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A data driven approach for portfolio decarbonization

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Abstract

An increasing number of institutional investors are integrating ESG and climate-related considerations into investment process. In this context, prevailing frameworks use backward-looking and forward-looking climate metrics, each with specific advantages and limitations. In addition, current practices often fail to capture the materiality of firms' activities for the transition.

Such approaches may result in paper decarbonization, in methodological complexity, and in a significant distortion in portfolio allocations across sectors and companies. To address these pitfalls, we propose a data-driven approach based on a commitment indicator and a classification of transition-relevant activities, integrating backward- and forward-looking information from multiple data sources. An empirical analysis shows that it is possible to decarbonize portfolio and simultaneously favour committed companies without deviating excessively from the benchmark. Compared with an unconstrained case, portfolios constructed using this approach exhibit higher exposure to "brown but committed" securities.

Keywords: Sustainable finance, Portfolio decarbonization, Climate transition commitments

JEL classification: G11, G12, Q56

Contents

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The views expressed herein are those of the authors and do not necessarily reflect those of the Bank of Italy.

Introduction

An increasing number of institutional investors are integrating environmental, social and governance (ESG) and climate-related considerations into investment and risk-management strategies. Sustainability criteria are typically introduced alongside traditional financial objectives in the risk–return space. In line with emerging practices, investors may also seek alignment with carbon-neutrality goals by leveraging available climate-transition data while preserving the portfolio's risk–return profile.

In this context, current frameworks increasingly rely on both backward-looking and forward-looking climate metrics. Each offers strengths and limitations. Backward-looking indicators are widely available and methodologically transparent, but they present a key shortcoming: reducing exposure to high emitters and reallocating it to low emitters helps achieve portfolio-level decarbonization targets yet does not necessarily contribute to real-economy emissions reductions. These naïve decarbonization strategies have been described as forms of *paper decarbonization* (GFANZ, 2023; Angelini, 2024).

An emerging paradigm, instead, promotes supporting high emitters that are genuinely engaged in transition efforts. From this perspective, a truly green company is not necessarily a low emitter, but rather a "virtuous" high emitter that effectively and transparently works to reduce its carbon footprint. Investors are therefore encouraged to channel capital toward transition leaders, underweight exposures to laggards, and reward ambitious and credible decarbonization plans. Forward-looking metrics offer a potentially powerful framework to assess transition alignment, yet their implementation remains hindered by methodological complexity and limited transparency.

Moreover, most investment strategies overlook the material relevance of firms' activities in driving or hindering the low-carbon transition. In such cases, applying forward-looking metrics broadly and under carbon constraints may generate adverse effects on portfolio construction. Without distinguishing between activities that are genuinely material for the transition and those with limited impact, investors risk overweighting companies or sectors with strong formal commitments but limited real influence on aggregate emissions.

To address these challenges, the paper proposes a two-pillar approach:

(i) a forward-looking indicator based on firms' decarbonisation commitments, to be used alongside the backward-looking carbon-intensity metric;

(ii) a classification of transition-relevant activities.

The commitment indicator combines multiple data sources and captures three key dimensions: the level of carbon-neutrality ambition; the presence of time-bound commitments to reduce material emissions over at least a three-year horizon; and the alignment of medium- and long-term decarbonisation trajectories with a 1.5°C scenario.

Transition-relevant activities are identified within the NACE sector classification by isolating those associated with the highest direct emissions in the European Union, along with activities whose products or services generate high indirect (scope 3) emissions.

As an illustration, we present the results of an optimization that combines the *commitment indicator* with the *classification based on material activities*. We simulate portfolios managed against a traditional benchmark, which are progressively tilted towards increasingly ambitious levels of the commitment indicator. The optimisation shows that, compared to the case of a more traditional tilting, that does not rely on the proposed methodological innovations:

a) the overall exposure to high-emitting firms increases as the constraint on the indicator becomes more ambitious; at the same time, within such exposure, the share of firms with stronger commitments increases as well, at the expense of those with weaker commitments;

b) introducing a constraint on the indicator does not significantly increase the financial deviation from the benchmark (tracking-error volatility, TEV), except in the case of very ambitious constraints, where the reduced portfolio breadth leads to higher TEV.

The paper is structured as follows. Section 1 reviews current practices; Section 2 presents the proposed framework; Section 3 discusses the results of the portfolio-optimisation exercise.

1. Current practices

Current portfolio decarbonization practices rely on two main building blocks: climate-related metrics and the relevance of economic activities for the transition. The first concerns how investors assess firms' past and prospective contributions to decarbonization, typically combining backward-looking and forward-looking indicators. The second refers to how sectors and activities are classified according to their materiality for achieving the transition, which shapes the interpretation and application of metrics in portfolio construction. The following paragraphs consider key pitfalls associated with climate-metric use, as well as sectoral and firm-level allocation effects emerging in common portfolio decarbonization practices.

1.1 Carbon Metrics

Most transition strategies rely heavily on backward-looking indicators, such as carbon emissions and related metrics (e.g. footprints and intensities). These metrics are easily available and require limited input from firms' financial data, but their informational value is constrained by several limitations.

First, portfolio carbon metrics can be improved simply by underweighting or excluding high emitters — even when these firms have credible transition plans (Angelini, 2022a). Divesting may reduce exposure to transition risks but does not necessarily translate into real-economy emissions reductions. Making finance more expensive for high emitters may even induce them to retain polluting technologies that require less capital (Hartzmark and Shue, 2023).

Second, if many investors simultaneously stop financing high emitters before substitutes are available, the prices of carbon-intensive products may surge — an instance of the *fallacy of composition* (Angelini, 2022b). What is feasible for a single investor may not be feasible collectively unless major technological breakthroughs or rapid shifts in consumption occur.

Third, backward-looking metrics offer limited insights into a firm's ability to follow a net-zero pathway. Since they exclude information on corporate transition plans, they can identify alignment only ex post.

Recent approaches increasingly incorporate forward-looking metrics, such as carbon transition scores, climate value-at-risk and implied temperature rise measures. These indicators take two main forms: (i) complex, model-based metrics and (ii) commitment-based metrics reflecting firms' decarbonization targets, notably those validated by the Science Based Targets initiative (SBTi).

Both approaches face limitations. Model-based metrics depend on heterogeneous assumptions and methodologies regarding emissions pathways, carbon-budget allocations across sectors and countries, the relationship between carbon-budget overshoots and long-term temperature outcomes, and the evolution of carbon prices. These modelling choices can yield inconsistent results across datasets and are often only partially disclosed, undermining transparency and replicability. Commitment-based metrics depend on SBTi coverage, which remains partial and concentrated in large, listed firms and specific sectors. Several high-emission or hard-to-abate sectors, including parts of the energy industry, still lack complete methodological guidance.

1.2 Activities

Most strategies overlook the material relevance of firms' activities in driving or hindering the transition. The EU Climate Benchmark Regulation (Regulation (EU) 2019/2089) distinguishes between high-climate-impact sectors (HCIS) and low-climate-impact sectors (LCIS) based on their contribution to total greenhouse gas emissions. HCIS include energy, utilities, transport, materials (e.g. steel and cement) and agriculture — sectors responsible for a large share of global emissions. These industries are expected to deliver substantial emission reductions. LCIS include finance, health care, information technology and communications, where alignment is assessed through indirect channels such as financing or supply-chain decisions.

Within EU Climate Transition Benchmarks (CTB) and Paris-aligned Benchmarks (PAB), exposure to HCIS must at least match their weight in the investable universe. The Technical Expert Group (TEG, 2020) mapped NACE classes to several sector classification systems, including BICS (Bloomberg), GICS (MSCI and S&P), ICB (FTSE) and TRBC (Refinitiv). Under GICS, 129 out of 185 sub-industries — around 70% — are classified as HCIS. This breadth has attracted criticism (Le Guenedal and Roncalli, 2022): nearly all economic activities are deemed critical for the transition. Only communication services and financials are classified exclusively as LCIS, while over half of health care and information technology sub-industries fall under HCIS.

The original rationale for the HCIS constraint was to ensure adequate financing for sectors essential to the transition, such as energy and utilities. With such a broad classification, however, the constraint becomes weak and may encourage substitutions *between* sectors or industries rather than *within* them (ESMA, 2022). This can lead to misalignments — for example, shifts from electricity generation to health-care equipment, rather than between green and brown electricity producers — a concern also highlighted in supervisory discussions (NGFS, 2023).

2. The proposed approach

To address these limitations, we propose an approach that integrates both backward-looking (carbon intensity) and forward-looking (commitment-based) information. The framework combines data from multiple sources and focuses on relevant activities for the transition. The following sections present a *commitment indicator* and a *classification of material activities*.

2.1 The commitment indicator

The *Commitment Indicator* (CI) measures the extent to which companies align with a net-zero pathway. It evaluates four key features drawn from leading frameworks on corporate transition plans (Climate Action, 2023; GFANZ, 2022; TPT, 2023). Each feature receives a binary score — 0 if the verification criteria are not met, 1 if they are — yielding an overall CI that ranges from 0 (no feature verified) to 4 (all features verified).

The features are as follows:

- an ambition to achieve carbon neutrality within a timeframe within a science-based timeframe
- a commitment to reduce material emissions over at least three years;
- the alignment of the decarbonisation trajectory with a 1.5°C scenario in the medium term;
- the alignment of the decarbonisation trajectory with a 1.5°C scenario in the long term.

Commitment indicator

Table 1

Feature	Description	Score
Net zero ambition	Net-zero targets expected to be achieved by 2050 (2040)	0/1
Commitment on material emission	Commitment to reduce material emissions over a time horizon of at least 3y	0/1
Medium term NZ alignment	Decarbonization trajectory in line with a 1.5°C scenario by 2030	0/1
Long term NZ alignment	Decarbonization trajectory in line with a 1.5°C scenario by 2050	0/1

Source: SBTi, TPI, ESG providers

Multiple data sources can be used, combining public information — such as SBTi, the Transition Pathway Initiative (TPI), and company reports or other disclosures — with private data from ESG providers. These sources provide complementary views of firms' climate performance: SBTi validates emission-reduction targets, TPI evaluates management quality and transition alignment, and ESG providers supply carbon and ESG datasets across companies. We describe each feature below.

Net-zero ambition. This feature refers to the formal statement of a company's strategic intention to achieve carbon neutrality within a timeframe consistent with climate-science recommendations. A key source of information is the SBTi Target Dashboard which lists companies have already set net-zero targets expected to be achieved by 2050, or by 2040 for firms in the power sector. The *net-zero ambition* feature is verified if the company has a "Target Set" status (SBTi, 2021).[1]

Alternatively, the ambition is also verified if the firm has publicly announced at least one comprehensive, self-declared net-zero target. This latter information can be sourced from company reports, press releases, other public disclosures, or from ESG data providers that collect and standardise such information.

$$\boldsymbol{NZ\ Ambition} = SBTi(NZ\ Target\ ) \vee self - declared\ NZ$$

1 The *SBTi Target Dashboard* lists companies and financial institutions that have either set science-based targets or committed to doing so. The "Net-zero SBTi" status indicates whether a company has already set net-zero targets ("Target Set" status) or has committed to setting such targets in accordance with the SBTi *Commitment Compliance Policy* ("Committed" status) (SBTi, 2021).

Commitment on material emissions. This feature captures whether a company has committed to reducing emissions that are material to its activities over a horizon of at least three years. The commitment is identified through the SBTi Target Dashboard, based on the presence of one or more "Active Targets" — near-term or long-term — aligned with a meaningful temperature ambition ("1.5°C", "Well-below 2°C", or "2°C") under the SBTi classification (SBTi, 2021). To cover firms outside the SBTi scope, the feature also considers whether a company has announced at least one comprehensive, firm-wide commitment to reduce material emissions, with full coverage and a target year of 2030 or later. In line with TPI's focus on relevant emissions — including sector-relevant Scope 3 where applicable — material emissions are defined as the set of scopes that, when ranked by size, cumulatively represent a significant share (e.g. 75%) of total emissions (TPI, 2024). This threshold is broadly consistent with leading transition frameworks (SBTi, 2021; TPI, 2024; Climate Bonds Initiative, 2023). Details are provided in Annex 1.

Estimated emissions are preferred in defining material emissions to ensure comparability across firms and sectors. Reported emissions often differ due to differences in accounting boundaries, reporting standards, and data quality — particularly for Scope 3. Using estimated emissions derived from harmonized models mitigates these divergences, providing a consistent basis for assessing commitments across companies and industries.

$$\boldsymbol{Commitment\ on\ material\ emissions} = SBTi(Active\ target\ \ 1.5, \mathrm{WB2}, 2) \vee (Mat.Emiss. \wedge Target_{cov} \wedge Target_{Year} \geq 2030)$$

Medium-term net-zero alignment. This feature captures whether a company's decarbonisation trajectory aligns with a 1.5°C pathway over the medium term, drawing on three data sources.

Firstly, the feature is verified when the company has an "Active" near-term target classified as 1.5°C-aligned by the SBTi (SBTi, 2021). Secondly, for firms outside the SBTi scope, the feature is verified leveraging the TPI carbon-performance assessment. It evaluates whether current and projected emissions are consistent with sector-specific 1.5°C pathways (TPI, 2024). We require alignment both today and by 2035. Thirdly, a further option relies on medium-term net-zero assessments from ESG data providers. For example, MSCI deems a company aligned if it plans at least a 95% cut in aggregate Scope 1–2 absolute emissions by 2030, and a 67% cut in estimated Scope 3 emissions by the same year (MSCI, 2024). These thresholds reflect SBTi definitions of required emissions coverage for different net-zero target years (SBTi, 2021).

$$\boldsymbol{Medium\ Term\ Alignment} = SBTi(Active\ near\ term\ target\ \ 1.5) \vee$$
$$\vee \left[\mathrm{TPI_{Align}}(2025) \wedge \mathrm{TPI_{Align}}(2035)\right] \vee \mathrm{Provider_{Align}}(2030)$$

Long-term net-zero alignment. This feature reflects the alignment of a company's decarbonisation trajectory with a 1.5°C scenario by 2050 or earlier. As for the medium-term alignment, the same data sources are considered. Firstly, the commitment is identified through the *SBTi Target Dashboard*, where it is inferred from the presence of an "Active" long-term target aligned with a 1.5°C scenario (SBTi, 2021). Secondly, for companies outside the scope of the SBTi, the feature is verified based on the carbon performance TPI assessment for the 2025, 2035 and 2050 aligned with a "1.5°C" scenario. Thirdly, data points coming from ESG data providers could be used to assess a long-term net zero alignment based on any ESG provider assessment for the 2030 and the 2050 (e.g. MSCI).

$$\boldsymbol{Long\ Term\ Alignment} = SBTi(Active\ long\ term\ target\ \ 1.5) \vee$$
$$\vee \left[\mathrm{TPI_{Align}}(2025) \wedge \mathrm{TPI_{Align}}(2035) \wedge \mathrm{TPI_{Align}}(2050)\right] \vee \left[\mathrm{Provider}(2030) \wedge \mathrm{Provider_{Align}}(2050)\right]$$

2.2 A classification focused on material activities

Commitment metrics can generate adverse effects on portfolio construction when applied broadly and in the presence of carbon constraints. Without distinguishing between activities that are truly material for the low-carbon transition and those that are not, investors may end up favouring companies or sectors with strong formal commitments but limited real impact on aggregate emissions.

We illustrate these effects by considering an investment strategy subject to portfolio-level constraints. In this setting, security and sector allocations are driven by the distribution of commitment scores. However, these allocations — both within sectors (favouring one security over another) and across sectors (favouring one sector over another) — do not account for the actual relevance of firms' commitments to the energy transition.[2] This can distort portfolio construction through both selection and allocation effects.[3] These effects are illustrated below.

Potential selection and allocation effects

Table 2

Case	Company (C) / Sector(S)	Materiality	Commitment indicator	Carbon intensity	Preference
1	Alpha (C)	Y	3	High	-
	Beta (C)	N	3	Low	+
2	Gamma (S)	Y	4	High	-
	Delta (S)	Y	4	High	-
3	Epsilon (S)	N	3.5	Low	+
	Zeta (S)	N	2.5	Low	-

The distorted **selection effect** arises when two companies (e.g., Alfa and Beta) within the same sector carry out activities with differing relevance to the energy transition (high for Alfa and low for Beta), yet both obtain the same score on the commitment indicator. Since activities that are less relevant to the transition (such as Beta's) typically exhibit lower carbon intensity, it follows that, all else being equal, the

2 For certain activities, in fact, setting an emission reduction target requires a significant effort. Consider, for example, a long-term net zero target validated by SBTi for a company operating in electricity generation. Achieving such a target entails substantial investments needed to replace fossil-fuel based production plants with renewable energy facilities. In contrast, a long-term net zero target validated by SBTi for a pharmaceutical company could be achieved with considerably less effort. Despite the differing relevance of these targets, the current framework does not differentiate between the objectives of the two companies. The same issue arises even among companies within the same sector that are involved in activities with varying degrees of relevance to the energy transition.

3 The inclusion of companies engaged in activities with differing relevance to the transition within the same sector is possible because the sector classifications used in the financial industry (e.g., the Industrial Classification Benchmark – ICB, or the Global Industry Classification Standard – GICS) group companies based on their core business and commercial operations. This classification logic differs from one based on relevance to the energy transition or on companies' emissions. Moreover, the level of sector aggregation used in ICB or GICS classifications can also result in grouping together companies with very different core businesses within the same sector. For example, under the highest level of sector aggregation in the ICB, the "Consumer Discretionary" sector includes both car manufacturers and media companies. This is also the case in the Bank's investment activity, which uses the ICB classification with a breakdown into 10 sectors (referred to as Industries).

company (Beta) engaged in the less transition-relevant activity and displaying lower carbon intensity (another portfolio constraint) would be preferred over the other (Alfa) (Table 2, Case 1).

The distorted **allocation effect** can emerge in two cases. In the first, two sectors (e.g., Gamma and Delta) have the same weighted average commitment score but differ in transition relevance — high for Gamma, low for Delta. Since Delta typically shows lower carbon intensity, the portfolio would tend to favour it (Table 2, Case 2). In the second, two sectors (e.g., Epsilon and Zeta) both exhibit low transition relevance but differ in commitment scores. The portfolio would then favour the higher-scoring sector (Epsilon), even though commitments in both cases have negligible importance for the transition (Table 2, Case 3).

To address these distortions, we identified the material activities within the NACE sector classification, considering:

a) activities with the highest direct emissions in the European Union;
b) activities related to the production of goods and services whose use entails high emissions.

For the first criterion, the included activities account for approximately 90% of the total direct emissions in the European Union, based on Eurostat data. The second criterion allows for the inclusion of activities with a significant share of scope 3 emissions, that is, the indirect emissions generated by end users, such as the production of automobiles or semiconductors. These activities are identified within the industry sectors of companies included in a broad euro-area equity market index that exhibit the highest total carbon intensities (scope 1, 2 and 3). This approach therefore captures additional activities that do not emerge under the first criterion because they exhibit low direct emissions but high scope 3 emissions.

Based on these criteria, the selection covers NACE macro-sectors A, B, D, E, and H, eleven activities falling under macro-sector C, and two activities belonging to macro-sectors F and G (Table 3).

Material NACE sectors

Table 3

NACE		Sectors	Contribution to EU Emissions*	Intensity**
A		Agriculture, forestry and fishing	17.0%	1.62
B		Mining and quarrying	1.9%	0.88
C		Manufacturing	25.9%	0.27
	17	-paper and paper products	1.0%	
	19	-coke and refined petroleum products	4.3%	
	20	-chemicals and chemical products	4.7%	
	22	-rubber and plastic products	**0.3%**	
	23	-other non-metallic mineral products	6.1%	
	24	-basic metals	5.2%	
	25	-fabricated metal products, except machinery and equipment	**0.4%**	
	27	-electrical equipment	**0.1%**	
	28	-machinery and equipment n.	**0.3%**	
	29	-motor vehicles, trailers and semi-trailers	**0.4%**	
	30	-other transport equipment	**0.1%**	
D		Electricity, gas, steam and air cond. supply	22.2%	1.5
E		Water supply; sewerage, waste management and remediation activities	5.5%	1.01
F		Construction	2.0%	0.06
	42	-Civil engineering	**0.0%**	
G	46	Wholesale and retail trade; repair of motor vehicles and motorcycles	2.8%	0.04
		-Wholesale trade, except of motor vehicles and motorcycles	**1.4%**	
H		Transportation and storage	17.5%	0.63
Total			2,674.80*	0.17**

* Tonnes of Greenhouse gases (GHG; CO2 and CO2 equivalent (N2O, CH4, HFC, PFC, SF6 and NF3)) and ** Kilograms of GHG per euro of gross value added. Scope 1 and 2 emissions; Bold for Scope 3.

Source: internal elaborations on the Eurostat dataset "Air emissions accounts by NACE" and "Air emissions intensities by NACE". European Union - 27 countries. Year 2023Absolute emissions (MtonnCO2e)

3. Empirical application of the approach

We present the results of an optimization that combines the *commitment indicator* with the *classification based on material activities*. We simulate portfolios managed against a traditional benchmark, which are progressively tilted towards increasingly ambitious levels of the commitment indicator. The benchmark used is the MSCI EMU ex-financials (excluding banks, insurance companies and financial services).[4]

The exercise is a standard constrained quadratic optimization problem. The objective function is the tracking error volatility ex-ante (TEV), given by the variance–covariance matrix pre-multiplied and post-multiplied the active weights. The variance-covariance matrix is estimated using the well-known macroeconomic multifactor Burmeister-Roll-Ross model (BIRR model, Burmeister et al., 1997).

To reflect a sustainable investor profile, the optimization includes the following constraints: an ESG score at least 5% higher than that of the benchmark, a weighted average carbon intensity (WACI) at least 50% lower than the benchmark, and sectoral and issuer concentration limits of 1% and 2%, respectively. The formal representation of the optimization is provided in the Annex 2.[5]

We show how portfolio allocation evolves across simulations (Table 4), from the unconstrained case to scenarios with progressively higher average commitment score levels. The portfolio allocation is analysed by grouping companies. Specifically, we first distinguish between those for which the indicator does not apply ("No material" column) and those for which it does ("Material" column). Within the latter group, companies are further classified according to their commitment score (from 0 to 4). The analysis considers both the number of securities included in each simulated portfolio - to assess the diversification effect - and their overall percentage exposure.

The overall percentage exposure to material companies remains broadly independent of the commitment score level imposed by the constraint (*blue panel*, Table 4). As the commitment score constraint becomes more ambitious, the portfolio's exposure to low-commitment securities decreases, while the exposure to high-commitment securities increases (*red and green arrows*, respectively).

Under the extreme solutions, portfolio cardinality falls (*dark-grey arrows*), and score-3 holdings decline in favour of score-4 securities, which remain fully included (*amber and green arrows*).

Table 4

Holdings and Weights by Commitment Score

					Material - Committment score breakdown									
	No material		Material		0		1		2		3		4	
Optimizations	**N**	**Weight**	**N**	**Weight**	**N**	**Weight**	**N**	**Weight**	**N**	**Weight**	**N**	**Weight**	**N**	**Weight**
Benchmark (3,07)	78	46,0%	81	54,0%	4	1,5%	1	0,1%	22	9,2%	34	25,4%	20	17,7%
Unconstrained (3,07)	66	46,7%	70	53,3%	4	1,6%	1	0,1%	17	9,7%	29	23,5%	19	18,4%
3,15	67	46,8%	68	53,2%	4	1,0%	0	0,0%	16	8,8%	29	23,7%	19	19,7%
3,25	66	47,3%	65	52,7%	2	0,5%	0	0,0%	15	7,0%	29	23,4%	19	21,9%
3,37	66	48,3%	55	51,7%	1	0,2%	0	0,0%	8	4,6%	26	22,2%	20	24,7%
3,49	65	49,2%	43	50,8%	0	0,0%	0	0,0%	4	3,6%	19	18,6%	20	28,7%
3,61	58	49,3%	33	50,7%	0	0,0%	0	0,0%	2	2,9%	11	13,8%	20	34,0%
3,73	36	44,4%	28	55,6%	0	0,0%	0	0,0%	2	1,4%	9	12,2%	17	42,0%

As the constraint on the commitment indicator becomes more ambitious (Figure 1):

4 This index is described in terms of the number of constituents (cardinality), sector composition, ESG score, and weighted average carbon intensity.

5 All constraints are linear, except for the one related to the commitment indicator, as the active weights considered apply only to the subset of stocks classified under the material activities.

• the tracking error volatility (TEV) increases more than proportionally; however, it remains possible to favour committed companies without deviating excessively from the benchmark (TEV < 1%);

• the exposure across carbon-intensity quintiles remains largely stable.

Compared with the unconstrained case, portfolios constructed using the commitment indicator display higher exposure to brown securities (Q1; Figure 2) — and in particular to brown committed ones — while brown non-committed companies are further penalized.

Figure 1.
Ex-ante TEV (left axis) and exposure to carbon intensity quantiles (right axis)

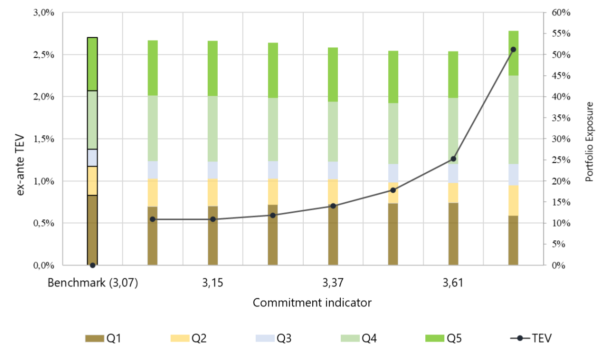
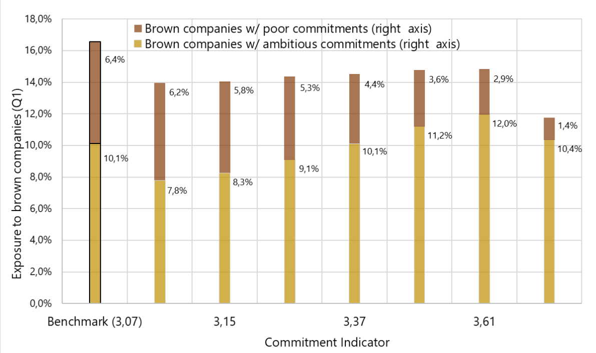


Figure 2.
Brown companies (Q1): overall exposure and breakdown on commitments



Conclusions

This paper proposes a data-driven approach to assessing portfolio decarbonization that combines forward- and backward-looking information while accounting for the materiality of firms' activities. By integrating commitment indicators with a classification of transition-relevant sectors, the framework mitigates the risk of paper decarbonization, thereby enabling a more credible alignment with real-economy transition pathways.

The empirical results show that it is possible to favour committed companies — including those in high-emission sectors — without materially deviating from the benchmark. This suggests that sustainable portfolio construction can be consistent with both financial and climate objectives, provided that commitments are credible and targeted toward material sources of emissions.

In line with recent reflections, effective decarbonization strategies should not rely solely on portfolio reallocation, but on approaches that strengthen the link between investment decisions and the real economy's transition dynamics. This calls for continued efforts to improve data quality, transparency, and methodological consistency in assessing transition alignment.

Annexes

Annex 1. Material Emissions

Let's consider a company with the following estimated GHG emissions by scope (in metric tons of CO_2 equivalent):

- Scope 1 (direct emissions): 100,000 tCO_2e
- Scope 2 (indirect emissions from purchased electricity): 250,000 tCO_2e
- Scope 3 (all other indirect emissions): 650,000 tCO_2e

Step 1: Total emissions
Total = 100,000 (S1) + 250,000 (S2) + 650,000 (S3) = 1,000,000 tCO_2e

Step 2: Order scopes by size (descending)

2. **Scope 3** = 650,000 → 65%
3. **Scope 2** = 250,000 → 25%
4. **Scope 1** = 100,000 → 10%

Step 3: Identify scopes covering at least 75% of total emissions
We add the scopes cumulatively until the 75% threshold is reached:

- Scope 3 (65%)
- Scope 2 (25%) → cumulative **= 90%** > 75%

Thus, Scope 3 and Scope 2 together are identified as material emissions, while Scope 1 is not considered material under this definition.

Annex 2. Optimisation problem

$$\min_x x^T \cdot \Sigma_{total} \cdot x$$

sub

$$\sum_{i=1}^{N} x_i = 0$$

$$\left|\sum_{i=1}^{N_s} x_{i|sector=s}\right| \leq \bar{\delta}$$

$$lb \leq x \leq ub$$

$$\sum_{i=1}^{N} x_i \cdot ESG_i \geq \overline{ESG}$$

$$\sum_{i=1}^{N} x_i \cdot WACI_i \leq \overline{WACI}$$

$$\frac{\sum_{i=1}^{Nmat} x_i \cdot CI_i}{\sum_{i=1}^{Nmat} x_i} \leq \overline{CI}$$

with

- $x = w_{port} - w_{bench}$, the N×1 vector containing the weight differentials of each security (x_i), obtained as the difference between the vector of weights in the replicating portfolio w_{port} and the vector of weights in the benchmark w_{bench};
- Σ_{total} , the N × N variance-covariance matrix of the securities in the benchmark;
- $\bar{\delta}$, the maximum deviation for each sector s, with N_s equal to the number of securities that make up the sector and $x_{i|settore=s}$ equal to the differential weight of each i-th security belonging to sector s;
- lb and ub , the N × 1 vectors containing respectively the lower and upper bounds of the active weights;
- ESG_i, $WACI_i$ and CI_i , denote the ESG scores, the carbon intensities and the commitment indicator of each stock;
- $\overline{ESG}$, $\overline{WACI}$, and $\overline{CI}$, the minimum desired levels of the ESG score, the weighted average carbon intensity, and the commitment indicator at the portfolio level.
- N_{mat} the number of stocks belonging to the material activities.

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A data-driven approach for portfolio transition

Irving Fisher Committee - De Nederlandsche Bank
Satellite Seminar on Sustainability data issues and central banks' experience

4 October 2025, Amsterdam

Marco Fanari and Francesco Savino
Financial Risk Management Directorate

Overview

Current practices on portfolio transition

Most practices rely on backward-looking information (carbon footprint)

Recent strategies include forward-looking metrics based on:

- complex metrics → ITR, Climate VaR
- commitment → SBTi targets

Potential pitfalls

Complex metrics suffer from heterogeneity of assumptions and methodologies

Commitments are based only on SBTi

Metrics disregard the materiality of each activity for the transition

Our analysis

blends carbon footprint and commitment data

feeds commitment data from multiple sources

focuses on material activities

Commitment indicator
Material activities

The commitment indicator (1)

Features	Description	Scores
Net Zero Ambition	Net-zero targets expected to be achieved by 2050 (2040)	0/1
Commitment on material emissions	Committment to reduce material emissions over a time horizon of at least 3 years.	0/1
Medium term NZ alignment	Decarbonization trajectory in line with a 1.5°C scenario by 2030	0/1
Long term NZ alignment	Decarbonization trajectory in line with a 1.5°C scenario by 2050	0/1

The **commitment indicator** (CI) assesses how companies are aligned with a Net zero pathway.
It covers **four features**. Each gets a score of 0 (not verified) or 1 (verified). Therefore, CI ranges from 0 (no feature verified) to 4 (all features verified).
Multiple data sources are used: SBTi, MSCI, TPI.

1) Net Zero Ambition

The company has the ambition to achieve net zero emissions by 2050 (2040 power sector)

→ SBTI: "Target set" for Net zero status

→ MSCI: company's net zero emissions ambition statement

2) Commitment on material emissions

The company is committed to reducing its material emissions*

Target criteria: *(i) material emissions, (ii) company-wide scope, (iii) 3-year horizon*

→ SBTi: active "Near-term target" or "Long-term target"

→ MSCI: datapoint on at least one target comply with these criteria

** Material emissions*

Scope 1-3 emissions, ranked in decreasing order, cumulatively account for X% of the company's emissions (e.g. 75%).

The commitment indicator (2)

3) Medium-term Net zero alignment

The decarbonization trajectory is in line with the 1.5°C scenario in the medium-term

→ Comparison of company's vs sector-specific carbon intensity pathway by 2030

- SBTI: "Target set" for Net zero status & "1.5°C" for Near term target classification
- MSCI: "Net zero 2030", science-based absolute emission reduction by 2030
- TPI: "1.5°C" for Carbon performance assessment in 2025 and 2035

4) Long-term Net zero alignment

The decarbonization trajectory is in line with the 1.5°C scenario in the long term

→ Comparison of company's vs sector-specific carbon intensity pathway by 2050

similar to Medium-term Net zero alignment with horizon in 2050 (2040)

Why focusing only on material activities?

A broad portfolio application of CI could generate adverse effects in the presence of carbon constraints

Case	Company/sector	Materialility	Score Commitment	Carbon intensity	Preference
1	Alpha (company)	Y	3	High	-
	Beta (company)	N	3	Low	+
2	Gamma (sector)	Y	4	High	-
	Delta (sector)	N	4	Low	+
3	Epsilon (sector)	N	3,5	Low	+
	Zeta (sector)	N	2,5	Low	-

Adverse selection effect

Case 1 – Company Beta, engaged in a non-material activity and exhibiting lower carbon intensity, is preferred over Company Alpha

Adverse allocation effect

Case 2 – Sector Delta, with non-material activities and a lower carbon intensity, is preferred over Sector Gamma

Case 3 – Sector Epsilon, with a higher score, is preferred over Sector Zeta, even though the commitments made by companies in both sectors are non-material

We propose a **focus on material activities**

How to identify material activities

We employ the **NACE classification** based on the **contribution to total EU's emissions**.

We consider:

- activities with the highest direct emissions in the economy (Scope 1&2)
- activities aimed at the production of goods and services whose use generates high emissions (Scope 3)

The included activities account for **88,4% of the EU's emissions**

		Material NACE sectors (1)	Contribution to EU Emissions (2)	Intensity (3)
A		Agriculture, forestry and fishing	17,0%	1,62
B		Mining and quarrying	1,9%	0,88
C		Manufacturing	25,9%	0,27
	17	Manufacture of paper and paper products	1,0%	
	19	Manufacture of coke and refined petroleum products	4,3%	
	20	Manufacture of chemicals and chemical products	4,7%	
	22	Manufacture of rubber and plastic products	0,3%	
	23	Manufacture of other non-metallic mineral products	6,1%	
	24	Manufacture of basic metals	5,2%	
	25	Manufacture of fabricated metal products, except machinery and equipment	0,4%	
	27	Manufacture of electrical equipment	0,1%	
	28	Manufacture of machinery and equipment n.e.c.	0,3%	
	29	Manufacture of motor vehicles, trailers and semi-trailers	0,4%	
	30	Manufacture of other transport equipment	0,1%	
D		Electricity, gas, steam and air conditioning supply	22,2%	1,50
E		Water supply; sewerage, waste management and remediation activities	5,5%	1,01
F		Construction	2,0%	0,06
	42	Civil engineering	0,0%	
G		Wholesale and retail trade; repair of motor vehicles and motorcycles	2,8%	0,04
	46	Wholesale trade, except of motor vehicles and motorcycles	1,4%	
H		Transportation and storage	17,5%	0,63
Total		**(2) Absolute emissions (MtonnCO2e)** **(3) Intensity (kCO2e/€)**	**2.674,8**	**0,17**

Contribution to Scope 1,2

Contribution to Scope 3

Source: internal elaborations on the Eurostat dataset "Air emissions accounts by NACE" and "Air emissions intensities by NACE".
Tonnes of Greenhouse gases (GHG; CO_2 and CO_2 equivalent (N_2O, CH_4, HFC, PFC, SF_6 and NF_3)) and Kilograms of GHG per euro of gross value added.
European Union - 27 countries. Year 2023

Portfolio construction

By way of example, we present the results of an optimization exercise using the commitment indicator

Assumptions

Portfolio is constructed against a traditional benchmark
(euro area equity, no financials)

Optimization problem

Min ex-ante Tracking Error Volatility (TEV)

Constraints (vs benchmark)

- enhanced ESG score (at least 5%)
- enhanced WACI (at least 50% and 7% decarbonization annually)
- sector (max 1%) and issuer (max 2%)
- composite indicator

Tilting towards increasingly ambitious levels

from the unconstrained case…

…to progressively higher scores

Constrained quadratic optimisation

$$\min_x x^T \cdot \Sigma_{total} \cdot x$$

sub

$$\sum_{i=1}^{N} x_i = 0$$

$$\left|\sum_{i=1}^{N_s} x_{i|sector=s}\right| \leq \bar{\delta}$$

$$lb \leq x \leq ub$$

$$w_{port} \cdot ESG \geq \overline{ESG}$$

$$w_{port} \cdot WACI \leq \overline{WACI}$$

$$\boldsymbol{w_{port} \cdot CI \leq \overline{CI}}$$

Results – exposure to committed companies

The overall exposure to material companies is independent of the commitment score level required by the constraint (*blue panel*)

As the commitment score constraint becomes more ambitious, the overall exposure to low (high-) committed companies decreases (increases) (*red/green arrow*)

In the extreme solutions,

- the cardinality of the portfolio is reduced (*dark grey*),
- a reduction in score 3 securities is also observed, along with an increase in exposure to score 4 securities (always included) (*amber/green arrow*)

					Material - Committment score breakdown									
	No material		Material		0		1		2		3		4	
Optimizations	N	Weight	N	Weight	N	Weight	N	Weight	N	Weight	N	Weight	N	Weight
Benchmark (3,07)	78	46,0%	81	54,0%	4	1,5%	1	0,1%	22	9,2%	34	25,4%	20	17,7%
Unconstrained (3,07)	66	46,7%	70	53,3%	4	1,6%	1	0,1%	17	9,7%	29	23,5%	19	18,4%
3,15	67	46,8%	68	53,2%	4	1,0%	0	0,0%	16	8,8%	29	23,7%	19	19,7%
3,25	66	47,3%	65	52,7%	2	0,5%	0	0,0%	15	7,0%	29	23,4%	19	21,9%
3,37	66	48,3%	55	51,7%	1	0,2%	0	0,0%	8	4,6%	26	22,2%	20	24,7%
3,49	65	49,2%	43	50,8%	0	0,0%	0	0,0%	4	3,6%	19	18,6%	20	28,7%
3,61	58	49,3%	33	50,7%	0	0,0%	0	0,0%	2	2,9%	11	13,8%	20	34,0%
3,73	36	44,4%	28	55,6%	0	0,0%	0	0,0%	2	1,4%	9	12,2%	17	42,0%

Results - TEV and carbon intensity quintiles

As the CI constraint becomes more ambitious:

- TEV increases more than proportionally (fig. 1); however, it is possible to favour committed companies, without deviating excessively from the benchmark (TEV<1%)
- Exposure to companies across the different carbon intensity quintiles remains largely stable (fig. 1)

Compared to the unconstrained case, portfolios built with the CI show higher exposure to brown companies (Q1; fig. 2) and, in particular, to transition-committed brown ones, while non-committed brown companies are further penalized

Figure 1. *Ex-ante TEV (left axis) and exposure to carbon intensity quantiles (right axis) across simulations*

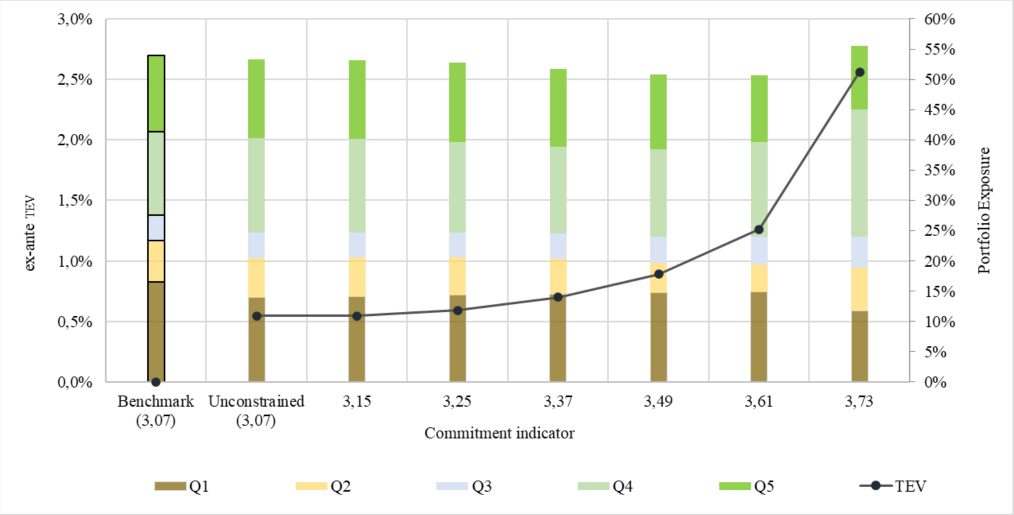
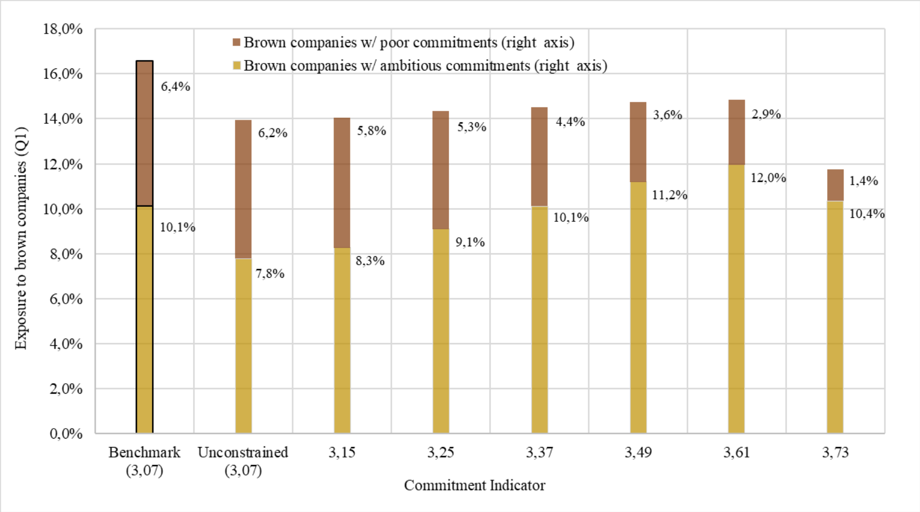


Figure 2. *Brown companies (Q1): overall exposure and breakdown on committments*



Thank you!

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