Net Zero Investing

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Speaker Series The Future of Finance — Net-zero Investing
12 March 2024, EDHEC Business School

[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.

Publications

Main references:

1. Net Zero Investment Portfolios – Part 1. The Comprehensive Integrated Approach, WP-135, 110 pages, October 2022
2. Net Zero Investment Portfolios – Part 2. The Core-Satellite Approach, WP-147, 78 pages, October 2023

https://research-center.amundi.com

How to define a net zero investment policy?

Net zero portfolios vs. low-carbon portfolios

- Low-carbon portfolio: static approach of decarbonization
- Net-zero portfolio: dynamic approach of decarbonization in order to reach net zero by 2050
- Confusion between net zero and decarbonization?

At least two main differences:

1. Net zero implies a self-decarbonization of the portfolios ($\neq$ sequence of decarbonization rates)
2. The transition must be financed ($\Rightarrow$ greenness of the economy)

Exogenous decarbonization pathway $\Rightarrow$ **endogenous** decarbonization pathway

Carbon Intensity + **Green Intensity**

Rebalancing vs. self-decarbonization

- The decarbonization rate at the beginning of year t is equal to 30%
- The objective of the NZE policy is to have a decarbonization rate equal to 35% at the beginning of year $t+1$

Bad case

- The effective decarbonization is equal to 25% at the end of year t
- Self-decarbonization $=0\%$ & Relabancing $=-10\%$

Mixed case

- The effective decarbonization is equal to 33% at the end of year t
- Self-decarbonization $=3\%$ & Relabancing $=-2\%$

Good case

- The effective decarbonization is equal to 36% at the end of year t
- Self-decarbonization $=6\%$ & Relabancing $=0\%$

We can always reach a decarbonization pathway by rebalancing the portfolio!

Decarbonization pathway(s)

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

Year	CTB	PAB	NZE
$\mathcal{R}^-$	30%	50%	IEA
$\Delta\mathcal{R}$	7%	7%	Scenario
2021	30.0%	50.0%	3.1%
2022	34.9%	53.5%	6.2%
2023	39.5%	56.8%	9.4%
2024	43.7%	59.8%	12.5%
2025	**47.6%**	**62.6%**	**15.6%**
2026	51.3%	65.2%	20.5%
2027	54.7%	67.7%	25.4%
2028	57.9%	69.9%	30.3%
2029	60.8%	72.0%	35.2%
2030	**63.6%**	**74.0%**	**40.1%**
2035	74.7%	81.9%	61.8%
2040	82.4%	87.4%	78.4%
2045	87.7%	91.2%	88.0%
2050	91.5%	93.9%	94.6%

What are the issues?

- We have to compare apples with apples ⇒ emissions vs. intensity
- Transition policy sequencing:
  1. Decarbonization and then financing?
  2. Financing and then decarbonization?
- Decarbonization policy sequencing:
  1. Utilities & Energy (85% before 2035)
  2. Materials (70% before 2035)
  3. Buildings (60% before 2035)
  4. Transport (55% after 2035)
  5. Industrials (60% after 2035)

Decarbonization pathway(s)

Figure: IEA, AO, CTB and PAB pathways

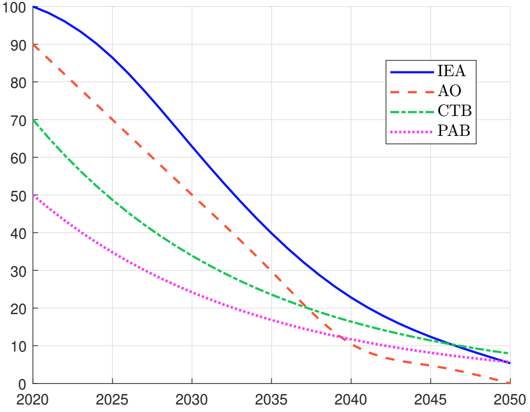
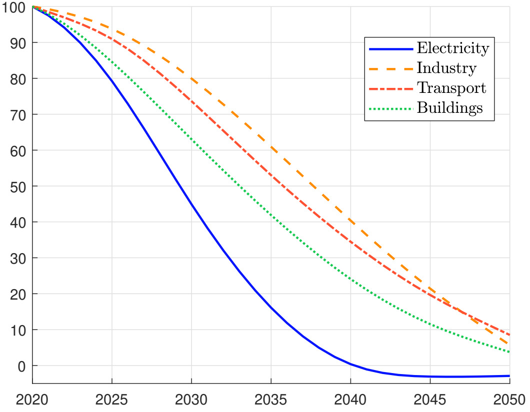


Figure: Sectoral decarbonization pathways



The financial cost of climate change

The Net Zero Transition: What it would Cost, What it could Bring

- McKinsey' Report (2022)
- Capital requirements under the NGFS Net Zero 2050 scenario: $275 trillion in cumulative spending on physical assets over the next 30 years
- This represents approximately $9.2 trillion per year between 2021 and 2050

> "*[...] The transition to net-zero greenhouse emissions by 2050 will require an extra $3.5 trillion a year in capital spending on physical assets for energy and land-use systems*"

That amount is the equivalent of:

- 1/2 of global corporate profits,
- 1/4 of total tax revenue,
- 7% of household spending in 2020,
- 4.1% of the world GDP

Two approaches

Integrated approach

- Equity and bond mutual funds
- ETFs
- Indexes

Core-satellite approach

- Multi-asset portfolios
- Thematic investment
- Strategic asset allocation

The integrated approach

$\Rightarrow$ Extension of portfolio decarbonization by considering self-decarbonization and transition issues

What are the issues?

1. Measurement definition
    - Scope 3 vs. scopes $1+2 \Rightarrow$ closed system
    - Location-based vs market-based scope 2 emissions $\Rightarrow$ **Carbon emissions may be negative!**
    - Forward-looking vs. current values
2. Data gaps
    - Noisy data & manual/human errors
    - Scope 3 emissions (15 categories)
    - Transition metrics: green revenues, green opex, green capex, green R&D

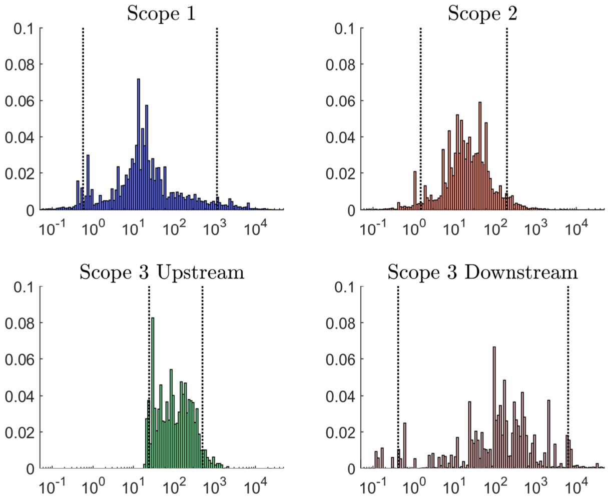
Static measure of carbon footprint

The GHG Protocol corporate standard classifies a company's greenhouse gas emissions in three scopes[2]:

- **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 (●●●●)

[2] Measurement robustness: from ○○○○ (very high) to ●●●● (very low)

Carbon intensity distribution by scope



Importance of the value chain

Table: Examples of 2019 carbon emissions and intensity

Company	Emission (in tCO_2e)				Revenue	Intensity (in tCO_2e/\$ mn)			
	$\mathcal{SC}_1$	$\mathcal{SC}_2$	$\mathcal{SC}_3^{up}$	$\mathcal{SC}_3^{down}$	(in \$ mn)	$\mathcal{SC}_1$	$\mathcal{SC}_2$	$\mathcal{SC}_3^{up}$	$\mathcal{SC}_3^{down}$
Amazon	5 760 000	5 500 000	20 054 722	10 438 551	280 522	20.5	19.6	71.5	37.2
Apple	50 549	862 127	27 624 282	5 470 771	260 174	**0.2**	**3.3**	**106.2**	21.0
BNP Paribas	64 829	280 789	1 923 307	**1 884**	78 244	0.8	3.6	24.6	**0.0**
BP	49 199 999	5 200 000	103 840 194	582 639 687	276 850	177.7	18.8	375.1	2 104.5
Caterpillar	905 000	926 000	15 197 607	401 993 744	53 800	16.8	17.2	282.5	7 472.0
Danone	722 122	944 877	28 969 780	4 464 773	28 308	25.5	33.4	**1 023.4**	**157.7**
Exxon	111 000 000	9 000 000	107 282 831	594 131 943	255 583	434.3	35.2	419.8	2 324.6
JPMorgan Chase	81 655	692 299	3 101 582	**15 448 469**	115 627	0.7	6.0	26.8	**133.6**
LVMH	67 613	262 609	11 853 749	942 520	60 083	1.1	4.4	197.3	15.7
Microsoft	113 414	3 556 553	5 977 488	4 003 770	125 843	0.9	28.3	47.5	31.8
Nestle	3 291 303	3 206 495	61 262 078	33 900 606	93 153	35.3	34.4	**657.6**	**363.9**
Pfizer	734 638	762 840	4 667 225	133 468	51 750	14.2	14.7	90.2	2.6
Samsung Electronics	5 067 000	10 998 000	33 554 245	60 978 947	197 733	**25.6**	**55.6**	169.7	308.4
Volkswagen	4 494 066	5 973 894	65 335 372	354 913 446	282 817	15.9	21.1	231.0	1 254.9
Walmart	6 101 641	13 057 352	40 651 079	32 346 229	514 405	11.9	25.4	79.0	62.9

Source: Trucost (2022) & Authors' calculations.

On the difficulty of estimating emissions from scope 3 activities

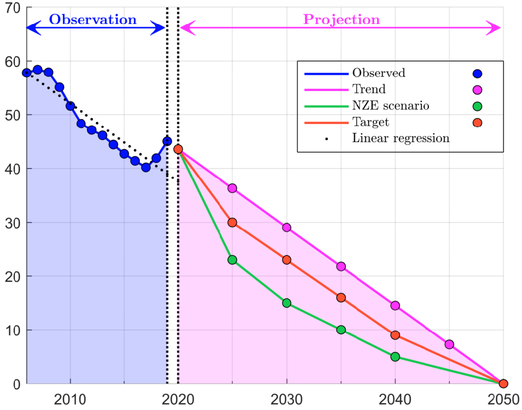
- S&P500: 53 companies have reported Scope 3 in 2022, 11 companies in 2021
- Scope 3 upstream emissions vs. Scope 3 downstream emissions
- Estimated vs. reported emissions

All upstream Scope 3 emissions in commercial databases are estimated using input-output analysis

1. Purchased goods and services
2. Capital goods
3. Fuel and energy related activities
4. Upstream transportation and distribution
5. Waste generated in operations
6. Business travel
7. Employee commuting
8. Upstream leased assets

Measuring self-decarbonization with carbon momentum

Figure: Illustration of the $\mathcal{PAC}$ framework



- We assume a linear constant trend model:

$$\mathcal{CE}(t) = \beta_0 + \beta_1 \cdot t + u(t)$$

- The carbon momentum is the ratio between the slope and the current carbon emissions:

$$\mathcal{CM}(t) = \frac{\hat{\beta}_1(t)}{\mathcal{CE}(t)}$$

Measuring self-decarbonization with carbon momentum

Table: Statistics (in %) of carbon momentum $\mathcal{CM}(t)$, whole Trucost database

Statistics	Carbon emissions			Carbon intensity		
	$\mathcal{SC}_1$	$\mathcal{SC}_{1-2}$	$\mathcal{SC}_{1-3}^{\text{up}}$	$\mathcal{SC}_1$	$\mathcal{SC}_{1-2}$	$\mathcal{SC}_{1-3}^{\text{up}}$
Median	**1.7**	**2.6**	**2.6**	**−2.3**	**−1.7**	**−1.6**
Negative	43.3	37.7	34.9	69.5	66.6	72.0
Positive	56.7	62.3	65.1	30.5	33.4	28.0
$< -10\%$	22.7	17.5	13.3	21.1	14.4	6.5
$< -5\%$	30.0	24.4	19.9	31.5	22.1	13.3
$> +5\%$	34.5	37.6	35.6	11.6	13.2	7.5
$> +10\%$	**17.1**	**17.6**	**15.0**	**5.8**	**6.5**	**3.3**

Source: Trucost (2022) & Authors' calculations.

Sequential decarbonization
(portfolio rebalancing)

versus

Self-decarbonization

Static measures of greenness

- 3-step approach of the EU taxonomy for defining the green intensity:

$$\mathcal{GI} = \frac{\mathcal{GR}}{\mathcal{TR}} \cdot (1 - \mathcal{P}) \cdot \mathbb{1}\left\{\mathcal{S} \geq \mathcal{S}^{-}\right\}$$

- The first term is a proxy of the turnover KPI and corresponds to the green revenue share:

$$\mathcal{GRS} = \frac{\mathcal{GR}}{\mathcal{TR}}$$

By construction, we have $0 \leq \mathcal{GRS} \leq 1$

$\mathcal{GR}$ is the **green revenues** deduced from the objectives

$\mathcal{TR}$ is the **total revenues**

$\mathcal{P}$ is a penalty coefficient reflecting the DNSH **Do No Significant Harm** constraint

$\mathcal{S}$ is the minimum safeguard score, $\mathcal{S}^{-}$ is the threshold

Dynamic measures of greenness

Green intensity trend

$$\mathcal{GI}(t) = \gamma_0 + \gamma_1 \cdot t + v(t)$$

- $\hat{\gamma}_1$ is a dynamic measure of greenness
- no deep history

Green CAPEX

- Early indicator
- Data availability : very weak
- Mandatory to disclose under the EU taxonomy
- Does not necessarily result in innovation

Low carbon patent

- Lagging indicator
- Data availability : good
- A company may decide not to file a patent and still benefit from its innovation

Portfolio decarbonization problem

The goal is to minimize the tracking error variance **under a decarbonization constraint**:

$$
\begin{aligned}
x^{\star} & = \arg\min \frac{1}{2}(x-b)^{\top}\Sigma(x-b) \\
& \text{s.t.} \left\{ \begin{array}{ll} \mathcal{CI}(x) \leq (1-\mathcal{R})\cdot\mathcal{CI}(b) & \longleftarrow \quad \text{Decarbonization (\textbf{static})} \\ x \in \Omega_1 \cap \Omega_2 & \longleftarrow \quad \text{Portfolio constraints (diversification, liquidity, etc.)} \end{array} \right.
\end{aligned}
$$

where Σ is the covariance matrix, b is the benchmark, $\mathcal{R}$ is the reduction rate, $\mathcal{CI}(b)$ is the carbon intensity of the benchmark b and $\mathcal{CI}(x)$ is the carbon intensity of the portfolio x

Portfolio decarbonization (equity portfolios)

Table: Sector allocation in % (MSCI World, Jun. 2022, $\mathscr{C}_0$, scope $\mathcal{SC}_{1-3}$)

Sector	Index	Reduction rate $\mathcal{R}$						
		30%	40%	50%	60%	70%	80%	90%
Communication Services	7.58	7.95	8.15	8.42	8.78	9.34	10.13	12.27
Consumer Discretionary	10.56	10.69	10.69	10.65	10.52	10.23	9.62	6.74
Consumer Staples	7.80	7.80	7.69	7.48	7.11	6.35	5.03	1.77
Energy	**4.99**	4.14	3.65	3.10	2.45	**1.50**	**0.49**	**0.00**
Financials	**13.56**	14.53	15.17	15.94	16.90	**18.39**	**20.55**	**28.62**
Health Care	14.15	14.74	15.09	15.50	16.00	16.78	17.77	17.69
Industrials	9.90	9.28	9.01	8.71	8.36	7.79	7.21	6.03
Information Technology	21.08	21.68	22.03	22.39	22.88	23.51	24.12	24.02
Materials	**4.28**	3.78	3.46	3.06	2.56	**1.85**	**1.14**	**0.24**
Real Estate	2.90	3.12	3.27	3.41	3.57	3.72	3.71	2.51
Utilities	**3.21**	2.28	1.79	1.36	0.90	**0.54**	**0.24**	**0.12**

Source: MSCI (2022), Trucost (2022) & Barahhou *et al.* (2022).

Strategy **long on Financials** and **short on Energy, Materials and Utilities**

Portfolio decarbonization (bond portfolios)

Table: Sector allocation deviation in % (Global Corp., Jun. 2022, scope $\mathcal{SC}_{1-3}$)

Sector	Index	Reduction rate $\mathcal{R}$ 30%	40%	50%	60%	70%	80%	90%
Communication Services	7.34	0.01	0.00	0.03	0.09	0.09	−0.03	−0.04
Consumer Discretionary	5.97	0.00	−0.01	−0.03	−0.04	−0.51	−1.49	−2.42
Consumer Staples	6.04	0.00	0.00	0.00	0.00	−0.02	−0.65	−1.98
Energy	6.49	**-1.00**	**-2.07**	**-2.65**	**-2.80**	**-3.26**	**-3.91**	**-3.97**
Financials	**33.91**	**0.73**	**1.75**	**2.05**	**2.18**	**3.45**	**4.95**	**5.09**
Health Care	7.50	0.00	0.00	0.00	0.00	0.00	0.02	−0.02
Industrials	8.92	**0.46**	**0.70**	**1.27**	**2.42**	**3.15**	**4.63**	**9.21**
Information Technology	5.57	0.00	0.02	0.02	0.03	0.03	−0.05	−0.30
Materials	3.44	**-0.01**	**-0.13**	**-0.26**	**-0.32**	**-0.80**	**-1.19**	**-1.58**
Real Estate	4.76	−0.02	−0.02	−0.02	−0.02	−0.10	−0.15	−0.83
Utilities	10.06	**-0.17**	**-0.24**	**-0.42**	**-1.54**	**-2.02**	**-2.14**	**-3.18**

Source: ICE (2022), Trucost (2022) & Barahhou *et al.* (2022).

Strategy **long on Financials and Industrials** and **short on Energy, Materials and Utilities**

Portfolio decarbonization (equity portfolios)

Table: Green intensity in % (MSCI World, Jun. 2022, $\mathscr{C}_0$)

	Scope	Index	Reduction rate $\mathcal{R}$						
			30%	40%	50%	60%	70%	80%	90%
$\mathcal{GI}$	$\mathcal{SC}_1$	5.24	5.21	5.19	5.18	5.16	5.12	5.08	**5.01**
	$\mathcal{SC}_{1-2}$		5.17	5.14	5.09	4.99	4.83	4.64	**4.52**
	$\mathcal{SC}_{1-3}^{\text{up}}$		5.15	5.07	4.89	4.69	4.42	3.90	**0.68**
	$\mathcal{SC}_{1-3}$		5.17	5.12	5.05	4.97	4.80	4.55	**3.73**

Source: MSCI (2022), Trucost (2022) & Barahhou *et al.* (2022).

Positive correlation between **carbon intensity** and **green intensity**?

Net Zero optimization problem

The goal is to minimize the tracking error variance **under net zero constraints**:

$$
\begin{array}{rcl}
x^{\star}(t) & = & \arg\min \frac{1}{2}(x-b)^{\top}\Sigma(t)(x-b) \\
& \text{s.t.} & \left\{\begin{array}{ll}
\mathcal{CI}(t,x) \leq (1-\mathcal{R}(t_0,t)) \cdot \mathcal{CI}(t_0, b(t_0)) & \longleftarrow \quad \text{Decarbonization (dynamic)} \\
x \in \Omega_{\mathcal{T}ransition}(t) & \longleftarrow \quad \text{Transition (NZE)} \\
x \in \Omega_1 \cap \Omega_2(t) &
\end{array}\right.
\end{array}
$$

The transition constraints can encompass:

1. a **self-decarbonization** maximum threshold: $\{x : \mathcal{CM}(t,x) \leq \mathcal{CM}^{\star}\}$
2. a **greenness** minimum threshold : $\{x : \mathcal{GI}(t,x) \geq (1+\mathcal{G}) \cdot \mathcal{GI}(t, b(t))\}$
3. an **exclusion** constraint: $\left\{\mathcal{CM}_i(t) \geq \mathcal{CM}^{+} \Rightarrow x_i = 0\right\}$

Net Zero optimization problem

Tracking error volatility of net zero portfolios (MSCI World, Jun. 2022, $\mathcal{G} = 100\%$, $\mathcal{CM}^\star = -5\%$, PAB)

Figure: $\mathscr{C}_0$ constraint

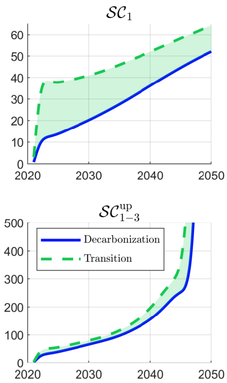
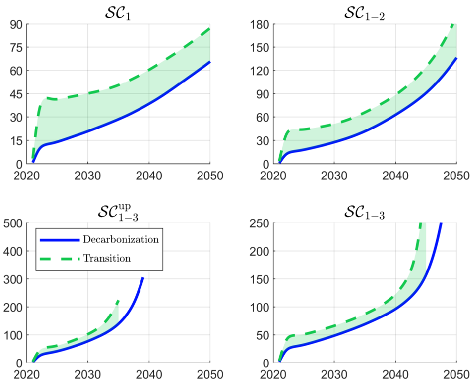


Figure: $\mathscr{C}_3(0,10,2)$ constraint



Source: MSCI (2022), Trucost (2022) & Authors' calculations.

Net Zero optimization problem

Tracking error volatility of net zero portfolios (MSCI EMU, Jun. 2022, $\mathcal{G} = 100\%$, $\mathcal{CM}^{\star} = -5\%$, PAB)

Figure: $\mathscr{C}_0$ constraint

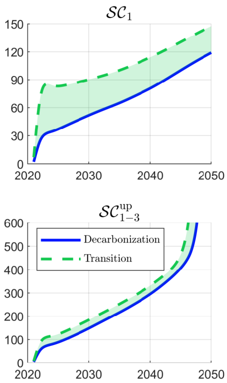
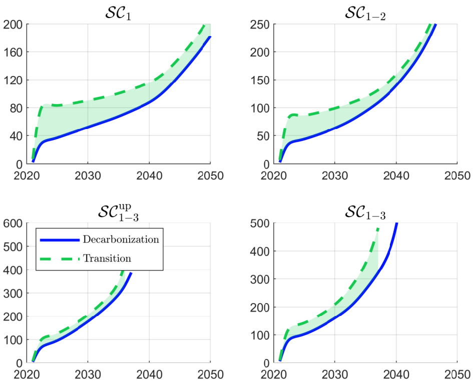


Figure: $\mathscr{C}_3(0, 10, 2)$ constraint



Source: MSCI (2022), Trucost (2022) & Authors' calculations.

Net Zero optimization problem

Tracking error volatility of net zero portfolios (MSCI USA, Jun. 2022, $\mathcal{G} = 100\%$, $\mathcal{CM}^{\star} = -5\%$, PAB)

Figure: $\mathscr{C}_0$ constraint

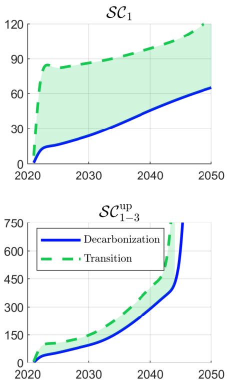
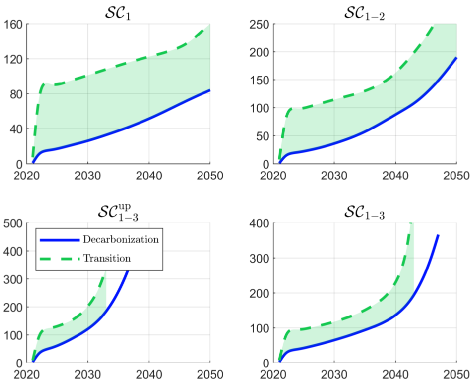


Figure: $\mathscr{C}_3(0, 10, 2)$ constraint



Source: MSCI (2022), Trucost (2022) & Authors' calculations.

What about other costs?

The tracking risk seems manageable. However, net zero alignment bears two hidden risks :

1. **Diversification cost**: due to sectoral concentration
2. **Liquidity cost**: companies providing solution to tackle the climate change are often pure players (small cap stocks)

Investment universe shrinkage

MSCI World, Jun. 2022, $\mathscr{C}_3(0,10,2)$ constraint, $\mathcal{G} = 100\%$, $\mathcal{CM}^\star = -5\%$, scope $\mathcal{SC}_{1-3}$

Figure: Net zero policy

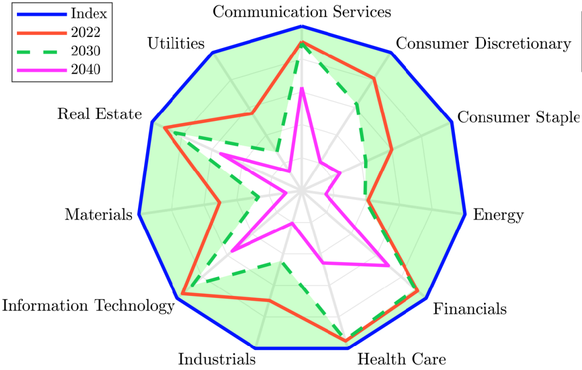
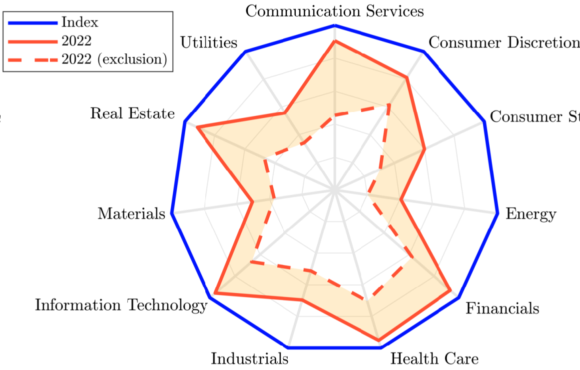


Figure: Momentum exclusion $\mathcal{CM}^+ = 0\%$

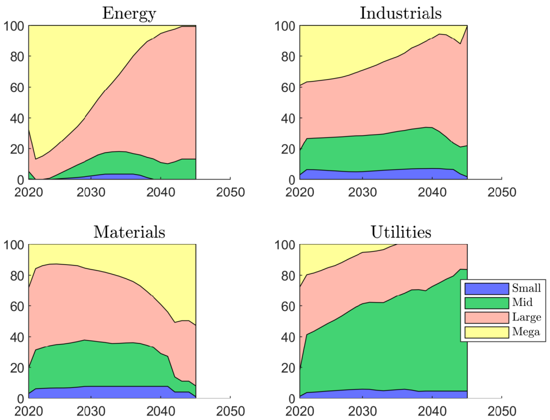


Source: MSCI (2022), Trucost (2022) & Authors' calculations.

Liquidty risk

MSCI World, Jun. 2022, $\mathscr{C}_3(0,10,2)$, $\mathcal{G} = 100\%$, $\mathcal{CM}^\star = -5\%$, PAB, scope $\mathcal{SC}_{1-3}$

Figure: Breakdown of net zero allocation with respect to the market capitalization



The core-satellite approach

Two building blocks of NZE portfolios

Decarbonized portfolio

- Carbon intensity
- Decarbonization pathway(s)
- Top-down approach
- Portfolio construction
- Net zero **carbon** metrics

$+$

Transition portfolio

- Green intensity
- Financing the transition
- Bottom-up approach
- Security selection
- Net zero **transition** metrics

$$1-\alpha(t)\%$$

$$\alpha(t)\%$$

The core portfolio

Optimization problem (core equity portfolio)

The objective function is to minimize the tracking error variance:

$$
\begin{aligned}
x(t) & = \arg\min \frac{1}{2}(x-b)^\top \Sigma (x-b) \\
\text{s.t.} & \left\{
\begin{array}{l}
\mathbf{1}_n^\top x = 1 \\
\mathcal{CI}(t)^\top x \leq (1-\mathcal{R}(t_0,t))\,\mathcal{CI}(t_0,b,\mathscr{F}_{t_0}) \\
\mathbf{0}_n \leq x \leq \mathbf{1}_n
\end{array}
\right.
\end{aligned}
$$

- Problem $\mathscr{P}_1$: optimization with $\mathscr{C}_0$ constraint;
- Problem $\mathscr{P}_2$: optimization with $\mathscr{C}_3(0,10,2)$ constraint, $\mathcal{CM}^\star = -3.5\%$, $\mathcal{CM}^+ = 10\%$;
- Problem $\mathscr{P}_3$: optimization with $\mathscr{C}_3(0,10,2)$ constraint, $\mathcal{CM}^\star = -3.5\%$, $\mathcal{CM}^+ = 10\% +$ IEA NZE scenario for the electricity sector

The core portfolio

Optimization problem (core bond portfolio)

The objective function is to minimize the active risk:

$$\mathscr{R}(x \mid b) = \underbrace{\varphi \sum_{s=1}^{n_{\mathscr{S}ector}} \left| \sum_{i \in s} (x_i - b_i) \cdot \mathrm{DTS}_i \right|}_{\mathrm{DTS}\ \text{component}} + \underbrace{\frac{1}{2} \sum_{i \in b} |x_i - b_i|}_{\text{AS component}} + \underbrace{\mathbb{1}_{\Omega_{\mathrm{MD}}}(x)}_{\text{MD component}}$$

where DTS_i and MD_i are the duration-times-spread and modified duration factors, $\Omega_{\mathrm{MD}} = \{x : \sum_{i=1}^{n} (x_i - b_i) \cdot \mathrm{MD}_i = 0\}$ and $\mathbb{1}_{\Omega}(x)$ is the convex indicator function

- Problem $\mathscr{P}_1$: optimization with $\mathscr{C}_0$ constraint;
- Problem $\mathscr{P}_2$: optimization with $\mathscr{C}_0$ constraint, $\mathcal{CM}^{\star} = -3.5\%$, $\mathcal{CM}^{+} = 10\%$;
- Problem $\mathscr{P}_3$: optimization with $\mathscr{C}_0$ constraint, $\mathcal{CM}^{\star} = -3.5\%$, $\mathcal{CM}^{+} = 10\%$ + IEA NZE scenario for the electricity sector

The core portfolio

Without the IEA NZE scenario for the electricity sector (Problem $\mathscr{P}_2$)

Figure: Decarbonization pathway of the electricity sector (MSCI World, Dec. 2021)

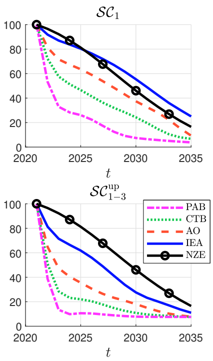
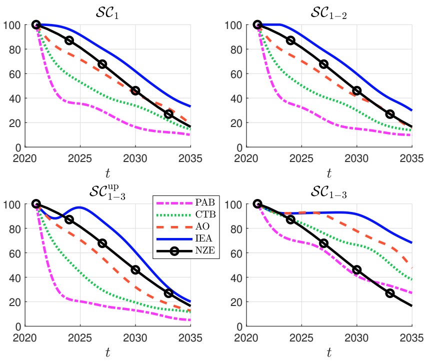


Figure: Decarbonization pathway of the electricity sector (Global Corporate, Dec. 2021)



Source: MSCI (2023), Trucost (2023), Bloomberg (2023) & Ben Slimane *et al.* (2023).

Implications for strategic asset allocation

Figure: Implied risk premium $\Delta\tilde{\pi}_j$ in bps of the Utilities sector (MSCI World, Dec. 2021, Scope $\mathcal{SC}_{1-2}$)

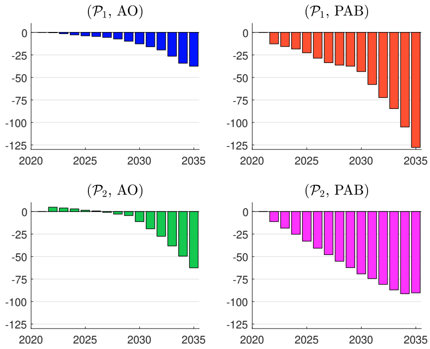
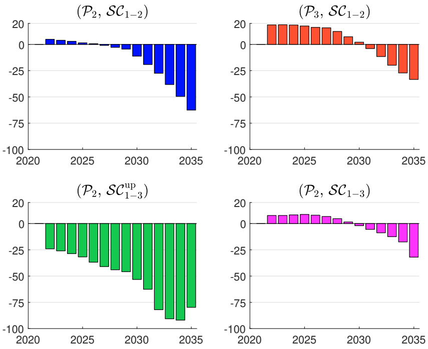


Figure: Implied risk premium $\Delta\tilde{\pi}_j$ in bps of the Utilities sector (MSCI World, Dec. 2021, AO pathway)



Source: Ben Slimane *et al.* (2023).

How to achieve net zero emissions

The main transformation involves the power sector in two directions:

1. Massive electrification of the world economy
2. Greening electricity to achieve clean power generation

Table: The 2050 net zero scenarios

2020			2050		
Production	Energy Intensity	Carbon Emissions	Production	Energy Intensity	Carbon Emissions
30 000 TWh	**500** g/kWh	**15** $GtCO_2e$	100 000 TWh	**20** g/kWh	**2** $GtCO_2e$

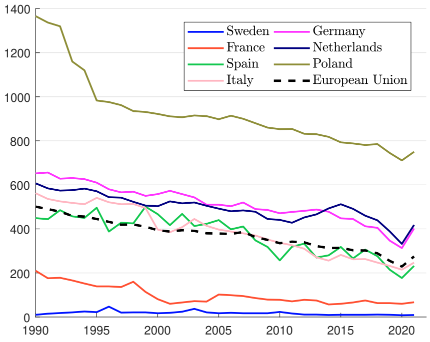
How to achieve net zero emissions

Table: Emission factor in gCO_2e/kWh of electricity generation in the world

Region	$\mathcal{EF}$	Country	$\mathcal{EF}$	Country	$\mathcal{EF}$	Country	$\mathcal{EF}$
Africa	484	Australia	531	Germany	354	Portugal	183
Asia	539	Canada	128	India	637	Russia	360
Europe	280	China	544	Iran	492	Spain	169
North America	352	Costa Rica	33	Italy	226	Switzerland	47
South America	204	Cuba	575	Japan	479	United Kingdom	270
World	442	France	58	Norway	26	United States	380

Source: Roncalli (2023).

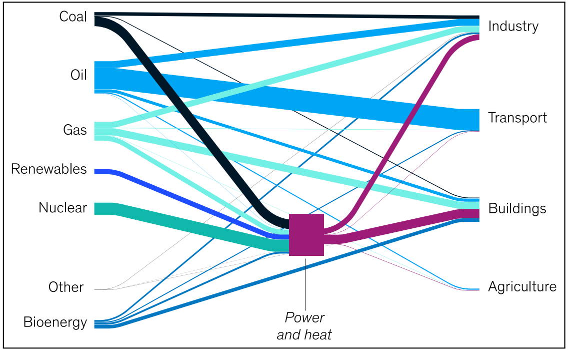
Figure: Emission factor in gCO_2e/kWh of electricity generation (European Union, 1990 – 2022)



Source: Roncalli (2023).

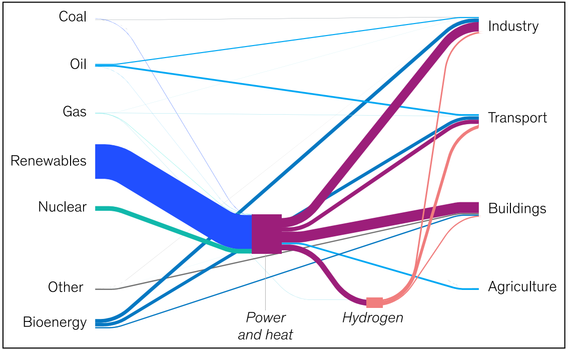
Transforming the global value chain into a net zero economy

Figure: 2017



Source: McKinsey (2023, Exhibit 6B, page 12).

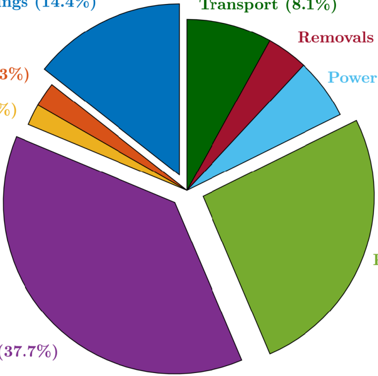
Figure: 2050



Source: McKinsey (2023, Exhibit 6B, page 12).

Funding requirements

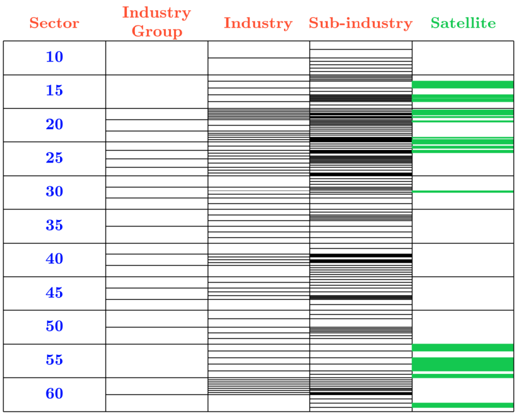
Figure: Net zero capital investments



Source: Energy Transitions Commission (2023a, page 6) & Authors' calculations.

Narrow definition of the satellite investment portfolio

Figure: Narrow specification of the satellite investment universe



Other net zero issues

- Materials and critical minerals, e.g. rare earths ($\Rightarrow$ geopolitical issues)
- Who will finance the transition? ($\Rightarrow$ debt sustainability issues)
- How to track net zero progress? ($\Rightarrow$ monitoring issues)

Investment universe

- Green, sustainability and sustainability-linked bonds
- Green stocks
- Green infrastructure
- Sustainable real estate

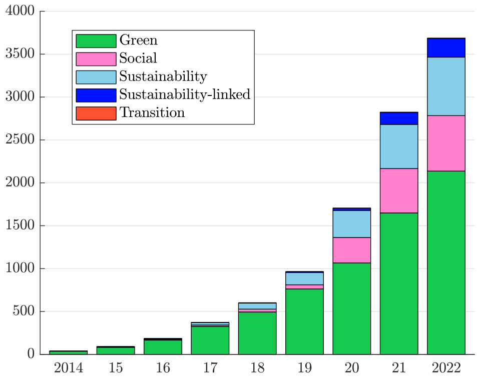
Investment universe
Green bonds

Table: GSS+ bond issuance

Year	GB		SB		SuB		SLB	
	#	$ bn	#	$ bn	#	$ bn	#	$ bn
2022	1 784	531.6	542	152.8	614	174.8	382	144.3
2021	1 971	686.1	554	242.1	646	233.2	343	161.5
2020	1 076	291.2	273	172.0	308	154.8	47	16.5
2019	877	268.0	99	22.2	333	85.2	18	8.9
2018	582	165.3	48	16.5	52	22.1	1	2.2
2017	472	160.9	46	11.8	17	9.2	1	0.2
2016	285	99.7	14	2.2	16	6.6	0	0.0

Source: Bloomberg, GSS+ Instrument Indicator

Figure: Outstanding of GSS+ debt (in $ bn)



https://www.climatebonds.net/market/data.

Investment universe

Green bonds

- Upper bound ≈ \$900 bn (25%)
- Lower bound ≈ \$400 bn (12%)

Table: What the GSS+ bond market does and does not finance

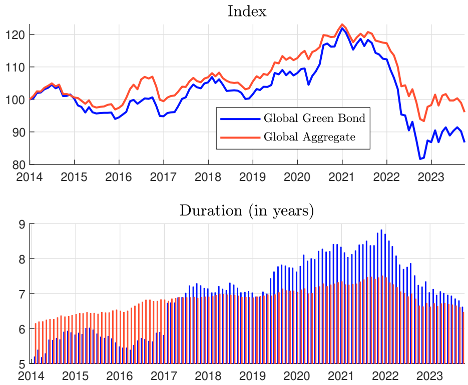
Sector	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	4
Power generation	1310	37.7%	207	6.0%	1103	31.7%	**15.8%**
Power networks	900	25.9%	135	3.9%	765	22.0%	**15.0%**
Power storage	200	5.8%	27	0.8%	173	5.0%	**13.5%**
Buildings	500	14.4%	225	6.5%	275	7.9%	45.0%
Transport	280	8.1%	180	5.2%	100	2.9%	**64.3%**
Removals	135	3.9%	90	2.6%	45	1.3%	**66.7%**
Hydrogen	80	2.3%	9	0.3%	71	2.0%	**11.3%**
Industry	70	2.0%	27	0.8%	43	1.2%	38.6%
Total	3475	100.0%	900	25.9%	2575	74.1%	25.9%

Source: Authors' calculations.

(1a) Funding requirement (in \$ tn), (1b) Break-down (in %), (2a) Financed (in \$ tn), (2b) Financed (in %), (3a) Non-financed (in \$ tn), (3b) Non-financed (in %), (4) Funding ratio (in %)

Investment universe
Green bonds

Figure: Performance and duration of the bond indices

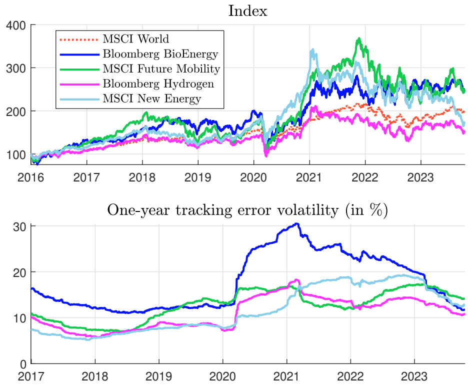


Tracking error volatility $\approx$ 3%

Source: Bloomberg (2023).

Investment universe
Green equities

Figure: Performance and tracking error volatility of thematic equity indices

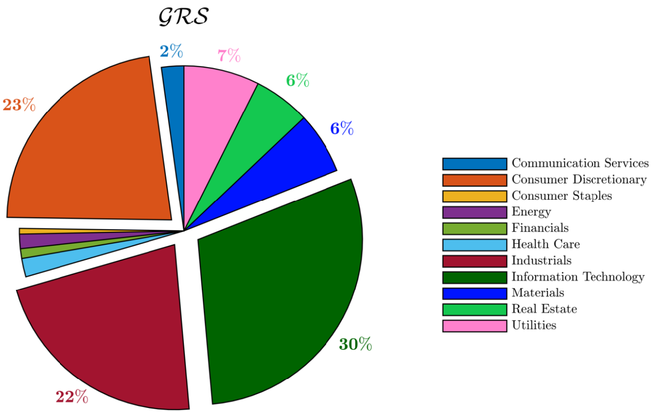


Tracking error volatility $\approx$ 20%

Source: Bloomberg (2023) & MSCI (2023).

Investment universe
Green equities

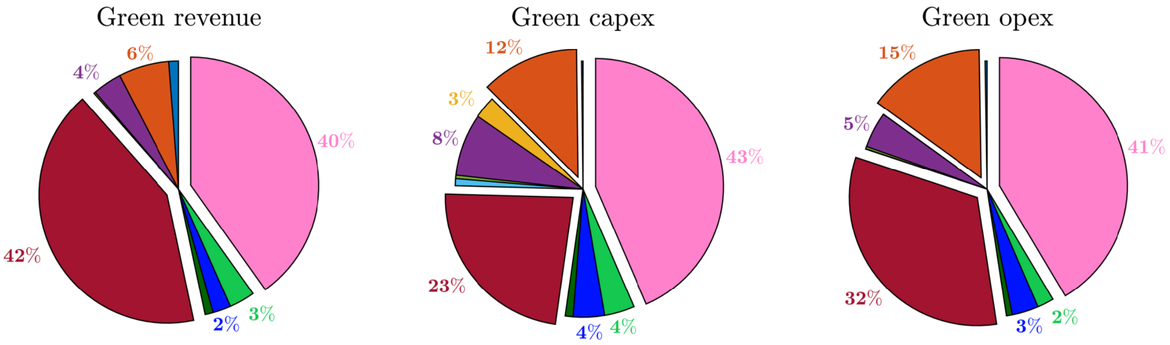
Figure: Breakdown in % of green intensities (MSCI World, Dec. 2021)



Investment universe

Green equities

Figure: Breakdown in % of green intensities (MSCI World, Dec. 2021)



Investment universe

Other asset classes

1. Sustainable infrastructure
2. Sustainable real estate
   - CRREM (Carbon Risk Real Estate Monitor) $\Rightarrow$ whole-building approach for in-use emissions
   - GRESB $\Rightarrow$ GHG Protocol principles to the real estate industry (corporate approach)
   - SBTi Building Guidelines
   - PCAF/CRREM/GRESB joint technical guidance $\Rightarrow$ Accounting and reporting of financed GHG emissions from real estate operations (GHG Protocol)

Tracking error risk of the core/satellite portfolio

Assumptions

Tracking error

- Core equity portfolio = 2%
- Core bond portfolio = 25 bps
- Satellite equity portfolio = 20%
- Satellite bond portfolio = 3%

Correlation

- Lower bound: $\rho = 0\%$
- Upper bound: $\rho_{\text{intra-class}} = 80\%$

Table: Estimation of the tracking error volatility of the core/satellite portfolio (in %)

	α	Bond	Defensive	Balanced	**60/40**	Dynamic	Equity
	10%	0.38	0.62	1.36	1.62	2.15	2.69
LB	**20%**	0.63	1.00	2.18	**2.60**	3.45	4.31
	30%	0.92	1.43	3.11	3.71	4.93	6.16
	10%	0.53	1.18	2.16	2.49	3.15	3.80
UB	**20%**	0.80	1.76	3.20	**3.68**	4.64	5.60
	30%	1.07	2.34	4.24	4.87	6.13	7.40

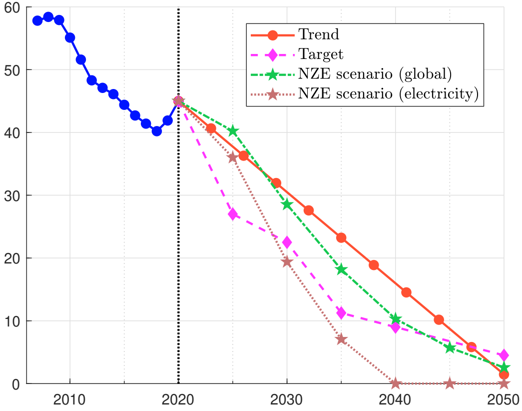
Conclusion

- Net zero investment strategy $\neq$ low-carbon investment strategy
  - Static **exogenous** decarbonization $\Rightarrow$ Dynamic **endogenous** decarbonization
  - How to assess **self-decarbonization**?
  - **Transition** matters!
  - Issues on the short run will decrease on the long run if the ~~finance~~ **economy** decarbonizes
- The additional cost for equity portfolios will be greater than for bond portfolios (wrt to business-as-usual investing)
  - We must distinguish stock of capital and new fresh capital
  - Equity market portfolios are driven by old capital (**secondary market**)
  - Bond market portfolios are driven by fresh capital (**primary market**)
  - The **structure of bond benchmarks** changes faster than the structure of equity benchmarks
- **There are solutions**
  - Don't go too fast in terms of decarbonization pathway
  - Deeply understand the transition dimension and the relationships between net zero metrics
  - **Less is more**

Self-decarbonization

The $\mathcal{PAC}$ framework

Figure: Carbon trend, targets and NZE scenario of company A

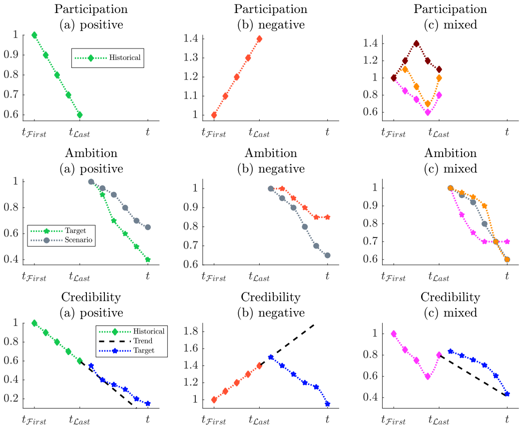


Three pillars:

- **P**articipation
- **A**mbition
- **C**redibility

Self-decarbonization
The $\mathcal{PAC}$ framework

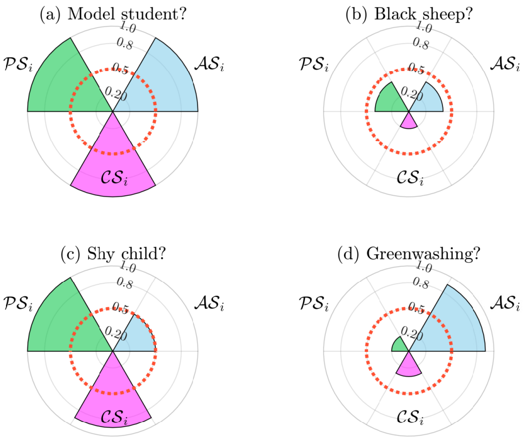
Figure: Assessment of the $\mathcal{PAC}$ pillars



Self-decarbonization

The $\mathcal{PAC}$ framework

Figure: The $\mathcal{PAC}$ scoring system



Self-decarbonization

Using temperature ratings

Table: Frequency of temperature ratings (in %)

Range	CDP Scope 1+2+3	CDP Short-term	CDP Mid-term	CDP Long-term	Iceberg
$\mathcal{T} \leq 1.0°C$	0.00	0.00	0.00	0.00	1.01
$1.0°C < \mathcal{T} \leq 1.5°C$	1.44	2.92	10.68	2.71	2.60
$1.5°C < \mathcal{T} \leq 2.0°C$	6.20	1.26	13.03	3.94	3.14
$2.0°C < \mathcal{T} \leq 2.5°C$	6.86	3.07	7.46	2.68	21.76
$2.5°C < \mathcal{T} \leq 3.0°C$	7.64	1.99	4.21	0.48	30.87
$3.0°C < \mathcal{T} \leq 3.5°C$	76.95	89.77	62.80	90.07	32.30
$3.5°C < \mathcal{T} \leq 4.0°C$	0.78	0.81	1.44	0.09	2.23
$4.0°C < \mathcal{T} \leq 4.5°C$	0.12	0.18	0.36	0.03	3.31
$4.5°C < \mathcal{T} \leq 5.0°C$	0.00	0.00	0.00	0.00	0.77
$\mathcal{T} = 3.2°C$	52.09	88.50	61.39	89.95	0.01

Source: CDP Temperature Ratings Dataset, version 1.1, February 2021 & Iceberg Data Lab (2021).

How to achieve net zero emissions

Material and resource requirements

Table: Mineral requirements for clean energy technologies

	Aluminium	Chromium	Copper	Cobalt	Graphite	Lithium	Neodymium
Bioenergy	◐	○	●	○	○	○	○
CSP	●	●	◐	○	○	○	○
Electricity Networks	●	○	●	○	○	○	○
EVs and Battery storage	●	○	●	●	●	●	●
Geothermal	○	●	○	○	○	○	○
Hydrogen	◐	○	○	○	○	○	○
Hydropower	◐	◐	◐	○	○	○	○
Nuclear	○	◐	◐	○	○	○	◐
Solar PV	●	○	●	○	○	○	○
Wind	◐	◐	●	○	○	○	●

Source: IEA (2022, page 45).

How to achieve net zero emissions
Material and resource requirements

Table: Mineral requirements for clean energy technologies

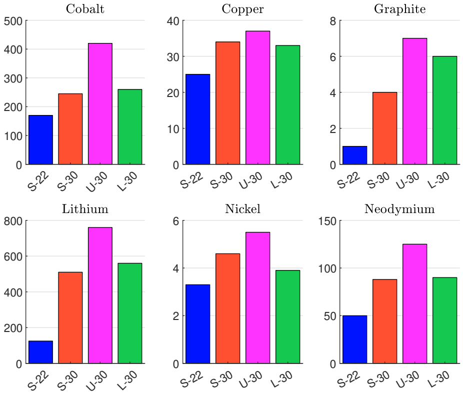
	Nickel	Platinum	Polysilicon	REEs	Silver	Steel	Uranium	Zinc
Bioenergy	○	○	○	○	○	○	○	◐
CSP	◐	○	○	○	○	○	○	◐
Electricity Networks	○	○	○	○	○	●	○	○
EVs and Battery storage	●	○	○	●	○	○	○	○
Geothermal	●	○	○	○	○	○	○	○
Hydrogen	●	●	○	◐	○	●	○	○
Hydropower	○	○	○	○	○	●	○	◐
Nuclear	◐	○	○	○	○	●	●	○
Solar PV	○	○	●	○	●	●	○	○
Wind	◐	○	○	●	○	●	○	●

Source: IEA (2022, page 45).

How to achieve net zero emissions

Material and resource requirements

Figure: Demand and primary supply in 2030



Source: Energy Transitions Commission (2023a).

How to achieve net zero emissions

Funding requirements — global analysis

Total investment: **3.5 trillion per year to 2050**

How to achieve net zero emissions

Funding requirements — sector analysis

Power ($2 400 bn)

- Total electricity supply from around 30 000 TWh today to over 100 000 TWh by mid-century
- Extension of transmission and distribution networks from about 70 million km to up to 200 million km
- Green hydrogen production of 500-800 Mt per year

Buildings ($500 bn)

- Need to retrofit older buildings and create new carbon-efficient buildings
- $500 bn per year invested in the buildings sector: incorporate new green technologies ($230 bn), purchase renewable heat ($130 bn) and install new heat pumps ($150 bn)

How to achieve net zero emissions

Funding requirements — sector analysis

Mobility ($280 bn)

- The largest part of the transition from ICE (internal combustion engines) to EVs will require $130 bn per year to develop charging and refuelling facilities
- $70 bn will be spent on sustainable aircraft manufacturing facilities and aircraft batteries
- $40 bn will be spent on greening the shipping system through new infrastructure, vessels and investments

Sustainable agriculture and land use requirements ($50 bn)

- The demand for wind and solar farms is far greater than the previous demand based on the fossil fuel system, but still far less than the demand for agriculture
- Agriculture is the largest driver of deforestation

How to achieve net zero emissions

Funding requirements — sector analysis

Hydrogen ($80 bn)

- $80 bn investment will be allocated to the production and distribution of hydrogen
- $40 bn will be used to produce green and blue hydrogen and to recycle grey hydrogen
- $40 bn will help build pipelines, refuelling stations, exchange terminals and storage capacity

Industry ($70 bn)

- $10 bn will be used to decarbonise steel
- $10 bn for cement plants
- $40 bn to fully develop and integrate CCS and other decarbonisation technologies
- $10 bn to deploy low-carbon technologies in smelters and refineries

How to achieve net zero emissions

Funding requirements — sector analysis

Waste management and circular economy ($135 bn)

- Waste is generated at every stage of the transition, from food waste from agriculture to waste from solar panels, wind farms or even mining
- The energy transition will generate up to 13 billion tonnes of waste from all materials by 2050

Water management ($25 bn)

- Global water consumption will be 4000 billion m^3 per year in 2050, of which 70% is used for agriculture (2800 billion m^3), 58 billion m^3 for clean energy production and 37 billion m^3 for fossil fuels
- For clean energy production, water is used for nuclear power generation (14 billion m^3 per year), hydrogen production by electrolysis (11 billion m^3 per year), carbon capture (19–29 billion m^3 per year) and cleaning solar panels
- Global energy use in the water sector expected to double by 2040

How to achieve net zero emissions

Tracking net zero progress

Table: What's on track (energy system overview)

Energy Efficiency	yellow
Behavioural Changes	red
Electrification	yellow
Renewables	yellow
Bioenergy	yellow
Hydrogen	yellow
Carbon Capture, Utilisation and Storage	red
Innovation	yellow
International Collaboration	yellow
Digitalisation	yellow

green: on track, yellow: more efforts needed, red: not on track

Source: IEA (2023).

How to achieve net zero emissions

Tracking net zero progress

Table: What's on track (sector analysis)

Transversal Technologies & Infrastructure	Yellow	Electricity	Yellow
CO_2 Transport and Storage	Red	Coal	Red
CO_2 Capture and Utilisation	Yellow	Natural Gas	Yellow
Bioenergy with Carbon Capture and Storage	Red	Solar PV	Green
Direct Air Capture	Yellow	Wind	Yellow
Electrolysers	Yellow	Hydroelectricity	Yellow
District Heating	Red	Demand Response	Yellow
Data Centres and Transmission Networks	Yellow	Nuclear Power	Yellow
Transport	Red	Grid-scale Storage	Yellow
Cars and Vans	Yellow	Smart Grids	Yellow
Trucks and Buses	Red	Energy	Red
Rail	Yellow	Oil & Natural Gas Supply	Red
Aviation	Red	Methane Abatement	Red
International Shipping	Red	Gas Flaring	Red
Electric Vehicles	Green	Biofuels	Red
Industry	Red	Buildings	Yellow
Steel	Red	Heating	Yellow
Chemicals	Red	Space Cooling	Yellow
Cement	Red	Lighting	Green
Aluminium	Red	Appliances & Equipment	Yellow
Paper	Red	Building Envelopes	Red
Light Industry	Yellow	Heat Pumps	Yellow

How to achieve net zero emissions

Public vs. private investments

Figure: Public investment – relative difference in % compared with the baseline scenario

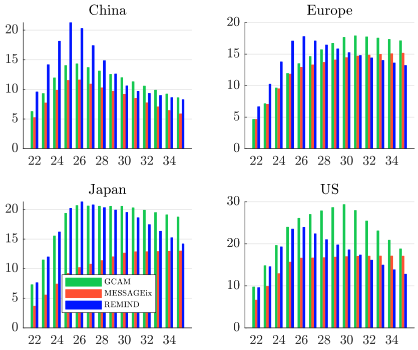
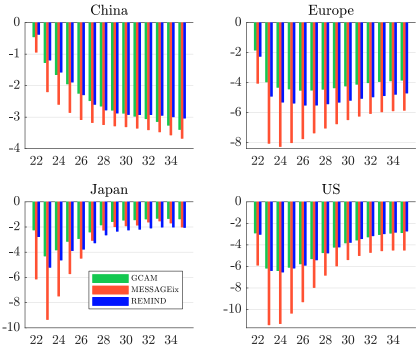


Figure: Private investment – relative difference in % compared with the baseline scenario



Source: NGFS (2022) & `https://data.ene.iiasa.ac.at/ngfs`.

How to achieve net zero emissions

Public vs. private investments

What are the narratives

- Net zero emissions scenario $\Rightarrow$ Huge cost
- This cost mainly concerns the Utilities sector

- Utilities $\Rightarrow$ Huge capex $\Rightarrow$ ROE $\searrow$
- Private investors are reluctant to finance the utilities sector
- Private investment $\searrow$

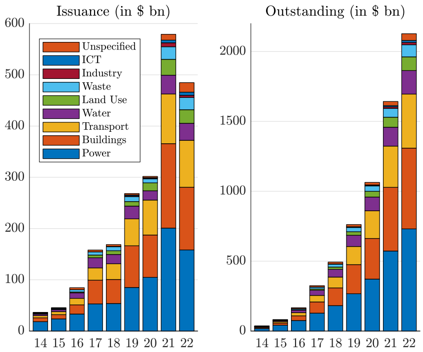
- A strong increase of public investment
- Debt $\nearrow$ $\Rightarrow$ Interest rates $\nearrow$
- Investors prefer to invest in sovereign bonds than financing directly net zero

Vase communication between public investment and private investment

Investment universe of the satellite portfolio

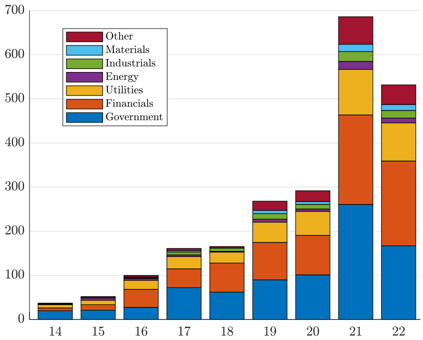
Green bonds

Figure: Issuance of GBs by use of proceeds



Source: https://www.climatebonds.net/market/data.

Figure: Issuance of green bonds by sectors

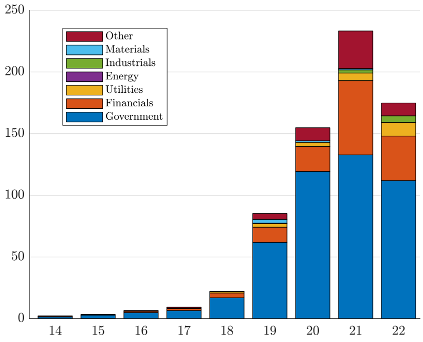


Source: Bloomberg, GSS+ Instrument Indicator.

Investment universe of the satellite portfolio

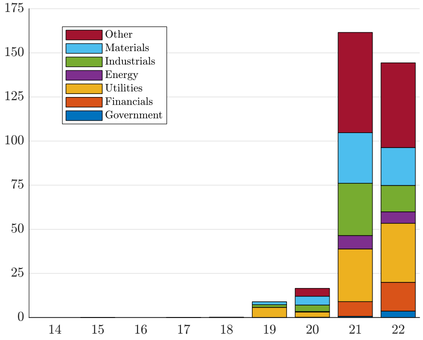
Green bonds

Figure: Issuance of sustainable bonds by sectors



Source: Bloomberg, GSS+ Instrument Indicator.

Figure: Issuance of SLBs by sectors



Source: Bloomberg, GSS+ Instrument Indicator.

Investment universe
Green equities

Table: Statistics of the narrow definition (MSCI World, Dec. 2021)

Sector	Code	MSCI World CW	MSCI World Alignment	MSCI World Breakdown	Satellite Target
Communication Services	50	8.35%			
Consumer Discretionary	25	12.25%	28.62%	30.9%	5 – 15%
Consumer Staples	30	6.91%	1.32%	0.8%	0 – 5%
Energy	10	3.12%			
Financials	40	13.16%			
Health Care	35	12.62%			
Industrials	20	10.21%	38.97%	35.0%	10 – 20%
Information Technology	45	23.68%			
Materials	15	4.10%	29.42%	10.6%	5 – 15%
Real Estate	60	2.79%	1.32%	0.3%	0 – 5%
Utilities	55	2.74%	92.80%	22.3%	50 – 70%
Total			11.37%	100.0%	

Investment universe

Green equities

Net zero contribution metrics

- Green revenue share
- Green turnover (EU taxonomy)
- Green Opex (EU taxonomy)
- Green Capex (EU taxonomy)

Table: Average green intensities in % (MSCI World, Dec. 2021)

Sector	Code	GRS	Revenue	Capex	Opex
Communication Services	50	2.79	0.07	0.02	0.02
Consumer Discretionary	25	19.59	0.25	0.98	0.89
Consumer Staples	30	0.85	0.00	0.40	0.00
Energy	10	4.79	0.57	2.46	1.06
Financials	40	0.77	0.01	0.03	0.02
Health Care	35	1.52	0.00	0.07	0.00
Industrials	20	22.86	1.98	2.21	2.34
Information Technology	45	13.28	0.02	0.04	0.02
Materials	15	15.41	0.26	0.92	0.59
Real Estate	60	21.18	0.56	1.33	0.55
Utilities	55	28.88	7.08	15.46	11.13
Total		10.64	0.48	0.97	0.73

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