Network for Greening the Financial System

Technical document

Climate-related risks and impact in sovereign investments

Data, metrics and implementation issues for central banks

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Executive summary

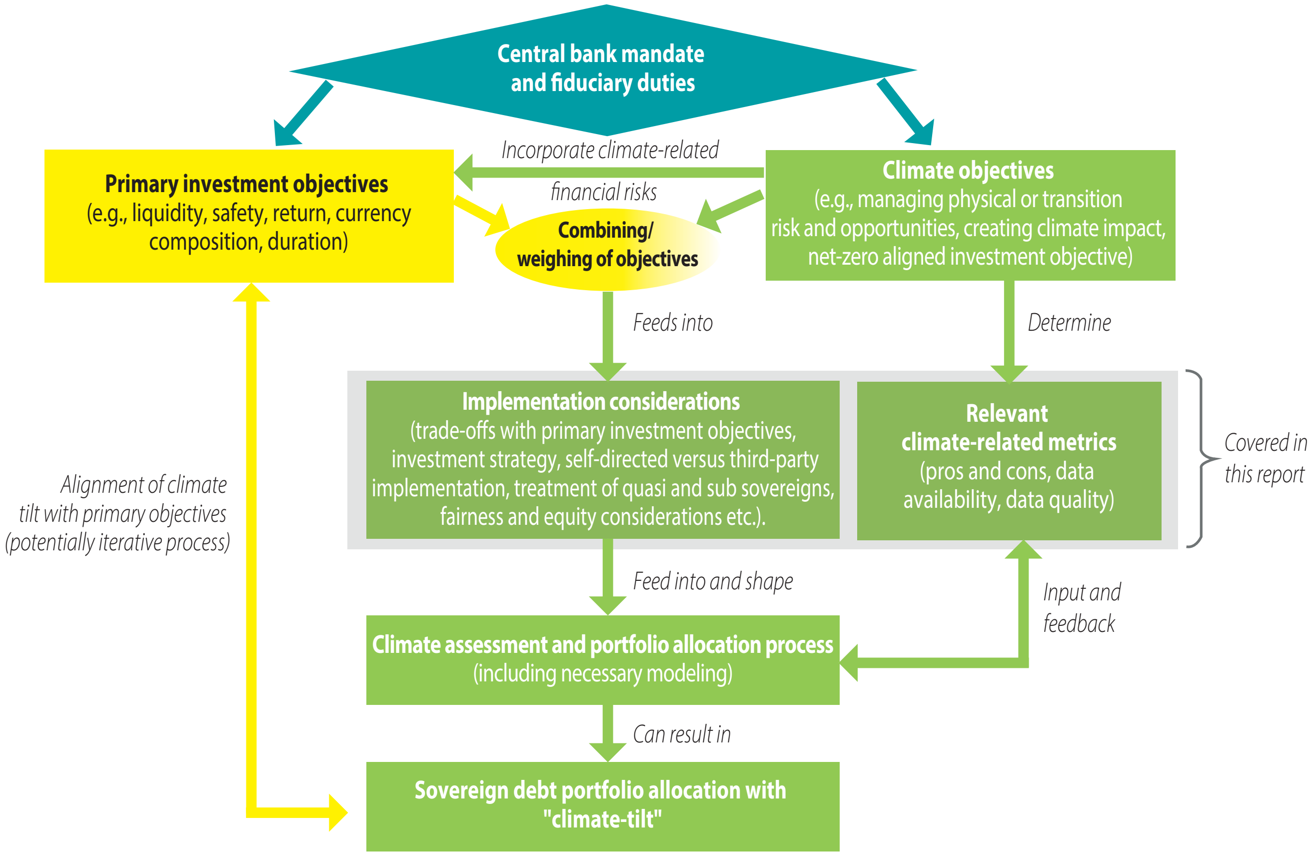
Sovereign portfolios are not immune from climate and sustainability risks. A meaningful part of central bank investments consists of sovereign bonds or quasi-sovereign debt securities, such as sub-sovereign or agency securities. Sovereign bonds typically have a special role in central banks' balance sheets. Domestic sovereigns are instrumental to monetary policymaking while foreign sovereigns are a core feature of reserve management. Fundamentally, they typically have characteristics (liquidity, risk) that are unique within the investment spectrum. These considerations tend to affect investment decisions of central banks. However, climate and sustainability risks can affect any kind of security. As the management of these risks falls squarely within the mandate and duties of central bank investment managers, this Technical Document (TD) first considers sovereign portfolios in a discussion about climate risks. Secondly, it considers the issue of achieving a carbon emissions reduction impact *via* investment management, which goes beyond a narrow definition of risk management and can be considered by those central banks whose mandate is consistent with this objective. This TD does not consider portfolios of sovereigns held for monetary policy purposes.

Sovereign debt securities are different in their characteristics from other securities, such as corporate bonds and equities. They have so far received relatively less attention when it comes to data, metrics, methodologies, and available tools for assessing climate-related risks, opportunities, or impact. As this TD demonstrates, the relevant metrics and data are typically freely available and of high quality. However, established methodologies to translate relevant climate metrics into investment decision-relevant outputs (e.g., modelling techniques to map climate risks into sovereign credit risk and sovereign bond prices) are still being developed. Some of the difficulties discussed in this TD are conceptual. Therefore, the implementation of climate-related considerations for sovereign debt portfolio management remains challenging.

This TD provides a reference for central bank (and potentially other) investment managers on some of the most relevant issues and information sources, with a two-fold objective:

- **Providing a "one-stop-shop" summarising a range of relevant data sources and metrics, and discussing their pros and cons, with a focus on freely available and high-quality sources.** To this end, this TD builds on a small number of recently published key reports as well as on the framework developed by the Assessing Sovereign Climate-related Opportunities and Risks (ASCOR) Project – a key investor-led initiative focussed specifically on sovereign securities and their climate-related risks and opportunities. In addition, this TD covers sovereign climate risk indices, sovereign ESG scores, green and other sustainable bonds, as well as climate sovereign bond indices– all of which are options that central bank investment managers may be considering.
- **Discussing implementation issues and constraints.** In implementing their investment strategy for sovereign debt portfolios, central banks face a series of challenges, that are illustrated in what follows. For instance, they will need to decide how to best combine their climate-related objectives with their primary (financial) investment objectives (Figure 1). The range of implementable investment solutions will thus depend on this combination. In addition, there are several practical and conceptual implementation challenges. For instance, just transition issues prominently feature among the latter.

Figure 1 **Central bank investment portfolios – stylised process for incorporating climate-related considerations in sovereign debt portfolio allocation**



Source: NGFS technical group members.

The TD distinguishes between risk-based measures vs. impact measures. The former seek to measure the exposure of sovereign debt securities to physical and transition risks. The latter seek to measure the impact of a given sovereign security on climate. These two perspectives, in principle distinct although to some extent overlapping, broadly represent how central bank mandates and fiduciary duties can allow the incorporation of climate-related considerations in central banks' investment portfolios.

Due to a series of practical as well as conceptual problems, there is no one-size-fits-all or one-off solution for the implementation of climate-related considerations in central banks' management of sovereign debt portfolios. Implementation is bound to be an evolving process, as investment managers need to build expertise and experience amidst the constantly evolving landscape of climate data, climate-related accounting, conceptual advancements and portfolio decarbonisation practices.

Risk and opportunity metrics and data

High quality climate-related data for sovereigns are typically freely available in most jurisdictions. To assess acute physical risks, high-quality data on natural disasters and disaster-related monetary damages can serve as relevant proxies. Scientifically rigorous and standardised data for past and current GHG emissions of individual jurisdictions are freely available, though typically with a time lag of around 2 years. Some central banks have published GHG emissions metrics for their sovereign securities at the portfolio level based on the recommendations of the Task force on climate-related financial risk disclosure (TCFD).

Climate scenarios, such as the NGFS scenarios, can provide relevant data on longer-term physical risks, which can be measured using a range of different variables. For a comprehensive physical risk assessment, a long-term forward-looking perspective should be considered, including planned adaptation measures, limits and residual risk (risk that remains following adaptation and mitigation efforts) and possible unintended consequences (risk of maladaptation).

Several metrics can be used to proxy transition risks at the country level. Climate scenarios can also provide valuable insight and generally suggest that transition risks are higher for countries that rely significantly on fossil fuels exports, as well as imports. The ASCOR framework proposes some additional measures, such as transparency on net zero emission targets and climate laws. In many countries, the climate transition will create significant opportunities which can counterbalance potential risks. The ASCOR framework, for instance, recommends looking at the potential for renewable energy development. Environmental, Social and Governance (ESG) scores are also frequently used by investment managers to assess non-financial risks more broadly, though there are challenges associated with the construction and use of sovereign ESG scores.

At this point it is difficult to quantify the exact impact of climate change on the financial performance of sovereign bonds. The concept of transition risks for a sovereign issuer needs some tailoring, given the interaction between private and public actions and the various channels to consider (overall macroeconomic implications of the transition, specific impacts on taxes, other revenues and public expenditures, etc.). An additional dimension of transition risks is related to the possibility of changes in legislation, which in the case of sovereign issuers are largely endogenous. While carbon metrics may be linked to a country's exposure to transition risks, GHG emissions metrics of sovereigns raise double-counting issues and conceptual differences with corporate GHG metrics should not be overlooked. Generally, backward- and forward-looking GHG emissions metrics alone should not be seen as proxies for transition risks to central banks' investment portfolios, although they may serve as a starting point for risk as well as impact analysis.

Climate impact metrics and data

Impact metrics aim to cover the effect of sovereign investments on climate, and crucially depend on the ambition of a country's policy commitments and actions. Metrics that translate realised policies and policy commitments into future GHG emissions pathways are highly relevant and freely available from a range of sources. However, they remain subject to uncertainties both around modelling as well as the actual implementation of policy commitments. Examples of metrics that could be used to assess the strength of policy commitments are those that proxy the level of ambition and the legal basis of climate policy commitments, or the prevalence and characteristics of carbon pricing mechanisms.

As climate policies are multi-faceted, climate policy indices can be a useful summary metric. Widely used and freely available indices include, among others, those provided by e.g., Germanwatch and Climate Action (CCPI), the University of Notre Dame (ND-Gain) or OECD (CAPMF and other indices). Policy indices vary in their methodology and composition and therefore not all indices are necessarily a good fit for a given central bank's use case.

Central banks with impact objectives can include green and other labelled sovereign sustainable bonds in their portfolios. In the case of green bonds, impact reports – available currently for all sovereign green bonds and most of green bonds issued by supranationals – directly assess climate impact, but as there are no global standards or requirements, additional due diligence is required to assess them. Another promising option is sustainability-linked bonds – instruments whose contractual conditions are explicitly linked to a set of indicators. Bonds of this type are currently issued by two Latin American sovereigns.

For the central banks who have adopted net-zero targets for some of their investment portfolios, portfolio alignment metrics are increasingly relevant. Various metrics can be constructed which compare a given sovereign debt portfolio with the desired benchmark, such as the emissions gap or the carbon budget overshoot, or the so-called implied temperature rise.

Central banks may also want to consider fairness, just transition and effectiveness issues. Fairness can span a wide range of issues, which are examined in a large body of literature. One can consider the countries' historical contributions to present day carbon concentration. A related concept is that of just transition – that combines the achievement of positive climate impact with the pursuit of socio-economic welfare.

From the climate impact viewpoint, another unresolved issue concerns the practical effect of portfolio choices (both for corporates and sovereigns). Changing a portfolio composition away from certain issuers need not necessarily induce these issuers to adopt more climate conscious policies. The issue is an empirical one and needs further investigation (Angelini, 2024).

Implementation challenges and constraints

Potential portfolio tilting for sovereign bond portfolios would need to comply with central banks' primary investment objectives. Liquidity, safety and return considerations as well as a desired share of reserve currency holdings (for the major international currencies) are likely to constrain large shifts in portfolio weights.

Another fundamental implementation challenge and likely constraint is the limited investable universe of sovereign issuers. Naturally, the number of sovereign issuers that central banks can consider is limited. Decarbonisation of a sovereign portfolio therefore might require relatively large changes in constituent weights.

Technical implementation challenges stem from methodological gaps in translating climate metrics into investment decision-relevant indicators. For instance, there are no well-established methodologies for translating physical or transition risk metrics into financial risks for sovereign bonds. Relevant techniques, such as climate scenario analysis, are much more advanced for corporate debt securities than for sovereign ones.

For mixed (sovereign and corporate) portfolios, there are conceptual and technical hurdles for a holistic assessment, as climate metrics for sovereign bonds are, for good reasons, often different from those for corporate bonds (e.g., the measurement of carbon emissions or emission intensity metrics).

Securities issued by sub-sovereigns, supranationals and agencies (SSAs; e.g. multilateral or national development banks) present specific practical implementation issues. Some SSAs have explicit sustainability mandates, which may also be taken into account in assessing the climate-related characteristics of their securities.

Engagement with corporate issuers can yield important climate-related benefits. Engagement with sovereigns requires careful consideration by central banks. Many central banks are important interlocutors for sovereigns; at the same time, they need to safeguard their independence and avoid potential conflicts of interest. In the case of foreign sovereigns, foreign policy considerations may also come into play. Engagement regarding sustainability targets or the issuance of labelled sustainable bonds (e.g., green bonds or sustainability-linked bonds) may be pursued through regular meetings of sovereign issuers with investors.

Complexity is another key implementation challenge. Understanding climate metrics and the quality of the underlying data requires a high level of expertise. As this document demonstrates, there is a broad range of available metrics, covering different types of climate characteristics. Identifying, understanding and combining the most suitable measures is a complex task.

As biodiversity and climate are intimately related, nature-related risks will deserve more attention going forward. However, significant data gaps remain and work on how to integrate biodiversity risks and impact into investment management is still at an early stage.

Choosing a climate-related strategy for sovereign portfolios is not straightforward. Popular strategies adopted for corporate portfolios are negative screening, or best-in-class strategies, that rank issuers within homogeneous peer groups (e.g. sectors) according to their climate-related characteristics. Also, "best-in-progress" strategies focus on the speed of improvement in climate metrics over time. For the reasons illustrated above, adapting these strategies to sovereign portfolios presents additional challenges.

1. Introduction

Sovereign debt securities are a key asset class for central banks across their investment portfolios[1]. The NGFS cover Report on "Sustainable and responsible investment in central banks' portfolio management – practices and recommendations" (NGFS, 2024a) takes stock of the characteristics of central banks' investment portfolios and the current state of Sustainable and Responsible Investment (SRI) practices across the NGFS membership. It also discusses challenges as well as good practices specific to central banks, and demonstrates that many central banks have, either directly or through external fund managers, initiated a combined use of strategies for different climate alignment or decarbonisation goals including (but not exclusively related to) those under the label of ESG integration. Despite the significance of sovereign security portfolios, central banks (and private financial institutions) thus far have made substantially more progress in incorporating climate-related considerations for *corporate* security holdings (see the NGFS Technical Document on "Decarbonization strategies for corporate portfolios of central banks" (NGFS, 2024b)). This is reflective of recent and rapid advances in climate-related data disclosures, sustainable finance taxonomies, and net-zero investment frameworks made mainly for corporate securities rather than sovereign debt.

As this technical document demonstrates, there are already a wide range of relevant metrics and corresponding publicly available data for assessing climate-related aspects of sovereign debt. In part, this is due to the efforts by international organisations, investor-led initiatives (e.g. UN PRI), NGOs, academia, and governmental organisations themselves to monitor and project climate outcomes at the country level.

Recently, several key reports have laid important conceptual groundwork. In the area of climate-related reporting for sovereign debt portfolios, the Partnership for Carbon-Accounting Financials (PCAF) has proposed a number of measures – which have, among others, been adopted by the ECB and the euro area central banks. GFANZ's Net-Zero Asset Owner Alliance (NZAOA) as well as the Institutional Investors Group on Climate Change (IIGCC) have now included sovereign debt in their net-zero investment frameworks. While these frameworks are still mostly focused on corporate securities, they offer important initial views on sovereign debt securities as to which metrics to consider as well as on implementation issues. An important recent development is the framework for assessing sovereign climate-related opportunities and risks by the ASCOR group within the UN Principles for Responsible Investment (UN PRI). Their methodology note was published in November 2023 and provides a set of key metrics for which data will be made freely available on an ASCOR website[2].

This Technical Document presents a summary of climate-related characteristics for sovereign securities, which central bank investment managers may consider, building and expanding on the aforementioned recent advances. It is intended to be a "one-stop-shop" summarising a range of relevant metrics with a focus on publicly and freely available (and in some limited cases commercial) data. It is *not* intended to ascertain which measures central banks should or should not consider, nor how central banks should design their portfolio allocation processes. The appropriate investment framework will vary significantly across central banks and will depend ultimately on the mandate and investment objectives of central banks. The document does discuss – where relevant – the pros and cons of relevant metrics and available data.

Various potential implementation challenges remain for central banks, as highlighted in the last section of this document. As existing frameworks and guidance for sovereign debt have only been developed recently, implementation solutions are still lacking and ready-made products, such as sovereign bond climate indices, may not be a suitable solution for all central banks and investment portfolios.

1 Climate-related considerations for monetary policy portfolios are not part of this report and will be covered in a future NGFS report on this issue. The metrics, data and implementation issues discussed in this Technical Document are in principle relevant for all types of central bank investment portfolio, outside of monetary policy, (e.g. FX investments not held for monetary policy goals, own funds, pension fund etc.).

2 Some of the metrics discussed in this report are similar or the same as those proposed by ASCOR and the report, where applicable, refers to the approach taken by ASCOR. Appendix B provides an overview of the ASCOR framework and the commonalities and differences to this report.

A fundamental challenge arises from integrating and balancing primary investment objectives such as safety, liquidity and return with any climate objective. Considering climate risks is consistent with primary investment objectives, but need to be combined with other characteristics such as, currency composition, the credit rating or duration profile of a given sovereign bond portfolio.

In cases where central banks' portfolio managers pursue climate impact objectives (e.g., net zero targets), trade-offs are bound to arise with their primary investment objectives. These trade-offs are intensified by the naturally limited number of sovereign issuers in a given currency – a fundamental difference compared to corporate securities[3]. As a result, the rebalancing required to significantly improve climate-related characteristics of a sovereign debt portfolio is likely to alter its financial characteristics.

In addition, central bank investment managers face various practical implementation challenges. Central banks need to consider the suitable investment strategy and decide on whether (and how) to engage with sovereign issuers. Another challenge is illustrated by the broad range of metrics presented in this document which speaks to the multifaceted link between sovereign and climate change adaptation and mitigation. Central banks may want to consider a combination of several climate-related aspects relating to sovereigns, which entails the difficult choice of prioritising or weighing between them.

In selecting the appropriate climate metrics, central bank investment managers also should take account of several considerations that impact the geographical composition of their sovereign bond portfolio. For instance, tilting a portfolio towards countries with a lower emission pathway versus a tilt towards countries with historically low emissions may yield different results, as it entails the fundamental question of using forward-looking versus backward-looking metrics as well as how to consider fairness and just transition issues. The document attempts to cover selected measures along all of these important dimensions.

Another alternative is to invest in ready-made sovereign bond climate indices. The ease of implementation needs to be weighed, however, against a possible lack of flexibility to tailor the indices such that they strike the desired balance between the different investment objectives of central banks. Central banks may also consider thematic investments such as the investment in labelled sustainable bonds. Determining the climate-related benefits and aligning thematic investments with central banks' climate objectives may also present challenges.

Further practical challenges include the treatment of sub-sovereign, supranational and agency securities, which can be an important part of central bank's sovereign portfolios. The climate-related characteristics of these securities and the involvement of these issuers in climate change adaptation and mitigation, however, can differ from those of specific sovereigns.

Important methodological and data gaps remain, such as the lack of well-established methodologies to translate climate-related risks into sovereign bonds risks. While publicly available climate-related data for sovereigns has become widely available in high quality, some relevant data gaps persist, such as data on exposure to acute and chronic physical risk events.

Notwithstanding implementation challenges and remaining methodological and data gaps, a gradual integration of climate-related considerations in sovereign bond portfolios is practicable at this stage. A wide range of relevant metrics and publicly available data enable central bank investment managers to pick those climate-related characteristics compatible with their mandate and investment objectives.

3 This is less of a limitation in the case of corporate securities, where issuers are far more numerous and therefore portfolio rebalancing to improve climate-related metrics can be achieved with relatively small effects on the geographical and sectoral composition as well as other relevant financial characteristics such as return, ratings and duration. See the sister NGFS technical report on "Net zero Alignment for Portfolios of Equities and Corporate Bonds" (NGFS (2023)).

1.1 How to read this document

The first two sections of this document distinguish between risk-based and impact-based measures akin to the first NGFS Report on sustainable and responsible investment (NGFS 2019)[4]. The last section discusses implementation issues. Appendix A lists and summarises all data sources mentioned in this document.

Each measure takes one subsection within sections 2 and 3 of this Technical Document. A measure represents the "what" – the type of climate-related issues that central banks may want to consider, such as GHG emissions measures of transition risk or portfolio alignment measures as a proxy for climate impact. Typically, there are several potential metrics for each measure – the "how". For each metric, the document lists potential data sources – the "where" – with a focus on freely available and scientifically sound data sources. The covered metrics and data refer to countries and thereby are directly applicable to bonds issued by a central government, while the treatment of SSAs is discussed in section 4.5.

Within each category – risk-based and impact-based measures – the Technical Document attempts to cover a broader perspective and hence a wider set of potential categories and measures than the aforementioned net-zero investment frameworks or the ASCOR framework (summarized and discussed in Appendix B).

4 The NGFS report on "A sustainable and responsible investment guide for central banks' portfolio management" distinguishes between financial and extra-financial sustainable and responsible investing objectives (NGFS 2019).

2. Climate risk and opportunity measures

Climate risks can be broadly categorised into physical risk (flood risks, extreme temperatures etc., section 2.1) **and transition risks (risks resulting from policy changes and the resulting costs of the required actions to achieve climate goals**, section 2.2). Past and projected emissions are an important proxy for transition risks, as countries with higher emissions run the risk of having to adopt more disruptive policies to transition to a low-emission economy. In addition, there are metrics beyond those related to GHG emissions that can proxy for transition risks (section 2.3). Fossil fuel producing countries and countries heavily reliant on fossil fuels are likely to be exposed to higher transition risks. A much broader risk and opportunity measure are sovereign E(SG) scores (section 2.4)[5]. Apart from risks, it is important to also consider transition opportunities of countries that may benefit from, for instance, the renewable energy transition and the development of low-carbon technologies (section 2.5). Indices which combine a wide range of climate-related risk measures are discussed in section 3.2. All data sources mentioned in this section are listed and summarized in Appendix A.1.

2.1 Physical risk measures

Governments will likely face with a more frequent occurrence of acute physical risks in the near-term but also with the long-term materialisation of chronic physical risks. A higher exposure to physical risks, in turn, can have an impact on the default probability of sovereign securities (Boehm, 2022). Compound events such as concurrent heatwaves and droughts are likely to occur more frequently according to the most recent assessment of the Intergovernmental Panel on Climate Change (IPCC). Historical trends confirm that the occurrence of natural disasters significantly increased in the past forty years, flooding and storms being by far the most frequent acute events (Figure 2).

Figure 2 **Climate-related disaster frequency**

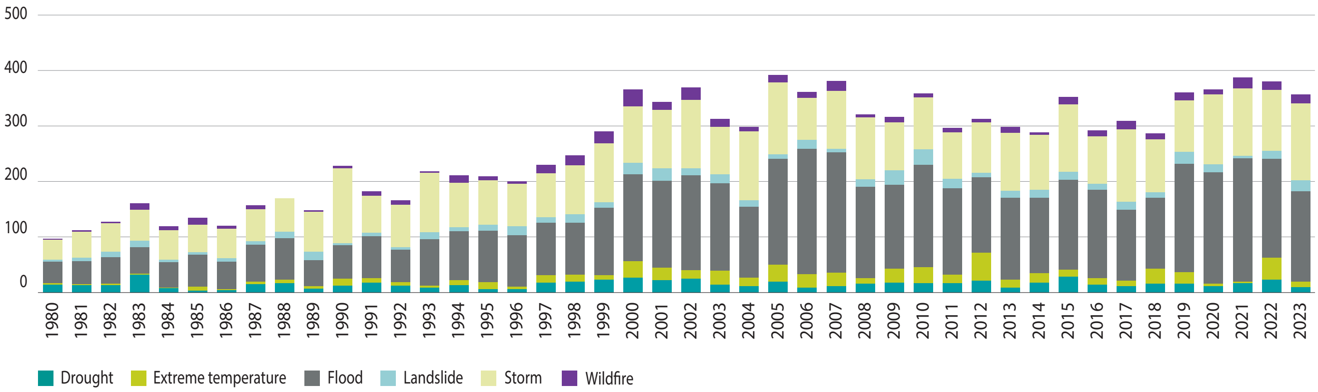


Figure by IMF, Source: EM-DAT, CRED/UC Louvain.

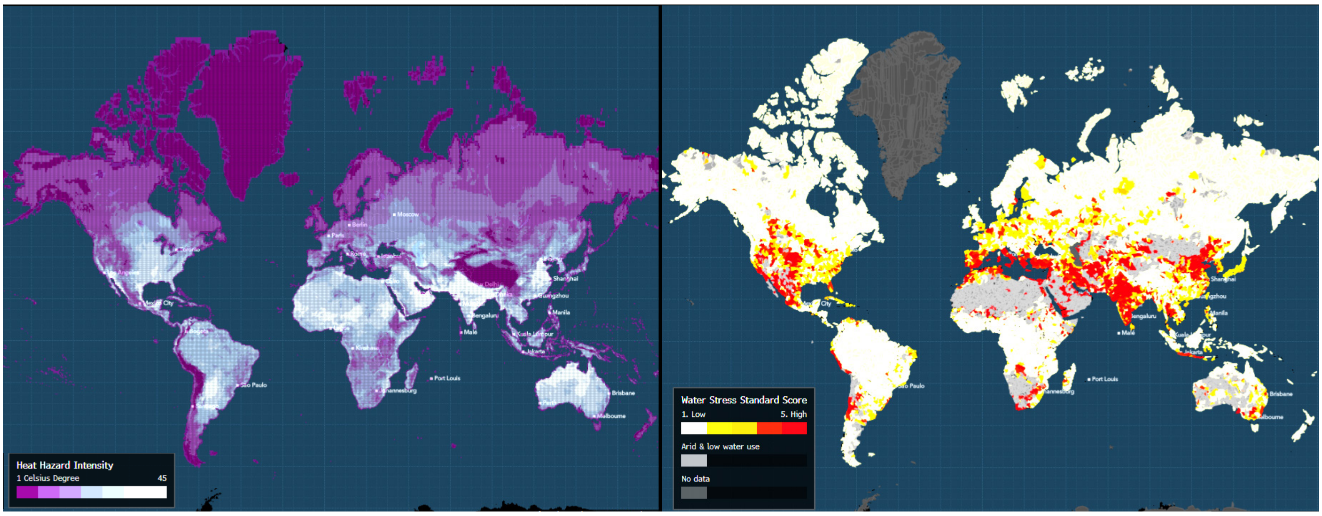
For sovereign debt securities it is useful to analyse physical risks on a country level to assess and mitigate investment risk (Figure 3). An assessment for acute physical risks usually includes a wide array of extreme weather events, such as heatwaves, droughts, or wildfires. For chronic physical risks, indicators such as changing temperature, permafrost thawing, soil erosion or changing wind patterns can be taken into consideration[6]. To better understand and evaluate physical risks, an assessment of the exposure, vulnerability and adaptation capacity of a country or region is relevant. The severity assessment of physical risks ideally takes into account the magnitude and likelihood of adverse consequences, the

5 In addition, there are climate indices, which typically combine risk, opportunity and impact measures. These indices are covered in section 3.2.

6 Examples for acute risks are: cold waves, wildfire, storm surges, hurricanes, heavy precipitation, and floods. Chronic risks can include changing temperature (air, freshwater, marine water), heat stress, permafrost thawing, changing wind patterns, changing precipitation patterns and types, sea level rise, water stress, soil and coastal erosion, soil degradation.

Figure 3 **Physical risks and country differences**

1. Extreme Heat Risk 2. Water Risk



Source: Bloomberg L.P.

temporal characteristics and the ability to respond to the risk (IPCC, 2022). "Tail" events (i.e., large-scale natural disasters) often cause disproportionate damage and therefore deserve particular consideration.

Extreme weather events and long-term changes in climatic conditions may severely affect food and water security, critical infrastructure, human health, and the services of ecosystems, among others (IPCC, 2022). These services contribute substantially to the functioning of an economy and their impairment or failure can cause significant challenges for a country or region. Some emerging and developing economies are particularly vulnerable – especially to acute events, rising sea levels and increasing heat. These countries also rely more on outdoor work and natural capital and have fewer financial means to adapt quickly. A changing climate in the next decade and beyond means the number and size of regions affected by substantial physical impacts will continue to grow, which should be taken into account in a forward-looking assessment of physical risk for a particular country or region (Table 1). Further, international (trade) relations of a country or region play an important role, as they can be transmission channels for climate-related physical risks.

Climate-related physical risks not only cause immediate economic cost due to disaster relief measures, aid for lost harvests, reconstruction of critical infrastructure, but also negatively impact economic growth (e.g., GDP loss) in the short and longer term. In an effort

Table 1 **Physical climate risks under a high emissions scenario**

Climate hazard	Most affected region
Increase in average temperatures	The Arctic
Extreme precipitation	Parts of China, Central Africa, and the east coast of North America
Hurricanes	Parts of the south-eastern United States and parts of Southeast Asia
Drought	Parts of the Mediterranean, southern Africa, and Central and South America
Lethal heat waves	Countries near the equator in Africa, Asia, and the Persian Gulf, especially urban areas in parts of India and Pakistan
Water supply	South Africa and Australia, Mediterranean region, and parts of the United States and Mexico are expected to see a decrease in water supply; Ethiopia and parts of South America, are projected to experience an increase in water supply

Source: "Climate risk and response (Physical hazards and socioeconomic impacts)", McKinsey Global Institute (January 2020); Woods Hole Research Center (WHRC), based on the RCP 8.5 scenario.

to address or mitigate climate-related physical risks or support adaptation measures, governments could face increased spending that can affect the resilience of national budgets and potentially lead to higher refinancing costs.

An important aspect for the analysis of physical risk is the scope of risks covered by the data sources. Many data sources reflect acute physical risks such as natural hazards rather than chronic physical risks (Table 2). The translation of natural hazards into projected economic impact and the comparison between countries and regions seems to be further developed than for long-term physical risks. While data for long-term climate-related changes are also available – and in many cases freely accessible – the translation of the data for chronic physical risk into investment-relevant financial risks is less developed. Some data sources also cover natural hazards that are non-climate-driven, such as earthquakes. It is therefore crucial to closely investigate and understand the data content and, where appropriate, break down the data into relevant sub-categories.

GDP is a key indicator for the economic performance and prosperity of a country. In this regard, past disaster-related monetary damages as a percentage of GDP, might be used as a backward-looking measure for the acute component of the physical risk. Data for monetary damage can be sourced, for example from the Emergency Events Database (EM_DAT) (Table 2). The assessment of the chronic physical risk and the adaptation capacity, which can partially offset the impact of both acute and chronic physical risk, however, is particularly challenging. A standard for chronic physical risk metrics is currently still lacking[7].

The projected economic loss from physical risks expressed as a percentage of GDP might give a forward-looking indication of the materiality of the risks. A short-term forward-looking view on physical risk (one year ahead) can be extrapolated from the property-catastrophe rates estimated by reinsurance companies and be used as a proxy for insurance premiums for the following year. Data for potential economic losses and long-term projections can be retrieved, for example from EEA and the NGFS scenarios (Appendix Table A.1). Most sources for forward-looking data, however, do not factor in planned mitigation actions and adaptation measures of countries. A crucial consideration for central bank investment managers is that a mere financial evaluation of physical risks might put further pressure on already vulnerable countries. A comprehensive analysis should also consider future mitigation actions and adaptation measures by countries. An alternative approach for the inclusion of environmental considerations and their linkages with the economy is the System of Environmental-Economic Accounting (IPCC, 2022) which was introduced by the UN[8, 9].

The assessment of climate-related physical risks and the subsequent investment decisions are associated with high uncertainties that can result from insufficient data and methodologies as well as from the nature of physical risks itself. Not only does the potentially long time-horizon over which climate-related physical risks can evolve create uncertainties. The nature of climate-related physical risks is dynamic and complex and dependent on various aspects, such as the exposure and vulnerability but also the respective (government) response to the risks. Non-linear behaviour, cascading and compounding effects add to the complexity. Ensuring transparency of the characteristics of the underlying data (up-to-datedness, completeness, and consistency) and the modelling techniques and weaknesses, allows for informed decision making[10].

7 The European Investment Bank working paper: Assessing climate change risks at the country level: the EIB scoring model (see Table 2) outlines possible ways of assessing the components of physical risk by leveraging on the existing economic literature to estimate chronic physical risk.

8 "The System of Environmental-Economic Accounting (SEEA) is a framework that integrates economic and environmental data to provide a more comprehensive and multipurpose view of the interrelationships between the economy and the environment and the stocks and changes in stocks of environmental assets. It contains the internationally agreed standard concepts, definitions, classifications, accounting rules and tables for producing internationally comparable statistics and accounts. The SEEA framework follows a similar accounting structure as the System of National Accounts (SNA)." See https://seea.un.org/content/homepage.

9 Additional financial stability considerations are outlined in the work of the Financial Stability Board, https://www.fsb.org/work-of-the-fsb/financial-innovation-and-structural-change/climate-related-risks/.

10 Strategies for decision-making under uncertainties are outlined in the Integrated Risk and Uncertainty Assessment of Climate Change Response Policies (IPCC, 2014) and in Climate Risk Informed Decision Analysis (Mendoza, 2018).

Table 2 **Types of physical risk metrics and data sources**

Dimension	Sub-dimension	Variable used	Unit	Source
Physical risk: acute	Hydrological (floods and landslides), meteorological (extreme temperatures and storms) and climatological (droughts and wildfires) impacts	Damage	% of GDP	EM-DAT
Physical risk: chronic	Fewer crops	Agriculture	% of GDP	WDI
		Production loss	% of GDP	FAO (2017)
	Impact of higher level seawater	GDP impact	% of total population	Diaz (2016)
		Population living in areas where elevation in below 5 metres	% of total population	WDI
		Land area where elevation is below 5 metres	% of total land area	WDI
	Need to upgrade infrastructure	Adaptation gap	% of GDP	World Bank (2016)
		Quality of infrastructure	Index	WDI
	Impact of heat on productivity	Labour productivity	%	McKinsey (2020)
		Monthly average temperatures	Degrees Celsius	World Bank
Adaptation capacity	Economic ability to respond	Fiscal revenues	% of GDP	IMF
		EIB internal sovereign rating	Rating scale	EIB/ECON
	Institutional ability and governance	Governance indicators	Index	WB
		Human Development Index	Index	UN

Source: "Assessing climate change risks at the country level: the EIB scoring model", EIB (May 2021).
https://op.europa.eu/en/publication-detail/-/publication/1a42783a-c283-11eb-a925-01aa75ed71a1/language-en.

For a comprehensive risk assessment, a long-term forward-looking perspective including planned adaptation measures, adaptation limits, residual risk (i.e., risk that remains following adaptation and mitigation efforts) and possible unintended consequences (risk of maladaptation) is essential. A constant monitoring and evaluation of the chosen strategy and derived indicators against current developments is necessary as it enables a swift recalibration of the strategy to optimally pursue the investment goal. To get a full picture of the risk exposure it is pertinent to monitor several indicators for a given risk as the reliance on one single indicator may lead to important aspects of the risk being overlooked. Analysing the consistency between the indicators helps to detect methodological shortcomings, simplifications, and interdependencies. Analysis of the correlation between indicators is key to detecting potential compounding risks.

2.2 Transition risk measures: GHG emissions metrics

Sovereign carbon metrics are an important starting point to assess climate-related transition risks and opportunities of countries. In this context, a distinction can be made between backward-looking and forward-looking metrics. There are particular challenges to computing sound metrics at both the issuer and the portfolio level, relating to emission scopes, double counting and the choice of denominator.

2.2.1 Backward-looking metrics

Backward-looking carbon metrics for sovereign bond portfolios are already increasingly available for investors including central banks, but the methodologies are still developing[11]. Currently, the guidance of the Partnership for Carbon Accounting Financials (PCAF) on sovereign emissions attribution is the most widely used standard (PCAF, 2022). It lists recommendations on how to calculate GHG emissions metrics including guidance on scopes

11 Central banks that have reported on carbon emissions of sovereign bond portfolios include among others the Bank of England, Banco Central do Brasil, the Swedish Riksbank and the Eurosystem (ECB and national central banks).

(or "allocations"), normalisation and attribution factors. The newly added sovereign debt methodology in the PCAF standard is pending GHG Protocol review and approval (see PCAF, 2022, pp. 5-6).

While these metrics may be linked to a country's exposure to transition risks, it is at this point unclear how they correlate with the financial performance of sovereign bonds (see also section 4.6). GHG

s metrics alone should not be seen as proxies for transition risks to central banks' investment portfolios, although they do serve as a starting point for risk as well as impact analysis (see section 3.1)[12]. Taking a longer term view to determining transition risk, central banks can assess countries' emission trends over time[13] and combine them with other transition risk measures discussed in section 2.3.

Reflecting the various dimensions of governments' involvement, role or responsibilities in climate change mitigation and adaptation, three different types of emission "allocations" are used to determine GHG emissions in the context of sovereign bonds. The first and most commonly applied allocation is *production emissions*, which includes all emissions within countries' physical borders[14]. Production emissions correspond to the UN Framework Convention for Climate Change (UNFCCC) definition of domestic territorial emissions, including emissions from the production of exported goods and services. They cover only direct carbon emissions from domestic production but do not cover, for instance, the implied carbon emissions from the burning of exported fossil fuels (McKibben, 2023; Davis et al, 2011; Davis & Caldeira, 2010). The second type of allocation, *consumption emissions,* addresses "carbon leakage" by adding emissions embedded in imports and deduct emissions related to exports. In many cases, developed countries record net import emissions from developing countries (i.e., the emissions embedded in their imports are usually slightly higher than those embedded in their exports). Therefore, using production-based versus consumption-based emissions can affect the geographical distribution of GHG emissions metrics. Few countries document consumption emissions, however, which can lead to potential data issues in case consumption emissions are estimated by data providers[15]. The guidance from PCAF highlights the holistic nature of consumption emissions and recommends reporting these as an additional metric when data is available. A third type of allocation, *government emissions*, solely covers emissions associated with government activity[16]. Government emissions are reported alongside the production and consumption emissions by some central banks, including many Eurosystem central banks. This type of allocation is useful, for instance, to capture emissions that are under the most direct control of a national government. It can also help to avoid double counting in investment portfolios in multiple asset classes (e.g., sovereign and corporate securities). However, this approach is currently not covered by PCAF. In contrast to scope 1, 2 and 3 emissions for corporate entities, the different types of sovereign emission allocations should not be summed but rather seen as providing complementary information[17].

Backward-looking GHG emissions can cover both absolute and normalised emission metrics. At the issuer level, there are three key metrics recommended by PCAF (Table 3). The Attributed Emissions metric quantifies the total emissions financed by investments in a sovereign. The PCAF standard for financed emissions recommends using purchasing power parity PPP-adjusted GDP as an "attribution measure"[18]. The formula for Attributed Emissions can be used for all sovereign emission regardless

12 PCAF, for example, suggests using the metrics to rank the emission intensities of countries and compare them with each other.

13 One example is the preliminary ASCOR framework, further discussed under 2.3 and 2.5.1, which uses the evolution of emissions over 5 years as an indicator to capture emission trends of sovereign issuers.

14 PCAF recommends reporting on two kinds of production emissions: including and excluding emissions through land use, land-use change, and forestry (LULUCF). Generally, these emissions account for a small part of countries' emissions but can be important for some countries.

15 The OECD's public database may be used for consumption emissions of OECD countries.

16 See for instance ISS (2023) for a more detailed discussion.

17 Note that PCAF (2022) distinguishes between scope 1-3 sovereign emissions analogous to the scopes for corporates. These scopes, however, do not correspond to the commonly used distinction between production, consumption and government emissions.

18 The GDP is PPP-adjusted to adjust for exchange rate effects and differences in purchasing power across economies. Over the last years, there has been much debate around the use of PPP-adjusted GDP versus a country's total debt as an attribution factor. Some central banks (e.g., Danmarks Nationalbank or the Deutsche Bundesbank) have also reported emission metrics using outstanding government debt as an attribution factor, which can also be helpful for calculating more easily interpretable portfolio-level metrics (footnote 25). See PCAF (2022), pages 113-116 for an overview and the rationale behind using PPP-adjusted GDP.

Table 3 **Issuer-level carbon emissions metrics proposed by PCAF**

Metric	Description	Formula
Attributed Emissions	Total emissions financed by investment in a sovereign (tons of CO_2- equivalents)	$Current\ value\ of\ exposure \times \frac{Country\ emissions}{GDP(PPP - adjusted)}$
Carbon Intensity (CI) – production emissions	Emissions of an issuer normalised by PPP-adjusted GDP (tons CO_2- equivalents per million of USD or Euro)	$\frac{Production\ emissions}{GDP(PPP - adjusted)}$
Carbon Intensity (CI) – consumption emissions	Emissions of an issuer normalised by population value (tons CO_2- eq. per capita)	$\frac{Consumption\ emissions}{Population}$

Note: Country carbon emissions can refer to any scope of sovereign emissions.

the allocation types. Since attributed emissions are directly dependent on investment size they are not suitable for issuer (and portfolio) level comparison at issuer and portfolio level. For this purpose, normalised metrics are used as an extension to Attributed Emissions. These metrics are typically referred to as carbon intensities (CI). PCAF defines the "normalisation factor" for production emissions as PPP-adjusted GDP, due to the link between a country's output (GDP), and the emissions associated with that output (production emissions). For consumption emissions, a different normalisation factor is used – population – since a country's demand is directly dependent on its population. The formulas provided by PCAF are listed in Table 3.

While the PCAF standard does not include portfolio-level metrics, some central banks have aggregated the issuer-level metrics to portfolio metrics for reporting purposes in alignment with the TCFD guidance for corporate securities. Table 4 present the portfolio-level metrics used by the central banks in the Eurosystem[19]. For the Total Carbon Emissions (TCE) metric, Attributed Emissions are summed for all investments (akin to PCAF guidance). A Carbon Footprint (CF) metric can be calculated by dividing TCE by the portfolio size. The Weighted Average Carbon Intensity (WACI) is calculated by taking weighted averages (weighted by the share of investment amount in the total value of the sovereign portfolio) of the carbon intensity[20]. As such, CF and WACI can be computed using both production and consumption emissions. The denominators of these metrics are different and hence the corresponding portfolio-level aggregates do not have the same interpretation. In addition, the interpretation of these portfolio measures is not straight-forward. Given the denominators recommended by PCAF (PPP-adjusted GDP or population), the portfolio-level aggregates are not directly proportional to the implied financed emissions[21]. For investment management purposes, there are specific portfolio-level measures such as portfolio alignment measures, which are described in detail in section 3.4.

Challenges remain for the calculation of backward-looking metrics. Firstly, central bank's sovereign portfolios often contain substantial investments in sub-sovereigns (such as states or provinces), whose emissions data coverage is still limited (see also section 4.5)[22]. Secondly, sovereign data often become available only with a two-year time lag, which makes assessing current portfolio emissions trends difficult. Finally, double counting may arise where the aggregation of emissions results in accounting for the same emissions more than once. Double counting is an issue within sovereign portfolios if central banks hold sub-sovereign and sovereign bonds from the same country, as the sub-sovereigns' emissions are reflected in those of the relevant sovereign. Analogously, double-counting issue also arise in mixed portfolios because the territorialised emissions of corporates and other issuers operating in a given sovereign territory are included in this sovereign's

19 For details, see for instance Annexes 1 and 2 in the inaugural "Climate-related financial disclosures of the ECB's non-monetary policy portfolios" by the European Central Bank (ECB (2023)).

20 The WACI and CF are the same for production emissions, as both use PPP-adjusted GDP in the denominator.

21 In the hypothetical case where a representative investor holds the entire sovereign debt (of a given country or a group of countries), the Total Carbon Emissions measure can be higher (or lower) than the actual emissions, if the ratio of sovereign debt over PPP-adjusted GDP exceeds (is lower than) 100%.

22 In the absence of granular data, some central banks choose to assign the parent nation's data to sub-sovereigns as a proxy.

Table 4 **Portfolio-level carbon emissions metrics as used in the Eurosystem**

Metric	Description	Formula
Total Carbon Emissions (TCE)	Total emissions financed by investment in a sovereign (tons of CO_2-equivalents)	$TCE = \sum_i Current\ value\ of\ exposure_i \times \frac{Country\ emissions_i}{GDP(PPP - adjusted)_i}$
Carbon footprint (CF)	Emissions of an issuer normalised by PPP-adjusted GDP (tons CO_2-equivalents per million of USD or Euro)	$CF = \sum_i \frac{Current\ value\ of\ exposure_i}{Value\ of\ sovereign\ portfolio} \times \frac{Country\ emissions_i}{GDP(PPP - adjusted)_i} = \frac{TCE}{Value\ of\ sovereign\ portfolio}$
Weighted Average Carbon Intensity (WACI)	Emissions of an issuer normalised by population value (tons CO_2-eq. per capita)	$WACI = \sum_i \frac{Current\ value\ of\ exposure_i}{Value\ of\ sovereign\ portfolio} \times Carbon\ Intensity_i$

Note: the subscript i denotes the issuer. Country carbon emissions can be any scope of sovereign emissions.

production and consumption emissions.

2.2.2 Forward-looking metrics

Forward-looking metrics can assess and incorporate countries' decarbonisation strategies. Forward-looking metrics are naturally more difficult to estimate but provide additional insight into the impact and risk characteristics of sovereign bond holdings. Ideally, they aim to illustrate an issuer's emissions pathway alignment based on its previous emissions, carbon reduction commitments and its decarbonisation trajectory derived from alignment with the goals of the Paris Agreement (see for example Faiella et al., 2021).

Key sources of data for projected emissions include, among others, Climate Watch, Climate Action Tracker, and Climate Analytics (see section 3.1 for more details). Climate Watch brings together dozens of datasets (including Climate Action Tracker and Climate Analytics) allowing users access to the latest historical greenhouse gas emissions data and track sovereigns' long-term strategies to reduce GHG emissions. Climate Action Tracker and Climate Analytics are independent scientific projects that provide quantitative estimates of future emissions based on given climate scenarios and policies.

Forward-looking metrics inherently imply substantial uncertainties. Methodologies behind forward-looking metrics are still evolving and differ per data provider. Projections for future emissions rely on a range of assumptions and on countries decarbonization commitments, for which the feasibility is hard to assess[23]. Moreover, the lag in historical emissions reporting affects also projected emissions that are mostly based on past data. Finally, national carbon budgets may change over time as climate science advances and are entirely dependent on underlying scenarios[24].

A combination of forward-looking and backward-looking metrics is therefore advisable to comprehensively assess climate-related transition risks and the alignment of sovereign portfolios with climate objectives. On the one hand, backward-looking metrics may serve as a good first step towards quantifying transition risks and are not subject to the uncertainties of forward-looking ones. Among these, normalised GHG emissions (i.e., emission intensities) are more suitable for target setting as they allow for comparing portfolios or different sizes and monitoring reduction trends over time. On the other hand, forward-looking metrics indicate a country's commitments to GHG emissions reduction but suffer from greater levels of uncertainty around whether countries can fulfil their commitment as well as the modelling of emission paths (see also section 3.1).

23 However, in contrast to corporates, a large number of sovereigns register their pledges to reduce carbon emissions with UNFCCC in the form of nationally determined contributions. These numbers are tracked in synthesis reports and are updated every five years, thus giving them stronger credibility.

24 This means, for example, that an identical equity portfolio might be 2 degrees aligned today, but 2.5 degrees aligned in 3 years if scenarios change or science advances.

2.3 Transition risk measures: Other proxies for transition risks

A holistic assessment of climate-related transition risks in sovereign investments may require the consideration of factors beyond GHG emissions metrics. This can provide additional insight, for instance, into how important fossil fuels are for an economy, and therefore the degree of governement commitment and ability to achieve a timely transition to low-carbon energy sources. There is no simple recipe for which metrics are relevant and how to weigh them against GHG emissions metrics. Furthermore, data on some of these metrics are not always readily available, requiring in some cases estimation via proxies. Below are a few relevant non-GHG emission metrics that can be incorporated into the analysis of sovereign climate-related transition risks.

Countries with higher levels of fossil fuel consumption or production are the most exposed to transition risk. Countries that rely heavily on fossil fuel consumption will face higher investment needs as the energy transition unfolds to shift products and business activities toward green alternatives. Major fossil fuel producing countries face risks such as loss of value of assets and a decline in carbon sector revenue which might be bolstering other parts of the economy. Fossil fuel exporters face additional potential transition risks in the form of deteriorating external balances. Data to examine fossil fuel consumption and production are available for many countries[25]. Where aggregate data is missing it is possible to calculate these values using more widely available data by summing oil, natural gas, and coal supply and demand values[26]. A note of caution when incorporating these metrics is that the underlying data may already be used as a direct input in the calculation of carbon emissions.

Current and projected investments in fossil fuels and carbon intensive industries could signal increased transition risks and be at odds with stated transition plans. Current and pending carbon-related investments face higher risks of becoming stranded assets as the energy transition unfolds. Additionally, a high rate of continued investments in these industries may imply a lack of commitment from the sovereign to achieve its nationally determined contributions that are at the heart of the Paris Agreement. Data on current and projected investments is available through several different reports[27]. An additional indicator that can be useful to consider is new patents on fossil fuels versus clean energy technologies, as these may provide early indicators of future investments in the energy space[28].

The share of carbon-intensive sectors' contribution to GDP provides an indication of how much of a country's economic activity and employment depend on fossil fuels. A higher share may signal increased transition risks and, in some cases, lower incentives to decarbonise. Industrial production and manufacturing are both sectors of the economy that require high levels of fossil fuel use, and data for the impact of these on GDP is available for OECD countries, while for other countries it can be assessed through respective GDP data releases[29]. Refinery capacity and output indicates the level of fossil fuel processing within a country. The total amount of refinery output less total refined products for export gives an indication of demand for refined products within the country which are used for a wide range of consumer products, electricity generation, transportation services, and heavy industry activity[30].

While a critical step in the transition toward a net zero economy, phasing out coal could have both economic and social costs in the short term, while requiring in some instances substantial investments in alternative energy sources. Direct financial costs are largely caused by weakening demand for coal and include the risk of assets becoming stranded, the need to invest in transforming coal-fired power generation to renewable energy sources, and the costs associated with decommissioning coal-fired plants[31]. Economic and social costs could be relevant in developing economies which are still highly dependent on coal. For example,

25 Fossil Fuels – Our World in Data; Extraction-based emissions accounts (robbieandrew.github.io).

26 Oil Information – Data product – IEA; Natural Gas Information - Data product – IEA; Coal Information – Data product – IEA.

27 World Investment Report 2022 | UNCTAD, World Energy Investment 2022, Investing in Climate, Investing in Growth | en | OECD.

28 Energy Technology Patents Data Explorer – Data Tools – IEA.

29 Table 2: GDP by sector (in percentage) (oecd.org).

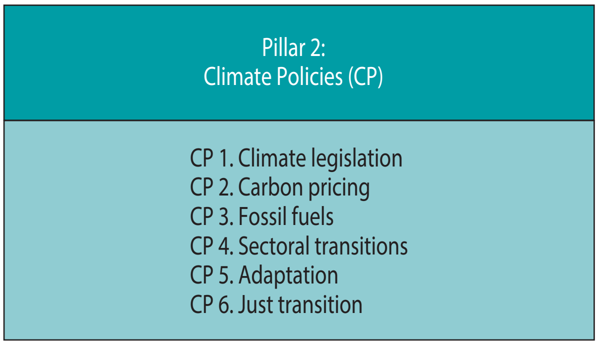
30 Monthly Oil Data Service (MODS) Complete – Data product – IEA.

31 Decommissioning US Power Plants: Decisions, Costs, and Key Issues (rff.org).

if a large share of a country's labour force is employed in the coal industry, shutting down existing capacity would have large impacts on unemployment which could negatively affect the whole economy[32]. Further, tracking taxable sales of coal indicates how much municipal or government revenue is at risk when coal is phased out[33]. A deeper analysis and more detailed social indicators on transition risks are reported in section 3.5.

The ASCOR framework (ASCOR, 2023b) includes a number of relevant qualitative indicators which investors can use to better gauge transition risk. On climate legislation, for instance, the ASCOR framework looks at whether a law stipulates a clear strategy for decarbonisation, sets out obligations to achieve targets and policies, and specifies clear accountabilities. The underlying metrics are built on the London School of Economics Climate Change Laws of the World database. Other important aspects covered by ASCOR are a country's commitment to phasing out of fossil fuels (and related subsidies), as well as whether a country has a sectoral climate strategy and targets (Figure 4).

Figure 4 **Non-GHG emission indicators in the ASCOR framework**



Source: ASCOR (2023b).

2.4 Sovereign ESG Scores

Many central banks have started to use ESG scores and ratings for their investment decisions and public reporting purposes. According to an NGFS survey conducted in 2023[34], 60% of respondents use ESG scores for their SRI practices – though primarily for their *corporate* investments[35]. Furthermore, ESG scores were already monitored or reported by 32% of respondents of respondents.

Sovereign ESG scores are usually provided by the same entities that produce corporate ESG scores. The ESG provider ecosphere has evolved over the last few years as the industry has become more established. The current backdrop consists of three broad groupings: (i) specialist ESG data providers who focus specifically on ESG product offerings; (ii) credit rating agencies[36] who have established their own sustainability service offering, facilitated by several takeovers and mergers of ESG providers in recent years; and (iii) specialist data providers focussed on specific sustainability issues such as climate-related risk[37]. There is also increased regulatory focus on the ESG rating industry. In jurisdictions such as the EU and UK proposals for regulating ESG industry have been put forward[38].

The sovereign ESG segment is distinct from the corporate ESG segment and requires separate treatment by investors, providers, regulators, and others (Gratcheva et al., 2021). Sovereign ESG scores display high similarity across the different providers, despite methodological differences and variations in weights. This is especially true for the composite ESG scores as well as the Governance and Social pillars. In this characteristic, revealed by several studies (Gratcheva et al., 2021; Bouyé & Menville, 2021), sovereign ESG scores differ greatly from

32 Overview – World Energy Employment – Analysis – IEA.

33 Still Not Getting Energy Prices Right: A Global and Country Update of Fossil Fuel Subsidies (imf.org).

34 See NGFS SRI cover Report (2024) "Sustainable and responsible investment in central banks' portfolio management – practices and recommendations".

35 The NGFS survey questions on ESG were targeting mainly central banks' corporate security portfolios. 31% were looking at broad ESG indicators and 31% a combination of ESG and climate specific indicators.

36 Each of the three main CRAs has established their own distinct sovereign ESG data product offerings- which are also distinct from their respective sovereign credit rating products.

37 For example, Bloomberg launched a comprehensive climate data product while Impact Cube offers an impact-focused sovereign ESG dataset focused on SDG alignment.

38 For the UK, see "Open consultation for Future Regulatory Regime for Environmental, Social, and Governance (ESG) Ratings Providers", March 30, 2023, https://www.gov.uk/government/consultations/future-regulatory-regime-for-environmental-social-and-governance-esg-ratings-providers. For the EU, see "Proposal for a Regulation of the European Parliament and of the Council on the transparency and integrity of Environmental, Social and Governance (ESG) rating activities", June 13, 2023, https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13330-Sustainable-finance-environmental-social-and-governance-ratings-and-sustainability-risks-in-credit-ratings_en.

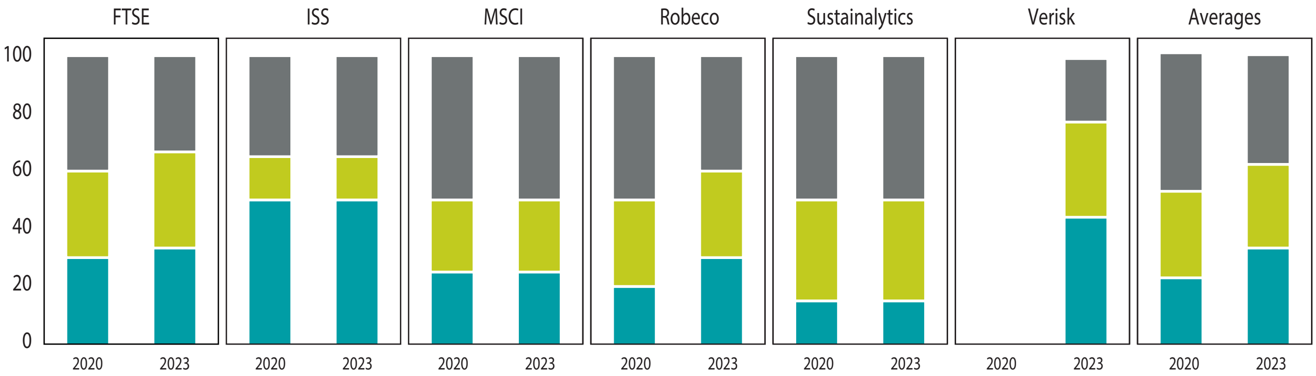
corporate ESG ratings (Berg et al., 2022). A first driver of the similarity of sovereign ESG scores across providers may be the high weighting of governance among the three ESG pillars (Figure 5), which exhibits a relatively high consistency among the underlying raw indicators. Second, many providers retrieve most of the data points used for their ESG ratings from the same (public) data sources, such as the World Bank ESG portal. And third, the high correlation between sovereign ESG scores and a country's income level.

A noticeable difference is the weightings allocated by providers to the E, S, and G pillars to get to the overall composite score (Figure 5). For the E pillar, there is still substantial disagreement across providers on the relevant measures, with climate factors not always receiving a significant focus (Figure 5).

A major driver of the convergence of sovereign ESG scores is their significant ingrained income bias, with higher (lower) income countries posting higher (lower) ESG scores as shown in Table 5 below. This is primarily due to the Social and Governance dimensions, while Environmental scores are much less correlated with income. This creates a potential problem, as direct applications of the scores might reinforce inequalities by diverting capital from lower-income countries toward higher-income countries. To correct this, investors can filter out the income effect from the ESG score, such as proposed in a specific tool in the World Bank Sovereign ESG Data Portal of the World Bank. However, this naturally requires a choice of methodology for applying such a correction.

While progress has been made, there is still a need for more clarity about articulating ESG measures as well as the exact data inputs. Gratcheva et al. (2024) find that the industry is making notable efforts to understand sovereign ESG factors better and develop approaches that factor sustainability issues for sovereign bonds and broader capital allocation decisions. For example, some ESG providers are either actively seeking to address the ingrained income bias through new approaches or are better articulating the reasons behind their scores being linked with the countries' income level. In response to greater investor focus on environmental and climate issues, a number of providers have increased the weight for the E pillar at the expense of the G pillar. Nevertheless, the continued wide dispersion of the E indicators and their convergence across providers indicates that a consensus on the environmental pillar and systematic inclusion of climate change issues in methodologies remains elusive.

Figure 5 **ESG pillar weights for various providers (2020 v 2023)**



Note: Verisk & ISS did not participate in the original World Bank study.
Sources: Gratcheva, E. and O'Reilly Gurhy, B. (2024).

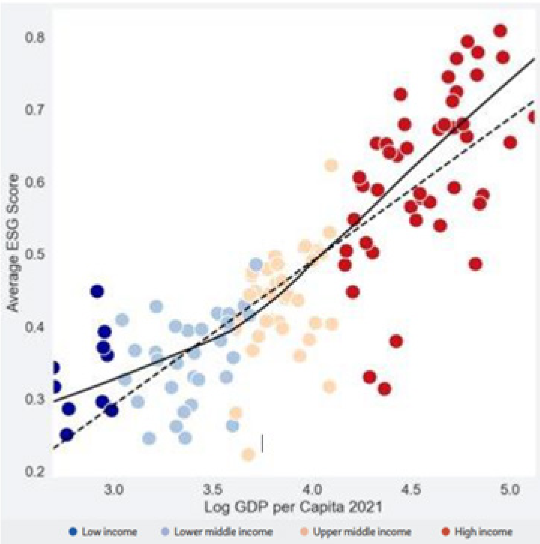
Table 5 **Overview of current ESG data provider methodologies**

ESG provider	Climate model	Weights of sub-categories public	Weights of individual indicators public	Unique data sources (E pillar)	Update frequency	Methodology	Included in 2021 study
ISS ESG	No	Yes	No^	Not provided	Annually	Absolute performance expectations and normalization	Yes
LSEG	Yes	No^	No^	9	Quarterly	Standardization and normalization to construct scores. Weighting sets for aggregation are based on a calibration methodology	Yes
MSCI	No	Yes	Yes	16	Annually	Minimum risk management score, average risk exposure score	Yes
RepRisk	No	Yes	No	–	Daily	Normalization	Yes
Robeco	Yes	Yes	No	27	Semi-annual	Normalization	Yes
Sustainalytics	Methodology not publicly available						
Verisk Maplecroft	Yes^^	No	No^	Not provided^	Quarterly	Cluster analysis across nine dimensions of risk and 37 inputs, with the outputs then used to develop probability weighted ESG, E, S and G scores	No

Source: Gratcheva, E. and O'Reilly Gurhy, B. (2024).

Notes: The table reflects whether company provides information publicly. If information is provided to paying clients, it is denoted with a "^". If element is included in methodology but not discussed in public methodology documents, it is denoted with "^^". "–" for RepRisk's number of unique data sources for the E pillar reflects the fact that RepRisk does not explicitly have E, S, and G pillar data, although they do give a percentage weight of the overall score for each pillar based on the number of incidents tracked by their algorithm for a particular country (e.g., the percent breakdown is different for each country)

Figure 6 **Average ESG scores are highly correlated with GDP per capital**



Source: Gratcheva et al. (2021).

2.4.1 ESG scores and sovereign portfolio management

From an implementation perspective, investors may use ESG scores at different levels of the investment process, depending on the nature of the portfolio chosen for implementation. Some investors integrate sovereign ESG scores in their credit research, thus influencing investment decisions at the issuer level. This may take the form of exclusion, when sovereign ESG scores are below a certain threshold. More frequently, investors can choose to factor ESG scores into their portfolio construction, following a so-called integration approach, such as by setting sovereign portfolio country weightings in proportion to ESG scores or by setting a portfolio ESG score target in order to tilt the portfolio holdings at country-level (possibly, by benchmarking ESG sovereign bond indices). In this integration approach, ESG scores may be combined with financial and macroeconomic data to adopt a holistic assessment.

In implementing ESG criteria, ESG scores can be used for assessing ESG risks as a whole, or the E, S and G pillars can be separated. ESG scores, by definition, indicate the overall ESG (risk) profile of sovereigns. As shown above, depending on the provider, the E, S and G pillars receive different weightings – for instance based on the perceived materiality. This can be useful for central banks taking a more holistic SRI investing approach. In turn, individual pillars or even sub-scores allow more focus on specific objectives (Ehlers et al., 2024). Central banks focussing on climate-related considerations may, for instance, assign a higher weight to environmental risk exposure and management by setting a portfolio target for the environmental pillar score – possibly alongside other climate-related targets such as net-zero targets.

Investment managers need to be aware of the current challenges when using sovereign ESG scores. As mentioned above, two key challenges are i) the lack of consistency and completeness of environmental assessment across providers, and ii) a relatively limited consideration of climate compared to other environmental issues. Central banks focussing solely on climate risk or impact may prefer more dedicated measures (see sections 2.2 and 3.1).

Central bank investment managers should also be aware that the increasing importance of physical risks does not appear to have been factored in by some providers. Different levels of physical risk are not always reflected in corresponding differences in terms of the measured environmental risks exposure and vulnerability in the E pillar across countries (Gratcheva et al., 2021).

A more conceptual implementation issue arises from the difficulty of pinpointing the time horizon of ESG risks targeted by ESG ratings. As ESG ratings combine a number of conceptually different factors, some risks reflected in these scores may be short-term and other more of a longer-term nature. The time horizon of ESG risks may therefore not match with duration of a given sovereign bond portfolio that central bank investment managers may be targeting.

Another challenge arises from the way current sovereign ESG scores are constructed, as described above. The significant correlation of sovereign ESG scores with income levels may induce an unwanted tilt towards high-income countries when using ESG scores, or S and G sub-scores.

The subscription costs for ESG risk scores and assessments may also be a consideration. The more climate-related metrics presented in this document, in contrast, are typically freely available. However, integrating ESG scores, or their sub-components, into an investment process might be less complex although it may require the payment of specific service fees to ESG providers.

2.5 Opportunity measures

For a more holistic view, central banks can consider measures and adequate data to reflect opportunities stemming from the low-carbon transition across countries and regions. While opportunities are manifold, key indicators include potential in renewable and clean energy development, critical minerals and metals, as well as opportunities in workforce development.

2.5.1 Identifying transition-relevant opportunities in the context of the low-carbon transition

The ASCOR framework defines transition-relevant opportunities as resources with strategic importance in a global low-carbon economy. The final ASCOR framework (ASCOR, 2023b) focusses on opportunities for renewable energy, in particular prospective solar, wind, geothermal and hydroelectric capacity. Relevant data sources include the World Bank's Wind and Solar Atlas, Zhou et al. (2015) and Coro and Trumpy (2020). The initial ASCOR framework (ASCOR, 2023a) also considered countries' potential in mining for energy transition minerals and nature-based solutions. An initial selection of 11 minerals based on research from the IEA (2021b) and available reserve data includes copper, cobalt, nickel, lithium, graphite, rare earth elements, zinc, manganese, chromium, molybdenum, and platinum. Relevant sources include mineral reserve data (United States Geological Survey, 2022), Copper equivalent (TPI, 2022), IEA's Critical Minerals Policy Tracker. Third, nature-based solutions are seen as a type of opportunity, given both the need for enhanced carbon sequestration in natural ecosystems to hold the rise in global temperatures below 1.5 °C, and the potential for ecosystem restoration in building climate resilience. Relevant metrics include forest restoration opportunities (World Resources Institute, 2014) and reforestation commitments (Bonn Challenge).

The initial ASCOR framework (ASCOR, 2023a) emphasised that each of the transition opportunities must be harnessed in ways that prevent negative social, environmental, and economic impacts at the local level. It proposed various indices to assess how responsibly a country acts, including the Resource Governance Index (from the Natural Resource Governance Institute), Regulatory Quality (World Bank), the Education Index (United Nations Development Programme), the World Press Freedom Index (Reporters Without Borders), Freedom in the World (Freedom House), and the Corruption Perceptions Index (Transparency International).

In addition, the IEA's Energy Technology RD&D Budgets Data Explorer provides measures for public budgets on energy RD&D, per sector, activity, and technology type, that is updated twice a year and contains data as far back as 1974. This type of measure helps understand existing and future opportunities for the energy transition within and across countries.

2.5.2 Addressing employment opportunities in the context of the low-carbon transition

Employment-related opportunity measures, especially in the energy sector, are additional key metrics. Accelerating efforts to decarbonise across all sectors of the economy will lead to rapidly shifting employment trends. The IEA estimates, for example, that in a net-zero scenario 14 million new clean energy jobs are created by 2030, while another 16 million workers shift to new roles related to clean energy. The IEA provides a global benchmark dataset for employment across the energy sector, providing estimates by activity, region, and value chain segment. IRENA provides a database for renewable energy employment by country, and by technology – that is used by the International Labour Organization for its own analysis and recommendations. Definitions may nonetheless vary across databases, reflecting different sets of opportunities (e.g., "clean energy" would encompass a wider range of activities and technologies, and therefore skillsets, than "renewable energy"). In addition, other measures relevant in the context of a just transition include the IEA's Gender and Energy Data Explorer, that provides detailed data on gender gaps in employment and wages in the energy sector – though for a limited set of countries (EU27, UK, US, Canada). Worth noting is that measures for employment opportunities outside the energy sector are often incomplete and performed at the country level based on specific indicators, scenarios, and policies, and therefore are of limited use for sustainable investment purposes.

3. Impact-based measures

Central banks can resort to a wide array of metrics and tools to measure the climate impacts of their sovereign bond portfolios. Most of the information is publicly and freely available, which ensures a high degree of comparability. Section 3.1 shows that assessing current and prospective climate policies and long-term goals (e.g., net zero targets) is highly relevant for central banks as investors, but at the same time it is hampered by methodological complexities and uncertainty. Section 3.2 describes some synthetic indicators – climate policy indices – that public institutions and private providers have developed, to provide a multi-faceted assessment of the sovereign risks and/or opportunities associated with climate change and a transition to a low-carbon economy. A different approach is to invest in sovereign sustainable bonds such as green bonds or sustainability-linked bonds, which can be linked to sovereign green goals (section 3.3). Relevant impact metrics on sovereign green bonds and sovereign sustainability-linked bonds can be used by investors to gauge their positive investment footprint, despite the challenges to come up with consistent portfolio metrics. More complex measures are portfolio alignment metrics such as an emission gap or implied temperature rise that can help investors to assess the alignment with a global warming target. These metrics can be used both as a tool for portfolio allocation strategies as well as for disclosure and reporting (section 3.4). Last but not least, central banks may want to complement climate impact considerations with measures relating to the potential social consequences of climate and energy transition to ensure their investment decisions contribute to a "just transition" (section 3.5). All data sources mentioned in this section are listed and summarized in Appendix A.2.

3.1 Transition policies

Almost all countries – currently 195 in total including the EU – are parties to the Paris Agreement and as such have committed to significantly reduce GHG emissions. The policies that countries implement to transition to a low-carbon economy are commonly referred to as transition policies.

Transition policies are typically categorized into a) medium and long-term policy goals (such as GHG emissions reduction targets by a specific future date); and b) policies that countries have already implemented or have committed to implement in support of their policy goals. It is naturally challenging to assess the chances that GHG emissions reduction goals will be met, the likelihood that future policies will be implemented, and what the impact of prospective and current policies will be. Conveniently, there are a range of publicly available databases which provide relevant and scientific measures which can be compared across a wide range of jurisdictions.

First, many countries have set medium term (e.g., 2030) and long-term (e.g., 2050) emissions reduction targets to fulfil the Paris Agreement's temperature goals[39]. The scope of these targets (sectoral and GHG-type coverage, adherence to Paris Agreement goals, etc.) can signal the level of ambition and the commitment to pursue climate goals. Net Zero Tracker provides a clear and comprehensive overview of quantitative targets (emission reduction target, timeline) as well as decision-relevant qualitative attributes such as the coverage of different types of GHG emissions and whether these targets are enshrined in law.

Second, current and prospective climate policies are key indicators to assess the ability of a country to achieve the GHG emissions reduction target. As per the Paris Agreement, the parties to the Agreement (194 countries) have committed to submit so-called nationally determined contributions (NDCs) and regularly update and improve them, under the UN Framework Convention for Climate Change (UNFCCC)[40]. The NDCs are summarized in a structured and consistent manner for instance in the

39 Net zero emission targets are typically related to achieving the 1.5 °C temperature goal of the Paris agreement and imply a reduction to net zero emissions by 2050 for many countries. Net zero means that GHG emissions are balanced by negative emission from carbon sinks and carbon capture and storage.

40 In their NDCs, countries outline the policy actions they commit to take to reach the goals of the Paris Agreement. NDCs therefore provide a comprehensive summary of a country's prospective transition policies. All NDCs are publicly available on the UNFCCC website (see Table A.2). UNFCCC countries were requested to submit the next round of NDCs (new NDCs or updated NDCs) by 2020 and every five years thereafter (e.g., by 2020, 2025, 2030), regardless of their respective implementation time frames. Many countries have submitted updated or new NDCs, but there can be significant lags for some countries until new policy commitments are reflected in NDCs.

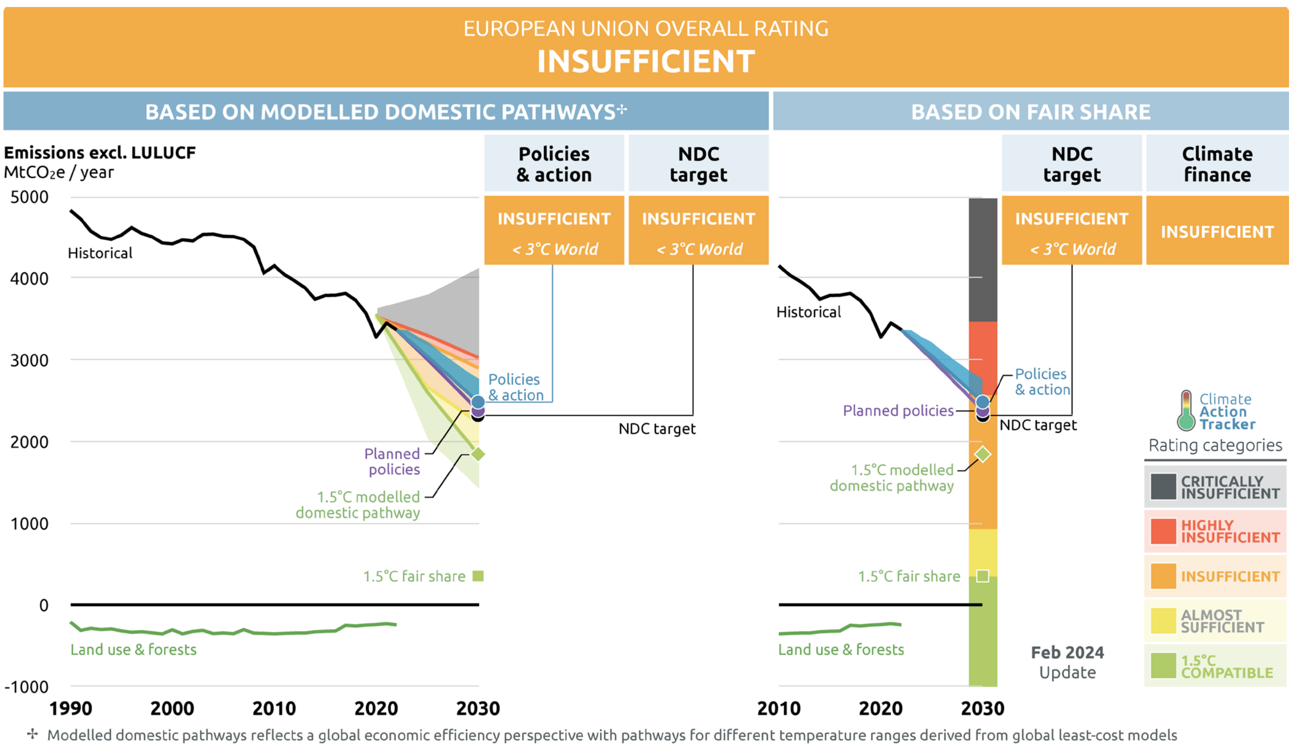
IGES NDC database or the NDC Explorer. A comprehensive review of current policies (rather than policy pledges mentioned in the NDCs) adopted across countries is the Climate Policy Database. In addition, the IEA policy database covers energy-sector policies which are key to achieving climate mitigation, and includes policies objectives that go beyond climate change mitigation.

3.1.1 Assessing the impact of climate policies

Some existing high-quality and science-based tools provide publicly and freely available data on estimated future GHG emissions pathways under different policy scenarios. These pathways are based on complex and comprehensive integrated assessment models (IAMs), which are maintained and run by several groups of expert scientists and regularly updated to reflect the latest data and advances in climate modelling. The two key data sources discussed below are both fully transparent in the underlying assumptions and data sources, which can vary across countries[41].

Climate Action Tracker is the most prominent and science-based data source for NDC pathway projections. The country summary view (available for 41 countries plus the EU) provides a user-friendly overview of the projected pathway for various policy scenarios (Figure 7). Depending on the country, these scenarios include one with current policies only (i.e., policies that are already in place) and scenarios that reflect pledges of future policies, such as those under a country's NDCs. For developing and some emerging economies, there can be a distinction between unconditional NDCs (the actual policy pledges in NDCs) and conditional NDCs, which include expected support provided by advanced economies[42]. The projections are typically for the period 2020-2030 (projections to 2030

Figure 7 **Example of pathway projection from Carbon Action Tracker**



Source: Carbon Action Tracker. https://climateactiontracker.org/countries/eu/.

41 Emissions for land-use, land-use change, and forestry (LULUCF) are not included in these projections, which can have an impact for countries with intensive land use or countries where land acts as a natural carbon sink (e.g., countries with large forest areas).

42 The UNFCCC does not distinguish between advanced economies, but between Annex II (more developed) and other countries (see https://unfccc.int/process/parties-non-party-stakeholders/parties-convention-and-observer-states for a list). Annex II countries are required to provide financial resources to developing countries.

are referred as "medium term" for emission pathways) and are frequently updated to reflect the latest policy pledges, data and modelling advances.

Another prominent and science-based data source is the 1.5 °C national pathway explorer by Climate Analytics, which is also a data source for the ASCOR project. Beyond including the data from Carbon Action Tracker, it allows comparing projected policy pathways with a range of emission pathways compatible with 1.5 °C global warming (in line with the objective of the Paris Agreement to limit global warming "well below 2 °C" and to target 1.5 °C), resulting from different IAMs using different scenarios. The global and regional emission pathways are then "downscaled" to the country level. This downscaling can also take into account fairness issues, by alleviating the burden on less developed countries and assuming higher reductions for developed economies (see Box A).

3.1.2 Policy impacts metrics

Both Carbon Action Tracker and the 1.5 °C national pathway explorer by Climate Analytics allow the easy calculation of various relevant key metrics. Current policies, for instance, could be assessed by the percentage reduction in GHG emissions until 2030. The data sources also allow the calculation of various emissions gap, such as between projected emission under current policies and a stated 2030 emission target ("current policies emissions gap"), or between emission pathways of NDCs and 1.5 or 2 °C global warming ("Paris emission gap"). They also allow the calculation of an ambition gap – the difference between NDC policies and a 1.5 °C pathway. Carbon Action Tracker further provides a simple rating system, classifying countries into 5 different categories, as well as sub-ratings for their current policies and their medium-term targets. While the classifications are ad-hoc, the methodology is simple and transparent (provided on the Carbon Action Tracker website).

3.1.3 Assessing the uncertainty of policy impacts and implementation

The resulting impact of current policies and NDC projections can be gauged from emission pathway estimates from Climate Action Tracker, which are naturally subject to significant uncertainties. While these projections are presented as a range, these ranges reflect merely the divergence due to different model runs (model uncertainty), rather than an uncertainty around the estimated emission pathways[43].

Another fundamental uncertainty arises from the question of whether the necessary and sufficient policies are actually implemented. While this depends on the unknown future political situation in a given jurisdiction, several indicators can help to assess the current level of commitment to achieving GHG emissions reduction targets. One such indicator is whether countries have enshrined net zero emission targets in law (available in Net Zero Tracker). Moreover, the above-mentioned emission gap measures are informative for assessing whether jurisdictions have already made sufficient progress in achieving their net-zero targets – a lower emission gap may signal a stronger commitment to achieving their set climate goals. Another type of relevant metric are climate policy indices, discussed in section 3.2 below.

A specific policy tool widely seen as highly meaningful to signal a high level of commitment is the presence of carbon pricing instruments, including carbon emissions trading systems and carbon taxes. The World Bank's Annual publication on the "State and Trends of Carbon Pricing" is widely viewed as the one of the most comprehensive data sources. Two key metrics contained in these reports, for which the underlying data for all figures is freely available, are the share of GHG emissions covered by carbon pricing and the price itself[44]. The tools and metrics described above as well as the key policy indices discussed below are summarised in Appendix A.2. Another source of information on climate policies is the OECD climate actions and policies measurement framework (CAPMF) database[45].

43 As for the latter, a technical constraint is due to the high computational burden of complex climate models used to estimate impact and sensitivity analyses (e.g., to assess difference in emission path outcomes due to changes in assumptions or model parameters).

44 Carbon prices for many jurisdictions are also available on the International Carbon Action Partnership website here: https://icapcarbonaction.com/.

45 The OECD also developed a green budgeting framework that can provide public finance relevant insight into countries' climate policy.

3.2 Climate policy (and risk) indices[46]

Over the last few years, an increasing number of climate policy and risk indices have been developed. These indices are based on a series of measures, tools, and metrics to cover a broad range of climate-related country characteristics. The multi-faceted nature of climate indices helps to easily integrate climate-related considerations in portfolio construction. At the outset, the relevance of indices depends on the climate-related investment objective of the central bank (e.g., climate risk or climate impact). There are several sovereign climate indices that incorporate risks and/or opportunities associated with climate change and a transition to a low-carbon economy.

3.2.1 Publicly available climate indices

Among the publicly and freely available indices that incorporate both risk and opportunity metrics is The Notre Dame Global Adaptation Index (ND-GAIN). The index assesses a country's current vulnerability to climate disruptions and readiness to make effective use of investments for adaptation actions. The vulnerability index measures a country's exposure, sensitivity, and ability to adapt to the negative impact of climate change in six life-supporting sectors: food, water, health, ecosystem service, human habitat, and infrastructure. The readiness index measures a country's ability to leverage private and public sector investment for adaptive actions considering economic, governance and social readiness.

The Climate Change Performance Index (CCPI) from Germanwatch, Climate Action Network and New Climate Institute is another widely used index which focusses on climate impact metrics. CCPI is an independent monitoring tool to enable transparency in national and international climate politics. The CCPI evaluates 59 countries and the European Union, which together generate 90 percent of global greenhouse gas emissions. The climate protection performance is assessed in four categories: GHG emissions, renewable energy, energy use and climate policy.

Customised indices can also be built by retrieving information from databases that offer relevant information about climate impact policies. For instance, the OECD provides the Climate Actions and Policies Measurement Framework (CAPMF), a structured and harmonised climate mitigation policy database across a long period, and for a large number of countries. The specific database is designed to enable the analysis of the effectiveness of climate policies in reducing GHG emissions.

3.2.2 Commercially available climate indices

Several commercial providers offer indices with a different focus on impact and climate policy commitment specifically designed for the purpose of sovereign investment. In many cases, central bank investment managers already have access to these indices through their regular subscriptions to financial market information providers. One commonly used index is Bloomberg Government Climate Scores. It measures how prepared a country or region is for meeting the Paris Agreement goals. The score is composed of three equally weighted sets of measures: carbon transition (measures the historical, current, and forward-looking emissions target), climate policies (measures progress on the net-zero target pledges, green debt issuance, and renewable energy policy frameworks) and power sector transition (measures progress and future effort towards power sector decarbonisation).

3.3 Green bonds and other labelled sustainable debt instruments

The sovereign green bond market has rapidly grown in last years to more than USD 400 bn outstanding from 34 issuers at the end of 2023[47]. After the peak in 2021 with $86.2 billion (five times of the amount in 2020), in 2022 sovereign green bond issuances experienced a slowdown in line with the overall fixed income market, mainly due to less favourable financing conditions and a slight rebound in 2023. The share of green bonds in total government outstanding debt is still around 4 per cent and may offer room for growth in the next years in light of rising demand and as also demonstrated by a relevant "greenium" (price premium of green bonds) at issuance (Fender et al., 2020).

46 Climate policy and risk indices summarize different climate metrics into one single numerical index. They are distinct from investment indices (i.e., ready-made investment products), which are discussed in section 4.3.

47 Data source: Bloomberg. France Treasury leads as the largest single source of sovereign GSS+ debt with USD 72 bn outstanding at the end of 2023.

Although sovereign green bonds have identical financial risk and very similar performance characteristics compared to conventional bonds (Doronzo et al., 2021), **central banks may have a positive impact on the environment by investing in green bonds.** The green bond label signals that the proceeds of the bonds are used for green projects, which can help to reduce emissions. Central banks may in this way support the net-zero transition and have a reputational benefit from disclosing green bond holdings in their portfolio.

Central banks can either invest in green bonds themselves or in ready-made green bond funds. The BISIP green bond funds, managed by the Bank for International Settlements (BIS), can represent a valid option for CBs which want to start investing in green sovereigns. The three funds currently offered by the BIS and solely available to central banks are investing in sovereign and quasi-sovereign green bonds and at present account for almost $4 billion of managed funds[48].

Sustainable bonds are another option, issued for instance by multilateral development banks to invest in projects linked to the UN Sustainable Development Goals[49]. There are further examples of innovative products such as non-vanilla sustainable bonds, forest-bonds, or blue bonds. The International Finance Cooperation (part of the World Bank Group) published a guideline for Blue Finance in early 2022. The International Capital Market Association (ICMA), the United Nations and other MDBs reportedly are working toward a blue bond framework. A draft mapping of biodiversity finance activities is included in Annex 1 of IFC Biodiversity Finance Reference Guide.

Impact metrics at the green bond level and at the portfolio level can be found in the issuers' impact reports and ICMA handbook (2023). They include, among others, both qualitative and quantitative indicators: GHG emissions reduced/avoided, renewable energy generation and installed capacity, energy efficiency, water savings, waste prevented or recycled, reduction of air pollutants in clean transportation, new green networks, and transports, protected areas and species by biodiversity projects. Climate change adaptation, circular economy/eco efficient and biodiversity/living natural resources indicators are also available. Allocation and impact reports also show allocated and unallocated proceeds, if applicable.

One current challenge of the sovereign green bond market is the lack of comparability, transparency and availability of impact measures to compare green bonds issued by different governments (NGFS, 2022)[50]. Recent initiatives such as the Partnership for Carbon Accounting Financials (PCAF) or the newly adopted European Green Bond Standard are trying to address those issues.

Sovereign Sustainability-Linked Bonds (SLBs) can signal a country-wide climate commitment of government beyond single projects as in the case of green bonds[51]. Moreover, an SLB design could be particularly attractive for investors who want their portfolios to be aligned with a certain climate scenario. To date only a few sovereign institutions (Chile and Uruguay among central governments and some Swedish municipalities) have issued SLBs, given the novelty of the instruments (SLBs appeared in late 2019, the first green bond was issued in 2007) and the challenges in measuring key performance indicators (KPIs) in a timely fashion, especially those relating to GHG emissions. Some examples of relevant impact KPIs and the corresponding sustainability performance targets, according to the ICMA SLB framework, include: GHG emissions per year; non-conventional renewable energy, as a percentage of total generation in the National Electric System; reduction of aggregate gross GHG emissions per real GDP unit with respect to reference year; and the maintenance of native forest area with respect to reference year[52].

48 See "BIS launches green bond fund for central banks", press release, 26 September 2019. https://www.bis.org/press/p190926.htm.

49 Among risk measures, backward-looking indicators can include carbon emissions and energy systems' dependency on fossil fuels' industries, while forward-looking ones can be based on countries' commitments and/or decarbonisation scenarios, as well as qualitative assessments (such as the EU Commission's assessment on climate-energy plans of individual countries).

50 NGFS (2022). "Enhancing market transparency in green and transition finance. April 2022. https://www.ngfs.net/sites/default/files/medias/documents/enhancing_market_transparency_in_green_and_transition_finance.pdf.

51 Green bonds can pose weak incentives in the absence of counter-factual demonstration of different usage of budgetary spending of issuers (Lehmann and Martins, 2023). Main building block on sovereign SLB are identified by Sustainability-linked Sovereign Debt Hub (2023).

52 Additional details on sovereign SLB KPI framework are reported in Green Finance LAC (2022) and Uruguay's Sovereign SLB framework (2022).

3.4 Portfolio alignment measures

Portfolio alignment measures help to capture how well an investment portfolio is aligned with a global warming target. The alignment measure can be either a single number or a range and can be an effective tool for portfolio allocation strategies and may facilitate reporting.

Typically, the global warming temperature target corresponds to the Paris Agreement's 1.5 °C or 2 °C temperature thresholds. As such, GHG emissions pathways compatible with the remaining carbon budget for a 50% chance to remain below 1.5 °C global warming imply net zero emissions by the early 2050s at the latest followed by net negative GHG emissions. Accordingly, alignment with this target is also referred to as "net-zero alignment" (IPCC, 2023, Box SPM.1). Interim targets, such as 2030 medium-term targets, can be derived analogously[53].

A first key step of constructing a portfolio alignment measure is to translate a temperature target into an emissions benchmark (see Appendix B). This benchmark can potentially embed burden-sharing or fair-share considerations in allocating emissions across countries (see Box A). The construction of the benchmark rests on a number of assumptions and complex analysis using climate models (see also section 3.1 on transition policies)[54]. To measure alignment of a *portfolio* of sovereign debt securities, the benchmark naturally needs to be consistent across the included set of jurisdictions.

A portfolio alignment measure can take two forms: i) a GHG emissions gap (often called carbon budget overshoot) between financed emissions of the sovereign debt portfolio and the benchmark; and ii) an implied temperature rise (ITR) which indicates the global warming level that a portfolio's emission pathway corresponds to. It is important to note that the implied temperatures in general cannot be "aggregated" to the portfolio level[55]. There are tools to calculate the ITR with the help of open source climate models such as MAGICC or Hector. A "rough and ready" method for marginal deviations from a given benchmark referring to nearer-term emissions targets (less than 10 years ahead) may be translated into additional warming by a simple science-based formula (as described below) – though the error band around this simple estimate is fairly wide. For more precise ITRs, in particular for longer horizons (e.g., 2050), a model-based ITR is more appropriate.

A small number of net-zero portfolio alignment frameworks now cover sovereign bonds as well, including the Institutional Investor Group on Climate Change (2021) and the Net-Zero Asset Owner Alliance (2023). These methodological documents contain some additional information relating to sovereign debt, though their main focus is on corporate debt securities.

A publicly accessible tool for calculating portfolio alignment measures of sovereign debt portfolios is not available yet[56]. Alignment measures can, however, be calculated reasonably well with publicly available data as described in Appendix B, though an appropriate calculation of ITRs requires knowledge and experience with the relevant open source climate models[57]. Several commercial service providers offer portfolio alignment measures for sovereign bonds, including MSCI (ITR) and S&P (ITR), Carbone 4 Finance (Carbon Impact Analysis), Ninety One (Net Zero Sovereign Index), FTSE Russell and Beyond Ratings, Ortec Finance (Climate ALIGN) and "right. based on science". Their methodologies are reviewed in detail in Noels and Jachnik (2022).

53 In contrast to the targets discussed in section 3.1, the target does not refer to a single sovereign bond issuer, but is a target set by the central bank (the investor), which in many cases will align with the target of the central bank's sovereign. Analogously, the relevant emissions (and emission pathways) are those of the sovereign debt portfolio of the central bank (the investor portfolio).

54 See PAT (2020) for a more detailed discussion on setting benchmarks.

55 It would not be admissible to, hypothetically, calculate the ITR of a portfolio as a weighted average of the ITR of the individual holdings. Rather, the ITR of a portfolio is the derived by comparing the absolute financed emissions of the whole portfolio with the benchmark emissions pathway corresponding to the target level of global warming. The deviation in absolute emissions (the carbon budget overshoot) can then be translated into an additional ITR over the target level of global warming.

56 For corporate bond portfolios, such measures are more established. See for instance CDP and WWF (2020) or PACTA.

57 Some examples of net zero implementation are in two recent academic papers (Cheng et al., 2022a; Kaul et al., 2022; and Barahhou et al., 2023).

Box A

Reflecting burden-sharing or fair share of GHG emissions reductions

Countries' historic emissions vary substantially and their capacity to make the necessary investments to limit global warming differs widely. The Paris Agreement takes these different circumstances into account in Article 4.3: "Each Party's successive nationally determined contribution will represent a progression beyond the Party's then current nationally determined contribution and reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances." Fairness issues reflected in countries' NDCs are recorded for instance by Paris Equity Check.

There are, however, no guidelines as to how burden-sharing among countries is to be implemented. An active literature has emerged around the issue of "fair share". Naturally, fairness is open to interpretation. The 5th Assessment Report of the IPCC has summarised a range of perspectives along four dimensions: responsibility, equality, capability and cost ffectiveness. These dimensions are covered by the fair share estimates from Climate action Tracker, for instance.

Within these four dimensions, there are some specific cases where burden sharing can be easily calculated such as equal historic cumulative emissions (historic responsibility) or equal consumption-based per capita emissions (equality). A widely used database for historic emissions is the PRIMAP-hist database (Gütschow & Pflüger, 2023).

ASCOR also provides guidance on fair share estimates, which are an equally weighted combination of responsibility, capability and population considerations. The weight (i.e., percentage share) of the global 1.5 °C-aligned emissions budget allocated to each country is the sum of one-third of the weight of a given country in historic per capital emissions *e* (ASCOR looks at 1970-2020), GDP per capita *y* and a countries population *pop*:

$$fair\ share_{c,t} = \frac{1}{3}\frac{\frac{1}{e_c}}{\sum_c^N \frac{1}{e_c}} + \frac{1}{3}\frac{\frac{1}{y_{c,t}}}{\sum_c^N \frac{1}{y_{c,t}}} + \frac{1}{3}\frac{pop_{c,t}}{\sum_c^N pop_{c,t}}$$

where c is a given country, N is the total number of countries and t is the (current) year. A country's fair share emission allocation is then calculated by multiplying *fair share* with the global emissions budget (ASCOR focusses on the 1.5 °C-aligned emissions budget in 2030). The emission allocation increases with lower historic emissions, lower GDP per capita, and/or a higher population.

3.5 Social impact and just energy transition

There are growing interest and attention among impact investors and institutions about adverse social side effects of the efforts towards a climate transition. To that extent, investment policies that consider climate and environmental issues can be supplemented by a well-designed and holistic approach to incorporate just transition and fairness issues. Some measures and metrics could be used by central banks, as investors, to integrate these issues.

Several social impact metrics relevant to the climate transition can be categorised under three social macro-themes: Employment, Social Implications and "Just Energy", i.e., the combination of renewable energy technologies with social issues (see appendix A.3 for a list of relevant metrics). These metrics cover broad issues that can be influenced by many factors beyond climate-related ones. A combination of relevant metrics can provide an indication of social impact.

Social issues are particularly important for emerging markets and for those countries whose energy mix is still dependent on high-carbon intensive sources, such as coal, and where the energy affordability is a relevant issue in the light of a foreseeable increase in energy demand. Box B below describes the Just Energy Transition Partnership in Indonesia, which tries to align social issues together with the need to decarbonise an economy still highly dependent on coal-fired power plants. This holds relevant lessons for the links between climate transition and social issues, which in turn can be taken into consideration for investment purposes.

Box B

Just Transition in Indonesia

To date, around 60% of the electricity generated in Indonesia is produced from coal-fired power plants. In addition, coal is also a primary fuel for steel and cement production. In 2022 domestic coal production reached 687 million tons, making Indonesia the world's third-largest coal producer according to the International Energy Agency. Coal represents 19% of Indonesia's total exports, with 1.6 million people employed in the sector.

Net-zero transition may represent a serious challenge for unemployment in Indonesia. Nevertheless, net-zero transition might also help to create new jobs in the renewable energy sector. Hence, training and education to develop renewable energy skills are needed and require collaboration among government, industry and universities.

In November 2022 a Just Energy Transition Partnership (JETP) was signed by Indonesia and international partners led by US and Japan, and supported by the EU, UK, Germany, France, Canada, Italy, Norway, and Denmark. The partnership aims to mobilise an initial $20 billion in public and private financing, with $10 billion coming from public sector pledges and the remaining $10 billion sourced by private investments under the Glasgow Financial Alliance for Net Zero (GFANZ) over a period of three to five years. According to the Energy and Mineral Resources Ministry, an estimated investment of $28.5 billion per year is needed to achieve Indonesia's net zero target by 2060.

In February 2023 JETP Secretariat was launched to foster the achievement of JETP objectives. The Ministry of Energy and Mineral Resources (ESDM Ministry) hosts the Secretariat, with the support of the Asian Development Bank (ADB) as a coordinator for internal and external stakeholders. The secretariat is also responsible for planning and developing critical projects for JETP.

The JETP is viewed as a crucial step towards achieving Indonesia's future climate and energy objectives, being part of Indonesia's commitment to limiting global warming to 1.5˚C and achieving net zero emissions by 2060 or earlier. As part of this commitment, Indonesia aims to develop an investment plan that will result in renewable energy accounting for 34 % of the country's total energy mix by 2030. The investment plan also aims accelerating the retirement of coal-fired power plants, which is expected to peak in 2030 with greenhouse gas emissions reaching 290 million tons of CO_2, against a "business as usual" scenario of 357 million tons of CO_2 in 2030.

According to a Fitch report of November 2022, transition towards clean energy could also result in greater investment in new renewable capacity, leveraging Indonesia's position as the world's largest producer of nickel and the second-largest producer of tin, key minerals for clean energy technologies. In addition, JETPs could serve as a catalyst for promoting investment and ensuring fair and inclusive processes and outcomes.

4. Implementation considerations and constraints

In implementing a climate strategy for their sovereign bond portfolios, central bank investment managers face some fundamental and practical challenges. A fundamental implementation challenge is managing trade-offs with other central bank objectives, which is intensified by the naturally limited number of sovereign issuers (section 4.1). The choice of investment strategy has a direct impact on the entire implementation process as well as the required expertise and resources (section 4.2). A simple and cost-effective way of implementing climate-related considerations in sovereign portfolio management is to invest in sovereign green bonds or use ready-made sovereign bond climate indices (section 4.3). If central banks choose the more complex option of selecting their own climate metric or a set of metrics, a natural challenge that arises is weighting different metrics of potentially different type (section 4.4). Using a customised set of metrics is bound to be more resource-intensive, but also creates opportunities as central banks build expertise in interpreting and using these metrics. An important practical implementation consideration is the treatment of securities issued by sub-sovereigns, supranationals, government agencies or other government-backed entities (section 4.5). These securities are often part of central banks' sovereign debt portfolios, but their climate-related characteristics can differ. Notwithstanding the wide range of freely available climate-related metrics, some methodological and data gaps remain (see sections 4.6, 4.7 as well as 4.8 on the materiality of biodiversity risk and natural capital degradation). A potential first step in developing an understanding of the metrics and methodologies can be climate-related disclosure by central banks, in particular related to their investment portfolios (NGFS, 2021).

There is no one size fits all solution for the implementation of climate-related considerations in central banks' management of sovereign debt portfolios. As new metrics and data become available and existing ones are being improved, implementation will be an evolving process rather than a one-off exercise.

4.1 Potential trade-offs with other central bank objectives

Central bank mandates and fiduciary duties play a significant role in determining the primary investment objectives for their investment portfolios (e.g., own funds, pension funds, or FX reserve portfolio not held for monetary policy goals but earmarked for financial return generation) **such as safety, liquidity, and return** (Figure 1)[58]. Within their mandate, **central banks can find ways to combine these primary objectives with possible climate-related objectives. This may create various implementation challenges, depending on the type of investment portfolio[59].** For central banks' own portfolios or pension funds there is generally more leeway to incorporate climate-related considerations, while combining climate-related and primary objectives may be more complex in the case of FX investments (not held for monetary policy goals)[60]. For instance, investing in sustainable debt instruments may pose liquidity challenges because these assets may not offer the same level of liquidity as traditional reserve assets, such as conventional sovereign bonds (Fender et al., 2020). Sustainable debt instruments tend to have longer maturities and therefore may make it more challenging to manage duration risks. Additionally, adjusting the portfolio's currency composition based on climate-related metrics has an impact on diversification strategies to reduce risk and achieve the desired financial returns. Investment objectives may also constrain such adjustments due to the need to hold sufficiently large amounts of sovereign securities denominated in major currencies – in particular in the case of FX reserve portfolios (Fender et al., 2022).

For sovereign debt portfolios, the challenges of complying with primary investment objectives are amplified by the naturally limited number of sovereign issuers in a given currency. The limited investment universe results in a relatively high degree of tilting to achieve a

58 Such considerations may be even more prevalent in the short-term during volatile market conditions as central banks may turn more sensitive to the paradigm of liquidity and safety.

59 As stated before, this report focusses solely on central bank investment portfolios.

60 See for instance ECB, Foreign reserves and own funds (europa.eu) or Fender, McMorrow and Zulaica (2022).

given sustainability target. Several recent research papers, for instance, show that decarbonisation of a sovereign portfolio requires relatively large changes in constituents' weights (Cheng et al., 2022a; Kaul et al., 2022; Barahhou et al., 2022).

As incorporating climate-related considerations in the management of sovereign portfolios is a relatively new field, central bank investment managers will likely have to embark on an iterative process to find the appropriate balance between primary investment objectives and potential climate-related objectives in implementing their investment strategy.

To maximise the climate impact of their investment strategy, central banks may consider engagement with the issuers. Corporate engagement is widely seen to yield important climate-related benefits by following up on climate and other sustainability targets and it is a long-standing and common practice. Engagement with sovereign issuers on climate-related issues, however, has received attention only very recently[63]. In the case of central banks, caution is warranted as they need to make sure not to undermine their independence and avoid potential conflicts of interest and reputational risks. In the case of foreign sovereigns, foreign policy considerations may also come into play.

4.2 Choosing a climate investment strategy and engagement with issuers

In implementing a climate portfolio tilt, a key consideration is the choice of climate investment strategy. Widely used strategies are negative screening and best-in-class strategies[61] which rank issuers according to their current climate-related characteristics – either versus peers or all countries within an investable universe. These strategies can be used in conjunction with a wide range of objectives such a managing climate risk exposures or improving a portfolio's carbon footprint. Other potential strategies like "best-in-progress" focus on the speed of improvement in climate metrics over time.

A closely related issue is whether and how to incorporate fairness issues (see Boxes A and B in sections 3.4 and 3.5). Some countries, in particular emerging markets, have historically contributed significantly less to global GHG emissions. Carbon emissions in particular remain in the atmosphere for a long period of time[62]. Taking into account historical emissions would therefore be particularly relevant for central banks incorporating impact-based considerations to avoid a bias against countries with a relatively smaller aggregate impact on global warming.

4.3 Using sovereign bond indices that incorporate climate-related considerations

Using ready-made government bond indices that already incorporate climate-related considerations can present an attractive option for central banks as this approach effectively outsources some of the methodological issues to be considered. Such indices may allow a resource-efficient implementation of climate-related considerations into their sovereign debt portfolios. Climate government bond indices are indices that incorporate a tilting methodology, adjusting the weights assigned to each country according to their relative climate performance. Examples of climate government bond indices include the Bloomberg Government Bond Carbon Scored Index, the FTSE Climate Risk-Adjusted Government Bond Index Series, and the ICE Sovereign Carbon Reduction Indices[64].

One of the advantages of using climate government bond indices is that they are constructed to generally maintain a high level of liquidity and safety – two key investment objectives for central bank portfolios (see section 4.1). For instance, the FTSE's Climate Risk-Adjusted Government Bond Index Series closely tracks the credit ratings of its parent index (FTSE World

61 See chapter 4 in NGFS (2019) for a detailed discussion of SRI investment strategies central banks can adopt.

62 Significant parts of emitted CO_2 (25% or so) stay in the atmosphere for several hundred or even thousands of years. See Inman (2008).

63 Such considerations also feature increasingly prominently in multilateral surveillance exercises (e.g. Article IV reviews by the IMF or reviews by the OECD).

64 These indices are listed for information and are not an endorsement of their suitability. Some of these government bond indices are constructed using the climate indices discussed in section 3.2.

Government Bond Index), and the Bloomberg Carbon-Scored Index is based on the market value weights to ensure that country allocations do not deviate too much from the parent index while limiting overexposure to markets with small capitalization and limited liquidity. Several maturity-constrained versions of the indices are available, ranging from 1-3 years to 10+ years, which allow central bank portfolio managers to pursue their portfolio duration target.

For central banks willing to target a more climate-active management style, the indices provide some scope for customisation. This includes overweighing specific factors or placing stronger/weaker tilts away from market value weights.

The methodology and metrics behind these climate government bond indices include a combination of backward- and forward-looking measures. Thereby, the indices capture the contribution of countries activities toward climate change along with the evolving nature of climate change. For instance, Bloomberg's Government Climate Tilted Bond Indices adjust the countries' market value weight according to the Bloomberg's Government Climate Risk Scores, which incorporate forward-looking measures such as the country's forward-looking emissions performance, and a country's planned effort towards power sector decarbonisation (see section 3.2.2).

While much progress has already been made on relevant data and methodology, there is still scope for improvement regarding the transparency in data selection and methodology of sovereign climate bond indices. For example, the rationale behind the type of scope and measurement methods of emissions data is sometimes not discussed in depth. Central banks may, however, require more detailed information on these crucial issues.

Lags in data publication and the low frequency of data are additional challenges in particular for central banks inclined to a more dynamic adjustment of portfolio weightings. Some indices review their country climate risk scores only once a year, and therefore the weights of the issuing countries in the index are also revised annually.

4.4 Considerations for combining and weighting climate-related metrics

Yet, there is little official technical guidance on how to combine or weigh different climate metrics. At the current stage, this also applies to the ASCOR framework, although ASCOR is planning to publish a set of implementation examples in the near future.

In some cases where the metrics to be combined are sufficiently consistent and comparable, the combination and weighting is more feasible. GHG metrics, for instance, are typically expressed in the same units (CO_2 equivalents) and have often been developed to allow for aggregation or subtraction. CO_2 equivalents present a physical and science-based weighting by translating different GHG emissions into CO_2 equivalents based on their so-called Global Warming Potential using official translation tables[65]. Historical physical risk metrics (e.g., floods, droughts, extreme temperatures) can be translated into damages by effectively weighting different types of physical risks by the economic damage they cause.

Combining different types of metrics typically requires some form of subjective weighting to create a decision-relevant overall ranking or score across issuers. If the metrics to be combined are significantly diverse to capture different climate-related issues (e.g., physical risk and impact-based metrics), a direct comparison between metrics is not feasible. Even a combination of forward and backward-looking metrics of the same type of measure, such as past GHG emissions and estimated future GHG emissions pathways, may require some weighting as these measures are constructed in fundamentally different ways. The subjective weighting can then be used to create an ordinal ranking across issuers within the eligible universe of sovereigns for a given portfolio or an overall score, which better reflects the relative differences across issuers.

65 See for instance the Global Warming Potentials tables by the UNFCCC or the Greenhouse Gas Equivalencies Calculator by the US EPA.

Weighting across different types of metrics would typically be guided by central banks' investment objectives for a given sovereign portfolio. For instance, if a central bank pursues a net-zero investment objective for some portfolios, then investment managers should naturally give a high weighting to metrics related to future emission pathways or portfolio alignment metrics (e.g., using net-zero emissions pathways to construct the benchmark portfolio).

Within the selection of climate-related metrics and their relevant weighting, central bank investment managers may want to consider the following points:

- Central bank investment managers should consider both backward and forward-looking measures to harness the advantages and mitigate the disadvantages of each kind of measure.
- Some data gaps can be addressed by considering a broader set of measures and developing approaches to determine relative weights.
- Using numerical scores can provide higher granularity and transparency compared to cardinal ratings (e.g., AAA/BBB/CCC).
- Within the climate-related assessment, fairness and just transition aspects might be considered (see section 3.5).
- Climate-related metrics are subject to rapid development as the disclosure of climate-related data and the improvement of assessment methodologies are increasing. This gives rise to a periodic review of the appropriate combination and weighting of climate-related metrics.

All in all, there is generally no single best strategy for combining and weighting climate-related metrics. At this stage, central bank investment managers will have to adopt an *ad-hoc* approach guided by their climate-related investment objectives for a given investment portfolio. Such a process would aim to identify the leaders and laggards across sovereign issuers. This in turn, can form a solid basis for introducing a climate-tilt in central banks' sovereign debt portfolios, allowing them to take a meaningful step towards achieving their sustainability objectives.

4.5 Treatment of sub-sovereign, supranational and agency securities (SSAs)

Central bank sovereign portfolios typically also include sub-sovereigns (i.e., sub-national government issuers), agency securities issued by government-owned or government-backed organisations as well as supranational issuers (e.g., international financial institutions such as multilateral development banks). This raises the important practical issue of how to treat such securities (see Box C). While risks and impact may be different for regional or municipal governments, the necessary data is often lacking (see section 4.7). Investment and risk managers may therefore choose to treat sub-sovereigns like sovereigns. Some government agencies are more akin to financial corporates and could usefully be treated as such, provided that the necessary data is available. Development banks and other SSAs in some cases have implemented sustainability practices, which may need to be taken into account to adequately assess the climate-related characteristics of the securities they issue. A special case is that of securities issued by supranational authorities such as the European Union (EU), which can sensibly be treated as a collective of national sovereigns (the EU member States). In many cases, climate-related metrics such as current GHG emissions or emission pathway projections do exist for the EU as a whole.

Box C

Treatment of exposures to supranational organisations, sub-sovereigns, and agencies (SSAs)

SSA bonds are an important asset class for central banks, especially developing country assets, due to their high credit quality. SSAs are also important issuers in the sustainable and green bond markets. For assessing climate-related risks and opportunities in this asset class, issuers can be separated into four categories:

- Sub-sovereign authorities: States (in a federation), provinces, cities, and municipalities.
- Agencies: Government-sponsored or government-backed entities.
- Supranational organisations: Administrative entities of a group of countries that engage in decision-making on a collective basis.
- Multilateral Development Banks (MDBs): Typically subsumed in supranational organisations but pursuing specific development or impact objective including climate-related ones.

Sub-sovereign authorities and agencies (such as the US GSEs) or development banks (such as the KfW in Germany, CDC in France or CDP in Italy) are located in a given country in which they primarily operate. Depending on the metric type, local authorities and agencies may have similar climate characteristics as their sovereign. For policy and impact-based measures, an important part may be associated with the sovereign although SSA specific climate mandate might suggest a more focused analysis, which could also benefit from considering their institution status. Risk-based metrics, such as those related to physical risks and GHG emissions, should reflect the specific geographic area where they operate and therefore would differ from the relevant sovereign. Given data limitations, however, climate metrics of the sovereign are often used as a proxy for sub-sovereign and agency issuers.

For supranational bodies, like the EU, a weighted average of sovereign metrics or scores based on the capital provided to the issuer by the respective sovereigns could be used as a proxy.

MDBs provide funding on a multi-national basis. In terms of climate-related risks and impact, they could therefore in principle be treated similarly to corporate issuers such as international banks. Yet, many MDBs have implemented sustainability actions and their assessment could usefully take this into account. Because a large part of their lending portfolios is directed to governments, MDBs are exposed to physical and transition risks of the respective sovereign, as these risks can negatively affect a government's ability to pay back its debt in the future. Therefore, the MDB's climate risk exposure is in part linked to the composition of their lending portfolio. However, these risks on their lending portfolios are mitigated by the fact that in many cases MDB's lending aims to reduce climate risk through specific policies and financing, and by the "preferred creditor status" they benefit from.

Another way to assess climate-related risks and opportunities for SSAs is through a more holistic approach, using ESG-like scores. The coverage, however, is very limited for SSAs. In many cases, SSAs and quasi-sovereigns consider United Nations Sustainable Development Goals (UN SDG) as a framework for their funding and investment policies, which can warrant a positive adjustment in relevant metrics using information that these organizations make publicly available through climate-related financial disclosure, and impact-reporting for investors.

1 In a study made for Peruvian International reserves in November 2023, less than 20 of 77 SSA issuers approved had ESG scores: Sustainalytics (19), Moody's (18), S&P Global (1), Fitch (3) and MSCI (0).

2 In the same study, the correlation found among ESG scores for the same 11 issuers covered by both Moody's and Sustainalytics was 0.71.

3 The case of development finance institutions and development agencies (such as the US DFC, the AFD in France, or the FMO in the Netherlands) would require further consideration owing to their overseas focus.

4.6 Methodology gaps

At the current stage, the concrete implementation of climate-related objectives and strategies is hampered by methodological gaps. A first important methodological gap is the translation of the climate-related metrics into an input that is operationally useful for portfolio allocation. For central banks looking to integrate climate risks, there are currently no well-established methodologies to translate physical or transition risks into default probabilities or impacts on sovereign bond prices. While academic work in this area has made significant advances[66], a commonly accepted method is arguably still lacking. Credit rating agencies have started to look at risks and opportunities from climate change, but the reflection of such risks in credit ratings appears to be limited thus far and is not always transparent (NGFS, 2022a). This may partly be due to the time horizon of credit ratings, which can be too short to fully capture climate-related risks (Gratcheva et al., 2023).

Scenario analysis – a methodology increasingly used to assess the impact of climate risks and which has started to be considered to inform asset allocation – is much less developed for sovereign bonds than for corporate securities. In part, this may be due to the historical uses of scenario analysis in stress-testing of the financial sector, TCFD reporting or assessing climate-related risks of corporate securities. In analysing risks for sovereigns, compound risks (risks due to simultaneous climate and other shocks) may be particularly relevant but are not fully reflected in current climate scenarios (NGFS, 2023).

A second methodological gap concerns the combination of different types of metrics, in particular if these metrics are measuring conceptually different climate-related aspects such as climate risk and climate impact metrics. The ASCOR framework translates each of the considered metrics into binary variables, which are aggregated for a given subset of metrics ("area assessment") according to a pre-defined rule (see Appendix B). Yet, the ASCOR framework does not include guidance on how to weight or aggregate these metrics into a single sovereign assessment. How to combine conceptually different metrics ultimately depends on the needs and objectives of a specific central bank. At this stage, central banks investment managers would have to develop their own weighting and scoring systems to reflect their requirements and preferences.

A third methodological implementation challenge concerns the aggregation of climate metrics for a single issuer (i.e., a single sovereign) to the portfolio level. In some instances, such as net zero alignment metrics, a portfolio aggregation can be based on methodologies already used for corporate securities (see Appendix C). Simple aggregations may abstract from potentially relevant interdependencies. For instance, physical risk exposures of neighbouring countries could be highly correlated. Analogously, the implementation of climate policies in a country (e.g., carbon taxes) may have direct economic effects on other countries via trade links.

Some financial service providers have started to offer innovative solutions aimed to tackle these methodological gaps. At this early stage, it is important for central banks investment managers to carefully review the underlying methodologies and solutions to understand their strength and weaknesses.

4.7 Data gaps

Limitations around data are apparent in the sovereign space, despite recent efforts to improve the availability and quality of sovereign climate-related information (Table 6). Data gaps and lags in reporting are different in nature and generally more acute in emerging markets and developing economies (EMDEs) than in advanced economies. Data gaps at sub-sovereign level are often important, both for physical risks and transition risks (e.g., greenhouse gas emissions data).

66 See for instance Bouyé et al., 2023; Fahr et al., 2023; Zenios, 2022; Mallucci, 2022; Battiston and Monasterolo, 2019. See Cevik and Jalles (2022) and Boitan and Marchewka-Bartkowiak (2022) for empirical studies of the effect of climate risks on sovereign risk and sovereign bond prices.

Table 6 **Data gaps identified in the document**

Physical risks	– Exposure to chronic and acute physical risk events for sovereigns is growing, but still lagging in many regions especially in EMDEs. – Insufficient capture of within-jurisdictions variations in physical risks. – Limited transparency of the characteristics of the underlying data (up-to-datedness, completeness, and consistency). – Lack of granular spatial data. – Inclusion of non-climate driven hazards (e.g., earthquakes) in data sources on natural hazards. – Limited availability of chronic risk data (long-term climate-related changes) and challenges related to their translation into investment-relevant financial risk data. – Limited but growing availability of data on physical risk vulnerability and government response. – Limited data on cascading and compounding effects of physical risks. – Data gaps on nature- and biodiversity-related risks.
Transition risks	– Scarcity of greenhouse gas emissions data in some EMDEs and most low-income countries, in addition to a two-year time lag for most transition-related sovereign data. – Limited availability and comparability of domestic consumption emissions. – Limited data and estimates on the impact of transition risks on government finances (including knock-on effects from declines in growth from other industries dependent on these sectors). – Limited data availability and underlying methodological uncertainties for future greenhouse gas emissions and other forward-looking measures of transition risk (e.g., regional and national transition pathways under specific climate scenarios). – Limited data availability for most non-emissions-related metrics.
Sovereign ESG scores	– Lack of consistency and completeness of environmental measurement across providers. – Transparency in data selection and methodology of indices.
Opportunity measures	– Data on gender gaps in employment and wages in the energy sector.
Impact-based measures	– Absence of data for agency-based securities for climate-related metrics such as current GHG emissions or emission pathway projections. – Limited data availability and comparability for planned mitigation actions and adaption measures of countries. – Limited availability of nationally determined contribution (NDC) pathway projections. – Limited availability of climate performance data for developing economies and low-income countries.

Availability of data related to exposure to chronic and acute physical risk events for sovereigns is growing, but still lagging in many regions especially in EMDEs. This constrains the level of specificity in risk analysis while limiting comparability across jurisdictions and potentially underestimating the magnitude of risks. Gaps often include a lack of granular spatial data. This type of data is key to assess the likelihood and exposure of locations to extreme climate-related weather events (*e.g.,* floods, wildfires, droughts, storms) and some types of chronic changes (*e.g.,* soil erosion). Worth noting is that even though some commercial data providers have developed catastrophe risk models to provide an estimate of expected losses from specific climate-related disasters, many of these models remain rarely available for EMDEs and are characterised by short time horizons (usually a year or so), which is typically not sufficient for physical climate risk analysis. In addition, the complexity of assessing the broader macroeconomic implications of climate change may stem from the fact that many EMDEs face broader macrofinancial vulnerabilities, which interact with climate-related risks (FSB, 2022). This contributes to the complexities in assessing these risks and increases the related data requirements. Finally, within-jurisdictions variations in physical risks are often insufficiently captured, or not at all. As a result, the exposure and vulnerability of regions to climate-driven hazards are difficult to assess. This creates challenges for the analysis of sub-sovereign issuers such as states or municipalities.

There are limited data and estimates on the impact of transition risks on government finances, including knock-on effects from declines in growth from other industries dependent on these sectors (FSB, 2022). This is despite the data collection by international organisations on the proportion of government tax revenues stemming from the generation of fossil-fuel based energy across jurisdictions. In addition, GHG emissions data is often scarce in some EMDEs and low-income countries (LICs), making the assessment of GHG emissions across value chains even more complex. Finally, data is also lacking on more forward-looking measures of transition risk, such as regional and national transition pathways under specific climate scenarios.

In this context, a variety of initiatives to expand data collection has emerged recently but would need to make further progress. Such initiatives include macro-level initiatives targeting multiple jurisdictions that are aimed at promoting a consistent set of climate risk metrics with a particular focus on the forward-looking nature of climate risk. In particular, the G20 Data Gaps Initiative and UNECE Conference of European Statisticians climate indicators set are aimed at improving data availability on climate exposures across different jurisdictions. It is worth mentioning the World Bank's Sovereign ESG Data Portal, that covers 71 ESG indicators with 40 additional indicators over 61 years and across 217 economies. Recently added data includes new environmental indicators with geospatial sources (land surface temperature, level of water stress, coastal protection and more), wealth accounting, including different forms of natural capital (*e.g.,* including minerals, forests, mangroves, marine fisheries.), as well as a tool to measure a country's land cover composition (*e.g.,* rate of deforestation, expansion of forest cover). In addition, the World Resources Institute's suite of data products already provides some data at sovereign and sub-sovereign levels for a range of climate-related factors (*e.g.,* water risks, forest landscapes). The advances in geospatial data collection are also promising. Most methods can be extended across different assets and locations, with ongoing improvements in temporal consistency, accuracy, and spatial resolution (World Bank, 2022). Finally, working to close the data gaps[67], the NGFS has collected in its Directory a unique data set of 750 climate relevant data sources, catering to the specific needs and use cases of financial sector stakeholders. The NGFS is currently working towards enhancing the Directory website.

4.8 Potential materiality of nature-related risks

While data and methods to analyse the risks associated with biodiversity loss and, more generally, nature degradation (together, nature-related risks) are still in development, these risks may have a significant impact on sovereign creditworthiness in advanced economies and in EMDEs (NGFS, 2022; F4B, 2022). EMDEs in particular are highly vulnerable to biodiversity and nature loss (NGFS, 2022). They host 85% of biodiversity hotspots and make up 15 out of the 17 megadiverse countries globally. An increasing destruction of megadiverse ecosystems such as tropical rainforests could trigger tipping points. The reduced pollination, fisheries, timber production, and related ecosystem services could result in a decline in global GDP of $2.7 trillion annually by 2030, with ripple effects across value chains and regions (Johnson et al. 2021). The loss of ecosystem services may lead to output losses and rising unemployment with adverse effects on public finances, while increasing acute climate-related risks and decreasing adaptation capacity due to ecosystems destruction may lead to sovereign debt risks (F4B, 2022). These risks also present opportunities for financial innovation such new types of debt instruments, as financial institutions increasingly pledge for a consistent approach to classify nature and biodiversity-related risks.

Ideally, portfolio risk management would include nature-related measures. Incorporating them into sovereign ratings would bear some similarities with geopolitical or other highly hard-to-assess risks (F4B, 2022). According to the World Bank (2022), the portion of a country's wealth that focuses on natural capital is generally not reflected in sovereign credit rating assessments, contrary to human or physical capital. The World Bank finds that if a credit assessment were conducted over a longer time horizon, natural capital would be more relevant for a thorough assessment of sovereign creditworthiness. The inclusion of biodiversity and nature-related aspects may therefore constitute an important insight on a country's longer-term growth model and thus be relevant for a sovereign credit assessment.

Further research on the linkages between sovereign debt and biodiversity and nature loss is therefore needed, in parallel with further integration of nature and biodiversity data in data collection across countries and regions. Current work pursued by the NGFS to design a conceptual framework for nature-related risks including those related to biodiversity loss in financial stability analysis, as well as nature-related scenarios, constitutes an important first step. In addition, the Taskforce for Natural-Related Financial Disclosures (TNFD) is working on a potential application of the TNFD disclosure framework for sovereign debt markets.

67 NGFS, Progress report on bridging the data gaps, 2021 ; NGFS, Final report on bridging the data gaps, 2022.

5. Conclusions

An increasing number of central banks and private sector investors are incorporating climate-related considerations in the management of their investment portfolios. Sovereign debt securities are key for central banks, as they comprise a large part of central banks' investment portfolios – including notably own funds, pension fund portfolios and FX investments (not held for monetary policy purposes). Yet, guidance on how to integrate climate-related issues into sovereign debt portfolios has been scarce until recently, compared to guidance for corporate portfolios.

This document has presented an overview of selected climate-related metrics and data for sovereign securities. It has also listed a series of conceptual and practical implementation challenges for portfolio managers who aim at incorporating climate considerations in their sovereign portfolios. The document is aimed at providing a "one-stop-shop" for central bank investment managers but also for the private sector. It builds on recent guidance including the framework developed by the ASCOR project within the UN PRI (ASCOR, 2023a and 2023b).

As this technical document demonstrates, there are a variety of metrics on individual sovereigns that central bank (and other) investment managers can choose from. In general, the necessary data to construct these metrics are freely available and represent the current state-of-the-art. Nevertheless, some relevant data gaps remain such as for chronic and forward-looking physical risk data. Key methodological gaps include the translation of climate-related risks to sovereign credit risks and bond prices, the aggregation of metrics and assessments for a single sovereign bond at portfolio level, and the climate-related assessment of mixed portfolios of both sovereign and corporate securities.

Implementing climate-related considerations for sovereigns into investment processes is a continuous process rather than a one-off exercise. Typically, implementation would lead to a "climate portfolio tilt" – i.e., a shift in portfolio weights of individual sovereign securities based on their climate-related characteristics. A key implementation challenge is to ensure that the climate portfolio tilt is consistent with other primary central bank objectives such as liquidity, security, and returns. For central banks' own portfolios or pensions funds there is typically more scope for dealing with possible trade-offs between climate and other primary financial objectives. For FX investments (not held for monetary policy goals), the scope is likely more limited – also due to the necessary liquidity requirements and currency composition targets.

Climate-related metrics are complex. Their understanding, selection and potential combination requires specialised expertise. The document lays out a selection of metrics and discusses their pros and cons. Yet, the set of available data and metrics is much broader and bound to expand over time. Keeping track of new developments will be necessary to ensure that central banks use the most up to date and state of the art inputs for their portfolio allocation processes.

In recognising climate-related opportunities, as well as fairness and equity issues, central banks can help to establish a balanced and more holistic view on how to weigh the climate-related characteristics of sovereigns. This may also spark more in-depth practical guidance by widely followed groups such as PCAF, GFANZ or UN PRI ASCOR on how to integrate climate-related considerations for sovereign debt portfolios in investment processes.

Central banks may also be able to utilise their deep research expertise in economics and finance to contribute to further develop metrics and models. As sovereign securities are starting to receive greater attention, more conceptual and practical work on portfolio-level metrics for sovereign debt would be an important first step. Importantly, a translation of physical risks into sovereign credit risks would be a key step to better assess climate-related risks of sovereign securities.

As central banks embark on the journey of assessing the climate-related characteristics of their sovereign debt portfolios, they will build expertise and experience. In disseminating this knowledge and supporting further development of data, metrics and methodologies central banks can make a significant contribution to advancing the assessment of climate-related characteristics of sovereign debt portfolios.

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Appendix

A. Data sources

A.1 Climate risk metrics – data sources

Table A.1 **Selected physical risk data sources and resources**

Data	Description
Worldbank ESG, Climate, and Disaster Risk Data: https://esgdata.worldbank.org/home?lang=en https://climateknowledgeportal.worldbank.org/ https://databank.worldbank.org/source/environment-social-and-governance-(esg)-data https://thinkhazard.org/en/	Collection of indicators for sustainable investment analysis, based on key sustainability criteria, drawn from multiple World Bank databases and external data providers. The Climate Change Knowledge Portal (CCKP) provides global data on historical and future climate, vulnerabilities, and impacts. Web-based tool enabling non-specialists to consider the impacts of natural hazards in individual areas developed and maintained by the Global Facility for Disaster Reduction and Recovery.
IMF Climate Change Indicators Dashboard: https://climatedata.imf.org/ **Climate-driven INFORM Risk:** https://climatedata.imf.org/datasets/7cae02f84ed547fbbd6210d90da19879/explore	Statistical tool linking climate and global economic indicators. Climate-driven INFORM Risk Indicator helps assess risk for climate-driven hazards. It has three dimensions: climate-driven hazard and exposure, vulnerability, and lack of coping capacity.
European Energy Agency: https://www.eea.europa.eu/countries-and-regions https://www.eea.europa.eu/ims	Indicators, country data, maps and charts for the trend (or status) of selected climate phenomena, over a given period of time, specifying whether or not associated policy objectives are being met and quantitative targets reached.
Climate Watch: https://www.climatewatchdata.org/	Open data, visualisations, and analysis on countries' climate progress, exploring GHG emissions and Nationally Determined Contributions (NDCs).
Global Resilience Index Initiative(GRII): https://www.cgfi.ac.uk/global-resilience-index-initiative/	Reference data on climate and natural hazard risks, aimed to assess macro-level and systemic physical climate risks.
Copernicus Climate Change Service (C3S): https://cds.climate.copernicus.eu/#!/home	Freely available climate indices, climate projections, *in-situ* observations, reanalysis, satellite observations, seasonal forecasts.
Climate Adapt: https://climate-adapt.eea.europa.eu/	Climate indices from the Copernicus Climate Change Service in support of climate change adaptation.
Eurostat SDG: https://ec.europa.eu/eurostat/web/sdi/database	Key findings of the Eurostat monitoring of the EU's progress towards the SDGs; information and data on the EU SDG indicators; data visualisation tools to see whether EU members make progress towards the SDGs.
XDI (The Cross Dependency Initiative) Gross Domestic Climate Risk: https://xdi.systems/xdi-releases-world-first-comparison-of-every-states-physical-climate-risk/	Ranking of the physical climate risk of every state, province and territory in the world.
FM Global Resilience Index: https://www.fmglobal.com/research-and-resources/tools-and-resources/resilienceindex	Country ranking of enterprise resilience to disruptive events, determined by 15 drivers of the three core elements of resilience: economic, risk quality and supply chain.

Caribbean Catastrophe Risk Insurance Facility (Member Countries | CCRIF SPC) **The Pacific Catastrophe Risk Insurance Company** (PCRIF Council of Members – PCRIC) **The African Risk Capacity** (Countries | African Risk Capacity Group (arc.int)) **The Southeast Asia Disaster Risk Insurance Facility** (The SEADRIF initiative)	Member countries of catastrophe risk pools that provide their members with insurance solutions against disasters and climate shocks and manage joint reserve funds that retain first losses (part of the ASCOR framework to assess sovereign bond issuers on climate change).
Bloomberg Professional MAP <GO> Sources of datasets: WRI (https://www.wri.org/data), the World Bank (https://maps.worldbank.org/analysis), and UNISDR (https://rix.undrr.org/)	Visualising geospatial datasets on a map and providing historical data, identifying location-based risks and assessment of the potential impact of natural events in selected regions, encompassing cyclone, excessive heat, storm surge, water risk and coral reefs.
The international disasters database: https://www.emdat.be/	Disaster-related economic damage estimates and disaster-specific international aid contributions.
Reinsurers Munich RE and Swiss RE reports on natural disasters: https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2023/natural-disaster-figures-2022.html https://www.swissre.com/institute/research/sigma-research/sigma-2022-01.html	Yearly reports on Natural disaster losses, estimating the economic losses and global economic damages from natural catastrophes with a regional overview.
Assessing climate change risks at the country level: the EIB scoring model (May 2021): https://op.europa.eu/en/publication-detail/-/publication/1a42783a-c283-11eb-a925-01aa75ed71a1/language-en	Assessment of the climate change risks faced by more than 180 countries. The two sets of scores for physical and transition risks aggregate exposures to various risk factors, taking into account the adaptation and mitigation capacity of each country. The acute component of the physical risk scores is measured with data sourced (and later transformed as impact on GDP) from EM-DAT.
Network for Greening the Financial Systems scenario database: https://www.ngfs.net/ngfs-scenarios-portal/data-resources/	The NGFS Climate Scenarios explore a range of scenarios that provide a common and up-to-date reference point for understanding how climate change and climate policy and technology trends could evolve in different futures.
Potsdam Institute for Climate Impact Research (PIK) https://www.pik-potsdam.de/en/output/software-data-models https://www.pik-potsdam.de/~hellmann/registry/all	Open-source Software, Data and Models that improve the understanding of natural and socio-economic systems, as well as providing future scenarios and pathways.
McKinsey Global Institute – Sustainability https://www.mckinsey.com/capabilities/sustainability/our-insights **Climate risk and response (Physical hazards and socioeconomic impacts)** (January 2020) https://www.mckinsey.com/capabilities/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts?sid=3046547320	McKinsey & Company's Sustainability Practice provide cross-disciplinary research and advise clients on sustainability, climate, energy transition, and environmental, social, and governance (ESG). Woods Hole Research Center (WHRC) produced the scientific analyses of physical climate hazards in "Climate risk and response (Physical hazards and socioeconomic impacts)", identifying regions' and countries' level of risk exposure to the climate hazards and to the impacted systems, highlighting a range of vulnerabilities to the changing climate.
Fossil Fuels – Our World in Data https://ourworldindata.org/fossil-fuels	Data on fossil fuel consumption.
Oil Information by IEA https://www.iea.org/data-and-statistics/data-product/oil-information	Annual time series of oil data including oil supply and consumption, trade and oil demand for 153 countries and 25 regions.
Natural Gas Information by IEA https://www.iea.org/data-and-statistics/data-product/natural-gas-information	Time series of annual gas supply balances, imports and exports for OECD and non-OECD countries.
Coal Information by IEA https://www.iea.org/data-and-statistics/data-product/coal-information-service	A comprehensive review of historical and current market trends in the world coal sector.

Energy Technology Patents Data Explorer https://www.iea.org/data-and-statistics/data-tools/energy-technology-patents-data-explorer	Data on clean energy and fossil fuel patents in 44 countries.
Table 2: GDP by sector (in percentage) https://stats.oecd.org/Index aspx?DataSetCode=AEO11_COUNTRYNOTES_TAB2_EN	Data on GDP by sector.
Monthly Oil Data Service (MODS) by IEA https://www.iea.org/data-and-statistics/data-product/monthly-oil-data-service-mods-complete	The complete data behind the IEA's monthly Oil Market Report.
Mineral reserve data United States Geological Survey 2022 https://pubs.usgs.gov/publication/mcs2022	The MCS is the earliest comprehensive source of mineral production data for the world. More than 90 individual minerals and materials are covered.
Copper equivalent (TPI, 2022) https://www.transitionpathwayinitiative.org/sectors/#carbon-performance	TPI's sectoral decarbonisation pathways meet the demand from all stakeholders – investors, companies, civil society organisations – for a credible, rigorous framework for assessing corporate climate change performance. They are recognised by investors as the authoritative translation of the IEA's scenarios into credible performance benchmarks for industry sectors and for individual companies.
IEA's Critical Minerals Policy Tracker https://www.iea.org/reports/critical-minerals-policy-tracker	The Critical Minerals Policy Tracker highlights prominent policies and regulations already in place around the world to enhance security of supply, incentivise new resource development and ensure sustainable and responsible production.
World Resources Institute https://datasets.wri.org/dataset/64b69c0fb0834351bd6c0ceb3744c5ad	Forest restoration opportunities.
Natural Resource Governance Institute https://resourcegovernance.org/publications/2021-resource-governance-index-collection	Indices are mentioned to assess how responsibly a country acts – Resource Governance Index.
Worldwide Governance Indicators by World Bank https://www.worldbank.org/en/publication/worldwide-governance-indicators	The WGI feature six aggregate governance indicators for over 200 countries and territories over the period 1996–2022; Regulatory Quality indicator.
Human Development Index by United Nations Development Programme https://hdr.undp.org/data-center/human-development-index#/indicies/HDI	The Human Development Index (HDI) is a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and having a decent standard of living.; Education Index Indicator.
Reporters Without Borders https://rsf.org/en/index	World Press Freedom Index.
Freedom House https://freedomhouse.org/report/freedom-world	Freedom in the World.
Transparency International https://www.transparency.org/en	Corruption Perceptions Index.
IEA's Energy Technology RD&D Budgets Data Explorer https://www.iea.org/data-and-statistics/data-tools/energy-technology-rdd-budgets-data-explorer	Provides measures for public budgets on energy RD&D, per sector, activity, and technology type, that is updated twice a year and contains data as far back as 1974.
IEA's World Energy Employment https://www.iea.org/reports/world-energy-employment/overview	The IEA provides a global benchmark dataset for employment across the energy sector, providing estimates by activity, region, and value chain segment.
IRENA's Renewable Energy Employment https://www.irena.org/Data/View-data-by-topic/Benefits/Renewable-Energy-Employment-by-Country	IRENA provides a database for renewable energy employment by country, and by technology – that is used by the International Labour Organization for its own analysis and recommendations.
IEA's Gender and Energy Data Explorer https://www.iea.org/data-and-statistics/data-tools/gender-and-energy-data-explorer?Topic=Employment&Indicator=Gender+wage+gap+conditional+on+skills	IEA's Gender and Energy Data Explorer, that provides detailed data on gender gaps in employment and wages in the energy sector – though for a limited set of countries (EU27, UK, US, Canada).

A.2 Climate impact metrics – data sources

Table A.2 **Selected data sources for transition policies (all publicly available)**

Data source and description	Characteristics
Net Zero Tracker https://zerotracker.net/analysis/net-zero-stocktake-2022 Net zero commitments of a comprehensive set of countries.	Easy to use database (https://download.zerotracker.net/csv/snapshot_2023-03-17_09-07-50.xlsx) with a host of quantitative and qualitative characteristics of countries' net zero commitments.
UNFCCC Nationally Determined Contributions Registry https://unfccc.int/NDCREG NDC original documents.	Collection of official NDC documents (text) for all countries that have submitted; not structured.
IGES NDC database https://doi.org/10.57405/iges-5005 Structured database of countries NDC commitments.	Structured database; distributed in one Excel file.
NDC Explorer https://klimalog.idos-research.de/ndc/ Explorer for countries' NDC commitments.	Web interface which allows comparisons across various dimensions.
Climate Policies database https://climatepolicydatabase.org/countries Database for current climate policies as well as NDCs.	Comprehensive set of countries; structured across various dimensions including sectoral policies.
IEA policy database https://www.iea.org/policies Database for energy sector policies.	Covers a broad range of energy-sector policies for a large set of countries, including policies relating to policy objective that go beyond climate change mitigation.
Climate Action Tracker https://climateactiontracker.org/countries/ Policy actions and pathway projections for current and planned policies as well as further details for >40 countries; provides a simple (ad-hoc) rating with five categories.	Most prominent and science-based source for emission pathway projections; for most countries projections for current policies and actions as well as planned policies (including NDCs), and medium-term (2030) emission reduction targets. Allows comparison with implied emission reductions (by 2030) for Paris goals (2 degrees and 1.5 degrees).
1.5 °C national pathway explorer by Climate Analytics https://1p5ndc-pathways.climateanalytics.org/ Implied emission pathways for around 60 countries.	Provides a range of estimates for the1.5 degree warming implied GHG emission pathways (until 2070) for different models and scenarios – including, in many cases, for fair share projections; contains projections for current policies (from Climate Action Tracker) and policy targets and thereby allows the calculation of a Paris emission gap as well as an ambition gap.
Climate Watch https://www.climatewatchdata.org/pathways/ Open data platform which includes the databases above.	In some dimensions, more comprehensive than Carbon Action Tracker and the 1.5 °C national pathway explorer. Requires more in-depth knowledge given the wide array of options for different types of projections.
World Bank State and Trends of Carbon Pricing http://hdl.handle.net/10986/13334 Report on carbon pricing and coverage across a broad range of jurisdictions.	Underlying data for all figures (including key figure on carbon price coverage and pricing) available in one excel file (https://openknowledge.worldbank.org/bitstreams/2f1fc385-20aa-5084-9229-397e5aaa571d/download).
International Carbon Action Partnership https://icapcarbonaction.com Carbon prices and other background information.	Provides, among other things, time series of carbon prices for a broad range of countries and trading venues.
The Notre Dame – Global Adaptation Index https://gain.nd.edu/our-work/country-index/ Public indices that incorporate both risk and opportunity metrics.	It is a publicly available index that assesses a country's current vulnerability to climate disruptions and readiness to make effective use of investments for adaptation actions.

Climate Change Performance Index (CCPI) from Germanwatch and climate Action https://www.germanwatch.org/en/CCPI Independent monitoring tool to enable transparency in national and international climate politics.	The climate protection performance is assessed in four categories: GHG emissions, Renewable energy, Energy use and Climate policy.
Climate Actions and Policies Measurement Framework (CAPMF) by OECD https://www.oecd.org/publications/the-climate-actions-and-policies-measurement-framework-2caa60ce-en.htm Climate mitigation policy database.	The specific database enables the analysis of the effectiveness of climate policies in reducing GHG emissions.
Bloomberg Government Climate Scores https://assets.bbhub.io/professional/sites/10/Government-Climate-Scores1.pdf	It measures how prepared a country or region is for meeting the Paris Agreement goals, in comparison with peers.
Sustainability-Linked Bond Principles https://www.icmagroup.org/sustainable-finance/the-principles-guidelines-and-handbooks/sustainability-linked-bond-principles-slbp/	Measuring key performance indicators (KPIs).
Paris Equity Check https://paris-equity-check.org/warming-check.html	Fairness issues reflected in countries' NDCs are recorded.
Fair share estimates from Climate action Tracker https://climateactiontracker.org/methodology/cat-rating-methodology/fair-share/	Summarised a range of perspectives along four dimensions: responsibility, equality, capability and cost effectiveness.
PRIMAP-hist database https://zenodo.org/records/7727475	Database for historic emissions.
Foreign reserves and own funds https://www.ecb.europa.eu/ecb/tasks/reserves/html/index.en.html	Data on Foreign reserves and own funds of ECB.
MSCI (ITR) https://www.msci.com/our-solutions/climate-investing/implied-temperature-rise	Net-zero alignment solutions by financial service providers.
S&P (ITR) https://disclosure.spglobal.com/ratings/en/regulatory/instrument-details/sectorCode/INFRA/entityId/568495/issueId/1401586	Net-zero alignment solutions by financial service providers.
Carbone 4 Finance (Carbon Impact Analysis) https://www.carbon4finance.com/product/carbon-data	Net-zero alignment solutions by financial service providers.
Ninety One (Net Zero Sovereign Index) https://ninetyone.com/en	Net-zero alignment solutions by financial service providers.
FTSE Russell and Beyond Ratings https://www.lseg.com/en/ftse-russell/beyond-ratings-data	Net-zero alignment solutions by financial service providers.
Ortec Finance (Climate ALIGN) https://www.ortecfinance.com/en/insights/product/climate-align	Net-zero alignment solutions by financial service providers.

Climate modelling tools

Tool	Description
Model for the Assessment of Greenhouse Gas-Induced Climate Change' (MAGICC) https://www.ipcc.ch/site/assets/uploads/sites/2/2022/06/SR15_Chapter_2_LR.pdf	MAGICC is a reduced complexity Earth system model that has been widely used in climate science for over three decades, most notably in multiple IPCC reports. It is most often used in a probabilistic setup, providing information not only about our best-estimate of future climate change but also the uncertainty that arises from interactions between the Earth system's many components. MAGICC is also as the climate component in multiple integrated assessment models (IAMs).
Hector https://jgcri.github.io/hector/	Hector is a simple and quick to run climate model that can translate GHG emissions into temperature increases.

A.3 Metrics for social impact and just energy transition

Table A.3 **Metrics for social impact and just energy transition**

Measures	Metrics	Explanation of metrics	How it can help just transition
Employment	Employment/ Unemployment rate	Percentage of working age population employed/unemployed.	A decrease in unemployment indicates that renewable energy is compensating jobs lost in polluting sectors.
	Labour Force Participation Rate	The percentage of working-age population that is either employed/actively seeking employment.	An increase in labour force participation rate potentially indicates the effectiveness of the transition policies in creating new job opportunities.
	Average Wage	Average amount of money earned (gross earnings) per employee in an industry during taxable year by the number of working days.	Increase in the average wage could suggest that the transition policies are contributing to the creation of higher-paying jobs.
	Job Training and Skill Acquisition	Number of people who have received job training or acquired new skills through the transition policies. Metrics can be measured through number of trainings per employee, course enrolment data, course completion data, etc.	Higher number indicates more people are equipped with new skills necessary to obtain new jobs or transition to new industries.
	Industry Growth	Growth of industries that focus on transition policies (percentage rate of industry's market size).	An increased growth indicates that the policies has managed to promote the growth of new industries and creating job opportunities in those sectors.
Social implications	Job Creation and Retention	The number of jobs created or retained as a result of the just transition policies. Percentage of employees who remain with a company over a certain period.	A positive (and increasing) number of job creation and retention indicate that the policies provide adequate and sustainable social protection for job losses in "brown" industries.
	Income Inequality	Distribution of income across the population that is calculated using Coefficient of variation (CV) by dividing the standard deviation of income distribution by its mean.	A decrease percentage of income inequality indicates that benefits of the transition are distributed equitably across all communities.
	Education and Training	Level of education and training provided to individuals affected by the just transition policies. Metrics can be measured through number of trainings per employee, course enrolment data, course completion data, etc.	Higher number of education level and training provided indicate that the workers are equipped with the skills necessary to obtain new jobs in the low-carbon economy.
	Public Health	The impact of the just transition policies on public health, including metrics such as air quality, water quality, and exposure to harmful pollutants.	Overall positive metrics on public health indicates improved public health condition as a result of transition policies.
	Community development	The revitalisation of communities affected by the transition policies. It includes metrics such as crime rates, access to affordable housing, and investment in public infrastructure.	Overall positive metrics (i.e., reduced crime rates, increased affordable housing, and increased investment in public infrastructure) indicates a positive impact of transition policies towards communities' revitalisation.
Just Energy	Job creation and retention	The number of jobs created or retained as a result of the transition to a low-carbon economy. Percentage of employees who remain with a company over a certain period.	Higher number indicates the effectiveness of policy in supporting the workforce and ensuring a just transition.
	GHG emissions reduction	The amount of GHG emissions reduced as a result of the transition to a low-carbon economy. Carbon Footprint = Activity Data x Emission Factor.	A decrease in GHG emissions indicates the effectiveness of JETP in reducing the carbon footprint and promoting a more sustainable future.
	Investment attraction	The amount of investment attracted to the low-carbon economy.	Higher investment flows indicate the signalling effect of climate policy, that is, its ability to create market confidence and attract investments in a more sustainable future.

	Stakeholder engagement	The level of engagement and collaboration with stakeholders, including local communities, industry, and civil society. Measure could be done by tracking the stakeholder engagement with their tier-based mapping (determined by their interest, influence, and discussion).	Higher stakeholder engagement activities indicate the effectiveness of climate policy in promoting partnerships and building consensus towards a just transition.
	Innovation and technological advancement	One method that could be used is Solow residual (Total Factor Productivity). Under the Solow Residual assumes that any variations in output that cannot be attributed to alterations in the number of workers or capital must be the result of advancements in technology.	A positive total factor productivity indicates climate policy is promoting the development of new technologies and driving innovation towards a more sustainable future.

B. Overview of the ASCOR framework and key difference to this report

ASCOR is an investor-led initiative with the specific aim of providing a tool for climate-related assessments of *sovereigns*. The ASCOR framework, developed with the help of the Transition Pathway Initiative Centre, consists of a set of indicators for the "assessment of the progress made by countries in managing the low-carbon transition and the impacts of climate change" (ASCOR, 2023b).

The ASCOR framework proposes a defined set of metrics to assess sovereign climate risks and opportunities. These are broken down into three pillars: Emission Pathways, Climate Policies and Climate Finance (Figure A.1). Each pillar covers a number of areas (e.g., area EP.1 Emissions Trends under the Emission Pathways Pillar). These areas are key for the overall assessment, as the ASCOR framework at this point does not envisage assessments at the pillar level nor prescribes how assessments should be aggregated across areas (for instance to reach a single overall assessment for a given sovereign).

Each area is comprised of two or more binary (i.e., Yes/No) indicators[68]. These indicators are based on climate metrics (e.g., metrics for GHG emissions) and transformed into binary indicators. For instance, the first indicator of EP1 Emission trends corresponds to the question "Have the country's emissions decreased in the last 5 years?". The ASCOR framework the proposed either a single or a range of climate metrics that are used to determine the corresponding binary climate indicator.

The indicators are then "aggregated" to an area assessment (e.g., for area EP.1 on Emissions Trends). The assessment is a variable that can take four values: Yes – if all underlying indicators are also Yes; Partial – if the underlying indicators are a mix of Yes and No; No – if all indicators are No; and exempt, if a given country is exempt from all indicators in a given area.

Figure A.1 **Overview of pillars and areas covered in the ASCOR framework**

Pillar 1: Emission Pathways (EP)	Pillar 2: Climate Policies (CP)	Pillar 3: Climate Finance (CF)
EP 1. Emission trends EP 2. 2030 targets EP 3. Net zero targets	CP 1. Climate legislation CP 2. Carbon pricing CP 3. Fossil fuels CP 4. Sectoral transitions CP 5. Adaptation CP 6. Just transition	CF 1. International climate finance CF 2. Transparency of climate costing CF 3. Transparency of climate spending CF 4. Renewable energy opportunities

Source : ASCOR (2023b).

68 In addition to Yes/No values, indicators also record cases where there is no data is available from the given data sources that the ASCOR framework relies on. Further, middle and lower-income countries (either according to the World Bank definition or by definitions specific to the parties to the UNFCCC) may be exempt from some of the indicators.

B.1 Commonalities and differences between the ASCOR framework and the approach taken in this report

The approaches of the ASCOR framework and this report are closely aligned in general, but there are notable differences in purpose, scope and the type of metrics proposed. Both the ASCOR framework and this report aim at providing a set of metrics for an assessment of climate-related risks and opportunities for sovereigns and focus on metrics and indictors based on publicly available data. ASCOR plans to make the broad and relevant set of metrics used in their framework publicly available on a dedicated website and therefore will provide a valuable resource.

A difference in purpose is that the ASCOR framework focusses on how governments manage the transition and climate risks and therefore does not attempt to assess climate-related sovereign risks directly. This report explicitly covers metrics to assess such risks – in particular physical risks.

A key conceptual difference of the ASCOR framework is its focus on a pre-defined set of metrics. It thereby serves the purposes of narrowing down the large number of potential metrics to a manageable set. This feature enables easier and faster implementation. Some central bank investment managers may choose to use different or more specific metrics with direct relevance to their central bank's investment or climate objectives.

Most metrics used in the ASCOR framework are also discussed in this report and therefore ASCOR is set to be a valuable data resource. In general, the ASCOR framework focusses more strongly on metrics based on data or directly reported by governments. This technical document covers a broader range of metrics – in particular composite indicators (e.g., various climate policy and risk indices), scores (e.g., sovereign ESG scores) and more complex but potentially relevant metrics capturing net-zero portfolio alignment (e.g., implied temperature rise (ITR)).

The use of binary indicators as a type of metric is another key conceptual difference of the ASCOR framework. Binary indicators are a transparent way of overcoming the challenge of combining fundamentally different types of indicators. Central bank investment managers could weigh and aggregate these indicators appropriate for their needs and investment processes. This report, in contrast, focusses on continuous metrics, which allow a finer differentiation between countries. Central bank managers may decide to translate climate-related metrics into scores or other types of ratings which reflect their assessment of and need for differentiation between better and worse performing sovereigns. Such scores and ratings could then also be used to combine different climate-related metrics.

C. Portfolio alignment measures – an application to sovereign debt securities

For corporate securities, there are several relevant guidance documents on how to construct portfolio alignment measures for *corporate securities* such as PAT (2020), GFANZ (2022) or the Alignment Cookbook (Institut Louis Bachelier et al. 2020), which compares the different alignment methodologies. Similar guidance for *sovereign securities* is still lacking.

The building blocks, however, are in principle the same as in the case of corporate securities – with the exception that sovereign securities are less complex to assess. First, a benchmark needs to be defined against which the portfolio should be assessed. In the case of corporate securities, this is a complex task as it naturally requires that climate targets (such as 1.5 °C or 2 °C pathways) have to be translated into a target for a given company (for instance by defining sectoral pathways and assigning the company to a given sector). In the case of sovereigns, this crucial step is not necessary as the country encompasses all sectors and all companies in it. In addition, and as detailed in the main report, data for country-level pathways is publicly available. The second step is then to calculate the alignment metric – either a carbon budget overshoot or an Implied Temperature Rating (ITR). Here, again, data for calculating a countries' performance can be based on publicly available data – say using the emission levels implied by a countries' NDC or actually implemented policies.

Hence applying the techniques used for corporate securities, it is in principle possible to calculate a portfolio alignment for a portfolio of sovereign securities based on publicly available data. As mentioned in the main report, calculating an ITR is more complex, but can be approximated in some cases with a simple formula as mentioned below. The following outlines how such a calculation could look like.

C.1 Calculating the portfolio benchmark

As outlined in section 3.1 on transition policies, Climate Action Tracker provides data for absolute emissions in 2030 for 1.5 °C and 2 °C modelled pathways, as well as a fair share targets[69]. The 1.5 °C national pathway explorer by Climate Analytics provides emission reduction targets compatible with a 1.5 °C pathway for individual years for a range of pathways (derived using different climate models and different scenarios) for different reference years (1990, 2010 and 2020). These reductions targets for each country can be used to calculate portfolio benchmarks.

As noted above, it is crucial to use globally consistent national metrics to derive the portfolio benchmark. In the case of the 1.5 °C national pathway explorer, the downloadable data provides absolute emissions data per climate model and scenario. For each country, the same model-scenario combination needs to be used for calculating the benchmark[70, 71].

Climate Action Tracker presents an emission range for each of their rating category, which corresponds to pathways for different scenarios and model runs. The pathways corresponding to the 5 different rating categories correspond to global warming levels above 4 °C (critically insufficient), 3 °C 4 °C (highly insufficient), 2 °C 3 °C (insufficient), 1.5 °C 2 °C (almost sufficient or 2 °C compatible) and a 1.5 °C compatible pathway[72]. Using Carbon Action Tracker, therefore, lends itself to using a benchmark range using the lower end and upper end of the range.

An absolute carbon emissions benchmark can then be calculated as follows:

$$Sov\ portfolio\ benchmark\ emissions_{temp\ target,t+h}^{scenario,model} = \sum_{c=1}^{C} \omega_{benchmark}^{c} \times modelled\ Sov\ \ emissions_{temp\ target,t+h}^{c,scenario,model}$$

where c is a given issuer country, C is the set of issuer countries included in the benchmark, $t+h$ is the time horizon (e.g., 2030), and *temp target* is the desired temperature target. The benchmark weighting for each country is chosen by the central bank and can potentially reflect a wide range of aspects. A natural choice is current portfolio weights of a central bank's sovereign debt portfolio, which facilitates a portfolio alignment measure that reflects the improvement from adjustments in portfolio allocations.

A benchmark range can be calculated analogously. The lower (upper) bound of the benchmark can be calculated using the low (upper) end of the modelled emission range for each countries' modelled emissions to be included in the benchmark portfolio. Aggregating the ranges across countries leads to a portfolio benchmark range that is potentially too wide[73]. In practice, this bias may not be very large, but it can be relevant if the portfolio alignment measure is close to the lower or upper bound of the range.

The absolute carbon emissions benchmark can form the basis for a range of possible metrics (see also section 2.2 for a discussion of the pros and cons of different emission metrics). Central banks could choose a "fair share" metric, for

69 Fair share targets are calculated using a complex framework and allow for various definitions of fairness, distinguishing between responsibility, equality, capability, and costs. Hence in the Carbon Action Tracker these estimates are presented as a range. The UN PRI ASCOR project uses a simpler method to calculate fair share weights for a given country by a simple average of historic emission per capita, GDP per capita and population.

70 The choice of model-scenario combination depends on preference. Different emission pathway outcomes cannot be directly related to structural features of the model or specific modelling assumptions. Therefore, there is no "better" or "worse" choice of model. Some scenarios (for a given model) are designed to generate lower or higher emission outcomes, which may help to determine the preferred choice.

71 See https://climateactiontracker.org/methodology/cat-rating-methodology/modelled-domestic-pathways/.

72 The same model-scenario combinations are consistent across countries as global emission pathways are downscaled to the country level. The individual national / domestic pathways are therefore globally consistent by construction.

73 This bias arises as a given scenario may be a scenario with the highest emissions for one country, but not for another country. Aggregating the lower and upper bounds across countries will therefore lead to an emission range this is too wide. This bias increases with the number of countries included in the benchmark. At the same time, such a bias may be acceptable given the inherent uncertainties in the estimation of global emissions pathways more generally.

instance, to reflect the fact that countries with historically lower emissions or a lower level of development should shoulder less of the carbon reduction burden. Instead of absolute emissions, the benchmark could be calculated as emission intensity – for instance as absolute emissions divided by PPP-adjusted GDP (as in PCAF (2022)) or as emission per capita. In practice, this normalisation by different metrics presents a different weighting across countries (a different allocation of the global "carbon budget") and requires expert judgement (see also Box A in the main document on the complex issue of fair share).

Another highly relevant option, as described in detail below, is to transform the absolute emissions for a given date into a relative emission reduction target (e.g., 55% between 2020 and 2030) or even an annual percentage for carbon emissions reductions[74]. As regards setting possible carbon intensity benchmarks, Cheng et al (2022) simulate different paths of sovereign portfolio carbon intensity based on various annual targets of carbon emissions reductions. With an annual reduction target of 5% for portfolio carbon intensity, the portfolio can achieve a cumulative reduction in portfolio carbon intensity by 24% over five years. Should the annual target increase to 10%, the cumulative reduction could reach 44.5%. In comparison, a "business-as-usual" benchmark can only achieve 8.5% of reduction in portfolio carbon intensity over the same period.

C.2 Portfolio alignment metrics

Portfolio alignment metrics can be either forward-looking ($t + h$) or based on recent past trend of emissions which are typically backward looking, as sovereign emission data typically comes with a delay of 1-2 years. Most alignment methodologies focus solely on forward-looking modelled emissions (CDP-WWF (2020), GFANZ (2022), Institut Louis Bachelier et al (2020), NZAOA (2023), PACTA, etc.). Natural candidates are emissions based on current policies as provided by Carbon Action Tracker or the Business as Usual (BaU) emissions projections in the IMF Climate Indicators dashboard[75].

Analogous to the benchmark calculation above, the financed portfolio-level emissions can be calculated as:

$$Sov\ portfolio\ emissions_{t+h}^{policy\ scenario} = \sum_{c=1}^{C} \frac{amt\ sov\ bond^{c}}{total\ amt\ sov\ portfolio} \times projected\ sov\ \ emissions_{t+h}^{c,policy\ scenario}$$

A straight-forward measure is the emission gap or carbon budget overshoot (expressed in percentage terms):

$$emission\ gap(\%)_{temp\ target,t+h}^{policy\ scenario} = \frac{Sov\ portfolio\ emissions_{t+h}^{policy\ scenario} - Sov\ portfolio\ benchmark\ emissions_{temp\ target,t+h}^{scenario,model}}{Sov\ portfolio\ benchmark\ emissions_{temp\ target,t+h}^{scenario,model}} \times 100$$

The portfolio emission pathway can be translated into an implied temperature rise (ITR). If the sovereign portfolio emissions are equal to, say, a 2 °C benchmark then the ITR is 2 °C. With a positive emissions gap, the ITR is higher than the temperature target. As noted above, the appropriate method to calculate an ITR is to use the carbon pathway of the portfolio as an input to climate models that then calculate the ITR (such as MAGICC or Hector). A "rough and ready" method for calculating the ITR with small deviations from the benchmark (measured in Gigatons of CO_2 (Gt CO_2)) is to use a simple science-based formula:

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

74 Using the 1.5 °C national pathway explorer data, annual reduction targets can be precisely calculated to reflect the changing dynamics of reductions over time implied by a given model-scenario pathway.

75 Portfolio alignment may also be measured reflecting pledged future policies such as NDCs. As this introduces additional uncertainty (see section 3.1) and does not reflect the "current state of affairs", measuring alignment based on current policies and actions appears a more natural choice.

The IPCC in its latest synthesis report (IPCC (2023) section B 5.2) notes, however, that 0.00045 °C per $GtCO_2$ warming potential is a best estimate with a likely range from 0.00027 to 0.00063 °C per $GtCO_2$. Using this approximation would therefore call for the reporting of an ITR range reflecting the uncertainty around this linear estimate.

An alignment measure can also be computed by comparing benchmark emissions for a past date with reported emissions. A prominent case, for instance, are the EU climate benchmarks, which set a 7% annual financed emission reduction target for investment funds that aspire to use a "Climate Transition Benchmark" or "Paris-Aligned Benchmark" label[76]. In the case of forward-looking (i.e., projected emissions), a natural choice are the projections reflecting current policies, as provided (where available) by Carbon Action Tracker or in the 1.5 °C national pathway explorer by Climate Analytics.

For reported emissions, different scopes (scope 1-3) or different types (production-based versus consumption based) may be available. It is important to note, however, that the data for emission benchmarks, which are estimated from complex climate models, currently reflect production-based scope 1 emissions excluding land use, land use change and forestry. A like-for-like comparison would therefore be restricted to exactly those emissions. If benchmarks are translated into annual percentage emissions reduction targets, using other scopes and types of reported emissions to measure alignment may still yield a reasonably consistent measures and correct for some of the weaknesses of production-based scope 1 emissions as discussed in section 2.2.

76 The EU benchmark regulation sets a 7% carbon intensity reduction target on the portfolio level and represents an approximation based on IPCC's 1.5 °C trajectory with no or limited overshoot (Years 2020-2030, Table 2.1, Rogelj et al., 2018). The regulation only applies to equities and corporate bonds, however. See EU TEG (2019).

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Glossary

Carbon footprint: A measure to assess carbon emissions associated with the investments held within a financial institution's portfolio.

Carbon leakage: situation where, due to stringent climate policies or reputational reasons, businesses were to transfer carbon-intensive production to other firms outside the corporate group perimeter or to countries with laxer emission policies, which may lead to an increase of emissions. The additional emissions resulting from such actions is considered carbon leakage.

Decarbonization and "paper decarbonization": while decarbonization is a deliberate process of reduction of carbon emission pursued by an organization (e.g. issuer or investor), "paper decarbonization" may entail a pure nominal (and potentially unintentional) reduction of carbon metrics (e.g. carbon intensity or footprint) due to monetary or financial reasons, which do not lead to real-world carbon emissions reduction.

ESG integration: An SRI strategy that aims to enhance traditional financial (risk) analysis by systematically including ESG criteria in the investment analysis to improve risk-adjusted returns.

Extra-financial objective: A set of sustainability goals, which can be determined either in general (e.g., ESG score) or in specific objectives (e.g. climate, environmental, social, governance).

Fiduciary duty: Obligation of an investment manager to act in the fiduciary's best interest, according to a pre-agreed set of investment objectives.

Financial objective: A set of goals set for the investor's portfolio in terms of return, risk, and liquidity, which can be determined either in absolute terms or relative to a benchmark.

GHG emissions: Gases released into the Earth's atmosphere that contribute to the greenhouse effect and global warming. The primary greenhouse gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases.

Green bonds: Bonds for which the proceeds should be used exclusively for (predefined) green projects.

Impact investing: An SRI strategy that aims to achieve a quantifiable positive impact alongside financial returns.

Investment strategy: A set of principles and criteria based on risk tolerance, time horizon, and investment objectives, designed to guide investor's decision to achieve investment goals.

Labelled bonds: Bonds that have specific environmental, social, or governance (ESG) or sustainability purposes. The collected proceeds are used to funding projects or expenditures with ESG benefits or facilitating improvements to an issuer's sustainability targets.

Metrics: Indicators summarizing the evaluation of an issuer's sustainability performance, exposure, and management ability with regard to sustainability risks/opportunities.

Negative screening: A SRI strategy that systematically excludes companies, sectors, or countries from the investment universe.

Net zero strategy: A SRI strategy that aims to align investment portfolios with the goal of achieving net zero greenhouse gas emissions.

Own funds: Any portfolio of a central bank that is not related to a formally mandated (policy) goal, but that is held, for example, to make up for operating expenses or for gathering market intelligence.

Pension funds: Portfolios managed by central banks that serve as long-term savings accounts for retirement and have a longer investment horizon.

Policy portfolios: Any portfolio which has been formally mandated to the central bank, e.g., for monetary policy purposes, foreign exchange interventions, etc.

SRI: Sustainable and Responsible Investment – used as an umbrella term under which multiple strategies and investment practices can be placed that explicitly take climate or broader ESG criteria into account.

Scope 1 greenhouse gas emissions: Direct emissions of greenhouse gases that occur from sources that are owned or controlled by the reporting corporate entity.

Scope 2 greenhouse gas emissions: Indirect emissions of greenhouse gases associated with the consumption of purchased or acquired electricity, steam, heating, and cooling by a firm.

Scope 3 greenhouse gas emissions: Indirect emissions that occur along the value chain of a firm, including both upstream and downstream activities that are outside the corporate direct operational control.

Sustainability risks: Negative financial impacts stemming from a diversity of sustainability factors, e.g. climate-related, environmental, social and governance issues regarding the investee behaviour. These risks can entail different materiality of impacts on asset risk/return profile and can be measured through several data types.

Stewardship: Range of activities undertaken by shareholders to monitor, engage, and intervene on matters that may affect the long-term value of investee companies.

Strategic asset allocation: A portfolio strategy whereby the investor sets target allocations for various asset classes.

Sustainability-linked bonds (SLBs): Bonds where the financial terms, including the coupon rate or principal amount, are linked to the issuer's achievement of predefined sustainability targets or performance metrics.

Sustainable bonds: Bonds with proceeds earmarked for financing projects or activities that have positive environmental or social impacts.

Taxonomy: A set of criteria established as a basis for an evaluation of whether and to what extent a financial asset will support given sustainability goals.

Third-party assets: Assets that a central bank manages on behalf of a third party.

Tilting: A strategy where an investor adjusts the weightings of certain assets within their portfolio relative to a standard benchmark or index, with the aim to enhance returns, manage risk, or realise sustainability objectives.

Total carbon emissions: The sum of greenhouse gas emissions associated with the investments held within a financial institution's portfolio.

Voting and engagement: A SRI strategy that involves exercising ownership rights and "voice" to change a company's behavior with regards to ESG issues, such as the violation of international standards and norms.

Labelled bonds: Bonds with specific characteristics or purposes explicitly "labelled" at the time of issuance. These bonds often finance projects or initiatives that align with certain ESG criteria. Examples of labelled bonds include green bonds, social bonds, sustainability bonds.

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