Climate Risk Metrics & Portfolio Construction

Amundi Quantitative Research*

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[1] The opinions expressed in this presentation are those of the authors and are not meant to represent the opinions or official positions of Amundi Asset Management.

Amundi Research Project

1. Portfolio Construction with Climate Risk Measures, January 2022
2. Net Zero Carbon Metrics, February 2022
3. The Shift from Carbon Emissions to Net Zero Carbon Metrics on Portfolio Construction, March 2022
4. Multi-Period Portfolio Optimization & Application to Portfolio Decarbonization, March 2022
5. The Green Risk Premium & The Performance(s) of ESG Investing, March 2022
6. The Impact of Net Zero on Capital Allocation and Equity Portfolio Management, Forthcoming
7. The Impact of Net Zero on Bond Portfolio Management, Forthcoming

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The puzzle

- Portfolio decarbonization
- Portfolio alignment

Academic findings

- Portfolio decarbonization is easy
- Portfolio alignment is easy
- The cost of portfolio alignment may be low

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Asset owners & managers

- Portfolio decarbonization is easy
- Portfolio alignment is difficult
- The cost of portfolio alignment may be high

Asset allocation $\Rightarrow$ Portfolio weights x_i

Asset allocation $\Rightarrow \begin{cases} \textbf{Capital} \text{ allocation} \\ \text{Economy } \textbf{financing} \end{cases}$

Two visions of asset management

Carbon emissions

The GHG Protocol corporate standard classifies a company's greenhouse gas emissions in three scopes(*):

- **Scope 1**: Direct GHG emissions (○)
- **Scope 2**: Consumption of purchased energy (○○)
- **Scope 3**: Other indirect GHG emissions (●●)
  - **Scope 3 upstream**: emissions associated to the supply side
    1. First tier direct (●)
    2. Tier 2 and 3 suppliers (●●)
  - **Scope 3 downstream**: emissions associated with the product sold by the entity
    1. Use of the product (●●●)
    2. Waste disposal & recycling (●●●●)

(*) Measurement robustness: from ○○○○ (very high) to ●●●● (very low)

Carbon emissions

Figure: Total absolute scopes per GICS sector in $GtCO_2e$

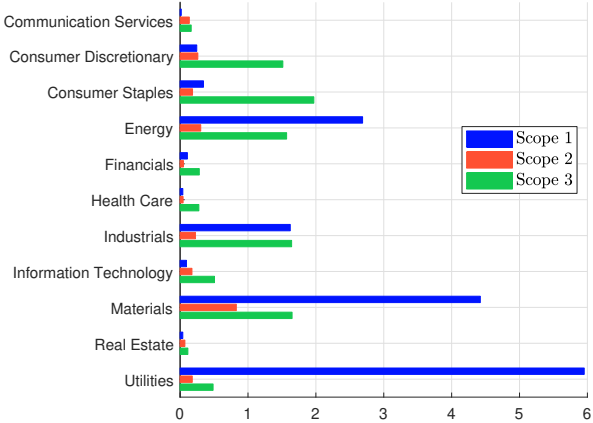
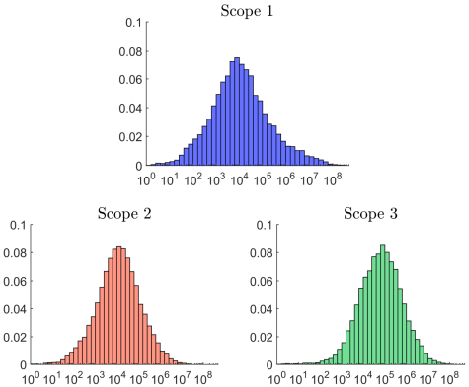


Table: Scope $1+2$ vs. scope 3

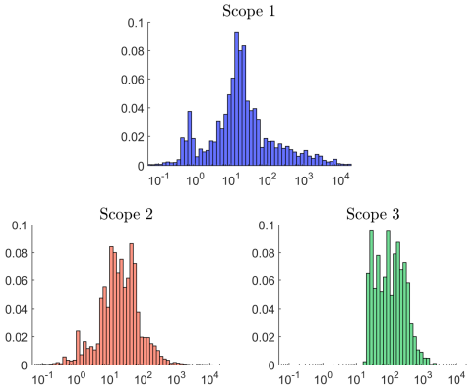
Sector	$\frac{\mathcal{SC}_3}{\mathcal{SC}_{1+2}}$
Communication Services	1.1
Consumer Discretionary	**3.0**
Consumer Staples	**3.7**
Energy	**0.5**
Financials	1.8
Health Care	**3.3**
Industrials	0.9
Information Technology	1.9
Materials	**0.3**
Real Estate	1.0
Utilities	**0.1**

Carbon intensity vs emissions

Emissions (log scale, tCO_2e)



Intensity(*) (log scale, tCO_2e/$ mn)



(*) Carbon intensity = carbon emissions / output (e.g., revenues)

Carbon intensity

Table: Examples of carbon emissions and intensity

Company	Emission (in tCO_2e)			Revenue	Intensity (in tCO_2e/\$ mn)		
	Scope 1	Scope 2	Scope 3	(in \$ mn)	Scope 1	Scope 2	Scope 3
Alphabet	74 462	5 116 949	7 166 240	161 857	0.460	31.614	44.275
Amazon	5 760 000	5 500 000	20 054 722	280 522	20.533	19.606	71.491
Apple	50 463	862 127	27 618 943	260 174	**0.194**	**3.314**	106.156
BP	49 199 999	5 200 000	103 840 194	276 850	**177.714**	18.783	375.077
Danone	722 122	944 877	28 969 780	28 308	**25.509**	**33.378**	**1 023.365**
Enel	69 981 891	5 365 386	8 726 973	86 610	**808.016**	61.949	100.762
Juventus	6 665	15 739	35 842	709	9.401	22.198	50.553
LVMH	67 613	262 609	11 853 749	60 083	**1.125**	**4.371**	**197.291**
Microsoft	113 414	3 556 553	5 977 488	125 843	0.901	28.262	47.500
Nestle	3 291 303	3 206 495	61 262 078	93 153	**35.332**	**34.422**	**657.647**
Netflix	38 481	145 443	1 900 283	20 156	1.909	7.216	94.277
Total	40 909 135	3 596 127	49 831 487	200 316	**204.223**	17.952	248.764
Volkswagen	4 494 066	5 973 894	65 335 372	282 817	15.890	21.123	231.016

Carbon intensity

Table: The case of Danone (total emissions breakdown)

Year		2019	2020
Scope 1		2.70%	2.60%
Scope 2		2.20%	1.80%
	Purchase of goods and services: Agriculture - milk	**35.50%**	**36.90%**
	Purchase of goods and services: Agriculture - dairy ingredients	**15.40%**	**15.10%**
	Purchase of goods and services: Agriculture - other raw materials	**9.00%**	**8.40%**
	Purchase of goods and services: Packaging	10.30%	9.60%
	Purchase of goods and services: Purchase of finished products	5.60%	6.20%
Scope 3	Upstream transportation and distribution of goods	1.40%	1.20%
	Downstream transportation and distribution of goods	8.10%	6.20%
	Use of sold products	7.10%	7.20%
	End-of-life treatment of sold products	**0.90%**	**3.00%**
	Fuel and energy related activities	1.20%	1.10%
	Waste generated in operations	0.60%	0.60%
Agricultural emissions breakdown			
	Milk	59.20%	61.10%
	Dairy ingredients	25.70%	25.00%
	Other raw materials	15.10%	13.90%

Source: Danone, Exhaustive 2020 Environmental Data.

Portfolio decarbonization

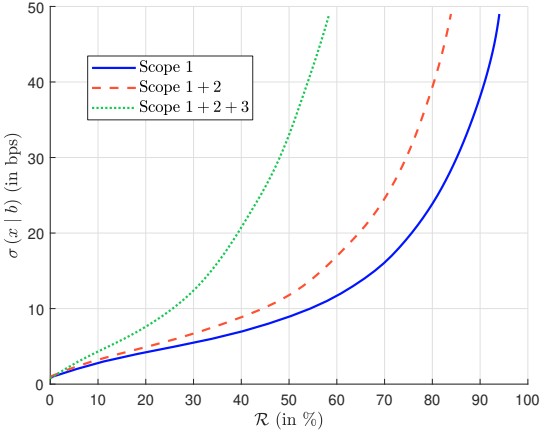
- The optimization problem is:

$$
\begin{aligned}
x^{\star}(\mathcal{R}) \quad &= \quad \arg\min \frac{1}{2}(x-b)^{\top}\Sigma(x-b) \\
\text{s.t.} \quad & \begin{cases} \mathbf{1}_n^{\top} x = 1 \\ x \geq \mathbf{0}_n \\ \sum_{\mathbf{i}=1}^{\mathbf{n}} \mathbf{x_i} \cdot \mathcal{CI}_{\mathbf{i}} \leq (\mathbf{1}-\mathcal{R}) \cdot \mathcal{CI}(\mathbf{b}) \end{cases}
\end{aligned}
$$

  where x is the portfolio and b is the benchmark portfolio
- $\mathcal{R}$ is the reduction rate of the carbon intensity
- The underlying idea is to obtain a decarbonized portfolio $x^{\star}$ such that the tracking error with respect to the benchmark b is the lowest
- The benchmark b can be a current portfolio (active management) or an index portfolio (passive management)

Portfolio decarbonization

Figure: Impact of the carbon scope on the tracking error volatility (S&P 500 index, October 2021)



Portfolio alignment

Paris-aligned benchmarks

- A year-on-year self-decarbonization of 7% on average per annum, based on **scope 1, 2 and 3 emissions** $\Rightarrow$ postponed in 2023? 2024? 2025?
- A minimum carbon intensity reduction $\mathcal{R}^-$ compared to the investable universe
- A minimum exposure to sectors highly exposed to climate change:
  1. Narrow measure of HCIS (non official, e.g. $\approx$ 19% of the S&P 500)
  2. Broad measure of HCIS (official, e.g. $\approx$ 55% of the S&P 500)
- Issuer exclusions (controversial weapons and societal norms violators)
- ~~Minimum green share revenue~~

CTB

$$\mathcal{R}^- = 30\%$$

PAB

$$\mathcal{R}^- = 50\%$$

Decarbonization pathway

Figure: Decarbonization pathway of PAB labels (base year = 2020)

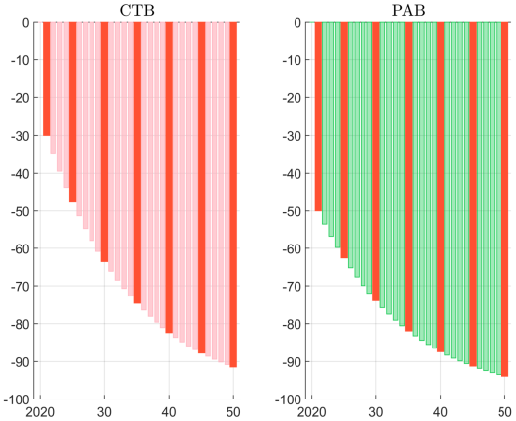


Table: Reduction $\mathcal{R}(2020, t)$

Year	CTB	PAB
2021	30.0%	**50.0%**
2022	34.9%	53.5%
2023	39.5%	56.8%
2024	43.7%	59.8%
2025	47.6%	**62.6%**
2026	51.3%	65.2%
2027	54.7%	67.7%
2028	57.9%	69.9%
2029	60.8%	72.0%
2030	63.6%	**74.0%**
2035	74.7%	81.9%
2040	82.4%	87.4%
2045	87.7%	91.2%
2050	91.5%	93.9%

Optimization problem

We have:

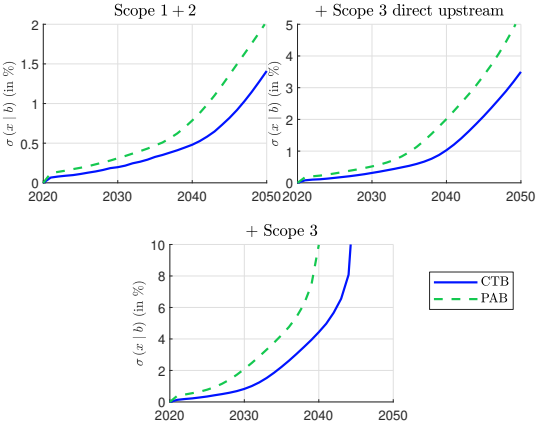
$$
\begin{aligned}
x^\star(t) &= \underset{x(t)}{\arg\min}\, \frac{1}{2}\sigma^2(x(t) \mid b(t)) + \lambda\,\tau(x(t) \mid x^\star(t-1)) \\
\text{s.t.} & \begin{cases} \mathbf{1}_n^\top x(t) = 1 \\ x(t) \geq \mathbf{0}_n \\ \mathcal{CI}(x(t)) \leq (1-\mathcal{R}(t_0,t)) \cdot \mathcal{CI}(b(t_0)) \\ \mathbf{HCIS}(x(t)) \geq \varphi \cdot \mathbf{HCIS}(b(t)) \end{cases}
\end{aligned}
$$

where $\lambda \geq 0$, $\sigma(x(t) \mid b(t))$ is the tracking error risk and $\tau(x(t) \mid x^\star(t-1))$ is the one-way turnover of the portfolio between $t-1$ and t

$\Rightarrow$ Dynamic rebalancing (e.g., every quarter)

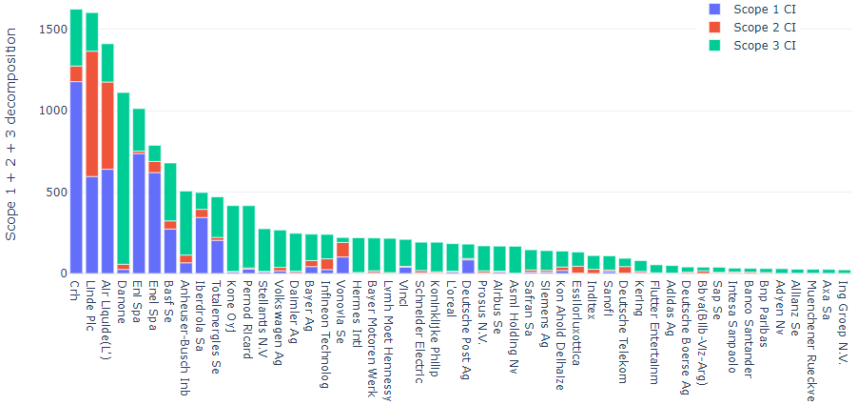
The scope 3 issue (which scope 3?)

Figure: Tracking error of CTB and PAB labels when implementing the broad HCIS constraint (S&P 500 index, October 2021)



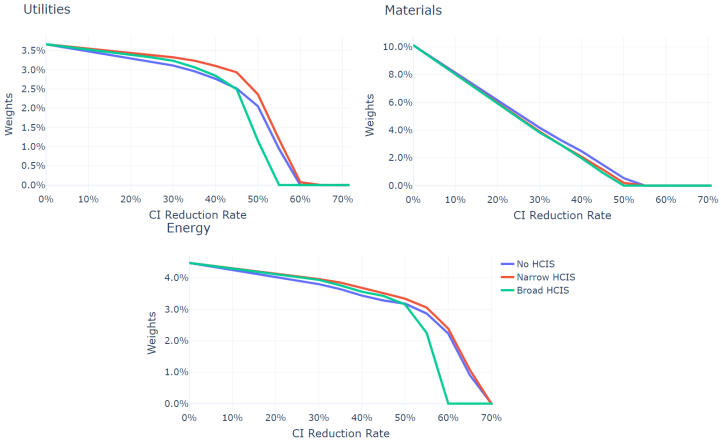
Impact of the scope 3

Figure: Breakdown of the scope $1+2+3$ carbon intensity (Eurostoxx 50 index)



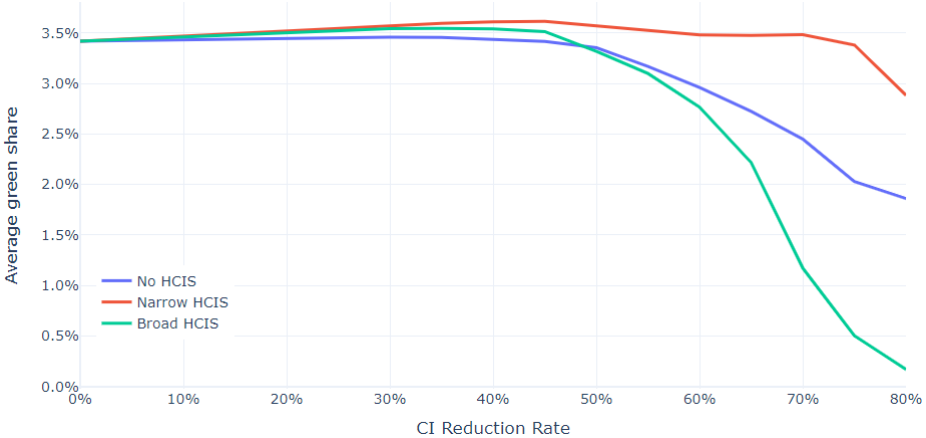
Impact of the reduction rate $\mathcal{R}$ on sector allocation

Figure: HCIS constraints do not help to keep strategic sectors in the allocation (Eurostoxx 50 index)



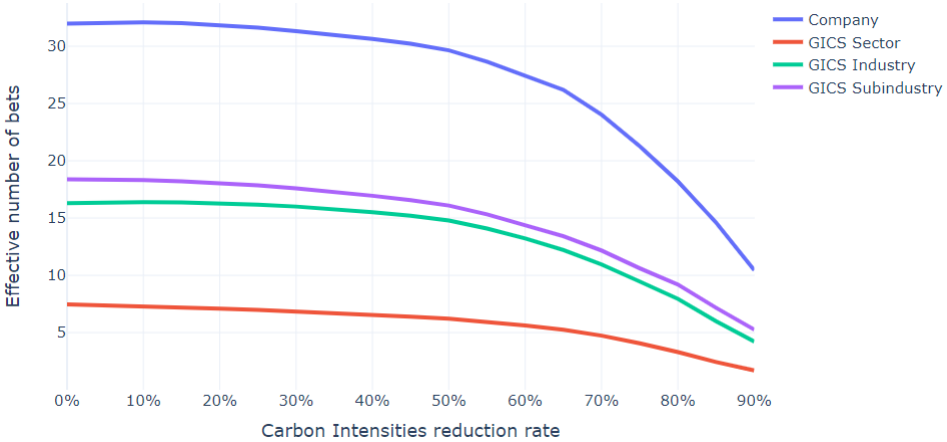
Impact of the reduction rate $\mathcal{R}$ on green share revenues

Figure: Average green share (Eurostoxx 50 index)



Impact of the reduction rate $\mathcal{R}$ on diversification

Figure: Herfindahl index (Eurostoxx 50 index)



Comparison of CTB, PAB and IEA NZE scenarios

Figure: Utilities (Eurostoxx 50 index)

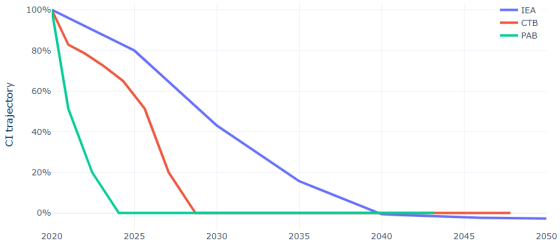
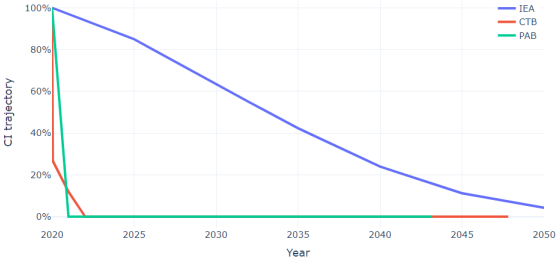


Figure: Construction Materials (Eurostoxx 50 index)



CTB and PAB approaches decarbonize faster the strategic sectors than expected by IEA!

The arithmetic of net zero

"Using global mean surface air temperature, as in AR5, gives an estimate of the remaining carbon budget of 580 *$GtCO_2e$ for a* 50% *probability of limiting warming to* 1.5°C, *and* 420 *$GtCO_2e$ for a* 66% *probability (medium confidence)" (IPCC, 2018).*

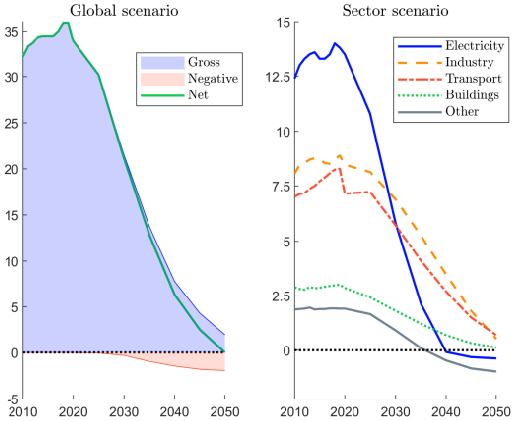
$$\begin{aligned}
\Pr\{\mathcal{T} \leq 1.5^\circ\mathrm{C} \mid \mathcal{CB}(2019,2050) \leq \mathbf{580}\ \mathrm{GtCO_2e}\} &\geq 50\% \\
\Pr\{\mathcal{T} \leq 1.5^\circ\mathrm{C} \mid \mathcal{CB}(2019,2050) \leq 420\ \mathrm{GtCO_2e}\} &\geq 66\% \\
\Pr\{\mathcal{T} \leq 1.5^\circ\mathrm{C} \mid \mathcal{CB}(2019,2050) \leq 300\ \mathrm{GtCO_2e}\} &\geq 83\%
\end{aligned}$$

Remark

- Current carbon emissions ≈ 36 $\mathrm{GtCO_2e}$ per annum
- $580/36 = 16$ years (2035)

The arithmetic of net zero

Figure: CO_2 emissions in the IEA NZE scenario



Carbon budget

$$\mathcal{CB}_i(t_0, t) = \int_{t_0}^{t} \mathcal{CE}_i(s)\, \mathrm{d}s$$

NZE scenario

$$\begin{cases} \mathcal{CB}(2019, 2050) \leq 580 \text{ GtCO}_2\text{e} \\ \mathcal{CE}(2050) \approx 0 \text{ GtCO}_2\text{e} \end{cases}$$

The arithmetic of net zero

Table: IEA NZE global scenario (in $GtCO_2e$)

Year	2019	2025	2030	2035	2040	2045	2050
Gross emissions	35.90	30.30	21.50	13.70	7.77	4.30	1.94
CCS	0.00	−0.06	−0.32	−0.96	−1.46	−1.80	−1.94
Net emissions	35.90	30.24	21.18	12.74	6.31	2.50	0.00
Reduction (in %)	0.00	15.60	40.11	61.84	78.36	88.02	94.60

Table: IEA NZE sectoral scenario (in $GtCO_2e$)

Year	2019	2025	2030	2035	2040	2045	2050
Electricity	13.80	10.80	5.82	2.12	−0.08	−0.31	−0.37
Industry	8.90	8.14	6.89	5.25	3.48	1.80	0.52
Transport	8.29	7.23	5.72	4.11	2.69	1.50	0.69
Buildings	3.01	2.43	1.81	1.21	0.69	0.32	0.12
Other	1.91	1.66	0.91	0.09	−0.46	−0.82	−0.96

By assuming linear interpolation, we find the following values for $\mathcal{CB}_i(2019, 2050)$ in in $GtCO_2e$:

- Global scenario
  - Gross: 512.35
  - CCS: −27.85
  - Net: 484.5
- Sectoral scenario
  - Electricity: 138.225
  - Industry: 158.99
  - Transport: 133.57
  - Buildings: 42.685
  - Other: 11.185

NZE framework

Net zero emission tools

- **Absolute carbon emissions**
- Carbon target
- Carbon trend
- Carbon budget

Net zero emission metrics

Static NZE metrics

- Gap
- Slope
- Budget
- Duration

Dynamic NZE metrics

- Time contribution
- Velocity
- Zero-velocity & burn-out scenarios

The $\mathcal{PAC}$ framework

Three questions:

- Is the trend of the issuer in line with the net zero emissions scenario? $\Rightarrow$ **P**articipation
- Is the commitment of the issuer to fight climate change ambitious? $\Rightarrow$ **A**mbition
- Is the target setting of this issuer relevant and robust? $\Rightarrow$ **C**redibility

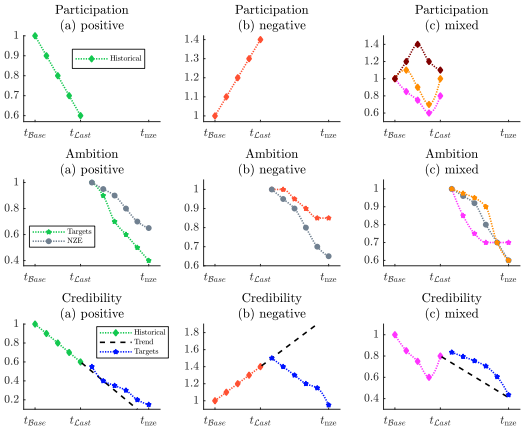
The three pillars depends on the carbon trajectories $\mathcal{CE}_i(t)$, $\mathcal{CE}_i^{\mathcal{T}rend}(t)$, $\mathcal{CE}_i^{\mathcal{T}arget}(t)$ and $\mathcal{CE}_i^{\text{nze}}(t)$ where:

1. $\mathcal{CE}_i(t)$ is the time series of historical carbon emissions
2. $\mathcal{CE}_i^{\mathcal{T}rend}(t)$ and $\mathcal{CE}_i^{\mathcal{T}arget}(t)$ are the estimated carbon emissions deduced from the trend model and the target
3. $\mathcal{CE}_i^{\text{nze}}(t)$ is the market-based NZE scenario

$t_{\mathscr{B}ase}$ is the base date, $t_{\mathscr{L}ast}$ is the last reporting date and t_{nze} is the target date of the NZE scenario

The $\mathcal{PAC}$ framework

Figure: Illustration of the participation, ambition and credibility pillars



The $\mathcal{PAC}$ framework

Table: The three pillars of an effective NZE strategy

Pillar	Metric	Condition
Participation	Gap	$\mathcal{G}ap_i^{\mathcal{T}rend}(t_{\mathscr{L}ast}) \leq 0$
	Reduction	$\mathcal{R}_i(t_{\mathscr{B}ase}, t_{\mathscr{L}ast}) < 0$
	Time contribution	$\mathcal{TC}_i(t_{\mathscr{L}ast}+1 \mid t_{\mathscr{L}ast}, t_{\text{nze}}) < 0$
	Trend	$\hat{\beta}_{i,1} < 0$ and $\mathbf{R}_i^2 > 50\%$
	Trend	$\mathcal{CE}_i^{\mathcal{T}rend}(t)$ for $t > t_{\mathscr{L}ast}$
	Velocity	$\boldsymbol{v}_i^{(1)}(t_{\mathscr{L}ast}) \leq 0$
Ambition	Budget	$\overline{\mathcal{CB}}_i^{\mathcal{T}arget}(t_{\mathscr{L}ast}, t_{\text{nze}}) \leq \overline{\mathcal{CB}}_{\mathscr{S}ector}^{\mathcal{T}arget}(t_{\mathscr{L}ast}, t_{\text{nze}})$
	Budget	$\mathcal{CB}_i^{\mathcal{T}arget}(t_{\mathscr{L}ast}, t_{\text{nze}}) \leq \mathcal{CB}_i^{\mathcal{T}rend}(t_{\mathscr{L}ast}, t_{\text{nze}})$
	Duration	$\boldsymbol{\tau}_i^{\mathcal{T}arget} \leq t_{\text{nze}}$
	Gap	$\mathcal{G}ap_i^{\mathcal{T}arget}(t_{\text{nze}}) \leq 0$
Credibility	Budget	$\mathcal{CB}_i^{\mathcal{T}arget}(t_{\mathscr{L}ast}, t_{\text{nze}}) > \mathcal{CB}_i^{\mathcal{T}rend}(t_{\mathscr{L}ast}, t_{\text{nze}})$
	Burn-out Scenario	$\mathcal{BO}_i(t_{\mathscr{L}ast}+1, \mathcal{CE}_i^{\text{nze}}(t^{\text{nze}})) \geq \varphi_{\mathcal{BO}} \cdot \mathcal{CE}_i(t_{\mathscr{L}ast})$
	Duration	$\boldsymbol{\tau}_i^{\mathcal{T}rend} \leq t_{\text{nze}}$
	Gap	$\mathcal{G}ap_i^{\mathcal{T}rend}(t_{\text{nze}}) \leq 0$
	Gap	$\mathcal{G}ap_i^{\mathcal{T}rend}(t_{\text{nze}}) \leq \mathcal{G}ap_i^{\mathcal{T}arget}(t_{\text{nze}})$
	Slope	$\overline{\mathcal{S}lope}_i(t_{\text{nze}}) \geq \overline{\mathcal{S}lope}_{\mathscr{S}ector}(t_{\text{nze}})$
	Slope	$m_i^{\mathcal{S}lope} \ll 1$
	Trend	$\mathbf{R}_i^2 > 50\%$
	Zero-velocity	$\mathcal{ZV}_i^{(1)}(t_{\mathscr{L}ast}+1) \geq \varphi_{\mathcal{ZV}} \cdot \mathcal{CE}_i(t_{\mathscr{L}ast})$

The $\mathcal{PAC}$ scoring system

Figure: Examples

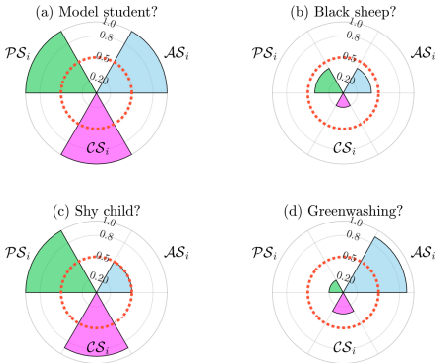
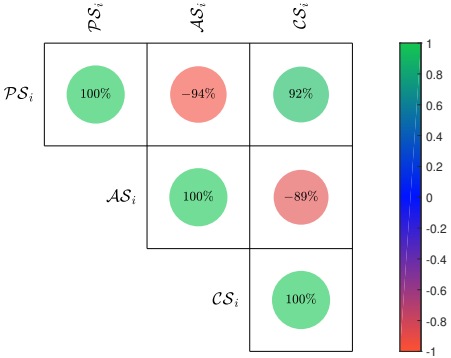
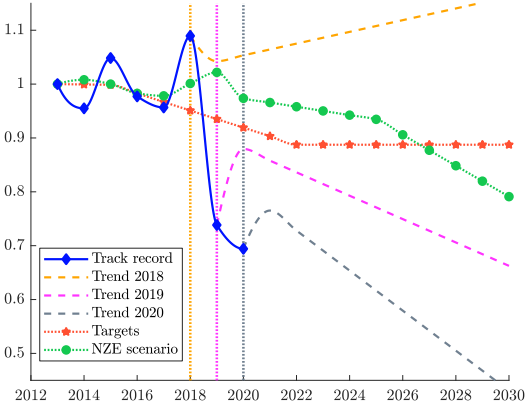


Figure: Rank correlation matrix



Empirical results

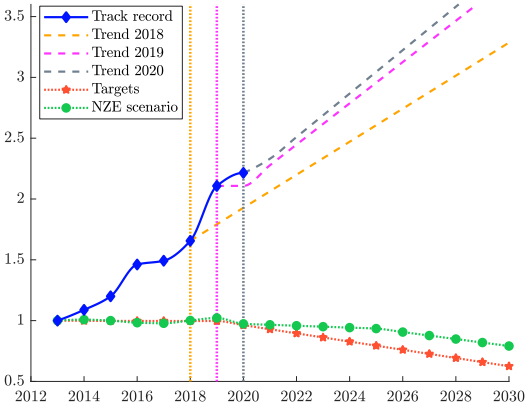
Figure: Carbon emissions, trends and targets and NZE scenario (Company A)



Source: CDP database (2020) & Le Guenedal *et al.* (2022).

Empirical results

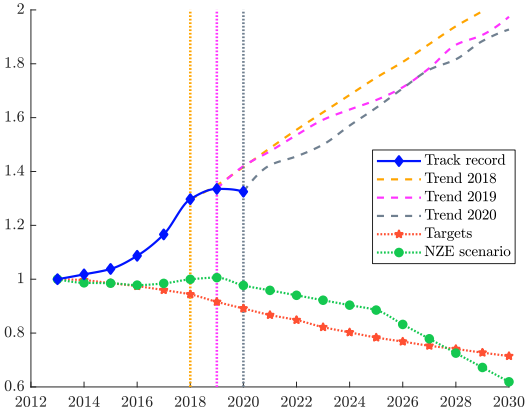
Figure: Carbon emissions, trends and targets and NZE scenario (Company C)



Source: CDP database (2020) & Le Guenedal *et al.* (2022).

Empirical results

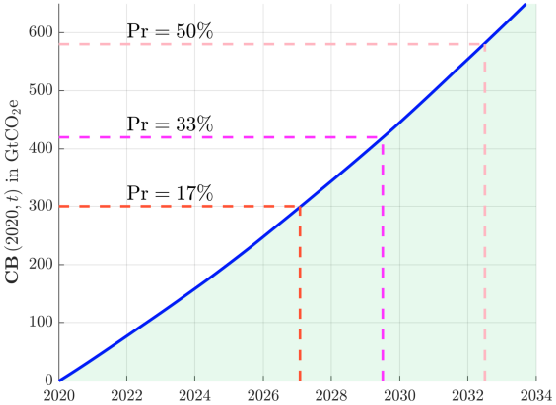
Figure: Carbon emissions, trends and targets and NZE scenario (global analysis)



Source: CDP database (2020) & Le Guenedal *et al.* (2022).

Empirical results

Figure: Probability to reach 1.5°C



Source: Le Guenedal *et al.* (2022).

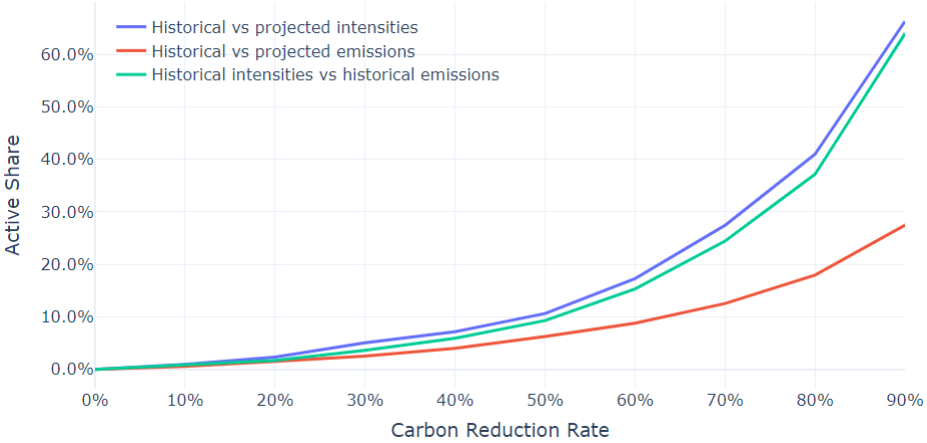
Comparison of NZE portfolios

We consider 4 climate risk metrics:

1. the Scope $1 + 2 + 3$ carbon intensity
2. the Scope $1 + 2 + 3$ carbon emissions
3. the projected Scope $1 + 2 + 3$ carbon intensity (linear trend model)
4. the projected Scope $1 + 2 + 3$ carbon emissions (linear trend model)

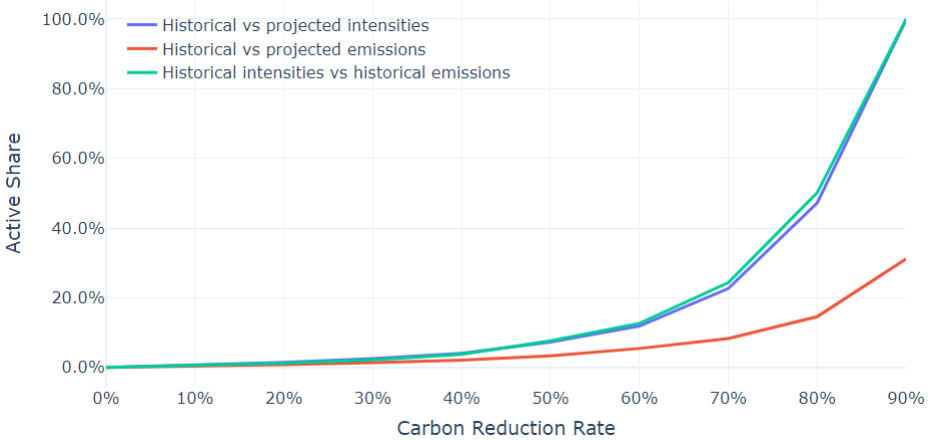
Comparison of NZE portfolios

Figure: Active share between the NZE portfolios (MSCI EMU)



Comparison of NZE portfolios

Figure: Active share between the NZE portfolios (MSCI USA)



Conclusion

- Scope 3 $\Rightarrow$ portfolio decarbonization is more difficult
- Negative correlation between green revenues and carbon emissions/intensity
- HCIS constraint $\Rightarrow$ sector distortion (Financials/Luxury solution)
- Solution with carbon emissions $\neq$ solution with carbon intensity
- Solution with carbon trends $\neq$ solution with historical figures
- **Negative externalities**: food & beverages, utilities, construction materials

Portfolio decarbonization $\neq$ portfolio alignment

Asset allocation issue: Diversification $\searrow$

Gap between finance and economy decarbonization $\nearrow$

What could be a NZE portfolio alignment policy?

Two building blocks of NZE portfolios

Decarbonized portfolio

- Decarbonization pathway
- Top-down approach
- Portfolio optimization
- Carbon metrics

$\alpha\%$

$+$

Green solution portfolio

- Financing the transition
- Bottom-up approach
- Security selection
- $\neq$ Carbon metrics

$(1-\alpha)\%$

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