Achieving net zero: Investment frameworks and best practices

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Abstract

Leveraging the latest research and industry best practices, the paper describes four specific frameworks for institutional investors to align equity portfolios with net zero pathways: a forward-looking approach using BNP Paribas Asset Management's "Net Zero Achieving, Aligned, Aligning" (NZ:AAA) screens, the Paris-aligned benchmark (PAB) rules, fossil fuel exclusions and clean energy thematic investing. The strengths and weaknesses of each framework are analysed, along with an evaluation of their potential to support the goals of various institutional investors in guiding their portfolios towards achieving net zero commitments.

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1. Introduction

In response to the pressing issue of climate change, institutional investors are actively seeking methods to align their portfolios with targets for net zero financed emissions. There is no unique framework for reaching this goal, and currently proposed frameworks range from traditional fossil fuel exclusions and carbon footprint reduction to frameworks that prioritise increasing investment exposure to companies whose revenue, or operating expenditure and capital expenditure, are aligned with the environmental transition. Many investors put a strong focus on corporate engagement and public policy advocacy in their approach to achieving net zero portfolios (in addition to, or instead of, other frameworks).

In this paper, we extend our original analysis published in Leote de Carvalho et al (2025) by exploring four investment frameworks, namely BNP Paribas Asset Management's (BNPP AM) "Net Zero Achieving, Aligned, Aligning" (NZ:AAA) screens, the Paris-aligned benchmark (PAB) rules, fossil fuel exclusions and a clean energy thematic investment (index) framework.

The PAB rules and fossil fuel exclusions effectively reduce the carbon intensity of investment portfolios by design, as they exclude companies that are currently the biggest emitters of greenhouse gases (GHGs). PAB rules also provide a clear pathway to net zero by defining a trajectory for reducing the portfolio's carbon intensity over time. However, these frameworks are based on backward-looking carbon intensity reductions, relying on historical emissions data which are often not reported but rather estimated by data vendor models and which are characterised by uncertainty. The frameworks do not formally incorporate a more forward-looking dimension,[8] eg companies' credible plans to decarbonise, nor do they consider that companies in different sectors have varying starting points and that, therefore, different levels of effort are required to achieve net zero by 2050. Moreover, by disinvesting from the biggest emitters today, or from fossil fuel companies altogether, a PAB-based approach and/or fossil fuel exclusions will not incentivise investor engagement and stewardship with such companies aimed at accelerating progress toward net zero targets.

On the other hand, the emerging alignment frameworks are based on forward-looking data. They put less focus on decarbonising today and more focus on finding companies that, even if they are high emitters today, are taking climate change seriously, ie companies that are committed to net zero by 2050 and that have a strategy to get there. These frameworks are being put forward by the **Institutional Investors Group on Climate Change** (**IIGCC**) and have been designed to align with the recommendations of the **UN-convened Net-Zero Asset Owner Alliance** and the **UN High-Level Expert Group** (**HLEG**) **on the Net Zero Emissions Commitments of Non-State Entities**. Unlike the PAB rules and fossil fuel exclusions, alignment frameworks facilitate engagement with a view to reducing real world emissions by not excluding all high emitters. Here we outline how an alignment framework can be implemented in practice and compare it with the other frameworks.

[8] The EU PAB regulation does recommend that the weight of companies that set and publish GHG emission reduction targets be increased in PAB benchmark indices, provided that they publish targets and can demonstrate success in their reduction of emissions. However, the implementation of this recommendation is voluntary and, while it is implemented by some providers of PAB indices, it is not considered here.

The paper is organised as follows: in section 2, we discuss the four different frameworks, including the NZ:AAA screens, the PAB rules, fossil fuel exclusions and a clean energy thematic index approach. In section 3, we provide a comparative analysis of these frameworks by examining the impact of the exclusions of the different frameworks on the breadth of the investment universe and on the market capitalisation available in regions and sectors for investing after exclusions. We investigate the impact on the risk, expected returns and sustainability of minimum tracking error portfolios relative to their respective market capitalisation-weighted benchmarks. Finally, we discuss the strengths and weaknesses of each framework, noting that each has its own merits and limitations. Finally, in section 4, we discuss some of the limitations of our analysis and propose further research on the topic.

2. Frameworks for net zero pathways

In this section, we present four different frameworks. The first is based on classifying companies in terms of their efforts towards alignment with a "net zero by 2050" strategy. The second is the EU's PAB framework. The third is the simple exclusion of fossil fuels from portfolios, and finally we consider a dark green portfolio that invests only in clean energy companies. For simplicity's sake, we consider these approaches in the context of equity investments. A subsequent paper could explore the implications for fixed income and private market investments.

2.1. Net Zero Achieving, Aligned, Aligning (NZ:AAA) screens

BNPP AM's proprietary NZ:AAA screens are based on a forward-looking framework inspired by the net zero framework of the Paris Aligned Investment Initiative (PAII) proposed by the IIGCC. The framework addresses two major themes: (i) activity-based alignment with the environmental transition and (ii) carbon footprint reduction targets. Companies are categorised as "Achieving", "Aligned" or "Aligning" if they report sufficient revenues associated with climate mitigation linked to the **UN Sustainable Development Goals** (**SDGs**) or aligned with the EU Taxonomy, or if they have published carbon reduction targets assessed to be consistent with efforts to limit global warming to 1.5°C or 2°C. Data sources include the **Science Based Targets initiative** (**SBTi**) or the **SBTi** tool using data from the **Carbon Disclosure Project** (**CDP**), the **Transition Pathway Initiative** (**TPI**) and the **Climate Action 100+** (**CA100+**) **Net Zero Company Benchmark**. In particular, companies are classified as:

a. **Achieving net zero:** These are companies already achieving the emissions intensity required for net zero by 2050 and with an investment plan or business model that ensures continued achievement of that goal over time, or with revenues contributing significantly towards climate change mitigation, which is assessed by looking for:
    - companies committed to net zero and whose current carbon performance is at (or close to) what is needed for its sector to reach net zero global emissions by 2050;
    - companies with at least 50% of their revenues aligned with EU Taxonomy on climate change mitigation; or

- companies with at least 50% of their revenues aligned with climate mitigation-linked SDGs[9] and no more than 20% of their revenues misaligned with any SDGs.

b. **Aligned to a net zero pathway:** These are companies that have a 2050 net zero ambition, with short- and medium-term targets for emissions reduction; appropriate disclosure of scope 1, 2 and material scope 3 emissions;[10] a quantified decarbonisation strategy and capital spending plans consistent with achieving net zero emissions by 2050, or with revenues contributing towards climate change mitigation, which is assessed by looking for:

- companies committed to net zero emissions by 2050 and that have a carbon reduction target assessed to be aligned with a scenario of a global temperature increase at or below 1.5°C;[11]
- companies with at least 20% of their revenues aligned with EU Taxonomy on climate change mitigation; or
- companies with at least 20% of their revenues aligned with climate mitigation-linked SDGs[12] and no more than 20% of their revenues misaligned with any SDGs.

c. **Aligning to a net zero pathway:** These are companies that have set short- and medium-term targets for emissions reduction, with appropriate disclosure of scope 1, 2 and material scope 3 emissions and a plan relating to how they will achieve these targets, which is assessed by looking for:

- companies that have a carbon reduction target assessed to be aligned with a scenario of a global temperature increase of below 2°C[13] and which are not otherwise considered Achieving or Aligned.

9 SDG target numbers: 7.2, 7.3, 7.a, 7.b and 9.4.

10 The scopes of company carbon emissions are defined by the Greenhouse Gas Protocol (ghgprotocol.org/): Scope 1 is the sum of direct GHG emissions from sources that are owned or controlled by the company, which include stationary combustion, eg burning oil, gas, coal and others in boilers or furnaces; mobile combustion, eg from fuel-burning cars, vans or trucks owned or controlled by the firm; process emissions, eg from chemical production in owned or controlled process equipment such as the emission of CO2 during cement manufacturing; and fugitive emissions from leaks of GHG gases, eg from refrigeration or air conditioning units. Scope 2 is the sum of indirect GHG emissions associated with the generation of purchased electricity, steam, heat or cooling consumed by the company. Scope 3 is the sum of all other indirect emissions that occur in the company's value chain, including upstream emissions from purchased goods and services, capital goods, fuel and energy-related activities, transportation and distribution, waste generated in operations, business travel or employee commuting; and downstream emissions from leased assets, processing of sold products, use of sold products, end-of-life treatment of sold products, franchises or investments.

11 Companies with 1.5°C temperature alignment are determined based on a variety of different inputs: SBTi or the SBTi tool using CDP data produces at or below 1.5°C output for any assessed time frame; TPI Management Quality Level 4 with short- and medium- or long-term carbon performance at or below 1.5°C; Indicator 1 to 6 in the CA100+ benchmark (Structure and Methodologies | Climate Action 100+).

12 SDG target numbers: 7.2, 7.3, 7.a, 7.b and 9.4.

13 Companies with 1.5°C–2.0°C temperature alignment are determined based on a variety of different inputs: SBTi or the SBTi tool using CDP data produces at or below 1.5°C output; TPI Management Quality at least Level 3 with a short-, medium- or long-term carbon performance between 1.5°C and 2°C; Indicator 1 to 3 in the CA100+ benchmark (Structure and Methodologies | Climate Action 100+); committed to net zero emissions by 2050 and below 2°C using BNPP AM's enhanced Implied Temperature Rise.

With this framework, we screen out all companies with non-existent or insufficiently robust climate commitments.

According to the PAII, this kind of classification enables investors to set and measure the performance of the portfolio against the net zero targets and should also inform their strategy for alignment actions; companies not showing adequate progress towards meeting NZ:AAA criteria should be the priority for engagement or re-weighting in portfolio construction.

When it comes to divestment or exclusions, the PAII recommends a focus on companies that fail to meet any criteria indicating the potential to transition within a specified time frame aligned with a global net zero pathway. Companies that do not continue to improve performance against the criteria over the longer term should also be investigated.

2.2. PABs: Paris-aligned benchmarks

In May 2018, the European Commission proposed an amendment to its Regulation (EU) 2016/1011, which establishes the framework for benchmarks in financial instruments, financial contracts or investment funds in the European Union. The resulting Regulation (EU) 2020/1818 introduces standards for the methodology of low-carbon benchmarks in the EU, in line with its **Action Plan on Financing Sustainable Growth**. The act outlines minimum requirements for the design of **PABs** and **EU Climate Transition Benchmarks** (**CTBs**), which are based on the commitments set forth in the Paris Agreement and therefore rely on the use of the 1.5°C scenario, with no or limited overshoot, referred to in the **Intergovernmental Panel on Climate Change's** (**IPCC**) special report on global warming of 1.5°C.[14]

The amended regulation is consistent with the Commission's objective of attaining net zero GHG emissions by 2050. Paris-aligned benchmarks (PABs) and CTBs share similar objectives, the only difference being their level of ambition.

This paper will focus solely on PABs, and in our PAB portfolio we apply only the minimum requirements as outlined in the regulation and described in detail in the Appendix. Of these, we did not include scope 3 emissions, not even for the energy and mining sectors as required from inception. Our choice is motivated by the poor quality of scope 3 data (Nguyen et al (2022)). The minimum standards of the PAB regulation can be summarised as:

- **baseline reduction of GHG intensity**, so that it is at least 50% lower than the GHG intensity of the investable universe;
- **establishment of a decarbonisation trajectory** to reduce the average GHG intensity by at least 7% a year;

[14] See IPCC, *Global warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development and efforts to eradicate poverty*, 2018.

- **establishment of an allocation to high-impact[15] sectors** that is at least equivalent to the aggregated exposure of the underlying investable universe to those sectors; and
- **exclusion of companies** based on their activity in controversial weapons, tobacco, hard coal and lignite, oil fuels and gaseous fuels.

Following the EU regulation, the GHG intensity of each company is calculated by dividing the sum of its GHG emissions by its enterprise value including cash (EVIC). The regulation determines that, when calculating the decarbonisation trajectory, each company's GHG intensity is divided by an inflation adjustment factor defined as the ratio of the average EVIC of the benchmark at the end of the calendar year to the average EVIC of the benchmark at the end of the previous calendar year. These choices, imposed by regulation, have two consequences which are not always fully appreciated.

The first is that the inflation adjustment factor forces the absolute emissions of the PABs to fall over time. Without this adjustment, it would have been possible for the absolute emissions of the PAB portfolio to increase for as long as the EVIC of its constituent companies increased faster than their emissions, for example from sufficiently large increases in share prices from one year to the next. This adjustment is thus crucial for PABs to reduce their absolute emissions over time.

The second consequence is that a company's GHG intensity may fall even if its carbon emissions increase, as long as its EVIC increases faster than the GHG emissions. Similarly, even if a company is successfully reducing its carbon emissions, its carbon intensity can still rise. This happens when its EVIC falls faster than its emissions, for example due to a sharp drop in its share price.

2.3. Fossil fuel exclusions: coal, unconventional oil and gas and other fossil fuels

Investors use fossil fuel divestment as a strategy to manage stranded asset risks associated with the energy transition and to address climate change by putting pressure on fossil fuel companies to shift their focus. Divestment is expected to achieve these objectives by avoiding exposure to potential stranded assets, by increasing the cost of capital for fossil fuel companies and/or by stigmatising them, which can result in a loss of their social licence to operate.

Rohleder et al (2022) analysed a sample of actively managed mutual funds and found that companies with higher carbon intensity experienced greater selling pressure, leading to a decline in their stock prices. They also found that those same companies subsequently reduced their carbon emission intensity after investors divested. More recently, empirical research by Gehricke et al (2023) measured coordination in divestment by investigating the impact of a higher number of environmental, social and governance (ESG) exchange-traded funds (ETFs) divesting from a firm in the same quarter, and found that divestment not only has a prolonged negative impact on a company's share price but also increases the cost of capital. These findings suggest that divestment, in particular coordinated divestment, can be

[15] Section A: Agriculture, forestry and fishing; Section B: Mining and quarrying; Section C: Manufacturing; Section D: Electricity, gas, steam and air conditioning supply; Section E: Water supply, sewerage, waste management and remediation activities; Section F: Construction; Section G: Wholesale and retail trade, repair of motor vehicles and motorcycles; Section H: Transportation and storage; Section L: Real estate activities.

an important tool in the sustainability transition, even though it increases sustainable performance only indirectly. In turn, Dordi and Weber (2019) examined how stakeholder awareness of public divestments of the top 200 global oil, gas and coal companies by proven reserves could affect future cash flows and increase reputational risks. The study found that the effects of divestment announcements were more pronounced over longer event windows, suggesting a shift in investor perception. The study also found that divestment announcements related to campaigns, pledges and endorsements all have a significant effect over the short-term event window. Additionally, the study noted that divestment may directly depress share prices or stigmatise the industry's reputation, resulting in lower share values.

The idea of fossil fuel divestment started on US college campuses in 2011, with students campaigning for their administrations to shift endowment investments away from the fossil fuel industry and into clean energy and communities most affected by climate change (Gibson and Duram (2020)). As of October 2021, 1,485 institutions worldwide, representing USD 39.2 trillion in assets, had committed to divesting from fossil fuels.

In this paper, we consider first the complete exclusion of all fossil fuel companies. Additionally, we analyse coal exclusions, defined as the exclusion of:

- the set of companies from the NACE[16] level 2 industry mining of coal and lignite which:
    - are developing or planning to develop thermal coal extraction capacities (new mines or expansion of existing ones) or
    - derive more than 10% of their revenues from the mining of thermal coal or
    - produce more than 10 million tonnes of thermal coal per year or
    - do not have a strategy to phase out thermal coal activities by 2030 in EU and Organisation for Economic Co-operation and Development (OECD) countries and by 2040 for the rest of the world; and
- the set of electricity producers which:
    - are adding operational coal-fired power generation capacity to their power portfolio or
    - have a carbon intensity above 400 gCO2e/kWh today[17] or
    - still have coal capacity in their generation mix by 2030 in EU and OECD countries and by 2040 for the rest of the world.

Finally, in our analysis we considered the exclusion of unconventional oil and gas companies, defined as:

- pure upstream oil and gas companies, on the basis of their reserves, excluding those with more than 10% of unconventional reserves;

[16] Nomenclature of Economic Activities (NACE) is the European statistical classification of economic activities.

[17] This should be tightened further in the future following the Paris-compliant trajectory for the sector as determined by the International Energy Agency's Sustainable Development Scenario, which means that the carbon intensity of electricity producers will fall to 346 gCO2e/kWh by 2025.

- diversified energy companies with an Unconventional Ratio[18] above 10%;
- energy companies that generate more than 10% of their revenues from unconventional oil and gas;
- trading companies for which unconventional oil and gas resources represent more than 30% of their business; or
- companies that own or operate pipelines or export terminals of liquified natural gas (LNG) supplied with more than 30% of their volume in unconventional oil and gas.

2.4. Dark green: clean energy thematic investing

"Green investing" is a rather broad term that has long been used to refer to a variety of investment frameworks related to climate change, resource efficiency and other environmental issues. There are qualitative and quantitative definitions, aiming to measure different grades of greenness. In particular, "dark green" refers to a portfolio of investments that is more focused on environmental issues and has a higher degree of greenness than a "light green" portfolio.

As an example of a dark green framework, we chose to rely on stocks in the WilderHill Global Clean Energy Index, which tracks the performance of US companies that stand to benefit substantially from a transition to clean energy, and the WilderHill New Energy Global Innovation Index, which tracks the performance of companies worldwide, mainly outside the United States, advancing green energy and efficiency. ETFs tracking the latter index can apply to be classified as Article 9 under the **European Union's Sustainable Finance Disclosure Regulation** (**SFDR**) because its investment strategy was specifically designed to comply with the investment constraints imposed by this regulation.

These two indices explicitly avoid fossil fuel and nuclear power companies. Details about the thresholds used to select stocks for these indices are provided by Solactive. For this paper, in our analysis, we keep only the stocks from these two indices that are also constituents of the MSCI ACWI (All Country World Index), MSCI World, MSCI Europe and/or S&P 500 indices to facilitate comparability.

3. Comparative analysis of frameworks

In this section, we compare the various frameworks introduced above. First, for each of the four frameworks, we investigate how many companies are excluded in each region and sector and how much market capitalisation is excluded from the full investment universe. Second, we consider minimum tracking error portfolios to investigate the impact on the expected risk, returns and sustainability of an investment strategy that aims at replicating the performance of the underlying market cap index while implementing the constraints of each framework. Finally, we summarise our views on the strengths and weaknesses of each framework.

[18] The Unconventional Ratio is defined as the share of total revenues from a company's upstream activities multiplied by the share of non-conventional reserves.

3.1. Impact on the breadth of the investment universe

Here we compare the impact that the exclusions embedded in the four frameworks have on the breadth of the investment universe.

In Table 1, we show the number and the market cap of the stocks that pass each filter from each framework as at the end of May 2023. Here, A is used for companies classified as Achieving; AA for companies classified as Aligned or Achieving; and AAA for companies classified as Aligning, Aligned or Achieving.

The first observation is that few companies qualify as truly achieving net zero under the NZ:AAA framework. Those that do are recognised primarily based on their green revenues rather than for the alignment of their emissions with net zero goals.

Number of stocks and market cap from each region screened using different net zero filters — Table 1

Investment universe	Description	Index	NZ:AAA				PAB		Fossil Fuel Exclusions				Dark Green	
			A	AA	AAA	Not AAA	PAB	Not PAB	Not Fossil Fuels	Fossil Fuels	Coal, unc O&G	Coal	Clean Energy	Not Clean Energy
MSCI ACWI	Number of stocks	2883	149	666	1065	1818	2473	410	2640	243	27	20	34	2849
	% of stocks	100%	5.2%	23.1%	36.9%	63.1%	85.8%	14.2%	91.6%	8.4%	0.9%	0.7%	1.2%	98.8%
	% of market cap	100%	3.5%	41.5%	61.1%	38.9%	89.4%	10.6%	90.6%	9.4%	1.3%	0.1%	1.4%	98.6%
MSCI World	Number of stocks	1506	74	499	798	708	1338	168	1378	128	25	2	25	1481
	% of stocks	100%	4.9%	33.1%	53.0%	47.0%	88.8%	11.2%	91.5%	8.5%	1.7%	0.1%	1.7%	98.3%
	% of market cap	100%	3.6%	44.4%	64.3%	35.7%	89.6%	10.4%	90.6%	9.4%	1.4%	0.0%	1.5%	98.5%
MSCI Europe	Number of stocks	423	25	223	302	121	394	29	395	28	0	0	12	411
	% of stocks	100%	5.9%	52.7%	71.4%	28.6%	93.1%	6.9%	93.4%	6.6%	0.0%	0.0%	2.8%	97.2%
	% of market cap	100%	5.0%	60.8%	78.7%	21.3%	89.6%	10.4%	90.0%	10.0%	0.0%	0.0%	1.2%	98.8%
S&P 500	Number of stocks	503	19	142	252	251	440	63	458	45	12	0	6	497
	% of stocks	100%	3.8%	28.2%	50.1%	49.9%	87.5%	12.5%	91.1%	8.9%	2.4%	0.0%	1.2%	98.8%
	% of market cap	100%	3.0%	44.6%	63.5%	36.5%	90.0%	10.0%	91.4%	8.6%	1.2%		1.8%	98.2%

Data for NZ:AAA and PAB sourced from Leote de Carvalho et al (2025).

We can also see that applying the AAA criteria significantly narrows the number of investable companies, but those that qualify still represent a large share of market capitalisation, especially in Europe and, to some extent, in developed markets. This suggests that while the NZ:AAA framework is selective, it retains strong market representation.

On the other hand, the PAB regulation allows a large number of companies to pass its initial screens. However, this doesn't guarantee significant portfolio weight for all of them, as additional constraints, in particularly on carbon intensity, can limit their final weight in portfolios. The impact of these constraints is considered separately.

In turn, a fossil fuel exclusion framework is relatively permissive, allowing the vast majority of companies in the MSCI ACWI index to qualify. Few companies are excluded, as coal and unconventional oil and gas firms make up a small fraction of the index, in particular in Europe and the United States.

Finally, a dark green investment framework based on the constituents of clean energy indices like WilderHill Global Clean Energy and WilderHill New Energy Global Innovation is the most selective, with only a tiny fraction of companies qualifying across major indices. It is even more restrictive than the NZ:AAA framework's Achieving category.

Number of stocks from each sector screened using different net zero filters

Table 2

Sector GICS 1	Investment universe	Index	NZ:AAA				PAB		Fossil Fuel Exclusions				Dark Green	
			A	AA	AAA	Not AAA	PAB	Not PAB	Not Fossil Fuels	Fossil Fuels	Coal, unc O&G	Coal	Clean Energy	Not Clean Energy
Communication Services	MSCI ACWI	158	1	48	64	94	146	12	156	2				158
	MSCI World	89		38	48	41	87	2	87	2				89
	MSCI Europe	26		22	25	1	26		25	1				26
	S&P 500	24		7	9	15	24		24					24
Consumer Discretionary	MSCI ACWI	292	8	79	117	175	271	21	287	5			6	286
	MSCI World	157	3	64	90	67	149	8	155	2			3	154
	MSCI Europe	52		34	41	11	51	1	52					52
	S&P 500	53	1	17	24	29	53	0	52	1			1	52
Consumer Staples	MSCI ACWI	229		66	102	127	201	28	229					229
	MSCI World	110		52	78	32	103	7	110					110
	MSCI Europe	39		26	32	7	36	3	39					39
	S&P 500	37		13	26	11	35	2	37					37
Energy	MSCI ACWI	114			25	89		114	9	105	42	16		114
	MSCI World	57			23	34		57	4	53	24			57
	MSCI Europe	11			10	1		11	1	10				11
	S&P 500	23			9	14		23	2	21	12			23
Financials	MSCI ACWI	477		50	126	351	454	23	468	9	1	1		477
	MSCI World	239		36	96	143	230	9	232	7	1	1		239
	MSCI Europe	81		25	43	38	81		80	1				81
	S&P 500	72		8	28	44	71	1	70	2				72
Healthcare	MSCI ACWI	255		48	66	189	245	10	255					255
	MSCI World	142		46	61	81	142		142					142
	MSCI Europe	40		16	20	20	40		40					40
	S&P 500	65		22	28	37	65		65					65
Industrials	MSCI ACWI	453	44	121	188	265	412	41	405	48			8	445
	MSCI World	266	22	87	147	119	249	17	244	22			7	259
	MSCI Europe	81	9	42	58	23	80	1	77	4			4	77
	S&P 500	76	6	17	32	44	70	6	70	6			1	75
Information Technology	MSCI ACWI	324	30	104	136	188	305	19	323	1			8	316
	MSCI World	157	9	66	81	76	151	6	156	1			4	153
	MSCI Europe	16	2	12	13	3	16		15	1				16
	S&P 500	64	2	25	33	31	64		64				3	61
Materials	MSCI ACWI	304	6	44	96	208	245	59	272	32	4	3	3	301
	MSCI World	115	1	29	59	56	101	14	103	12	2	1	2	113
	MSCI Europe	38		17	27	11	34	4	35	3			1	37
	S&P 500	29	1	8	18	11	25	4	26	3			1	28
Real Estate	MSCI ACWI	136	21	41	57	79	131	5	135	1				136
	MSCI World	96	18	37	53	43	95	1	95	1				96
	MSCI Europe	14	4	9	10	4	14		14					14
	S&P 500	30	4	9	20	10	30	0	29	1				30
Utilities	MSCI ACWI	141	39	65	88	53	63	78	101	40			9	132
	MSCI World	78	21	44	62	16	31	47	50	28			9	69
	MSCI Europe	25	10	20	23	2	16	9	17	8			7	18
	S&P 500	30	5	16	25	5	3	27	19	11				30

In Table 2, we investigate the impact of the filters on the number of screened stocks in each sector as at the end of May 2023. As shown, there are currently no companies from the consumer staples, energy, financials and healthcare sectors classified as achieving net zero. This reflects the fact that, at present, there are still no companies in these universes that comply with the Achieving criteria for emissions. All companies classified as Achieving do so through the alignment of their revenue stream with the **EU Taxonomy on climate change mitigation** or climate-mitigation-linked SDGs. It is the case that such companies are found in sectors such as industrials, information technology, real estate and utilities. However, the picture changes significantly when we include Aligned companies. Only the energy sector does not

have any company that is either Achieving or Aligned. If we include companies that are Aligning, we find AAA companies from every single sector.

Market cap of stocks from each sector screened using different net zero filters — Table 3

Sector GICS 1	Investment universe	Index	NZ:AAA				PAB		Fossil Fuel Exclusions				Dark Green	
			A	AA	AAA	Not AAA	PAB	Not PAB	Not Fossil Fuels	Fossil Fuels	Coal, unc O&G	Coal	Clean Energy	Not Clean Energy
Communication Services	MSCI ACWI	7.5%	0.0%	2.5%	2.6%	4.9%	7.4%	0.1%	7.5%	0.1%				7.5%
	MSCI World	7.3%		2.2%	2.3%	5.0%	7.3%	0.0%	7.2%	0.1%				7.3%
	MSCI Europe	3.3%		3.2%	3.3%	0.0%	3.3%		3.2%	0.1%				3.3%
	S&P 500	8.7%		1.9%	2.0%	6.7%	8.7%		8.7%					8.7%
Consumer Discretionary	MSCI ACWI	10.7%	0.9%	5.9%	7.3%	3.4%	10.5%	0.2%	10.6%	0.1%			0.9%	9.8%
	MSCI World	10.5%	1.0%	6.4%	7.8%	2.8%	10.4%	0.1%	10.4%	0.1%			1.0%	9.5%
	MSCI Europe	11.5%		8.2%	9.2%	2.2%	11.5%	0.0%	11.5%					11.5%
	S&P 500	10.1%	1.5%	6.5%	7.5%	2.6%	10.1%		10.0%	0.1%			1.5%	8.6%
Consumer Staples	MSCI ACWI	7.5%		3.9%	5.9%	1.7%	6.8%	0.7%	7.5%					7.5%
	MSCI World	7.7%		4.1%	6.3%	1.4%	7.0%	0.7%	7.7%					7.7%
	MSCI Europe	12.8%		11.0%	12.0%	0.8%	11.7%	1.1%	12.8%					12.8%
	S&P 500	6.9%		2.7%	5.5%	1.5%	6.3%	0.6%	6.9%					6.9%
Energy	MSCI ACWI	4.8%			1.8%	2.9%		4.8%	0.2%	3.2%	1.3%	0.1%		4.8%
	MSCI World	4.7%			2.0%	2.7%		4.7%	0.2%	3.2%	1.4%			4.7%
	MSCI Europe	5.8%			5.8%	0.1%		5.8%	0.1%	5.8%				5.8%
	S&P 500	4.3%			1.2%	3.1%		4.3%	0.3%	2.8%	1.2%			4.3%
Financials	MSCI ACWI	15.5%		2.6%	7.4%	8.1%	14.6%	0.9%	14.6%	0.9%	0.0%	0.0%		15.5%
	MSCI World	14.7%		2.7%	7.9%	6.8%	13.7%	1.0%	13.7%	1.0%	0.0%	0.0%		14.7%
	MSCI Europe	17.0%		3.8%	8.9%	8.1%	17.0%		16.8%	0.2%				17.0%
	S&P 500	12.6%		3.0%	6.8%	5.8%	10.9%	1.6%	10.9%	1.7%				12.6%
Healthcare	MSCI ACWI	12.1%		5.5%	6.8%	5.3%	12.1%	0.0%	12.1%					12.1%
	MSCI World	13.1%		6.2%	7.5%	5.6%	13.1%		13.1%					13.1%
	MSCI Europe	16.1%		11.0%	11.3%	4.8%	16.1%		16.1%					16.1%
	S&P 500	13.6%		6.0%	7.6%	6.1%	13.6%		13.6%					13.6%
Industrials	MSCI ACWI	10.3%	1.0%	3.7%	6.0%	4.3%	9.3%	1.0%	9.0%	1.3%			0.2%	10.1%
	MSCI World	10.8%	1.1%	4.0%	6.5%	4.3%	9.8%	1.0%	9.5%	1.3%			0.2%	10.6%
	MSCI Europe	14.9%	2.5%	9.9%	12.3%	2.5%	14.7%	0.1%	14.5%	0.4%			0.6%	14.2%
	S&P 500	8.3%	0.5%	1.9%	3.8%	4.5%	7.5%	0.8%	7.3%	1.0%			0.1%	8.3%
Information Technology	MSCI ACWI	21.9%	0.4%	13.9%	17.5%	4.4%	21.7%	0.2%	21.9%	0.0%			0.2%	21.7%
	MSCI World	22.0%	0.4%	15.1%	18.1%	3.9%	21.8%	0.2%	21.9%	0.1%			0.1%	21.9%
	MSCI Europe	6.9%	0.3%	6.1%	6.6%	0.3%	6.9%		6.6%	0.3%				6.9%
	S&P 500	28.0%	0.1%	19.8%	24.1%	3.9%	28.0%		28.0%				0.2%	27.8%
Materials	MSCI ACWI	4.6%	0.1%	1.1%	2.3%	2.2%	3.8%	0.7%	3.7%	0.8%	0.1%	0.0%	0.1%	4.5%
	MSCI World	4.1%	0.1%	1.0%	2.2%	1.9%	3.6%	0.6%	3.3%	0.7%	0.1%	0.0%	0.1%	4.0%
	MSCI Europe	6.8%		3.2%	4.5%	2.3%	5.6%	1.2%	5.7%	1.1%			0.1%	6.7%
	S&P 500	2.4%	0.1%	0.5%	1.3%	1.2%	2.1%	0.3%	2.2%	0.3%			0.1%	2.4%
Real Estate	MSCI ACWI	2.3%	0.4%	0.7%	1.3%	1.0%	2.3%	0.0%	2.3%	0.0%				2.3%
	MSCI World	2.4%	0.4%	0.7%	1.4%	0.9%	2.4%	0.0%	2.3%	0.0%				2.4%
	MSCI Europe	0.7%	0.3%	0.5%	0.6%	0.1%	0.7%		0.7%					0.7%
	S&P 500	2.4%	0.3%	0.6%	1.6%	0.8%	2.4%		2.3%	0.1%				2.4%
Utilities	MSCI ACWI	2.8%	0.7%	1.8%	2.3%	0.6%	0.8%	2.0%	1.4%	1.4%			0.1%	2.7%
	MSCI World	2.8%	0.7%	1.9%	2.4%	0.4%	0.7%	2.1%	1.3%	1.5%			0.1%	2.7%
	MSCI Europe	4.2%	1.9%	4.0%	4.2%	0.1%	2.1%	2.1%	2.0%	2.2%			0.5%	3.8%
	S&P 500	2.7%	0.4%	1.6%	2.2%	0.4%	0.3%	2.4%	1.2%	1.5%				2.7%

No company from the energy sector passes the exclusions criteria for the PAB framework. We can also see that PAB exclusions screen out not only stocks from the energy sector, but also stocks from all other sectors, at least for the global indices.

Fossil fuel exclusion frameworks have a relatively minor impact on the investable universe compared with PAB or NZ:AAA filters. In contrast, dark green frameworks focused solely on clean energy stocks are the most restrictive, excluding entire sectors and allowing only a small number of companies, mainly from the utilities, tech,

industrials and consumer discretionary sectors. Unlike the NZ:AAA Achieving screen, they exclude sectors like real estate entirely.

In Table 3, we show the sum of the market cap weight of the stocks in each sector that pass the different screens as at the end of May 2023. The figures are not rebased and represent just the sum of the weight in the market cap-weighted index of all the stocks from a given sector that pass each respective screen.

Although most of the market cap of utilities stocks is classified as AAA, the sector itself is small and only slightly larger than real estate. Thus, its impact on the broader index is limited due to its relatively small size. Other small sectors such as materials, real estate and energy show much more limited AAA alignment.

The information technology sector, despite being the largest by market cap at global level, has a slightly lower share of AAA-classified companies. Other large sectors, like consumer discretionary, staples, financials and industrials, tend to have at least half of their market cap represented by AAA companies.

Unlike the NZ:AAA framework, the PAB framework lets through most of the market cap of all sectors except for energy and utilities. The same is true for fossil fuel company exclusions, where again the energy and utilities sectors have a larger share of market cap affected by exclusions, though the effect is less pronounced than under the PAB framework.

Finally, the dark green framework excludes most of the market cap from each sector and, as seen before, many sectors are actually excluded completely. Moreover, the combined market capitalisation of clean energy stocks within the utilities, information technology, industrial and consumer discretionary sectors remains relatively small within their respective sectors. Even compared with Achieving stocks, the sum of the market cap weight of clean energy stocks is significantly smaller.

3.2. Impact on risk and returns

In this section, we look at the impact of the different filters on the risk and returns of portfolios designed to mimic as much as possible the fully invested market cap-weighted parent indices. For this purpose, we constructed portfolios which invest only in the screened stocks and allocate a weight to each stock chosen so as to minimise the tracking error against the parent market cap index, similar to what was proposed by Andersson et al (2016). The minimum tracking error framework is the most adapted strategy for investors that wish to implement a net zero portfolio strategy with the smallest possible expected impact on returns relative to the respective market cap parent index. For PAB portfolios, we include all other required constraints described in section 3 with details in the Appendix.

Risk of minimum tracking error portfolios Table 4

Investment universe	Description	Index	NZ:AAA			PAB	Fossil Fuel Exclusions	Dark Green
			A	AA	AAA	PAB	Not Fossil Fuels	Clean Energy
MSCI ACWI	Number of stocks	2883	82	444	856	1863	1964	33
	Tracking error		4.3%	1.3%	0.8%	0.4%	0.3%	7.7%
	Volatility	17.6%	17.9%	17.6%	17.6%	17.6%	17.6%	20.2%
	Beta	1.00	0.99	1.00	1.00	1.00	1.00	1.06
MSCI World	Number of stocks	1506	51	391	648	1100	1370	25
	Tracking error		4.7%	1.4%	0.8%	0.5%	0.4%	8.0%
	Volatility	17.9%	18.3%	17.9%	17.9%	17.9%	17.9%	20.5%
	Beta	1.00	0.99	0.99	1.00	1.00	1.00	1.05
MSCI Europe	Number of stocks	423	25	198	298	357	378	12
	Tracking error		6.7%	1.3%	0.7%	0.8%	0.7%	9.0%
	Volatility	19.6%	20.9%	19.6%	19.6%	19.6%	19.6%	21.8%
	Beta	1.00	1.01	1.00	1.00	1.00	1.00	1.02
S&P 500	Number of stocks	503	19	135	243	398	443	6
	Tracking error		6.8%	2.0%	1.2%	0.7%	0.5%	14.9%
	Volatility	18.7%	19.9%	18.6%	18.6%	18.7%	18.7%	26.0%
	Beta	1.00	1.00	0.99	1.00	1.00	1.00	1.15

Data for NZ:AAA and for PAB sourced from Leote de Carvalho et al (2025).

The results in Table 4 are based on data as at the end of May 2023. We show that the tracking error of the portfolio invested in AAA stocks is small, at only 0.8% for the global portfolios and 0.7% for the MSCI Europe. For the S&P 500, it is higher at 1.2%, but still relatively small. Moreover, the beta is effectively 1 in all cases.[19] Thus, we do not expect a significant difference in performance between the AAA portfolios and their respective market cap indices.

If we invest in AA stocks, the tracking errors are still moderately low, at 1.3% or 1.4% for global and European stocks. For US stocks, even at 2.0%, the tracking error is still not too high when compared with the typical tracking error of actively managed funds. For all these minimum tracking error portfolios, we have beta effectively equal to 1. Based on this observation, investing only in AA stocks in minimum tracking error portfolios would have a relatively small impact and could be envisaged to align portfolios more with net zero and a temperature increase at or below 1.5°C above pre-industrial levels.

However, this is no longer the case if we invest only in Achieving stocks. Despite the fact that the beta of the minimum tracking error portfolios is close to 1, tracking errors are large, ranging from 4.3% for the MSCI ACWI to 6.8% for the S&P 500. Thus, we can expect significant deviations in the performance of minimum tracking error portfolios that invest only in Achieving companies relative to the performance of the parent index even if, thanks to a beta of close to 1, those larger excess returns should have near-zero correlations with the returns of their respective parent indices.

For minimum tracking error portfolios based on the PAB framework, applying all other required constraints, including those on decarbonisation and the minimum allocation to emissive sectors, we find small tracking errors in all four cases, varying

[19] Systematic risk is the risk inherent to the entire market, attributable to a mix of factors which explain the co-movement of stock returns, while idiosyncratic risk is the non-diversifiable risk that is specific to each company. Minimum tracking error portfolios use portfolio optimisation to create constrained portfolios where the tracking error against a reference portfolio is minimised by keeping its exposure to individual risk factors aligned, as much as possible, with that found in the reference portfolio.

between 0.4% for the MSCI ACWI and 0.8% for the MSCI Europe. This is even smaller than for the AAA portfolios. The beta of the minimum tracking error PAB portfolios is equal to 1. All of this indicates that these portfolios should be able to mimic the market cap-weighted parent indices over the medium to long term even better than the AAA minimum tracking error portfolios and with an even smaller residual performance thanks to the less restrictive exclusion criteria.

The tracking errors are smaller if we exclude only fossil fuel stocks, and, again, the beta of these portfolios is 1. This indicates that such portfolios are likely to mimic the parent indices even better than either the PAB or the AAA minimum tracking error portfolios.

In turn, the minimum tracking error portfolios invested only in clean energy stocks from the WilderHill Global Clean Energy and WilderHill New Energy Global Innovation indices have quite large tracking errors against their respective market cap-weighted parent indices, ranging from 7.7% for the MSCI ACWI index to 14.9% for the S&P 500 index. This is much higher than the minimum tracking error portfolios invested only in Achieving stocks. Moreover, the optimiser no longer manages to find portfolios with a beta equal to 1 for the clean energy portfolios: all betas are above 1, which suggests that the excess returns of these dark green minimum tracking error portfolios have a positive correlation with the returns of their respective market cap-weighted parent indices, in particular for the United States, with a beta of 1.15 against the S&P 500 index.

In Table 5, we show the sector allocation of the minimum tracking error portfolios based on each framework as at the end of May 2023. Minimum tracking error portfolios based on the AAA and fossil fuel exclusion frameworks are the most sector-diversified, investing across all sectors. In contrast, the portfolios based solely on Achieving or clean energy stocks are the least diversified, excluding several major sectors such as energy, financials and healthcare. The AA- and PAB-based portfolios fall in between, well diversified but avoiding energy stocks entirely.

The clean energy portfolio is even less diversified than the Achieving portfolio, as it also excludes the real estate sector. These sector exclusions contribute to higher tracking error and may influence excess returns.

The information technology sector has the largest weight, not only in the US and global market cap-weighted indices, but also in the corresponding minimum tracking error portfolios. This remains true even when many stocks are excluded under the AAA framework, indicating that a significant allocation to the sector is required to minimise the tracking error despite limited stock diversification.

The energy sector is excluded from most minimum tracking error portfolios, except for portfolios invested in AAA stocks and portfolios with fossil fuel stock exclusions, since some energy stocks are not classified as fossil fuel companies.

Sector allocation of minimum tracking error portfolios

Table 5

GICS 1 sector	Investment universe	Index	NZ:AAA			PAB	Fossil Fuel Exclusions	Dark Green
			A	AA	AAA	PAB	Not Fossil Fuels	Clean Energy
Communication Services	MSCI ACWI	7.5%		4.9%	3.9%	7.4%	7.7%	
	MSCI World	7.3%		4.4%	3.2%	7.3%	7.5%	
	MSCI Europe	3.3%		5.9%	4.2%	3.2%	3.9%	
	S&P 500	8.7%		4.7%	2.8%	8.9%	9.0%	
Consumer Discretionary	MSCI ACWI	10.7%	4.6%	11.1%	10.9%	11.8%	10.9%	7.4%
	MSCI World	10.5%	4.7%	11.6%	11.1%	10.3%	10.4%	4.9%
	MSCI Europe	11.5%		12.0%	11.2%	11.6%	11.4%	
	S&P 500	10.1%	3.1%	13.0%	10.7%	9.6%	10.1%	7.0%
Consumer Staples	MSCI ACWI	7.5%		7.0%	7.8%	8.7%	8.3%	
	MSCI World	7.7%		6.0%	7.5%	9.0%	8.5%	
	MSCI Europe	12.8%		12.7%	13.2%	13.1%	13.1%	
	S&P 500	6.9%		5.4%	8.0%	7.4%	7.4%	
Energy	MSCI ACWI	4.8%			4.5%		1.8%	
	MSCI World	4.7%			4.5%		1.5%	
	MSCI Europe	5.8%			6.1%		1.1%	
	S&P 500	4.3%			3.3%		1.8%	
Financials	MSCI ACWI	15.5%		13.9%	14.7%	15.6%	15.5%	
	MSCI World	14.7%		13.1%	14.1%	14.7%	14.7%	
	MSCI Europe	17.0%		16.2%	16.4%	17.8%	18.4%	
	S&P 500	12.6%		9.0%	11.8%	12.1%	11.8%	
Healthcare	MSCI ACWI	12.1%		11.8%	11.5%	13.0%	12.4%	
	MSCI World	13.1%		13.0%	12.7%	13.8%	13.4%	
	MSCI Europe	16.1%		15.5%	15.1%	17.3%	16.5%	
	S&P 500	13.6%		13.6%	13.3%	14.6%	14.0%	
Industrials	MSCI ACWI	10.3%	32.9%	11.9%	10.9%	10.9%	10.6%	33.4%
	MSCI World	10.8%	36.5%	12.6%	11.3%	12.3%	11.4%	36.7%
	MSCI Europe	14.9%	45.0%	15.8%	15.0%	16.8%	15.6%	33.0%
	S&P 500	8.3%	42.2%	8.5%	8.5%	9.2%	8.7%	66.2%
Information Technology	MSCI ACWI	21.9%	25.0%	27.0%	26.1%	22.3%	22.3%	8.4%
	MSCI World	22.0%	19.8%	27.1%	26.1%	22.4%	22.3%	5.7%
	MSCI Europe	6.9%	12.0%	7.6%	7.5%	6.9%	6.9%	
	S&P 500	28.0%	3.5%	34.1%	33.6%	29.2%	28.8%	14.5%
Materials	MSCI ACWI	4.6%	4.4%	6.2%	4.3%	5.3%	5.3%	10.8%
	MSCI World	4.1%	2.6%	5.8%	3.7%	5.3%	5.1%	10.4%
	MSCI Europe	6.8%		8.9%	6.4%	8.5%	8.5%	11.1%
	S&P 500	2.4%	3.2%	4.1%	2.5%	4.5%	3.3%	12.3%
Real Estate	MSCI ACWI	2.3%	15.7%	2.5%	2.6%	2.3%	2.4%	
	MSCI World	2.4%	17.2%	2.8%	2.8%	2.3%	2.3%	
	MSCI Europe	0.7%	13.7%	0.4%	0.7%	0.6%	0.4%	
	S&P 500	2.4%	13.8%	3.1%	2.8%	2.4%	2.3%	
Utilities	MSCI ACWI	2.8%	17.4%	3.8%	2.8%	2.7%	2.9%	39.9%
	MSCI World	2.8%	19.2%	3.6%	2.8%	2.8%	2.9%	42.3%
	MSCI Europe	4.2%	29.3%	5.1%	4.2%	4.2%	4.2%	55.9%
	S&P 500	2.7%	34.2%	4.4%	2.8%	1.9%	2.9%	

Data for NZ:AAA and for PAB sourced from Leote de Carvalho et al (2025).

Due to the large number of exclusions, portfolios invested in Achieving stocks and clean energy stocks show the greatest sector deviations from the market cap index, in particular overweighting the industrials and utilities sectors. This contributes to the larger tracking errors of these portfolios.

In summary, minimum tracking error portfolios based on the AAA framework, PABs and fossil fuel exclusions closely mirror market cap indices thanks to beta equal to 1, small tracking error and minimal sector deviations. AAA portfolios even allocate to the energy sector. Portfolios based on AA stocks may still track reasonably well but

could show short-term deviations. In contrast, portfolios invested only in Achieving stocks or clean energy stocks are the most likely to diverge from market cap returns over time due to greater sector deviations, higher tracking errors and, for clean energy, a beta different from 1.

3.3. Impact on sustainability

In this section, we analyse the impact on sustainability performance measures of adopting each of the proposed frameworks while investing in portfolios that minimise tracking error against their respective parent market cap indices.

In Table 6, we show the sustainability performance of these same minimum tracking error portfolios as at the end of May 2023 as compared with their respective parent market cap indices.

The EU Taxonomy, which defines economic activities that can be considered environmentally sustainable, is based on Bloomberg data.

Carbon intensity s measured in ton CO2e/million euro EVIC and is based on several data sources, namely Trucost, CDP and Bloomberg for company emissions and Factset for the EVIC.

ESG scores are based on the BNPP AM methodology, which uses a sector-relative approach incorporating an average of 37 material factors across 80 peer groups (20 sectors in four regions). The selection of financially material factors is inspired by the Sustainability Accounting Standards Board (SASB) framework. Scores range from 0 (worst) to 99 (best), with 50 representing a neutral position. They rely on raw factor data from Sustainalytics and compare companies against their sector and regional peers. Additional data from Institutional Shareholder Services and Proxinvest are used specifically for governance-related factors.

Under the SFDR, sustainable investment is an investment in an economic activity that contributes to an environmental or social objective, does not significantly harm any environmental or social objective and follows good governance practices. For sustainable investment, we used the BNPP AM classification of companies.[20]

[20] The sustainable investment methodology is a binary qualification based on the European Union's SFDR. A sustainable investment is defined as: (i) having an environmental or social objective; (ii) doing no harm; and (iii) having good governance. The approach considered requires that companies meet at least one of the following criteria: (i) have a minimum alignment of the company's economic activities with the taxonomy of sustainable activities from the European Union; (ii) have a minimum alignment of revenues with the UN Sustainable Development Goals; (iii) be a company from a high-GHG emission sector that is transitioning its business models to align with net zero (implied temperature rise of <1.5%); and (iv) be a company with a leading contribution to either the environmental or social pillars or the ESG scores above. Companies are also required to do no significant harm when it comes to any other environmental or social objectives by making sure they are not involved in any significant controversies, classified in decile 10 of the ESG scoring model above or involved in the oil and gas sector. Finally, companies with the lowest governance scores according to the ESG scoring model above also fail.

Sustainable characteristics of minimum tracking error portfolios Table 6

Investment universe	Description	Index	NZ:AAA			PAB	Fossil Fuel Exclusions	Dark Green
			A	AA	AAA	PAB	Not Fossil Fuels	Clean Energy
MSCI ACWI	ESG	54.3	54.2	59.6	57.2	57.7	56.2	58.6
	CO2e intensity	72.6	81.1	54.7	62.5	36.3	56.8	39.2
	SI	37.9%	83.0%	46.2%	44.5%	39.6%	38.6%	94.8%
	EU Taxonomy	2.7%	26.9%	5.8%	4.2%	2.7%	2.5%	15.6%
MSCI World	ESG	54.4	54.6	59.3	57.1	57.7	56.4	58.7
	CO2e intensity	60.6	65.2	45.7	50.3	30.3	44.0	35.7
	SI	38.6%	87.8%	44.9%	43.5%	40.6%	39.4%	94.6%
	EU Taxonomy	2.7%	27.3%	5.3%	3.9%	2.7%	2.5%	16.7%
MSCI Europe	ESG	59.5	63.5	62.4	60.6	61.8	60.5	62.6
	CO2e intensity	77.7	37.7	91.2	82.6	38.8	70.6	34.9
	SI	55.4%	97.5%	63.8%	57.9%	59.6%	57.8%	92.4%
	EU Taxonomy	2.6%	28.5%	3.6%	2.6%	2.5%	2.1%	15.8%
S&P 500	ESG	53.1	52.0	58.4	56.0	57.0	55.1	53.1
	CO2e intensity	54.4	101.6	34.5	36.9	27.2	35.0	33.6
	SI	34.0%	74.1%	38.8%	39.0%	37.3%	34.3%	100.0%
	EU Taxonomy	3.1%	26.6%	5.8%	4.4%	3.4%	2.9%	15.2%

Data for NZ:AAA and for PAB sourced from Leote de Carvalho et al (2025).

For investors aiming to enhance sustainability performance while maintaining close alignment with traditional benchmarks, minimum tracking error portfolios built with these frameworks offer consistent ESG benefits. These portfolios naturally improve ESG scores without requiring explicit constraints.

However, portfolios focused solely on achieving stocks may not deliver consistent ESG improvements, particularly in the United States, where sector biases can also lead to higher carbon intensity. While these companies contribute to long-term sustainability goals (eg scope 3 emission reductions), their current operations may be more carbon-intensive.

In contrast, investors focused on reducing carbon intensities should consider PAB and fossil fuel exclusion frameworks as the strongest candidates.

Importantly, minimum tracking error portfolios invested in clean energy and achieving stocks show the highest alignment with SFDR and EU Taxonomy standards, making them attractive for investors prioritising sustainable impact through regulatory compliance.

3.4. Allocation to Achieving, Aligned, Aligning and fossil fuel stocks

In this section we investigate the allocation of the different minimum tracking error portfolios to Achieving, Aligned, Aligning and fossil fuel stocks.

In Table 7, we show the sum of the weights of stocks classified as Achieving, Aligned and Aligning in the minimum tracking error portfolios of the different frameworks as at the end of May 2023. We also show the sum of the weights of fossil fuel stocks in those same portfolios.

As shown, the allocation to Aligned stocks in market cap indices is greater than allocations to Achieving or Aligning stocks or fossil fuel companies. In contrast, allocations to Achieving stocks are the lowest.

The minimum tracking error portfolios invested in AAA stocks significantly overweight Aligned and Aligning stocks and slightly overweight Achieving stocks. Despite allocating to fossil fuel stocks, these portfolios tend to underweight them.

In turn, the PAB minimum tracking error portfolios tend to underweight fossil fuel stocks.

Allocation of minimum tracking error portfolios — Table 7

Investment universe	Description	Index	NZ:AAA			PAB	Fossil Fuel Exclusions	Dark Green
			A	AA	AAA	PAB	Not Fossil Fuels	Clean Energy
MSCI ACWI	Achieving	3.5%	100.0%	8.7%	6.2%	3.3%	3.3%	57.7%
	Aligned	38.0%		91.3%	57.7%	38.8%	39.1%	13.1%
	Aligning	19.6%			36.1%	18.6%	18.9%	
	Fossil fuels	9.4%	10.2%	3.5%	8.2%	4.1%		
MSCI World	Achieving	3.6%	100.0%	7.8%	5.5%	3.4%	3.4%	60.7%
	Aligned	40.8%		92.2%	60.3%	41.5%	41.9%	11.7%
	Aligning	19.9%			34.2%	18.7%	19.1%	
	Fossil fuels	9.4%	12.1%	3.7%	8.3%	3.2%		
MSCI Europe	Achieving	5.0%	100.0%	5.1%	5.4%	4.9%	4.2%	78.1%
	Aligned	55.8%		94.9%	70.4%	59.0%	59.0%	21.9%
	Aligning	17.9%			24.3%	13.6%	13.8%	
	Fossil fuels	10.0%	19.5%	2.4%	9.7%	2.5%		
S&P 500	Achieving	3.0%	100.0%	7.5%	4.4%	2.8%	2.7%	15.2%
	Aligned	41.7%		92.5%	62.7%	42.3%	42.6%	
	Aligning	18.9%			32.8%	19.3%	20.6%	
	Fossil fuels	8.6%	17.8%	5.6%	6.5%	1.9%		

Data for NZ:AAA and for PAB sourced from Leote de Carvalho et al (2025).

The dark green clean energy minimum tracking error portfolios overweight Achieving stocks significantly everywhere except the United States and have a smaller allocation to Aligned stocks than in the parent indices. In the case of the United States, there is no allocation to Aligned stocks at all. These portfolios do not allocate to fossil fuel stocks or to Aligning stocks.

3.5. Strengths and weaknesses of each framework

After presenting each framework in section 2 and conducting a comparative analysis in section 3, we now discuss the strengths and weaknesses of each approach from our perspective. We have compiled a summary of these strengths and weaknesses in Table 8.

Our assessment of the ability to create a diversified portfolio is based on the information presented in Tables 1–4. Frameworks that allow for more stocks and exclude fewer sectors will naturally provide stronger diversification. In this regard, the PAB and fossil fuel exclusion frameworks allow for stronger diversification. As demonstrated, we can construct portfolios with relatively low tracking errors compared with the respective indices, which indicates that it is possible to diversify away most of the active risk. Conversely, investing solely in Achieving stocks or clean energy stocks will not result in strong portfolio diversification due to the limited number of stocks available for investment. As a consequence, the tracking error is likely to be influenced not only by stock-specific risk but even by systematic risk factor exposures such as the absence of certain sectors.

When it comes to the likelihood that the portfolio will be aligned with a 1.5°C trajectory to net zero, investing in Achieving and Aligned companies should achieve this goal as long as companies deliver on their commitments, in line with the framework's design. However, the more we invest in companies classified as Aligning, which have a 2°C trajectory to net zero, the less likely this is to happen. On the other hand, investing in companies that concentrate on clean energy can be expected to help finance the energy transition, increasing the likelihood of aligning the economy with a 1.5°C trajectory to net zero. Similarly, companies that are classified as Achieving because they offer climate solutions will be contributing to the energy transition and thus to achieving net zero, even if they may have high emissions today.

Strengths and weaknesses of each framework Table 8

	NZ:AAA			PAB	Fossil Fuel Exclusions	Dark Green
	A	AA	AAA	PAB	Not Fossil Fuels	Clean Energy
Ability to diversify portfolio	weak	medium	strong	strong	strong	weak
Probability of alignment of portfolio with net zero by 2050	high	high	medium	high	low	high
Immediate decarbonisation of portfolio	weak	medium	medium	high	high	high
Accounts for companies' different efforts to reach net zero	yes	yes	yes	no	no	no
Focus on funding the energy transition	strong	medium	medium	weak	weak	strong
Forward-looking approach to net zero	yes	yes	yes	partially	no	yes
Ability to engage and for stewardship with higher-impact companies	strong	strong	strong	weak	weak	weak
EU Taxonomy exposure	strong	medium	medium	weak	weak	strong

Data for NZ:AAA and for PAB sourced from Leote de Carvalho et al (2025).

PABs, fossil fuel exclusions and dark green investing are the most effective approaches for achieving an immediate decarbonisation of the portfolio. In contrast, the NZ:AAA framework may not even reduce the portfolio's carbon intensity today when compared with the market cap index, as shown in Table 6. However, this should be seen as a feature of the NZ:AAA framework rather than a weakness.

To meet the prescribed decarbonisation rate, PAB strategies may need to reallocate capital to lower-impact industries, even within high-impact sectors. The PABs contribute to lowering real-world carbon emissions by encouraging investor divestment from high-emitting companies, which is expected to raise their cost of capital and thereby create financial pressure to accelerate their transition to low-carbon operations. However, by excluding companies that are not yet low-carbon but are actively transitioning, PAB strategies also fail to incentivise or support those firms in high-impact sectors that are crucial to achieving global net zero goals. This can undermine the potential for investors to drive change through engagement and stewardship.

Moreover, given that companies begin their Paris alignment journey from different starting points, some may achieve rapid initial improvements in their carbon profile before levelling off, while others may follow a more gradual decarbonisation

path. Therefore, applying rigid rules may be less effective than adopting a more nuanced approach that accommodates diverse transition trajectories.

Companies' net zero paths depend on how far they need to travel from their current business models to achieve alignment with the 1.5°C target. For some companies, the transition will be relatively easy, while for others, the trajectory will be much steeper and more difficult. A best-in-class framework in each sector and region encourages companies from all starting points to make the required incremental changes towards net zero by 2050. Creating a portfolio that supports an economy-wide transition to a 1.5°C world while also avoiding any unintended negative consequences that could hinder this goal is crucial. This is a key advantage of the proposed NZ:AAA framework, as it promotes a smooth transition towards net zero while recognising that some companies need to make more of an effort than others.

Several methodologies have been proposed to aggregate portfolio-level contributions towards net zero using implied temperature rise indicators. These approaches aim to assess a portfolio's climate alignment by combining metrics such as carbon intensity, exposure to companies with high climate scores and temperature benchmarks derived from one or more emissions pathways. However, Institut Louis Bachelier (2020) demonstrated that applying different methodologies to the same portfolio can yield significantly divergent results. Furthermore, de Franco et al (2023) found that asset-weighted temperature averages tend to underestimate the alignment of major equity portfolios. These inconsistencies have sparked debate over the reliability of temperature alignment metrics as proxies for transition risk and real-world climate impact. If we take into account the challenges associated with measuring Scope 3 emissions, investing solely based on emissions may lead to the exclusion of some climate solutions companies with high scope 1 and scope 2 carbon intensity. To better align with the net zero transition goals, a strategy which invests explicitly in solutions providers, emphasising not only the carbon intensity of their operations but also the climate impact of what they sell, is recommended. Both the AAA and dark green investment approaches offer this benefit, but the AAA framework covers a wide range of sectors beyond clean energy.

Moreover, investment of capital in assets whose emissions are decreasing over time may be more efficiently accomplished by staying invested in these assets and driving emissions reductions through stewardship and engagement with the companies that need to act the most. This can be one of the most effective ways to drive real-world impacts within public equity investments. For PAB strategies, fossil fuel exclusions and dark green frameworks, there are limited leverage points for engagement. In contrast, the NZ:AAA allows for targeted and nuanced conversations with companies in specific sectors and regions, which can lead to a focus on their future decarbonisation strategy rather than reliance solely on their past decarbonisation performance.

Finally, while the NZ:AAA framework is based on current and forward-looking alignment criteria that aim to capture companies' transition potential, this is less the case for PAB strategies, which rely primarily on companies' past carbon data and do not consider their anticipated future trajectory. And while the annual increase in required decarbonisation can be seen as forward-looking, as explained by Bolton et al (2022), the annual 7% carbon reduction specified in the PAB regulation should be adjusted to take into account the inception date and reflect the fact that the remaining carbon budget is finite and depleting rapidly. In that sense, a PAB index

created today requires a much faster rate of decarbonisation to still achieve net zero by 2050 than one which has been implemented since 2019.

4. Analysis of limitations and further research

As with any analysis relying upon quantitative tools for the assessment of performance impacts, caveats are warranted in determining the interpretation of the results. First of all, our analysis is based on portfolios constructed on a single date relying on current and recent historical data. Of course, this is not necessarily representative of the future, knowing that portfolios will be sensitive to how fast companies align with net zero pathways and how fast the transition to clean energy will occur. Portfolios will also have to be rebalanced periodically.

In an optimistic scenario in which all stays on track to net zero by 2050, the minimum tracking error portfolios constrained to investing in either NZ:AAA or PABs or excluding fossil fuel companies should converge towards the market cap portfolio as we get closer to 2050. In turn, clean energy should simply become mainstream. However, a delayed transition could lead to higher tracking errors than those shown here if an insufficient number of companies align with their net zero pathway fast enough and, as a result, the number of excluded companies grows over time.

Additionally, we recognise that current quantitative analytical frameworks have limitations when it comes to understanding the potential impact of climate change on portfolios. The above caveat is therefore doubly relevant in a future which looks different from the past.

Still, minimum tracking error portfolios offer a feasible solution that is likely to be useful for a large number of investors, in particular institutional investors, ie those with significantly large portfolios who tend to set constraints on the amount of tracking error risk they can accommodate relative to the market cap portfolio. It is also a pragmatic solution that can be used for as long as we do not have a good enough estimation of the net zero risk premium, which is required if we are to better size the risk budget allocation to that premium.

Going forward, it is clear that we should welcome further research which aims to quantify the potential risk premium associated with investing in net zero strategies and let investors use frameworks in which they comfortably take on active risk by implementing a portfolio based on whatever future climate scenario is anticipated to unfold, for example accommodating the sector tilts reflected in the Inevitable Policy Response Forecast Policy Scenario. This requires further integration of climate scenarios into portfolio analysis and possibly movement away from the use of myopic mean-variance-based tools such as minimum tracking error portfolios, which rely on historical data for risk and fail to accommodate extreme risk events. In addition, it would be beneficial to undertake an analysis similar to that in this paper, looking at the implications of different net zero portfolio approaches in the context of fixed income and private asset portfolios.

Conclusions

This paper explores various frameworks for achieving net zero pathways in investment portfolios. We presented four specific frameworks, namely Net Zero Achieving, Aligned, Aligning (NZ:AAA) screens, the Paris-aligned benchmark (PAB) rules, fossil fuel exclusions and clean energy thematic investing. We discussed the merits and weaknesses of each framework in terms of investment risk and portfolio construction, as well as how they can match the current ambitions of institutional investors when it comes to steering portfolios to meet their own net zero commitments.

The "Achieving" screens recognise companies that are already achieving the emissions intensity necessary for net zero by 2050 and/or are selling products and services aligned with that goal. "Aligned" screens identify companies that are essentially on a net zero 1.5°C pathway, while "Aligning" screens identify companies on a 2.0°C pathway. The AAA classification is based largely on forward-looking data and places less emphasis on achieving high levels of decarbonisation today, enabling investors to identify, engage with and steward high-emitting companies. It also maintains exposure to climate solutions providers.

The PAB framework, on the other hand, focuses primarily on strong decarbonisation by reducing portfolios' carbon intensity relative to the market cap-weighted index and establishing a trajectory to continue reducing carbon intensity every year until 2050. When considering only the EU regulation for PABs, this framework is based on historical emissions data and does not include a forward-looking dimension. Similarly, fossil fuel exclusions are effective at significantly reducing carbon intensity today by simply excluding companies that are currently responsible for most of the GHG emissions. PABs and fossil fuel exclusions do not support engagement and stewardship with many higher emitters since they involve divesting from them, without clarity that this divestment will lead to the closure of associated plants and thus the reduction of real-world emissions. On the other hand, clean energy thematic investing is an effective approach for investing in companies that produce or distribute clean energy technologies.

Our analysis shows that each net zero investment framework offers distinct strengths and trade-offs. Frameworks like PABs and fossil fuel exclusion are effective for immediate portfolio decarbonisation and offer strong diversification. However, their rigid exclusion rules may limit engagement opportunities and overlook companies in high-impact sectors that are actively transitioning. Dark green investing supports climate solutions, but faces significant diversification limitations and offers fewer opportunities for engagement with high-emitting companies undergoing transition. In contrast, the NZ:AAA framework provides a more nuanced approach by incorporating forward-looking alignment criteria and enabling targeted engagement, which supports a broader, economy-wide transition to net zero. However, it may not reduce portfolio carbon intensity in the short term by as much as PABs or fossil fuel exclusions, results in less diversification and higher tracking error, and relies on forward-looking alignment criteria and transition assessments, which require robust data and may be subject to uncertainty.

Regardless of the implementation framework selected, it is clear that reasonably diversified portfolios with a low tracking error can be constructed, which shows that investors can likely align their equity portfolios with net zero without unduly compromising their fiduciary obligations. In practice, many investors will likely use a combination of the frameworks studied in this paper across their public and private

investment allocations to equity, fixed income, private markets and other asset classes.

To conclude, we believe that institutional investors have a crucial role to play in driving the transition to a net zero emissions future. This paper helps to illustrate and clarify the strengths and weaknesses of various known frameworks for investing in net zero by 2050 and to understand their alignment with recommendations from organisations that aim to decarbonise the economy and achieve net zero emissions by 2050 and beyond.

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Appendix

Regulation (EU) 2020/1818 presenting the minimum standards for EU CTBs and PABs includes a number of articles with the guidance for constructing them. For PABs, these can be divided into:

A. Articles about the methodology of calculation:

- Article 4: Calculation of GHG intensity
    - Calculate the GHG intensity using the same currency for all assets
    - Recalculate the GHG intensity on annual basis
- Article 5: Phase-in of scope 3 GHG emissions data in the PAB methodology
    - Include scope 3 for at least the energy and mining sectors
    - Within two years, include scope 3 for at least the transportation, construction, buildings, materials and industrial sectors
    - Within four years, include scope 3 for all other sectors
- Article 8: Change in GHG intensity and absolute GHG emissions
    - Calculate as the % change between the portfolio's weighted average GHG intensity or absolute emissions of all constituents of the EU PABs at the end of year *n* and the same at the end of year *n–1*

B. Articles with compulsory criteria:

- Article 3: Equity allocation constraint
    - Allocation to the sectors in Sections A–H[21] and Section L of Annex I to Regulation (EC) No 1893/2006 that is at least equivalent to the aggregated exposure of the underlying investable universe to those sectors
- Article 7: Setting a decarbonisation trajectory
    - Decarbonisation trajectory of at least 7% reduction[22] in average GHG intensity per annum
    - Targets calculated in a geometric progression from the base year

[21] Section A: Agriculture, forestry and fishing; Section B: Mining and quarrying; Section C: Manufacturing; Section D: Electricity, gas, steam and air conditioning supply; Section E: Water supply, sewerage, waste management and remediation activities; Section F: Construction; Section G: Wholesale and retail trade, repair of motor vehicles and motorcycles; Section H: Transportation and storage; Section L: Real estate activities.

[22] For public equities.

    - If the average EVIC[23] of the benchmark has changed in the last calendar year, then each constituent's EVIC is adjusted by dividing it by an enterprise value inflation adjustment factor[24]
- Article 11: Baseline reduction of GHG intensity
    - GHG intensity, including scope 1 and 2 (and 3 as in Article 5) GHG emissions, shall be at least 50% lower than the GHG intensity of the investable universe
- Article 12: Exclusions for EU PABs
    - Companies involved in any activities related to controversial weapons
    - Companies involved in the cultivation and production of tobacco
    - Companies that benchmark administrators find in violation of the United Nations Global Compact (UNGC) principles or the OECD Guidelines for Multinational Enterprises
    - Companies that derive 1% or more of their revenues from exploration, mining, extraction, distribution or refining of hard coal and lignite
    - Companies that derive 10% or more of their revenues from the exploration, extraction, distribution or refining of oil fuels
    - Companies that derive 50% or more of their revenues from the exploration, extraction, manufacturing or distribution of gaseous fuels
    - Companies that derive 50% or more of their revenues from electricity generation with a GHG intensity of more than 100 gCO2e/kWh
    - Companies that are found or estimated by administrators of EU PABs or by external data providers to significantly harm one or more of the EU environmental objectives

C. Articles with voluntary criteria:

- Article 6: The weight of stocks that set and publish GHG emission reduction targets can be increased if those companies:
    - consistently and accurately publish their scope 1 and 2 (and 3 as in Article 5) GHG emissions; and
    - have reduced their GHG intensity or absolute GHG emissions, including scope 1 and 2 (and 3 as in Article 5) GHG emissions, by an average of at least 7% per annum for at least three consecutive years.

The use of a "green-to-brown share ratio" is not explicitly included in the regulation as those notions had not yet been defined at the EU level at the time of publication.

[23] EVIC stands for "enterprise value including cash", defined as the sum of the market capitalisation of ordinary shares at fiscal year-end, the market capitalisation of preferred shares at fiscal year-end and the book values of total debt and minorities' interests. No deductions of cash or cash equivalents are made to avoid the possibility of negative enterprise values.

[24] Inflation adjustment factor = (average EVIC of benchmark at the end of the calendar year) / (average EVIC of the benchmark at the end of the previous calendar year).

However, it is recommended and can be found in some versions of commercially available PABs. Other criteria that can also be found in commercially available PABs but are not required by the regulation include constraining the final ESG score of the PABs or constraining the weight of stocks with the highest energy transition risk.