 10 ICB Industries (vs 8 Industries for Sector Median, 7 for IDW Interpolation, 4 for Regression, 1 for the Input-Output model, as in Figure 18).

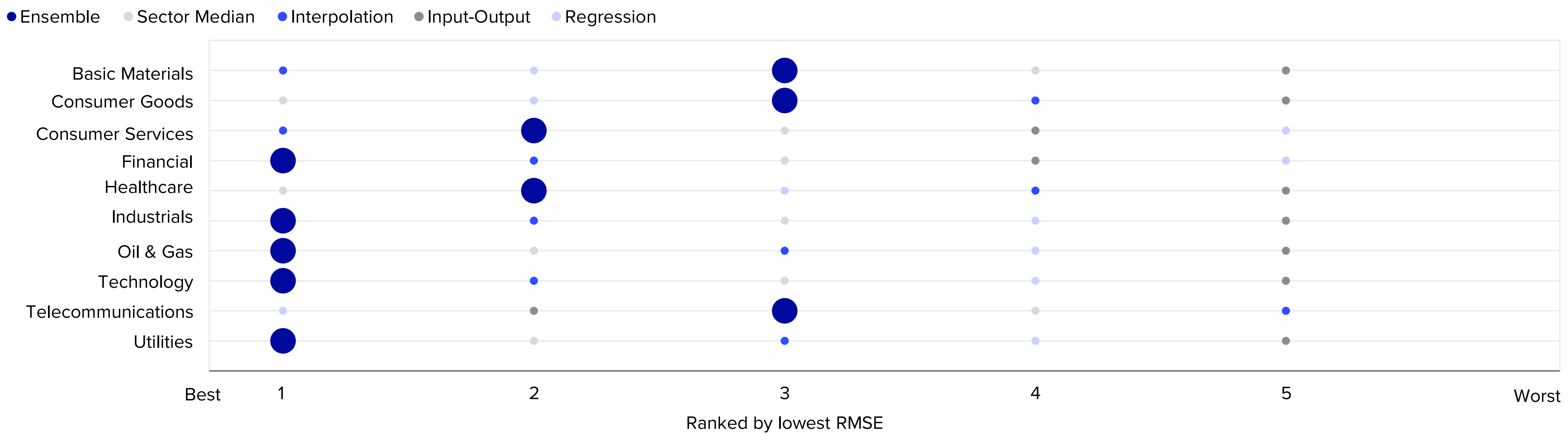
2) **Is less prone to underestimating emissions for individual constituents**—the Ensemble model underestimates emissions in 39% of cases, compared to 52% for the Sector Median model and over 60% for the Regression model. This advantage is consistent for the entire sample and critically also applies to large emitters above 50 ktpa of emissions (see Figures 20 & 22).

3) **Produces lower volatility in estimates**—the Ensemble produces a 12% lower median volatility than the Sector Median model, with 39% lower volatility than the Regression model, the highest volatility strategy (see Figure 21).

45 FTSE All World index constituents between 2014 and 2019. Estimated data is generated based on FTSE Russell's hierarchical estimation model for the year preceding a company's first instance of reporting emissions and then the compared to that reported figure. Industry classification is based on the FTSE Russell Industry Classification Benchmark (ICB).

Figure 18. Carbon Ensemble is among the best performers for all industries[45]

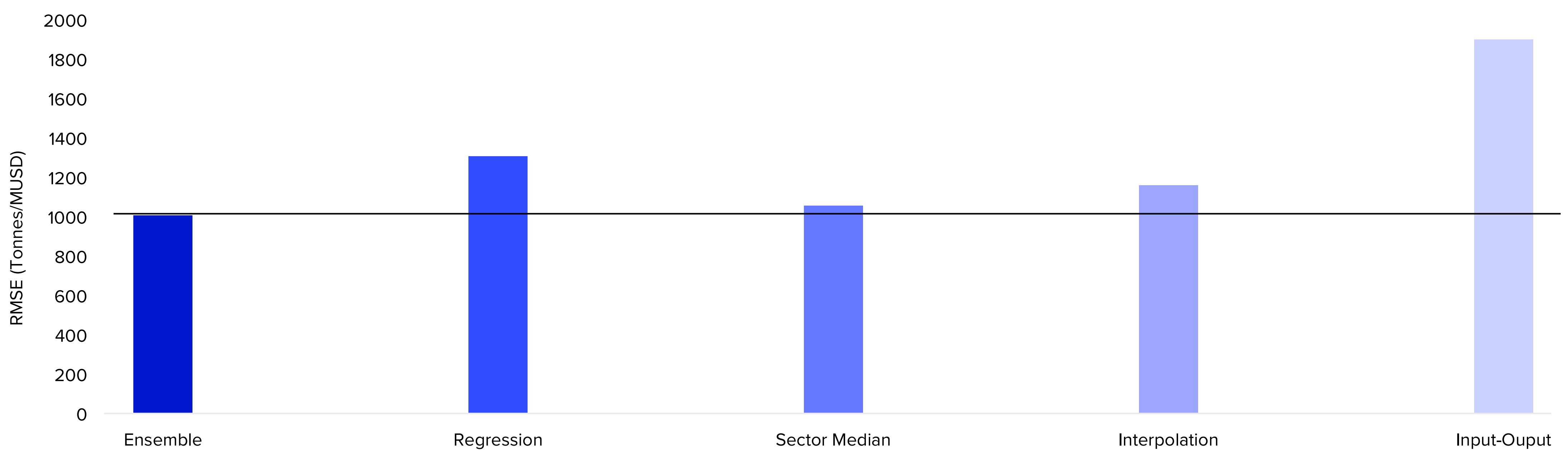
Ranked by RMSE of Carbon Intensity



Source: FTSE Russell.

Figure 19. Carbon Ensemble returns lower error than other strategies[45]

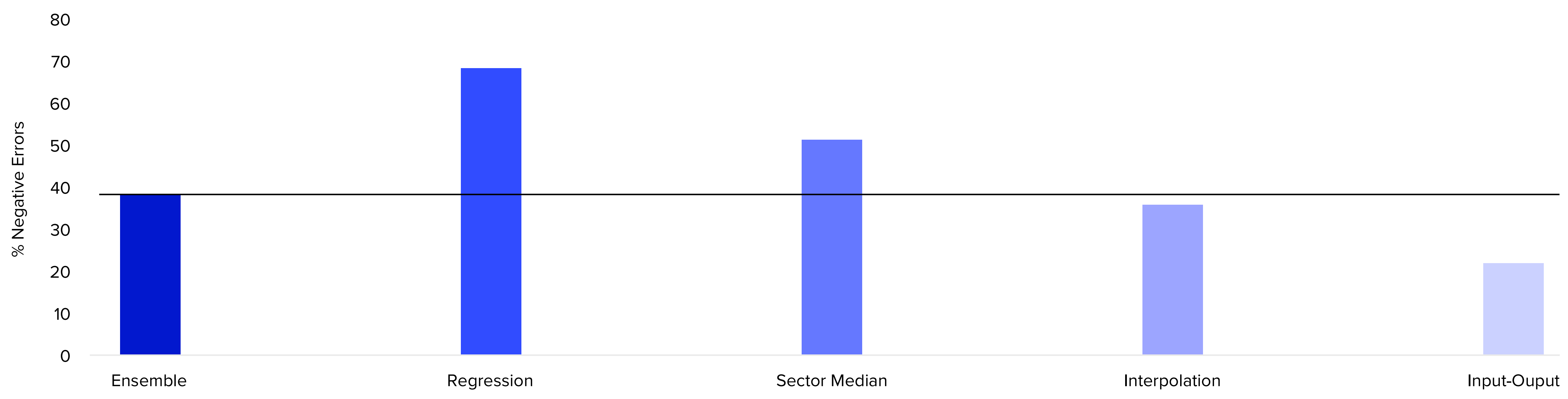
RMSE of Carbon Intensity for Estimation models



Source: FTSE Russell.

Figure 20. Sector Median and Regression models tend to underestimate emissions more frequently[45]

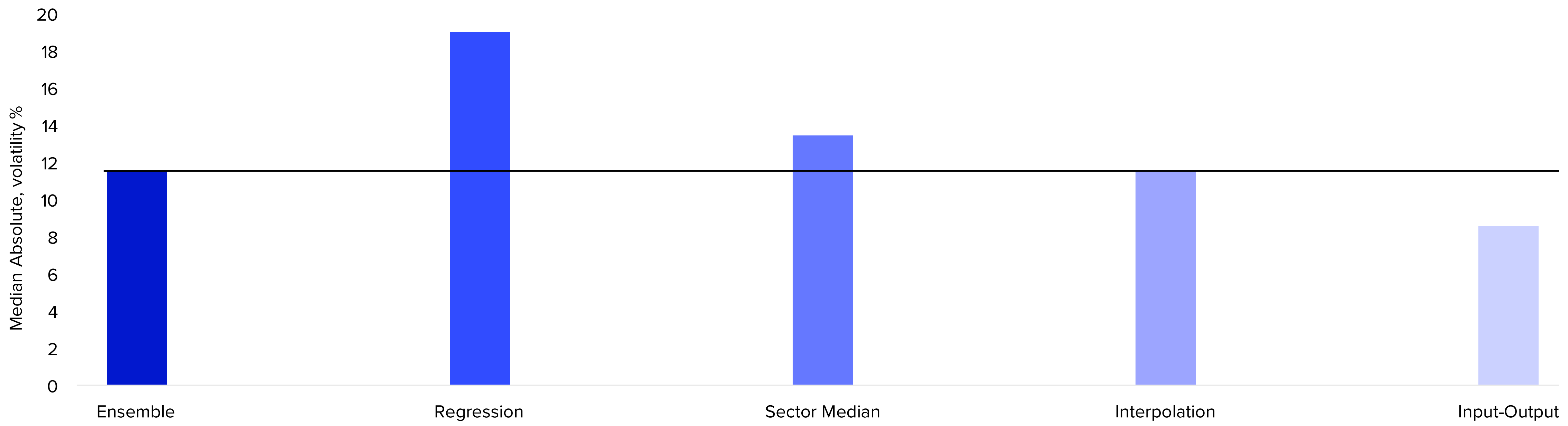
Proportion of negative errors for estimates for estimation strategies and Carbon Ensemble "Best Estimate"



Source: FTSE Russell.

Figure 21. Ensemble strategy is the least volatile strategy based on reported data[46]

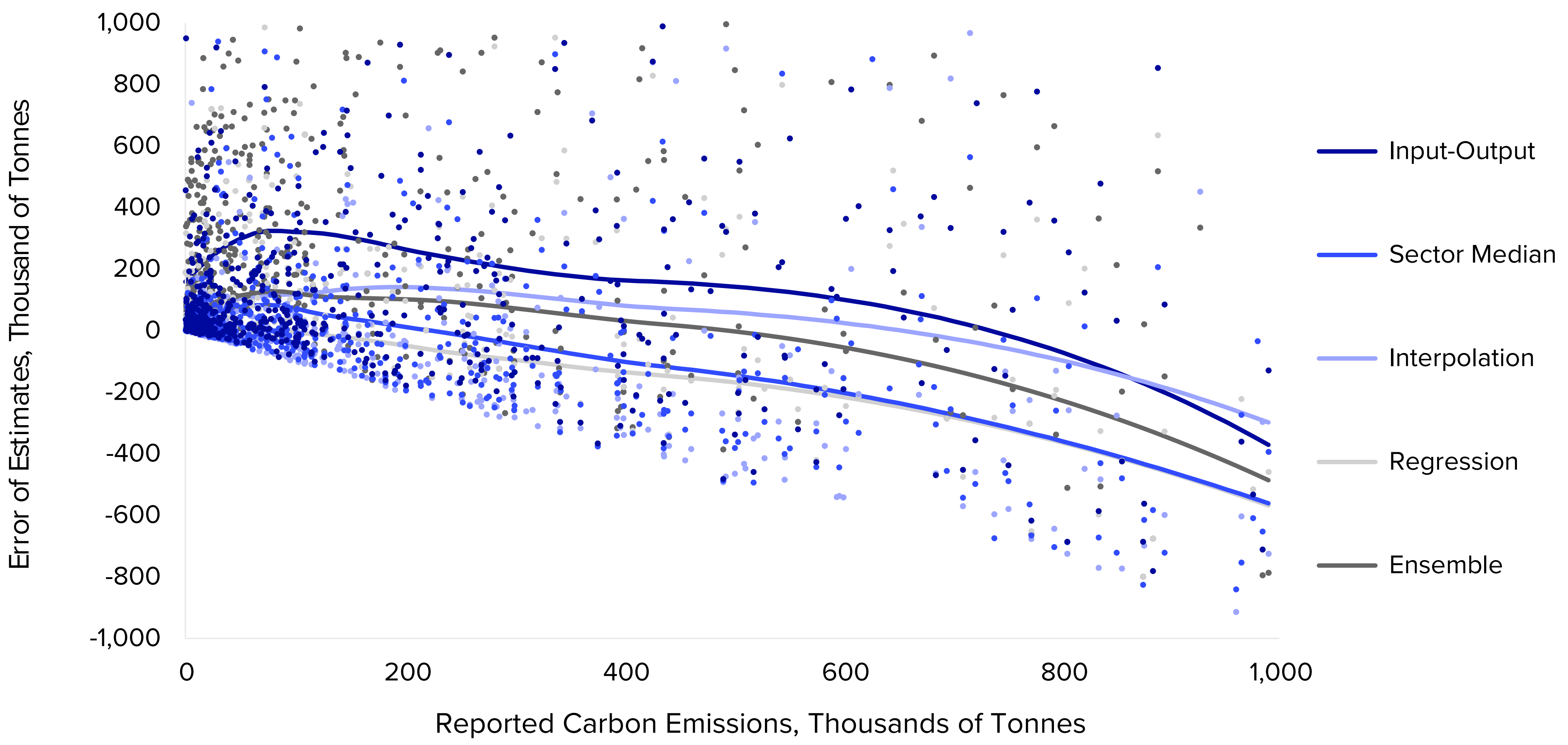
Median absolute volatility of emissions estimates for estimation strategies



Source: FTSE Russell.

Figure 22. The Input-Output approach provides a buffer against underestimation[47]

Absolute emissions associated with estimation errors for estimation strategies



Source: FTSE Russell.

46 FTSE All World index constituents for 2019. Volatility is computed as the median year-over-year relative change of emissions estimates for individual strategies.
47 Line of best fit is generated by Loess Regression.

The FTSE Russell Hierarchical Multi-Model Approach

1. Reported data

Reported data – published within publicly available company documents or CDP's annual surveys – is prioritized over the outputs of existing estimation strategies. Though quality is improving, reported data is certainly not without flaws; reporting errors remain, in part due to inconsistent and sometimes opaque carbon accounting methodologies.[48] Notably, third-party verification has yet to see universal adoption, with only around 60% of companies seeking independent verification of their operational GHG emissions data.[49]

To control for some of these issues, reported data undergoes a range of quality checks (see Appendix 1 for details). A small number of observations (less than 1 in 200) fail these checks and are excluded (i.e., treated as not disclosed). Additionally, we control for extreme values by winsorizing (i.e., replacing) intensity values at a given percentile (5%, 95%) by Year and SuperSector (ICB2). While retaining extreme observations as legitimate disclosures, this process reduces the impact of potential errors or methodological divergences, both to mitigate outlier impact on estimations and deliver more consistent distribution of reported results.

2. Extrapolation strategy

If emissions are no longer or not yet disclosed, reported data from previous years are extrapolated forward, assuming constant carbon intensity. While inferior to up-to-date reporting, scaling a company's past emissions by current revenues typically generates estimates with significantly higher accuracy than generalized estimation models. Over 74% of extrapolation estimates fall between +/-20% of the true value and over 90% fall between +/-50%—compared to just 18% and 42% respectively for the typical generalized estimation strategy.

3. Energy Production strategy for utilities

For companies in the utilities sector, where reported or extrapolated data is unavailable, we use a model based on reported energy production data. Utilities account for just 3.0% of companies but nonetheless warrant a dedicated modelling approach for two reasons.[50] First, their extreme carbon intensity: the Scope 1 & 2 emissions per unit revenue for the median utility are 33X higher than those for other sectors (see Figure 15), with absolute emissions also much higher than those of other industries (see Figure 4). Second, the extreme divergences of these carbon intensities as a function of varying fuel mixes. However, these fuel mixes are generally well-reported in available power generation data; by multiplying the volume of energy produced for each fuel type (e.g., coal, hydroelectricity, or solar) by a fuel-specific emission factor, we generate much more accurate emissions estimates for a relatively small number of typically very large emitters.

4. Carbon Ensemble "Best Estimate"

For companies where we have been unable to source data through 1), 2), or 3), we first generate estimates based on three generalized models that capture major competing estimation strategies developed in the literature and by practitioners.[51] Rather than prioritizing a particular strategy, we take the middle estimate of the values generated by these three methods to form a "best estimate" of a company's emissions intensity for each emissions scope respectively, balancing the strengths of different strategies and partially offsetting inherent biases.

48 Talbot, D., Boiral, O. GHG Reporting and Impression Management: An Assessment of Sustainability Reports from the Energy Sector. J Bus Ethics 147, 367–383 (2018). https://doi.org/10.1007/s10551-015-2979-4.

49 Based on analysis of the FTSE All World index as at 31/12/2020 using FY2019 disclosures.

50 FTSE All World constituents, as at 28/02/22.

51 Among the two techniques using Sector-level peer-group assignments, Regression and Sector Median, both show similar error rates with high correlation. The Regression strategy is excluded due as the overwhelming contribution of sector classification to the estimated carbon intensity, ineffectively distinguishing it from the simple median approach, with lower transparency of coefficients and sector-specific shortcomings in Financials.

Figure 23. FTSE Russell hierarchical carbon model process uses general estimation models as a last option[52]

Distribution of companies, emissions, and market capitalization across FTSE Russell's hierarchical carbon model

52 FTSE All World index constituents as at 31/12/2020. Estimated data is generated based on FTSE Russell's hierarchical estimation mode outlined. Calculations consider Scope 1 and 2 quantities separately.

Appendix I.
Delineating the carbon strategies

Common approaches to estimating corporate carbon emissions draw on a range of inputs and statistical techniques. Most frequently, a company's sector and region of operation, its reported financial metrics, and the emissions of peer firms are considered through an array of methods (e.g., simple peer comparisons, linear regressions), to generate an estimation of a company's carbon intensity. Another common technique derives the carbon intensity of industrial activities from environmentally-extended Input-Output (EEIO) tables rather than reported emissions figures.

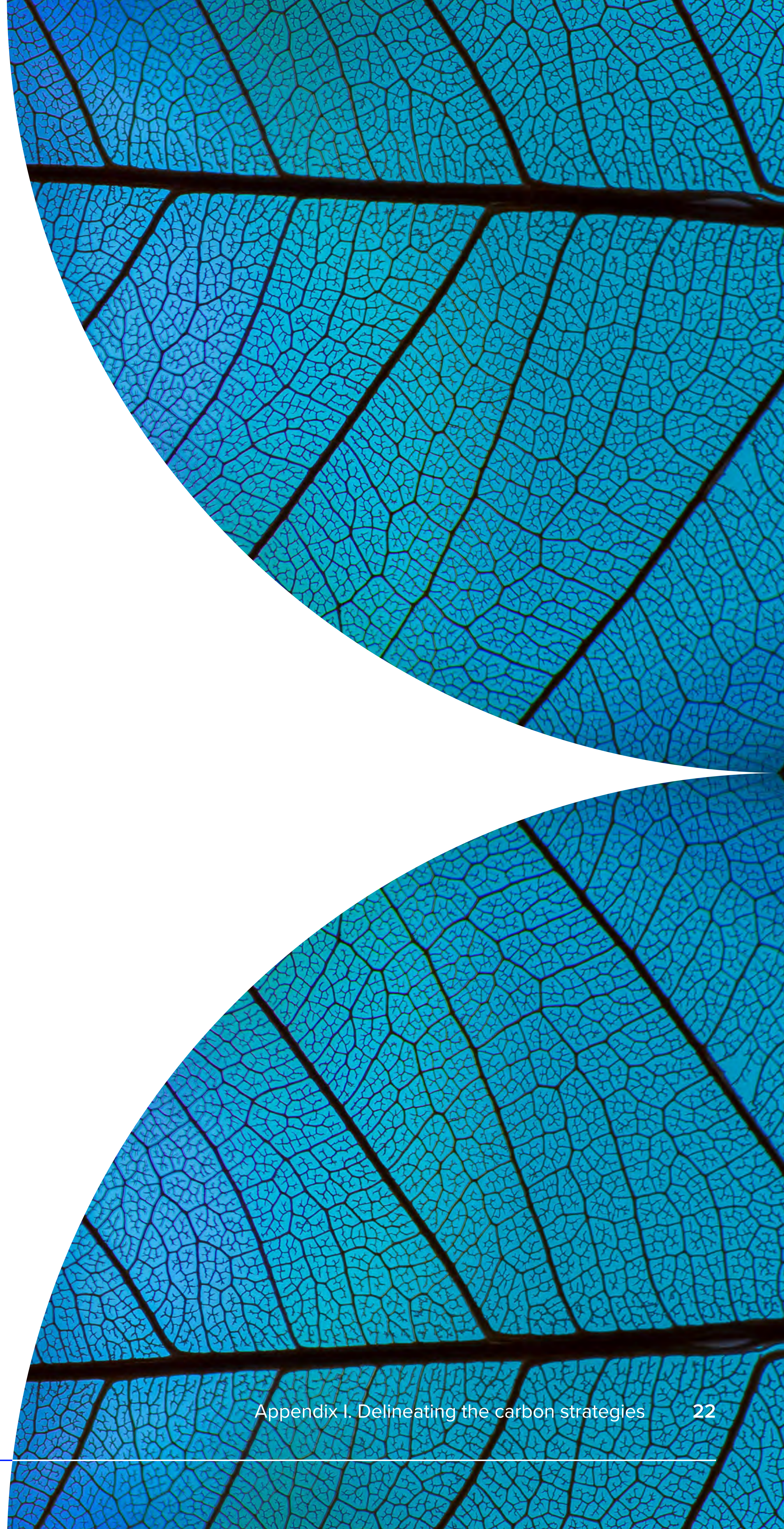
Figure 24. Core Carbon Emissions Estimation Strategies

Proportion of negative errors for estimates for estimation strategies and Carbon Ensemble "Best Estimate"

	MAP COMPANY TO PEER GROUP	CALCULATE REPORTED INTENSITIES	ESTIMATE INTENSITY FOR NON-REPORTERS	ESTIMATE EMISSIONS FOR NON-REPORTERS
Sector median	Assign company to sector and region 1 company to 1 sector & region	Divide by annual revenue	Calculate median carbon intensity for each sector	Multiply estimated intensity by company revenue
Regression	Assign company to sector and region 1 company to 1 sector & region	Divide by annual revenue	Regress predictor metrics against carbon intensity to generate coefficients	Multiply coefficients by predictor variables
Interpolation	Map company revenue to industrial activity segments 1 company to many segments	Divide by annual revenue	Calculate average carbon intensity for each segment	Multiply estimated segment intensity by company revenue segment
Input-Output	Map company revenue to industrial activity segments	n/a	Derive emissions intensities by activity from EEIO table	Multiply estimated segment intensity by company revenue segment

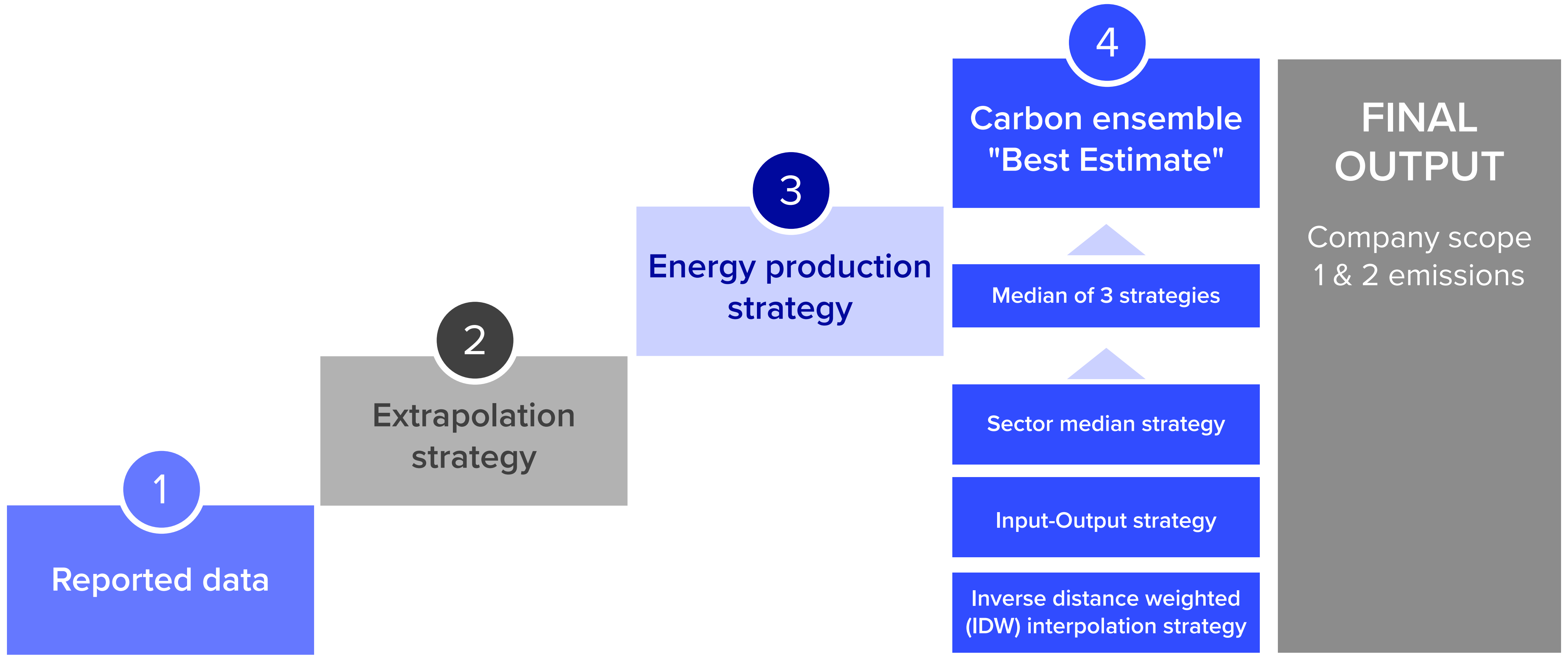
Source: FTSE Russell.

There is overlap in the core steps followed by common estimation strategies (see Figure 24); for example, most strategies rely on a sector mapping or revenue classification to appropriately designate a peer group for the firm. However, strategies differ in their statistical method, use of disclosed data, and how they classify and partition these industrial activities. Their effectiveness varies on a sector-to-sector and company-to-company basis, depending on the sector diversity and company activities, or how well strategies model the business context of a given firm.



FTSE Russell’s Hierarchical Multi-model approach

Figure 25. FTSE Russell hierarchical carbon model process uses general estimation models as a last option[53]



I. Reported Emissions

Scope 1 and 2 emissions data are sourced from company disclosures (e.g., Annual Reports, CSR Reports) and CDP annual surveys. Scope 2 Location-Based emissions are used as a default over Market-Based emissions; Location-Based emissions are a more consistent proxy for electricity usage by operations,[54] and reflect changes in the underlying electricity mix of the grid and efficiency of company operations.[55] In the specific case of Real Estate Investment Trusts (REITs), emissions data from property portfolios is preferred over the REIT’s office emissions alone.

We ask issuers to review the emissions data that we have collected and provide comments if they believe the information is incorrect or incomplete. We review all company feedback and incorporate changes to our dataset where appropriate.

Subsequently, all reported data are quality checked for incorrect units, extreme observations and minimum boundary conditions of the observations. As part of this process, a small number of reported datapoints (less than 1 in 200) are typically corrected or screened out.

Scope 1 & 2 emissions data are winsorized at the 5% most extreme observations in terms of carbon intensity for a given fiscal year and SuperSector (ICB2). Thus, carbon intensity observations lower than the 5th percentile or greater than the 95th percentile are set to the value of the 5th or 95th percentile respectively. The carbon emissions values are then rederived from the new carbon intensity value by multiplying by net revenue.

53 FTSE All World index constituents as at 31/12/2020. Estimated data is generated based on FTSE Russell’s hierarchical estimation mode outlined. Calculations consider Scope 1 and 2 quantities separately.

54 Matthew Brander, Michael Gillenwater, Francisco Ascui. Creative accounting: A critical perspective on the market-based method for reporting purchased electricity (scope 2) emissions. Energy Policy, Volume 112, 2018, Pages 29-33.

55 Location-Based Scope 2 emissions use grid-average emissions factors to calculate emissions from electricity consumption, whilst market-based figures use emissions factors based on contractual energy purchase (e.g., via renewable energy credits or power purchase agreements). For more information, please see Matthew Brander, Michael Gillenwater, Francisco Ascui, Creative accounting: A critical perspective on the market-based method for reporting purchased electricity (scope 2) emissions, Energy Policy, Volume 112, 2018, Pages 29-33, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2017.09.051.

2. Extrapolation strategy

If emissions data are no longer disclosed, company reported data from previous years are extrapolated to the current year assuming constant carbon intensity over time. In other words, previously reported carbon intensity is multiplied by current revenues to derive an emissions estimate. For this purpose, we consider up to three years of data, selecting the most recent available disclosure.

3. Energy Production Strategy

For the Utilities Industry, the Energy Production approach estimates company carbon emissions by applying emissions factors (i.e., emissions per unit energy) to corporate reported energy production. Where a company reports a breakdown of the fuel sources it has used to generate energy (e.g., coal, gas, or hydroelectricity), emissions factors used to generate absolute emissions figures from each source are summed to produce an aggregate emissions total from energy generation.

Emissions factors are derived from the IPCC emissions factor database, using the Life Cycle emissions for each emissions the more consistent and conservative value, especially among renewable resources. Energy sources considered include:

i. *Fossil Fuels—Coal, Oil, Gas and/or Combined Cycle Gas Turbines*

ii. *Hydroelectric*

iii. *Renewables—Wind, Solar, Geothermal, Biomass, Overall renewables (if not otherwise broken down)*

4. Carbon Ensemble “Best Estimate”

The FTSE Russell Carbon Ensemble Model is the median of the Sector Median, Interpolation, and Input-Output strategies on the level of company and emissions scope. If a value for one or more of the strategies is not available, the median will be completed on the remaining values.

4a. Sector Median strategy

The Sector Median strategy assigns a company the median carbon intensity of its sector and region peers. A company is attributed the median emissions intensity of the most granular peer group, for which there are at least 10 observations. Therefore, results can be easily interpreted as the typical carbon intensity disclosed within a company’s peer group. In our model implementation, we use reported observations from the last three years to generate the sector median in order to reduce potential volatility in the estimate.

The simplicity of the approach allows the selection of a highly-specific sector (e.g., North American waste management), while still yielding stable results. Drawing on disclosed emissions means that sector trends and recent operational efficiencies are immediately reflected in estimations.

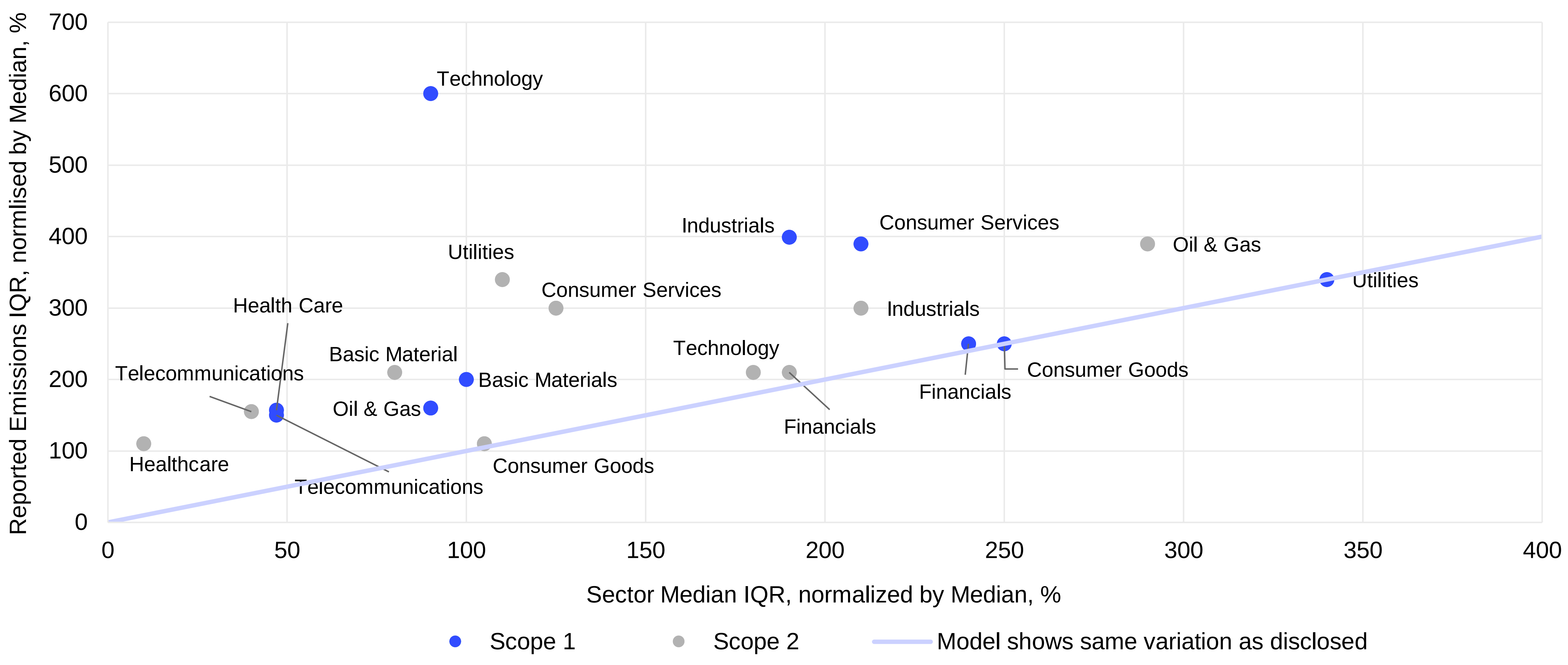
While showing low typical levels of error on aggregate, the Sector Median has two main drawbacks—relatively high volatility, and consistent underestimations. Around 52%[56] of model outputs are underestimates (see Figure 20), which in practice risks attributing lower carbon intensity to non-reporting companies than is warranted and disincentivizing timely disclosure.[57]

Underestimates might be driven by fact that the Sector Median strategy lacks the flexibility to account for highly diversified business models. Significant confidence is placed in ICB sector classification, as all companies within a sector peer-group will share a single carbon intensity. This can be seen in Figure 26, as the Sector Median implementation dramatically decreases intra-industry dispersion of carbon intensity as measured by the interquartile range[58] divided by the median value. By this metric, variability decreases by more than six-fold in the Technology industry, meaning the variation of emissions intensity of technology stocks is not captured by the strategy.

56 Returns a 7% lower overall portfolio Carbon intensity for the FTSE-All World index, even when utilising reported data where available.
57 Rogelj, J. et al. *Nature* 591, 365-368 (2021). Net-zero emissions targets are vague: three ways to fix (nature.com).
58 Interquartile Range (IQR) is defined as the distance in each distribution between the 1st and 3rd quartile or p75 – p25 in terms of percentile.

Figure 26. Sector Median strategy significantly simplifies emissions intensity profiles in various industries

Sector Median strategy and disclosed values compared using Normalized InterQuartile Range (IQR)Variability of Carbon Intensity:



Source: FTSE Russell.

4b. Input-Output Strategy

The Input-Output strategy estimates a company's emissions based on business segment intensities derived from the Exiobase Environmentally Extended Input-Output (EEIO) table, and is the only strategy which does not consider reported corporate data. Instead of relying on reported emissions, the Input-Output strategy offers an economy-wide perspective, estimating emissions[59] associated with various products by accounting for the production flows[60] between sectors and countries. Exiobase Environmentally Extended Input-Output (EEIO) is used to derive emissions intensity estimates by country and by business segment (NACE code). Carbon Intensities are then adjusted for inflation on a yearly basis.

EEIO tables are static representations of the economy, and are updated only periodically. This lack of connection to disclosed numbers, as well as variations in assumptions, resolution and update frequency, can create large differences in intensity estimation relative to contemporary corporate reporting.

59 Kitzes, Justin. 2013. "An Introduction to Environmentally-Extended Input-Output Analysis" Resources 2, no. 4: 489-503. https://doi.org/10.3390/resources2040489.

60 Miller, R. E., & Blair, P. D. (2021). Input-Output analysis foundations and extensions. Cambridge University Press.

Avoiding company disclosed data commensurately decreases realized volatility, but radically reduces the accuracy of estimations and results in consistent overestimates of carbon intensity across industries, with 78% of observations overestimated (see Figures 20 and 22). Results show estimations derived from our Input-Output strategy deliver a significant proportion of overestimations relative to reported corporate results across industries, with a majority of estimations in all industries, besides Basic Materials and Telecommunications, showing a positive bias.

4c. Inverse Distance Weighted (IDW) Interpolation

A unique offering at FTSE Russell, the Inverse Distance Weighted (IDW) Interpolation strategy uses company-level emissions data to estimate segment-level emissions intensity by SIC Industrial Segment, weighing the contribution of each company by the proportion of its revenues dedicated to that segment. Due to the complexity of interpolating segment level intensities from company level data, this strategy generates a higher error rate than both the Ensemble and Sector Median (See Figure 20). However, consideration of segment revenues results in a lower rate of underestimation and diminished volatility as compared to Sector Median approach (14% and 12% lower, respectively).

Taking an exponential of the revenue proportion (e.g., power of 2) increases the importance of ‘pure plays’, or companies that concentrate in relatively few activities, to the estimation of those activities’ carbon intensity. In our implementation, we use reported observations from the last three years to generate the IDW interpolation estimate in order to reduce potential volatility.

Figure 27. Segment Carbon Emissions intensity estimates

Segment Carbon Emissions Intensity Estimates are generated by calculating an adjusted weighted average of the firms who have exposure to this segment.

$$CI_j = \frac{\sum_{i,j}^{n} W_{i,j}^{k} * CO2_i}{\sum_{i,j}^{n} W_{i,j}^{k} * Sales_i}$$

Where $\mathbf{CI}_j$ is the Carbon Intensity of a segment, $W_{i,j}$ is the proportion of the revenues of *Company i* recieved from *Segment J* and **K** is an exponential constant (>1) which deweights contribution from companies with a low proportion of revenue exposure to this segment

Source: FTSE Russell.

IDW Interpolation strategy generates nuanced estimates for companies with complex business exposures that are not effectively summarized by a single sector assignment. For example, the Heavy Construction subsector has numerous common industrial segments. By considering each segment individually, the resulting carbon intensities diverge significantly (by more than 7x) from the top-line sector level, suggesting that a tailored approach which considers the segment revenues of each firm might be superior.

However, companies with a single industrial segment, which have the highest contribution to the Interpolation strategy relative to their revenues, constitute less than half of the overall firms in the equity universe. For instance, a high proportion of pure plays in Healthcare suggests that more accurate results will be generated for this sector than for Financials, which has a high diversification across business activity.

4d. Regression

Note that FTSE Russell maintains a Regression model, but this is not included in the hierarchical, multi-model approach

The FTSE Russell regression strategy quantifies a predictive relationship by sector peer group between multiple financial variables and reported carbon intensity; this relationship is then used to estimate emissions for non-reporting companies. The following financial variables are used as predictors: Gross Cost Revenues, Accumulated Depreciation, and Net Assets. Individual regressions are performed per sector peer group, with the highest resolution peer group for which there are at least 30 observations used to estimate emissions for a given firm. In our implementation, we use reported observations from the last three years to generate the IDW interpolation estimate to reduce potential volatility.

Since this strategy uses multiple variables to predict carbon intensity, differences in company attributes drive more nuanced estimates of carbon intensity, resulting in high dispersion of results within a given peer group. However, sector membership and proxy variables for size (such as Revenues) are by far the most important predictors.

The relative complexity of the Regression approach requires a greater number of datapoints, making it difficult to deploy on more granular sector groups. Additionally, regression strategies can be volatile (see Figure 21) and onerous to interpret, since the inclusion of multiple correlated variables can result in unpredictable and unintuitive coefficients.

Figure 28. Regression Equation

Regression coefficients are generated by running a multivariate regression between carbon intensity and a suite of financial variables on a sector-level

$$CI_i = \beta_{0j} + \beta_{1j}G_i + \beta_{2j}A_i + \beta_{3j}D_i$$

Where:

$\mathbf{B_j}$ are the coefficients for Sector j

$\mathbf{CI_i}$ is the Carbon Intensity of *Company i*,

$\mathbf{G_i}$ is Gross Cost of Revenues of *Company i*,

$\mathbf{A_i}$ is Net Assets of *Company i*,

$\mathbf{D_i}$ is Accumulated Depreciation of *Company i*

Appendix II. Data Sources

Financial Data

Company-level financial data are sourced from WorldScope as inputs into carbon intensity calculations and estimation strategies. This includes the following metrics:

- Revenue
- Segment Revenues (see Business Segment Taxonomy, below)
- EBITDA
- Total Assets
- Net Depreciation

Sector Taxonomies

FTSE Russell's Industry Classification Benchmark[61] (ICB) is used to create peer groups for several estimation strategies – Sector Median and Regression strategies – as well as in the winsorization of extreme values.

Model analysis in this paper was based on Legacy ICB—models will be migrated to New ICB in the second half of 2022.

Business Segment Taxonomy

Two business segment mappings, US SIC[62] and NACE taxonomies, are utilized to make use of multiple third-party data providers. By default, we utilize US SIC taxonomy to define business segments and segment revenue sourced by WorldScope. Exiobase, provider for the Input-Output data, uses NACE taxonomy to map business activities. We use an internal conversion table to map estimated intensities by NACE code to SIC code.

Environmentally Extended Input-Output (EEIO) tables

We use the Exiobase3 table to create Scope 1 & 2 business activity carbon intensities for the Input-Output strategy and energy-source based emissions intensities for the Energy Production model.

Exiobase is a "Multi-Regional Environmentally Extended Input-Output table" (MRIOT-EE) derived from national resource-usage tables.[63] Exiobase uses its own product and industry classification with any given industry producing one or more different products.

Energy Production Data

Energy production data and fuel mix proportions for utilities companies are sourced from the FTSE Russell ESG Rating data model.[64] Additionally, data on the proportion of renewable energy produced by companies is sourced from FTSE Russell.

61 Industry Classification Benchmark (ICB), FTSE Russell, accessed 10/03/2022.
62 Standard Industrial Classification (SIC) Manual, Occupational Safety and Health Administration, accessed 10/03/2022
63 Exiobase3 Data Download, Exiobase, accessed 08/02/2022.
64 ESG Ratings, FTS ERussell, accessed 10/03/2022.

Regional classification information

We assign companies to a region to create peer groups for several estimation strategies—the Sector Median and Regression strategies. For this, we largely align our regional definitions with those used within the FTSE Russell Global Equity Index Series,[65] but combine classifications for Japan, China, Asia Pacific ex China ex Japan to create a larger dataset of reported data for these regions where disclosure is often more limited.

Developed Europe	Emerging Europe	North America	Latin America	Asia Pacific	Emerging Asia	Middle East & Africa
Austria	Czechia	Canada	Brazil	Australia	China	Egypt
Belgium	Greece	United States	Chile	Hong Kong	India	Israel
Denmark	Hungary		Colombia	Japan	Indonesia	Qatar
Finland	Russia		Mexico	Korea	Malaysia	Saudi Arabia
France	Turkey		Peru	New Zealand	Pakistan	South Africa
Germany				Singapore	Philippines	UAE
Ireland					Taiwan	
Italy					Thailand	
Netherlands						
Norway						
Poland						
Portugal						
Spain						
Sweden						
Switzerland						
United Kingdom						

65 Global Equity Index Series, FTSE Russell, accessed 07/03/2022.

Disclaimer

Visit lseg.com/ftse-russell

About FTSE Russell (LSEG)

FTSE Russell is a leading global provider of index and benchmark solutions, spanning diverse asset classes and investment objectives. As a trusted investment partner we help investors make better-informed investment decisions, manage risk, and seize opportunities.

Market participants look to us for our expertise in developing and managing global index solutions across asset classes. Asset owners, asset managers, ETF providers and investment banks choose FTSE Russell solutions to benchmark their investment performance and create investment funds, ETFs, structured products, and index-based derivatives. Our clients use our solutions for asset allocation, investment strategy analysis and risk management, and value us for our robust governance process and operational integrity.

For over 35 years we have been at the forefront of driving change for the investor, always innovating to shape the next generation of benchmarks and investment solutions that open up new opportunities for the global investment community.

To learn more, email info@ftserussell.com; or call your regional Client Service Team office:

EMEA
+44 (0) 20 7866 1810

North America
+1 877 503 6437

Asia-Pacific
HONG KONG +852 2164 3333
TOKYO +81 (3) 6441 1430
SYDNEY +61 (0) 2 7228 5659

FTSE RUSSELL
An LSEG Business