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* Views expressed are those of the author and do not necessarily reflect official positions of De Nederlandsche Bank.

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## 1. Abstract

Investors are increasingly adopting Paris-aligned strategies to better manage climate risks and opportunities. Despite sovereign debt investments making up approximately half of global bond markets, frameworks for assessing Paris-alignment for sovereign portfolios are still in their infancy. This paper firstly advocates for Implied Temperature Rise (ITR) as a metric which investors can use to assess portfolio Paris-alignment, and to capture the embedded transition risks in current sovereign holding. It then proposes a new ITR methodology, further refining existing methodologies. This methodology differs from existing methodologies in that is does not rely on benchmark emission pathways, which we believe yields less volatile and more accurate results. Furthermore, the methodology can more easily include updated global temperature data, and takes a consumption based approach to emissions. Finally, the paper provides a worked example of the methodology, utilizing a hypothetical sovereign portfolio.

**Key words:** responsible investment; Paris-alignment; sovereign investments; implied temperature rise.

**JEL codes:** G12; G18; H63; Q58

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## 2. Introduction

The Paris Agreement, adopted in 2015, marked a watershed moment in international efforts to combat climate change, with its central goal of keeping global temperature rise this century well below 2°C above pre-industrial levels and aiming to limit the increase to 1.5°C (United Nations, 2015). Sovereigns play a critical role in achieving these targets, as government policies, investments, and debt financing are key to driving the large-scale transitions needed for a low-carbon future. Those sovereigns which fail to transition to low emissions may face downgrades to credit ratings, stranded assets, increased debt issuance, reduced access to capital markets, and economic stagnation. For sovereign bond investors, Collander et al. (2022) show there is already a positive relationship between emissions and sovereign bonds spreads, and that transition risks will play an even greater role in influencing these spreads over time. Against this backdrop, Paris alignment has emerged as a key strategy for sovereign investors aiming to mitigate climate transition risks by focusing on countries actively reducing emissions, while avoiding those vulnerable to instability from delayed transitions. Beyond risk mitigation, Paris-aligned investing also offers opportunities, as early adopters of renewable energy, sustainable agriculture, and low-carbon technologies are poised for long-term growth and access to climate finance, bolstering fiscal positions.

Despite over USD 70 trillion of government debt outstanding, making up approximately half of global bond markets (BIS, 2024), methodologies and guidance for Paris-aligning sovereign bond portfolios are still in their infancy. This often leads investors to avoid attempting to align sovereign bond portfolios with the Paris Agreement. The Institutional Investors Group on Climate Change (IIGCC) therefore encourages the creation or endorsement of methodologies to assess sovereign Paris-alignment of portfolios (IIGCC, 2024). In response to this, we advocate for utilizing ITR as a tool to assess Paris-alignment, and provide a new methodology for calculating an ITR for a sovereign portfolio.

An ITR, at its core, assesses the temperature implications of an investment portfolio by estimating the projected global temperature increase if its investees' emissions trajectories were extrapolated to the global economy. It is a forward-looking assessment of the portfolio's embedded climate footprint and is an easy-to-communicate metric, directly linking portfolio emissions to the 1.5°C and 2°C goals set out in the Paris agreement. An ITR is a proxy for embedded climate transition risks in investment portfolios, with a high implied temperature signalling a higher probability that temperature and emission targets will be exceeded. An ITR however, should not be used to proxy for an investment portfolios physical climate risks. The severity of physical risks is somewhat determined by the global response to climate change, and can vary depending on factors such as the geographical location and preparedness of the country.

In researching ITR methodologies, we identified several investor concerns with the metric. First, methodologies are rarely disclosed, making investors dependent on commercial providers for calculations and proprietary data. Second, portfolio ITR can vary significantly between providers, sometimes yielding unrealistic results. Third, ITR is complex to calculate and relies on inputs which are inherently uncertain. Yet, it presents a single-point without a range of possible outcomes, creating a false sense of accuracy despite the inherent uncertainties. Finally, given the uncertainty in ITR, some investors may find ITR unnecessary and prefer focusing on projected emissions and assessing sovereign policy and ambition gaps[1] instead.

This paper aims to address these investor concerns. We address the first concern by providing complete transparency on our methodology while using freely available data, which also allows for further investor scrutiny and refinements. We address the second concern by developing our own methodology which is non reliant on a Paris aligned benchmark pathway – often the main contributor to volatile and discrepant results. We also conducted our own robustness checks on portfolio results to ensure consistency with scientific estimates on expected global temperature rises. We address the third concern this by rounding our portfolio ITR to the nearest 0.1°C to avoid the perception of precision – we also recognise the potential to further refine our methodology to give confidence intervals for results. For the final concern, we also see the benefit of focusing on policy and ambition gaps, however the benefit of ITR is in its communication simplicity, explicitly linking the portfolio to the temperature targets outlined in the Paris agreement. Furthermore, ITR allows for portfolio aggregation and comparability across asset classes.

In developing our methodology, we built on existing sovereign ITR approaches, including those from the Network for Greening the Financial System (NGFS) and the London Stock Exchange Group (LSEG). Our approach is distinct in that it avoids reliance on a benchmark emissions pathway, resulting in less volatile outcomes. We found that using benchmark pathways introduced uncertainty, as selecting the appropriate benchmark was challenging, and the methods for converting emission overshoots into an ITR varied significantly across methodologies. Additionally, our methodology adopts a consumption-based approach, accounts for the full emissions trajectory rather than a single point-in-time estimate, and integrates the latest global temperature data. We believe these differences provide a more comprehensive and robust ITR methodology.

This paper is organized into the following sections. First, we review the Related literature on Paris-aligned sovereign investment portfolios and ITR methodologies, highlighting foundational studies that

[1] Policy gap refers to the difference between actual policies and a countries NDC. While ambition gap refers to the difference between a countries NDC and a Paris aligned policy.

informed our approach. We then analyse the Strengths and weaknesses of the ITR metric. The discussion progresses to the Challenges in applying existing ITR methodologies to sovereign portfolios, with an explanation of how our methodology addresses these difficulties. A practical worked example follows, demonstrating the calculation of a Methodology for calculating a sovereign portfolio's ITR, supported by a detailed rationale for each step. Finally, we examine the Limitations of our methodology and Conclusions and next steps with recommendations for further development and application.

## 3. Related literature on

### *3.1 Paris aligned sovereign portfolios*

Literature relating to constructing Paris-aligned sovereign portfolios is relatively underdeveloped and has primarily been based on backward-looking metrics, such as measuring and steering the portfolios carbon footprint. Cheng (2022) suggest constructing sovereign portfolios with reducing carbon emissions, at a rate consistent with the Paris agreement, through progressive divestment of higher emitting sovereigns[2]. Barahhou, Ferreira, & Maalej (2023) takes an initial portfolio and adds a net zero constraint and subsequently seeks to optimizes by reallocating to better aligned countries - also relying on divestment and ultimately divesting from most sovereigns before 2030, resulting in large skews to otherwise suboptimal countries. Monnin et al. (2024) outline why divestment and tilting to lower emitting sovereigns may not be always be possible for sovereign portfolios, and in particular for central bank portfolios. They suggest central banks should instead prioritize sovereign thematic bonds, such as green bonds, and look to increase allocation to sub-sovereign and supranational issuers. Compared to existing literature, we focus on measuring Paris-alignment on forward looking emissions, assuming that divestment or tilting is not possible, aiming to capture the embedded transition risk in the current sovereign holdings.

### *3.2 Implied Temperature Rise methodologies*

ITR methodologies for sovereign portfolios are also relatively underdeveloped in the literature due to the proprietary nature of commercial providers, though some existing work has informed our approach. Emin, Lancesseur, Emeric, & Clements (2021) use a CLAIM model[3] to develop a country's remaining climate budget and then compare the country's projected emissions based on Nationally Determined Contributions (NDCs). NGFS (2024) suggest a simple science-based formula which uses a base temperature (e.g., 1.5°C) and adds an adjustment based on percentage overshoot using a point-in-time

[2] As measured by carbon footprint. The PCAF recommended approach to calculate the carbon footprint is to divide sovereign production emissions by PPP-adjusted GDP.

[3] CLAIM (Climate Liabilities Assessment Integrated Methodology) allocates national carbon budgets based on principles of equity and efficiency, combining factors like historical emissions, mitigation capacity, and responsibility for climate impacts. It aims to create a fair and consensus-driven framework for assessing each country's contribution to global carbon reduction targets under the Paris Agreement.

(e.g., 2030) estimate over an emission benchmark. NGFS also suggest using climate models such as MAGICC[4] or Hector[5], however these models can be complex and not freely available. We discovered three main problems while researching sovereign ITR methodologies, for which this paper attempts to address:

- There is no agreement on sovereign ITR methodologies, which can complicate comparability.
- There is very little documentation to support existing methodologies. With underlying rationale behind methodologies very rarely being provided.
- Commercial providers, which can produce an ITR measure for sovereigns, use proprietary models which lack transparency and scrutiny. Some providers can also have large fees, reducing accessibility.

### *3.3 Literature informing our methodology*

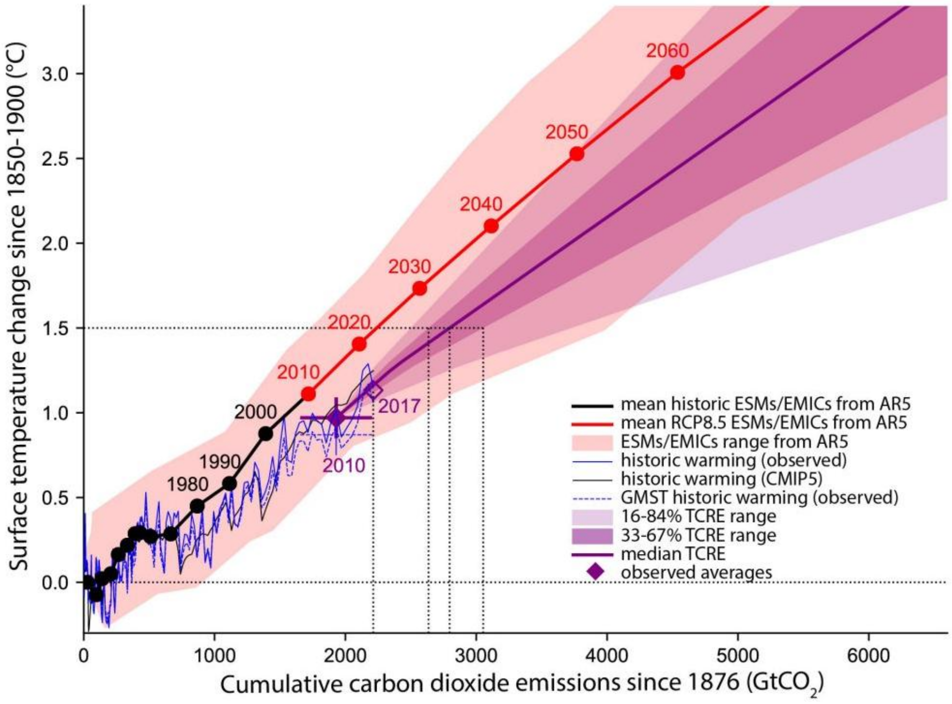
In developing our methodology, we relied on existing literature to guide our overarching principles. Barahhou, Ferreira, & Maalej (2023) discuss the benefits and drawbacks between a consumption and production based approach for sovereign emissions[6], and the impact on relative performance between countries. Our methodology uses a consumption based approach and utilized guidance from PCAF (2022) to help guide our decision as to how to scale consumption emissions. IIGCC (2024) discusses the differentiated responsibilities between sovereigns and the need to account for the differentiated responsibilities and capacities.

One of the key assumptions embedded in our ITR methodology, along with other methodologies, is determining the appropriate TCRE. The TCRE measures the response of global temperatures to cumulative emissions - that is, how much global average temperatures will rise per additional until of CO2 equivalent. IPCC (2023) suggests the TCRE likely falls between 0.27-0.63°C per 1000 GtCO2 emitted, with the best estimate of 0.45°C. Damon Matthews (2021) estimate a median TCRE of 0.44 °C and 5–95% range of 0.32–0.62 °C per 1000 GtCO2 emitted. Other sources such as Steinacher (2016) focus on estimating the TCRE for carbon, with estimates of 1.9°C per 1000 GtC and a confidence interval of 1.3 to 2.7°C. Converting this to a C02 equivalent TCRE at a rate of 3.67[7] would give an equivalent TCRE of 0.52°C per 1000 GtCO2. Leduc (2016) also makes the point that the TCRE differs between regions, with a pattern of higher values over land and at high northern latitudes. Nicholls (2020) also show the relationship between cumulative C02 emissions and C02 induced warming is unlikely to

[4] MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change) is a simplified climate emulator that projects global temperature, sea level rise, and other metrics by emulating complex Earth System Models (ESMs).
[5] Hector is an open-source, modular Earth system model that simulates global climate processes, including greenhouse gas cycles, temperature responses, and ocean acidification.
[6] Consumption based emissions = Production based emissions – Exported emissions + Imported emissions.
[7] The atomic weight of carbon is 12, while the weight of C02 is 44. Therefore converting carbon TCRE estimates to C02 equivalent, one would need to divide by 44/12, or 3.67.

be linear. While there is no clear consensus, the median estimates from our literature review are usually in the range of 0.4 to 0.5°C per 1000 GtC02, reflecting some consensus on the likely range of median estimates. In our methodology, we assume a linear TCRE of 0.45°C per 1000 GtCO2 for simplicity, which aligns with most other methodologies[8] and IPCC estimates.

**Figure 1: Surface temperature rise vs cumulative emissions[9]**




## 4. Strengths and weaknesses of the ITR metric

An ITR is a forward-looking metric and therefore uses both current and projected emissions by incorporating government policies targets, and expected technological advancements into the emission pathway. Unlike static measures such as carbon footprints, which only reflect current emissions, forward-looking projections are dynamic and account for the anticipated impact of robust transition plans and institutional capacities. This is especially critical for sovereigns that may currently exhibit a high carbon footprint but possess credible and ambitious decarbonization strategies. By capturing these future pathways, the ITR provides a more nuanced and accurate assessment of transition risks, revealing opportunities that static measures might overlook.

An important differentiator from metrics like carbon footprint is ITR encourages investment in countries committed to real-world decarbonization. While an investor could reduce a portfolio's carbon footprint over time to meet a Paris-aligned trajectory (e.g., a 7% annual reduction), this could be achieved simply

[8] Such as MSCI and NGFS. LSEG methodology use a TCRE of 0.544°C per 1000 GtCO2
[9] Source: *Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development* (IPCC)

by divesting from high-emitting countries, rather than reflecting genuine decarbonization efforts by governments. As noted by Barahhou et al. (2023) and Monnin et al. (2024), divestment is not always feasible and will likely become increasingly difficult. Therefore, assessing Paris alignment based on a static portfolio—assuming allocations cannot be changed—provides a more accurate reflection of the transition risks embedded in the current holdings, which is where the ITR measure excels.

Given the high level of assumptions in any ITR methodology – which are outlined throughout this paper – the precision of the calculated ITR should always be treated with some scepticism. While we believe the forward-looking nature of ITR is a benefit for the metric, it inherently relies on projections which can be subject to significant forecast errors, policy changes, and projections can vary between data providers. To avoid the perception of precision in our ITR methodology we round our calculated ITR to the nearest 0.1°C.

An ITR should also only be used as one of many metrics to steer portfolio decisions, as it is only a proxy to help estimate transition risks. In reality, many factors will influence the climate transition risks faced by any sovereign. Furthermore, an ITR gives limited (or no) consideration to physical risks, biodiversity risks and other factors which may be more impactful for portfolio returns. As such, we would advise to use ITR as only one of many assessment tools when considering climate risks for sovereign investment portfolios.

## 5. Challenges in applying existing ITR methodologies to sovereign portfolios

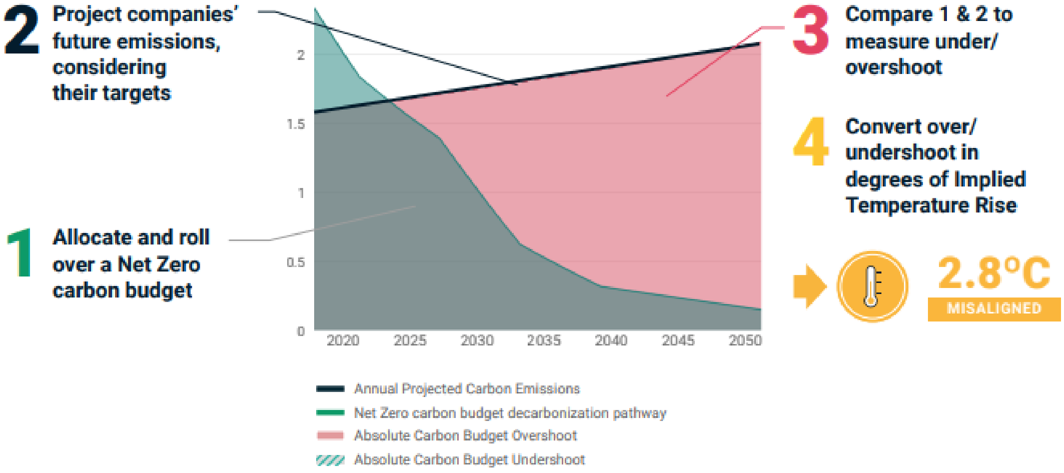
Most existing sovereign ITR methodologies use a similar approach to ITR methodologies developed for corporate investments. As Figure 1 shows, the first step is to determine a *Paris-aligned emission pathway*, for which the decarbonisation pathway would meet the goals set out in the Paris agreement. Often this Paris-aligned pathway is provided by data providers. Next, the *expected emission pathway* is projected based on current policies or explicitly set targets, such as NDCs. The difference between the *Paris-aligned pathway* and the *expected pathway* represents the carbon overshoot[10]. This overshoot is then used to calculate the excess global emissions, assuming the world overshot its carbon budget by the same proportion as the sovereign[11]. This excess emissions amount is converted into a temperature rise (e.g., 1.3°C) using a Transient Climate Response to Cumulative Emissions (TCRE), and added to the baseline temperature associated with the Paris-aligned pathway (e.g., 1.5°C) to estimate the implied temperature rise (e.g., 2.8°C). However, we believe this corporate-style approach may not be suitable

[10] Throughout this paper, carbon overshoot and excess emissions are referred to as it is more common than a carbon undershoot.

[11] For example, if a country overshot its carbon budget by 50%, one would calculate the excess emissions if the world also overshot its carbon budget by 50%.

for sovereign investments due to the inability to consider fairness, differences in scaling denominators, broader industry coverage for sovereigns, and the impact of international trade dynamics.

**Figure 2: Calculating an ITR for a corporate investment, most sovereign ITR methodologies take a similar approach**[12]

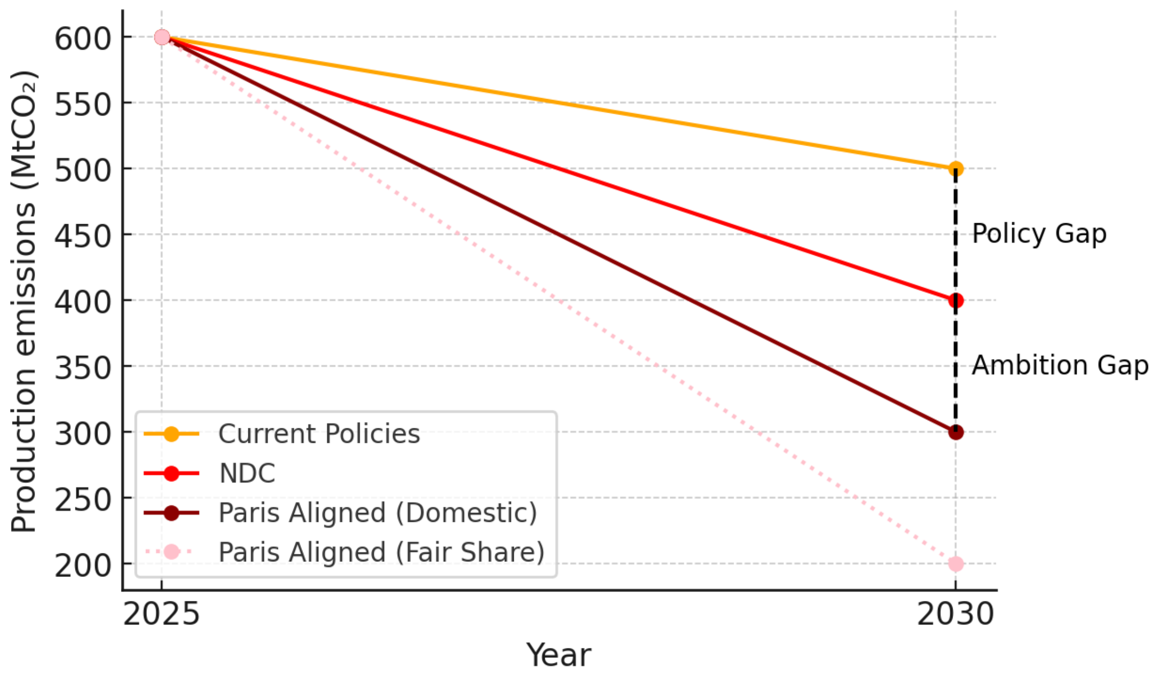



### *5.1 Utilizing Paris-aligned benchmark emission pathways*

For sovereign investments, projecting an appropriate benchmark emission pathway (as is common practice in most ITR methodologies) is complicated by the decision on whether to utilize a 'fair share' or a domestic-focused benchmark pathway, as shown by Figure 3. A domestic-focused benchmark only considers a country's pathway, in isolation, to achieve net zero emissions by 2050. In contrast, a 'fair share' benchmark incorporates the principle of 'common but differentiated responsibilities' from the Paris Agreement, which suggests that wealthier nations, with a history of benefiting from fossil fuels should follow more stringent pathways. Conversely, countries like India or Indonesia, with a lower historical footprint, may require a less stringent pathway. Because of this, using a 'fair share' benchmark often produces higher ITRs compared with a domestic-focused benchmark, given sovereign portfolios are usually composed of issuers from wealthier nations. These countries, while transitioning to service-based economies, can also outsource high-emitting activities to lower-income countries, which complicates the assessment of their true global climate responsibility. Furthermore, Todorova & Garcia Martinez (2024) also attribute 40-60% of sovereign emissions to structural factors, such as geography, rather than government policy - which may warrant further adjustments to benchmark pathways.

**Figure 3: Illustrative example of fair share vs domestic only emission pathway.**

[12] Source: MSCI, Implied Temperature Rise




We believe that a 'fair share' benchmark better aligns with the principles of climate justice, as it holds wealthier countries to stricter decarbonization standards due to their historical contributions to global emissions. However, we acknowledge that this approach is subjective, making the 'fair share' pathway challenging to implement and potentially overly conservative when assessing transition risks. When we experimented with existing ITR methodologies, it became increasingly clear that the results are highly sensitive to changes in the benchmark decarbonization pathway. We therefore focused on developing a methodology that was not reliant on a benchmark emission pathway. By eliminating reliance on benchmark pathways to calculate an ITR, our methodology removes one of the biggest assumptions which can create large variance in results. Our methodology therefore focuses on absolute rather than relative (to a benchmark) emissions.

### *5.2 Converting percentage carbon overshoot into an amount of excess emissions*

A secondary consequence of relying on benchmarks is the difficulty in converting percentage overshoots above benchmark pathways into excess emissions, which are then translated into temperature increases – that is, steps 3 and 4 as shown in Figure 1. The mechanism for doing so, varied between methodologies, with some simply applying the TCRE to the percentage overshoot, and others incorporating the remaining climate budget to convert percentage overshoot into an amount of emissions. For example, Friedlingstein et al. (2024) estimates the remaining budget for a 50% likelihood of limited global warming to 1.5°C is 235 GtCO2. If a sovereign were to overshoot a 1.5°C pathway by 50%, some methodologies would calculate the impact of an additional 50% increase above the carbon budget, that is, 235*50% = 117.5 GtCO2, and then calculate the corresponding temperature rise by applying the TCRE. However, this creates a problem: as the remaining carbon budget approaches zero, so too does the estimate of emission overshoot and the resulting calculated ITR. In an extreme case where the remaining budget for a 1.5°C pathway is zero, the portfolio's ITR would be 1.5°C regardless of how much the country overshoots its 1.5°C aligned benchmark. This limitation in converting percentage overshoots underscores the need for a methodology that does not rely on benchmarks.

## 6. Methodology for calculating a sovereign portfolio’s ITR

This section outlines our sovereign ITR methodology as summarized in Table 1, and provides a worked example. In our example, we use emission data provided by Climate Action Tracker[13], an independent scientific project that tracks government climate action. Where applicable, we also provide the rationale underlying our methodology, since we found this was rarely disclosed or documented in other methodologies.

**Table 1: Outline of steps for ITR methodology**

| | |
|---|---|
| Step 1 | Project the total cumulative production based emissions[14] for each country until 2050. |
| Step 2 | Convert the projected production based emissions into projected consumption based emissions[15]. |
| Step 3 | Scale the cumulative consumption based emissions to global equivalent consumption based emissions. |
| Step 4 | Calculate the weighted average, based on portfolio holdings. |
| Step 5 | Adjust to include emission leakage, such as aviation and shipping emissions. |
| Step 6 | Convert total cumulative emissions to an ITR uplift using TCRE. |
| Step 7 | Add the ITR uplift to a baseline temperature, based on recent temperatures. |

### *6.1 Project the total cumulative production based emissions for each country until 2050.*

For each sovereign holding, the first step is to develop a forward-looking emission pathway based on *current government policy*. Climate Action Tracker currently only provide this for production based emissions and until year 2030, so users must extrapolate emission pathways until 2050. For our example extrapolation, we used a simple linear trend continuing from the year 2030 until 2050. Another advantage to our methodology is that it can assume different trends between countries. One could use

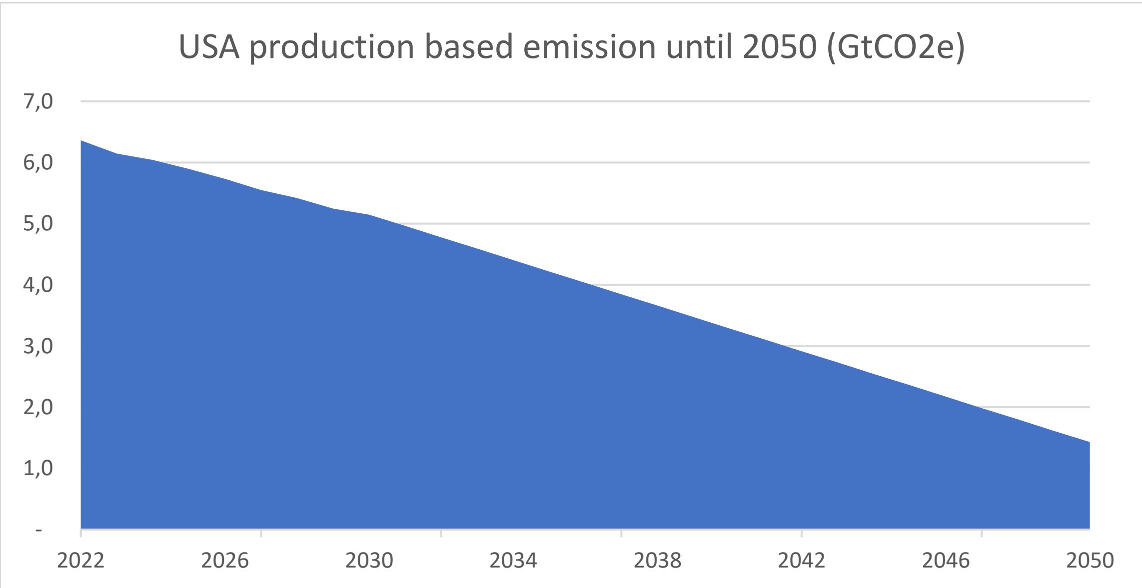
[13] As part of our review, we also reviewed other freely available and credible data sources such as Climate Analytics, but had a small preference for Climate Action Tracker due to its prominence and science based pathways.
[14] Emissions generated within a country from the production of goods and services, regardless of where those goods and services are ultimately consumed.
[15] Emissions associated with the consumption of goods and services within a country, including emissions from imported products and excluding emissions from exports.

a linear trend for more developing countries while a quadratic trend[16] for more developed countries. Once a pathway has been determined, calculate the cumulative sovereign emissions between the start date and 2050 by summing each year's emissions.

In our methodology, we exclude land use, land use change and forestry (LULUCF) to avoid additional modelling assumptions and it is generally more conservative to do so for developed sovereign markets. Excluding LULUCF may understate some countries ITR where LULUCF is a source of additional emissions. Users could also include LULUCF by incorporating these additional carbon sources or sinks into the emission pathway. Whether users include or not include LULUCF, it is important to do consistently across sovereigns and disclose whether LULUCF was included or not.

For example, we estimate that the USA total cumulative production (excluding LULUCF) based emissions between 2022 and 2050 will be approximately 115 GtC02.

**Figure 4: USA production (excluding LULUCF) based emissions[17]**




### *6.1.1 Underlying rationale behind projecting the total cumulative production based emissions for each country until 2050*

A robust methodology should consider cumulative emissions rather than rely solely on point estimates, to ensure the complete emission pathway is captured. For instance, two identical countries with different policies in place may reach the same level of emissions by 2050, and therefore using a point estimate in the year 2050 would result in identical ITRs. However, if Country A reduces its emissions steadily

[16] A parabolic trend with accelerating reductions after a few years to approximate a delayed transition.
[17] Source: USA | Climate Action Tracker and own calculations

over time, while Country B increases its emissions until 2045 before making a rapid decline, the cumulative emissions of Country B would be significantly higher. Consequently, Country B should have a higher ITR, given it has contributed more to global warming compared to Country A.

To avoid understating a portfolio's ITR, methodologies should use a 2050 horizon, capturing cumulative emissions rather than stopping at 2030. A 2030 limit focuses only on short-term reductions, missing emissions that persist until 2050, when global targets aim for net zero[18]. Despite introducing more model uncertainty, extending the horizon provides a more realistic reflection of long-term climate impacts.

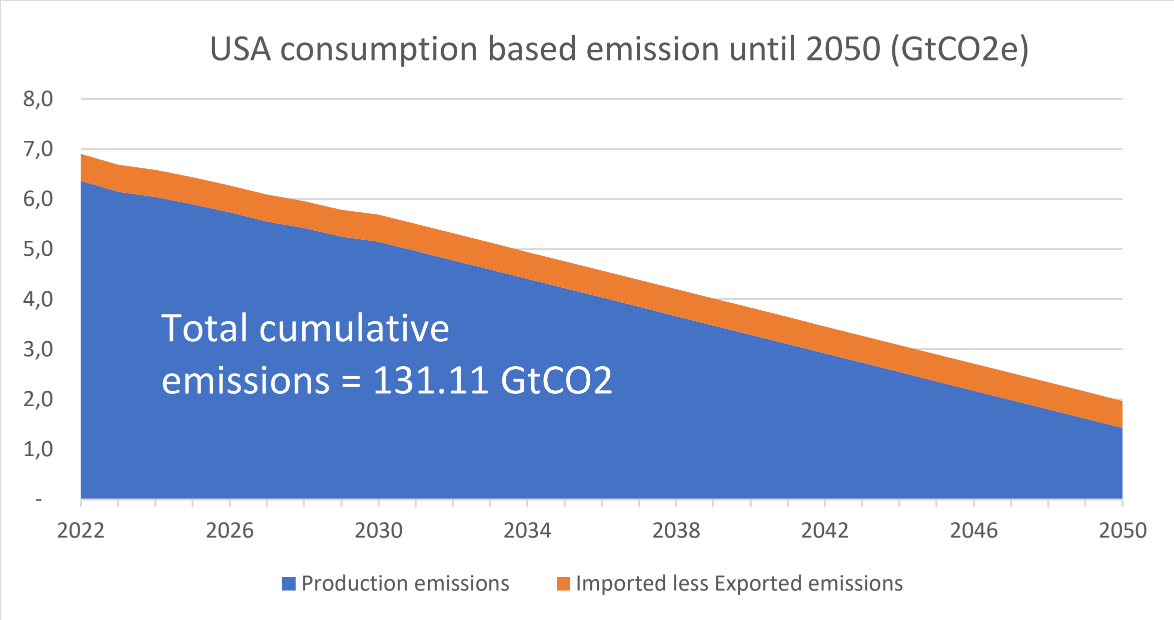
Since bond proceeds directly fund present government expenditures guided by current policies, we think it is essential to use emission pathways based on these current policies rather than NDCs or other targets. NDCs may set ambitious future targets, but they often do not align with real-time government actions, making current policies a more realistic basis for assessing expected emissions. Furthermore, sovereign bonds owned in a portfolio have financed current government spending and therefore the ITR calculation should reflect this.

### *6.2 Convert the projected production based emissions into projected consumption based emissions.*

If data providers offer consumption based emission pathways, users can use these to estimate cumulative emissions. However, if only production based emission pathways are available, users should adjust by adding a country's imported emissions minus its exported emissions to approximate the consumption based emission pathway. In the USA in 2021, imported emissions exceeded exported emission by 0.54 GtC02[19], and this difference has been relatively static over the last 20 years. Therefore, add an additional 0.54 GtC02 to each projected year for the USA[20].

**Figure 5: USA cumulative consumption based emissions (source: Our World in Data & own calculations)**

[18] Most developed countries have a 2050 net zero target enshrined in law (Energy & Climate Intelligence Unit).
[19] Source: How do CO2 emissions compare when we adjust for trade? - Our World in Data
[20] Users could use a more sophisticated approach, however for simplicity we use a historical spread.




### *6.2.1 Underlying rationale behind converting production based emissions into consumption based emissions.*

Consumption based emission, as calculated by adding net imported emissions to production emissions, offer a more accurate reflection of a country's climate impact by accounting for both imported and exported emissions, effectively correcting for outsourced emissions. Unlike production based emissions (which capture only domestic output), consumption based emissions encompass wider environmental impact, and more closely incorporate scope 3 emissions[21]. This comprehensive view is especially relevant for developed countries, which are often net importers of emissions. A consumption-based approach more equitably accounts for differentiated responsibilities by recognizing the emissions driven by international demand, ensuring that countries reliant on agricultural or manufacturing exports (typically developing countries) are not unfairly penalized for serving global markets. Although our methodology assumes no changes to import or export dynamics – something which is highly unlikely to eventuate - it is difficult to justify a different way to forecast trade dynamics. In recent history, trade dynamics have been surprisingly stable for countries we reviewed, providing some assurance that a historical spread is acceptable to use to adjust production based emission projections.

## ***6.3 Scale the cumulative consumption based emissions to global equivalent consumption based emissions.***

[21] The GHG Protocol's definitions of scope 1, 2 and 3 were developed for corporate investments and therefore cannot directly be used in the context of sovereigns. However, PCAF (2022) align production based emissions to scope 1, while align consumption based emissions to scope 1+2+3 less exported emissions.

This step attempts to scale a country's cumulative based consumption emissions to a cumulative global consumption based emissions, assuming that all countries emitted in the same proportion as the investee country. To do so, the user must scale using a proportional adjustment. We recommend dividing consumption based emissions by the percentage of population to scale to a global equivalent emission. This aligns with PCAF recommendations in using population to scale consumption based emissions.

For example:

- USA cumulative consumption based emissions = 131.11 GtC02
- USA percentage of global population in 2022 = 4.24%[22]
- Global equivalent emission = 131.11/0.0424 = 3092.28 GtCO2

6.3.1 *Underlying rationale behind converting consumption based emissions into global equivalent consumption emissions.*

This step is where our methodology diverges further from existing methodologies , which would usually compare calculated emissions to that of a Paris aligned benchmark. For example, in the "rough and ready" methodology provided by the NGFS (2024) report[23], this step looks to calculate the emission gap (in percentage terms) between the calculated emissions and the benchmark emissions, and then multiply by the TCRE. However the percentage overshoot is not an amount of carbon released and therefore shouldn't be converted to an ITR using the TCRE. As such, calculating an equivalent global emission amount is required, before utilizing the TCRE to calculate an ITR. Other methodologies we reviewed scaled to a global equivalent emission amount by utilizing the remaining carbon budget. However, as outlined in section 5, this inherently biases the results lower as the remaining carbon budget approaches zero.

### *6.4 Calculate the weighted average, based on portfolio holdings.*

Repeat steps 1-3 for all sovereigns in the investment portfolio. Subsequently, calculate a weighted average of the population adjusted emissions based on portfolio weights. In the below example, this would result in emissions of 2,487.84 GtCO2.

**Table 1: Weighted average based on portfolio holdings**

[22] Source: Worldometer (www.Worldometers.info)

[23] The NGFS provide a formula for calculating the ITR below:

$$ITR_{t+h}^{policy\ scenario} = temp\ target + \left(\frac{emission\ gap(\%)_{temp\ target,t+h}^{policy\ scenario}}{100}\right)\frac{0.00045\ °C}{Gt\ CO_2}$$

| | Holdings (EUR mil) | % of global population | Cumulative 2050 emissions (GtCO2) | Population adjusted (GtC02) | Weighted (GtCO2) |
|---|---|---|---|---|---|
| US | 2,000 | 4.24% | 131.11 | 3,092.28 | 1,236.91 |
| JPY | 1,000 | 1.62% | 26.69 | 1,647.25 | 329.45 |
| UK | 500 | 0.86% | 14.35 | 1,668.89 | 166.89 |
| NOK | 500 | 0.07% | 1.15 | 1,636.47 | 163.65 |
| CAD | 500 | 0.49% | 16.40 | 3,347.51 | 334.75 |
| AUD | 500 | 0.33% | 8.45 | 2,561.92 | 256.19 |
| **Total** | **5,000** | | | | **2,487.84** |

### *6.5 Adjust to include emission leakage, such as aviation and shipping emissions.*

This step is primarily to ensure there is a capture of those emissions which are not easily attributable to sovereign emissions, such as aviation and shipping, and therefore would understate a portfolios ITR otherwise. Using data from Climate Action Tracker, and taking the average between the high and low estimates of current policy projections, the expected cumulative emissions from 2022-2050 from the aviation and shipping industries is approximately 50.6 GtCO2. Therefore, adjust the emissions calculated in the previous step to include aviation and shipping (i.e 2,487.84 + 50.6 = GtCO2 2,538.4). This represents the additional emissions expected globally from 2022 to 2050 if the world emitted at the same rate as the portfolio's constituent countries, and shipping and aviation emissions continue to evolve as expected.

### *6.6 Convert total cumulative emissions to an ITR uplift using TCRE.*

The purpose of this step is to convert the embedded emissions into a temperature increase using the TCRE. As outlined in section 3, we use a TCRE of 0.00045°C per GtCO2 emitted. In our example, using a TCRE of 0.00045°C per GtCO2, the calculated additional temperature increase is approximately 1.14°C (i.e 2,538.4*0.00045 = 1.14°C). This figure becomes the ITR uplift, which is the additional temperature rise expected if the world were to emit the emissions calculated in step 6.5.

### *6.7 Add the ITR uplift to a baseline temperature, based on recent temperatures.*

In this step, we add the ITR uplift calculated to step 6.6, to a baseline temperature which captures historical emissions (i.e baseline temperature + ITR uplift = ITR). In our example, we projected emissions from 2022-2050 to calculate the cumulative emissions. Given these are projected emissions, it is intuitive to use the 2022 as the baseline temperature. However, average temperatures can be slightly volatile between years. As such, we recommend using an average temperature (above pre-industrial levels) of the median temperature rise of either side of the base year. Median temperatures were 1.20°C, 1.25°C and 1.54°C above pre-industrial averages for 2021, 2022 and 2023 respectively[24]. As such, it would be recommended to use a baseline temperature of 1.27°C (i.e the mean temperature across the three years). Combining this baseline temperature (1.27°C) with the ITR uplift (1.14°C), **the investment portfolio's ITR would be approximately 2.4°C.** It is recommended to round answers to the nearest 0.1°C to avoid the perception of too much precision in the calculated results.

### *6.7.1 Underlying rationale behind using recent temperatures as the baseline temperature*

One potential shortcoming with some other methodologies, is the inability to incorporate up to date temperature data, given most use the baseline temperature which is associated with the Paris aligned benchmark pathway (e.g., 1.5°C). We noted that other methodologies had no way to incorporate updated actual temperature data, making it inflexible and likely less accurate as time progresses. In 2024, global temperatures exceeded 1.5°C above pre-industrial levels (World Meteorological Organization, 2024) which our methodology would be able to incorporate by adjusting the base temperature in step 6.7, while others would still show a 1.5°C aligned portfolio having emissions until 2050, something we believe would understate the realized temperature rise.

## 7. Limitations of our methodology

Our methodology (along with any methodology we have reviewed) does not account for the relative historical outperformance of a sovereign compared to its peers. For instance, if a country has contributed minimally to climate change, the methodology does not reward that country with a higher forward-looking emission allowance. We attempt to capture an equitable forward-looking measure by utilizing a consumption approach and scaling a sovereign's emission pathway using population. However, given net zero target enshrined in law are usually domestic only focused, we think focusing on forward looking domestic focus is a better proxy for transition risks.

Our methodology only uses emission pathways until 2050. Therefore, it may understate the ITR if countries continue to emit beyond 2050. This is because the methodology assumes no emissions beyond 2050, which is by design. Most G10 countries have net zero emissions by 2050 enshrined in law[25], and projecting emissions beyond 2050 becomes particularly challenging due to the high levels of uncertainty.

[24] Source: Berkely Earth (Global Temperature Report for 2023 - Berkeley Earth)
[25] Source: Net Zero Tracker

Our methodology also treats sovereign investments in isolation, and may not be easily combined with a portfolio consisting of sub-sovereign, supranational, agency and corporate bonds. In reality, bond portfolios usually have a combination of both sovereign and non-sovereign investment, for which aggregation may be difficult. Double counting of emissions between sovereigns and corporates is inevitable under our methodology, and most likely with other methodologies. Further work is needed to incorporate a comprehensive ITR for a bond portfolio consisting of both sovereign and non-sovereign investments.

## 8. Conclusions and next steps

In this paper, we advocate for ITR as a metric to assess Paris-alignment for sovereign investment portfolios, while providing a methodology to calculate this metric. An ITR is a forward looking, simple to communicate, metric which captures embedded emissions and government policies of the sovereign holdings. We further refine, while also providing rationale for doing so, existing methodologies with key differences including; using cumulative emissions until 2050, removing reliance on benchmark emission pathways, using consumption based emissions, and incorporating up to date temperature data. We believe these changes enhance robustness, but also believe further refinements are possible and we welcome further scrutiny and improvements.

Further work is required to refine our methodology to incorporate other asset classes. Incorporating sub-sovereign, supranational, agency and corporate bonds into the methodology could better assist investors to apply the methodology more broadly to fixed income portfolios. In addition, incorporating avoided emissions from sovereign green bonds could further improve the methodology, and provide an avenue for investors to help better align their portfolios. Our methodology assumes fungibility with government spending under current policies, but given green bonds fund certain projects and assets, their attributed emissions would be different (and likely lower) than the general government spending. This may warrant adjustments to the projected emission pathways, and therefore (likely) helping lower a portfolios ITR.

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