Papeles de Energía

Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice

Nº33
Octubre 2026

High Level Conference Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice Soledad Núñez

Adapting to Physical Climate Risk: Evidence, Decisions and the Missing Bridge to Finance Iñigo J. Losada

Climate Risk and Sustainable Finance Anil Markandya

Financing the Transition. From Bridgetown to a new architecture for public and private climate finance: personal reflections Avinash Persaud

Climate and Nature-Related Risks: From Awareness to Action Frank Elderson

Incorporating Climate Change into Traditional Supervision Kevin Stiroh

Climate Risk and Central Bank Operations: Evolving Good Practices and Innovative Approaches Rob Patalano and Enrique Serrano Rodríguez

From Carbon to Collateral: Five Years of Greening the Plumbing of Monetary Policy Caspar Siegert and James Talbot

Central Bank Portfolios and the Climate Transition: From Market Neutrality to Leadership Through Transparency Juan Ayuso

Climate Data and Analytical Tools — the Role of Innovation Elena Triebskorn

Integrating the Climate Dimension into Economic Statistics: The Experience of the Banco de España Luis Ángel Maza

Comparable, Forward-Looking, Independent Climate Data as a Public Good Carmen Nuzzo

NGFS Climate Scenarios: Bridging Climate Realities with Policy Action Agnieszka Trzcinska

Clear Waters and Financial Stability: From Risk Recognition to Economic Resilience Yann Marin

funcas

Papeles de Energía

EDITOR

Pedro Linares

CONSEJO EDITORIAL

Claudio Aranzadi, Pablo Arocena, Laura Díaz Anadón, Gonzalo Escribano, M.ª Paz Espinosa, Natalia Fabra, Dolores Furió, Tomás Gómez San Román, Xavier Labandeira, Juan Luis López Cardenete, Mariano Marzo, Carlos Ocaña, Ignacio Pérez Arriaga, Desiderio Romero, Gonzalo Sáenz de Miera, Antonio Soria.

Papeles de Energía no se solidariza necesariamente con las opiniones, juicios y previsiones expresadas por los autores de los artículos incluidos en la publicación, ni avala los datos que estos, bajo su responsabilidad, aportan.

Edita: **Funcas**
Caballero de Gracia, 28. 28013 Madrid

Diseño y maquetación: Funcas

ISSN impreso: 2530-0148
ISSN digital: 2445-2726

Depósito Legal: M-7537-2016

© Funcas
Todos los derechos reservados. Queda prohibida la reproducción total o parcial de esta publicación, así como la edición de su contenido por medio de cualquier proceso reprográfico o fónico, electrónico o mecánico, especialmente imprenta, fotocopia, microfilm, *offset* o mimeógrafo, sin la previa autorización escrita del editor.

PATRONATO

Isidro Fainé Casas (Presidente)
Antonio Romero Mora (Vicepresidente)
Fernando Conlledo Lantero (Secretario)
Antón Joseba Arriola Boneta
Manuel Azuaga Moreno
José Manuel Domínguez Martínez
Carlos Egea Krauel
Miguel Ángel Escotet Álvarez
Amado Franco Lahoz
José María Méndez Álvarez-Cedrón
Pedro Antonio Merino García
Antonio Pulido Gutiérrez

Índice

3 **Introducción: Climate Risk and Sustainable Finances: Bridging Policy, Research and Practice**

9 **High Level Conference Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice**
Soledad Núñez

13 **Adapting to Physical Climate Risk: Evidence, Decisions and the Missing Bridge to Finance**
Iñigo J. Losada

37 **Climate Risk and Sustainable Finance**
Anil Markandya

53 **Financing the Transition. From Bridgetown to a new architecture for public and private climate finance: personal reflections**
Avinash Persaud

67 **Climate and Nature-Related Risks: From Awareness to Action**
Frank Elderson

77 **Incorporating Climate Change into Traditional Supervision**
Kevin Stiroh

89 **Climate Risk and Central Bank Operations: Evolving Good Practices and Innovative Approaches**
Rob Patalano and Enrique Serrano Rodríguez

111 **From Carbon to Collateral: Five Years of Greening the Plumbing of Monetary Policy**
Caspar Siegert and James Talbot

123 **Central Bank Portfolios and the Climate Transition: From Market Neutrality to Leadership Through Transparency**
Juan Ayuso

139 **Climate Data and Analytical Tools — the Role of Innovation**
Elena Triebskorn

151 **Integrating the Climate Dimension into Economic Statistics: The Experience of the Banco de España**
Luis Ángel Maza

163 **Comparable, Forward-Looking, Independent Climate Data as a Public Good**
Carmen Nuzzo

179 **NGFS Climate Scenarios: Bridging Climate Realities with Policy Action**
Agnieszka Trzcinska

189 **Clear Waters and Financial Stability: From Risk Recognition to Economic Resilience**
Yann Marin

INTRODUCCIÓN

Climate Risk and Sustainable Finances: Bridging Policy, Research and Practice

El cambio climático y la transición hacia una economía baja en carbono tienen implicaciones que van más allá de la política medioambiental y afectan al funcionamiento de la economía y del sistema financiero. Esta cuestión ya ha sido objeto de análisis en esta revista: en febrero de 2022 cubríamos el impacto del cambio climático en la economía española, tanto en términos de riesgos de transición como de riesgos físicos. Y la evaluación de estos aspectos, así como su incorporación al mundo financiero y a la supervisión bancaria, han seguido avanzando, y mucho, desde entonces.

El interés de los bancos centrales por las implicaciones del cambio climático responde, precisamente, a su potencial impacto sobre variables como la estabilidad financiera, la valoración de los activos, el crecimiento, la evolución del sistema energético o la inflación, lo que hace necesario profundizar en su análisis. Abordar estas cuestiones exige, además, combinar conocimientos y perspectivas procedentes de distintos ámbitos. La interacción entre bancos centrales, responsables de políticas públicas, académicos y expertos permite conectar los avances de la investigación con las necesidades de la toma de decisiones y la experiencia práctica. Este diálogo resulta especialmente relevante en un ámbito todavía en evolución, en el que persisten retos analíticos y de información y donde la cooperación y el intercambio de conocimiento contribuyen a desarrollar herramientas y enfoques más sólidos para comprender y gestionar los riesgos relacionados con el clima.

En esta línea de diálogo, el 25 de marzo de 2026, el Banco de España organizó junto con la Network for Greening the Financial System (NGFS), el Centre for Economic Transition Expertise (CETEx) y el Transition Pathway Initiative Centre de la London School of Economics, una conferencia de alto nivel sobre riesgo climático y finanzas sostenibles, en la que se intercambiaron opiniones de gran relevancia acerca de las políticas, la investigación y también la puesta en práctica de todas estas cuestiones. Gracias a la generosidad del Banco de España, y en particular a la colaboración de Clara I. González, coordinadora de finanzas sostenibles en la Oficina Ambiental, Social y de Gobernanza del Banco de España, y coeditora de este número, tenemos la suerte de ofrecer en esta edición las reflexiones de la gran mayoría de los ponentes que participaron en la conferencia.

Los artículos que integran esta publicación ofrecen una visión amplia de los principales retos que el cambio climático plantea a la economía y al sistema financiero, así como de los enfoques que se están desarrollando para abordarlos desde diferentes perspectivas.

En primer lugar, la subgobernadora del Banco de España, **Soledad Núñez**, advierte de la urgencia cada vez mayor de este diálogo, en un entorno geopolítico cada vez más complejo. También subraya la necesidad de reforzar la agenda climática, para impulsar la competitividad y construir economías resilientes, dos conceptos que se refuerzan mutuamente. Esta realidad supone un reto fundamental para los bancos centrales y entidades supervisoras: deben entender cada vez mejor los riesgos climáticos, cómo afectan a la economía y a la estabilidad financiera, todo ello como una parte integral de su mandato. Esto requiere contar con datos fiables, comparables, y suficientemente detallados y sobre todo, la colaboración entre instituciones, construyendo puentes entre la academia y la política, el sector público y privado, o entre jurisdicciones. Dilatar estas actuaciones solo aumentará el coste de la transición y los riesgos económicos y financieros.

A continuación, **Íñigo Losada**, profesor del IH Cantabria, expone claramente los riesgos físicos a los que nos enfrentamos a causa del cambio climático. Ahora bien, también plantea que la magnitud de ese riesgo dependerá de nuestras decisiones: de las que adoptemos respecto a qué queremos proteger de nuestras economías, en qué medida, para quién y cuándo. Estas decisiones se adoptan generalmente a nivel local, bajo gran incertidumbre y con criterios múltiples; y el sector financiero todavía tiene que internalizar estos aspectos.

El autor traslada cuatro mensajes relevantes: primero, el riesgo está en los extremos, su secuencia temporal y su refuerzo en magnitud; segundo, la adaptación debe basarse en el riesgo tolerado y la flexibilidad a nivel local; tercero, el déficit de implementación está en la gobernanza y la permeabilidad de la financiación entre administraciones; cuarto, el nivel de adaptación óptima no puede limitarse a minimizar el coste o lograr el aseguramiento. Losada concluye que la adaptación debe hacerse legible para el sector financiero, y que este sector debería dejar de considerarla como un elemento exógeno.

Anil Markandya, profesor de investigación del Centro Vasco para el Cambio Climático – BC3, repasa la conexión entre estos riesgos y las finanzas sostenibles, en el marco de una crisis planetaria triple e interrelacionada: cambio climático, biodiversidad y contaminación atmosférica. El autor señala que existe un déficit muy significativo de financiación, además sesgado a favor de la mitigación. La financiación de la adaptación no alcanza aún el 10 % de sus necesidades. Si se unen todas las necesidades, alcanzarían un 6,6 % del PIB global, con un 4,8 % aún por cubrir, fundamentalmente por parte del sector privado. Cerrar el hueco requerirá distintos instrumentos.

Ante esta necesidad de movilizar financiación, **Avinash Persaud**, asesor especial para Cambio Climático del presidente del Banco Interamericano para el Desarrollo, plantea una útil taxonomía para la financiación necesaria, en función de sus usos. Según Persaud, los distintos tipos de inversión necesaria difieren en cuanto a la posibilidad de obtener ingresos, o en los ahorros sociales, o en los costes que suponen. Y por tanto, considera necesario dividir las fuentes de financiación en función de ello. Así, el autor propone que el capital privado se dedique a las actividades con ingresos; que la inversión en resiliencia se financie mediante bancos de desarrollo multilaterales; y que los daños del cambio climático se cubran mediante ayudas y transferencias fiscales. En su opinión, esta división hará que se utilicen mejor los recursos públicos y se gestionen mejor los riesgos.

Entrando ya en el mundo de la supervisión bancaria, **Frank Elderson**, Vice-Chair del consejo de supervisión del Banco Central Europeo, comienza recordando que los riesgos físicos y los riesgos de transición son dos caras de una misma moneda: si la transición es desordenada, aumentará el riesgo para los bancos; y si se retrasa la acción climática, los riesgos físicos serán mayores. Por tanto, deben analizarse de forma conjunta, pero sin que esto suponga confinarlos como un tipo de riesgo aparte. Estos riesgos influyen en los riesgos de mercado, los riesgos de crédito y los riesgos operacionales, y por tanto son parte esencial del negocio diario de los bancos y de sus entidades supervisoras. Es preciso, pues, integrarlos en su práctica de gestión de riesgos y carteras, y usar la planificación de la transición como una herramienta prudencial. Y hacerlo de forma homogénea y consistente. La supervisión bancaria juega un papel fundamental en este proceso, pero los bancos no deben gestionar estos riesgos solo porque los supervisores lo exijan, sino porque los riesgos son reales, y su buena gestión puede suponer una importante ventaja competitiva para Europa.

Kevin Stiroh, senior fellow de Resources for the Future, incide en ideas similares. En primer lugar, defiende que los riesgos climáticos son riesgos materiales y, por tanto, deben incorporarse en los marcos actuales de gestión de riesgo y de supervisión. Esto a su vez requiere un ejercicio de prospectiva que cuantifique empíricamente los riesgos futuros (que no serán iguales que los pasados). Finalmente, considera imprescindible reconocer la heterogeneidad entre los bancos en cuanto a sus distintas exposiciones, huellas geográficas o foco sectorial. Las soluciones, por tanto, deberán ser particularizadas para cada banco, según su exposición, modelo de negocio y actitud frente al riesgo.

Robert Patalano y **Enrique Serrano Rodríguez**, investigadores del Centre for Economic Transition Expertise (CETEx), repasan las distintas formas en las que los bancos centrales están incorporando estas demandas, con particular atención hacia las reformas introducidas por el Banco Central Europeo y el Banco de Inglaterra. Los autores consideran que las autoridades monetarias están gradualmente moviéndose de la compra de activos "verdes" hacia la integración de las consideraciones climáticas en la valoración de colaterales y los marcos de gestión

de riesgo. Sin embargo, todavía queda camino por recorrer, extendiendo las metodologías de riesgo climático a otras clases de activos, aumentando la coherencia de las políticas y comenzando a incorporar otros riesgos materiales relacionados con la naturaleza. Todas estas mejoras enviarán una señal muy poderosa a los sistemas financieros y a la economía acerca del valor económico de la transición climática y ecológica.

Por su parte, **Caspar Siegert** y **James Talbot**, del Banco de Inglaterra, ilustran la evolución descrita con anterioridad a partir de la experiencia del Banco en la compra de activos, los marcos colaterales y las herramientas de pasivo. Los autores subrayan la importancia de articular claramente los objetivos del banco para seleccionar los instrumentos adecuados, así como de adaptar las soluciones a los distintos contextos nacionales y de contar con datos y métricas adecuados. El papel de la Network for Greening the Financial System (NGFS) es fundamental a este respecto.

Juan Ayuso, director general de Operaciones, Mercados y Sistemas de Pago del Banco de España, a su vez, presenta la experiencia del banco central español en cuanto a la integración de criterios de sostenibilidad y responsabilidad en la gestión de su cartera no relacionada con la política monetaria, y a la transparencia de las métricas climáticas. El autor ilustra esto con el informe 2026 del Banco, pero considera que la mayor contribución de los bancos centrales está en el ejemplo institucional y la credibilidad, algo que se construye a través de metodologías sólidas, transparencia y coherencia. En este sentido, la aún significativa falta de datos y métricas de calidad no debe suponer un obstáculo para avanzar.

Elena Triebskorn, responsable de datos de mercados financieros externos del Bundesbank, incide precisamente en la cuestión de los datos: coincide en que los datos relacionados con los impactos climáticos son generalmente incompletos, inconsistentes y difíciles de comparar, además de contar con numerosos huecos a nivel regional, sectorial o a futuro. Dado que las fuentes de datos son diversas, es necesario un esfuerzo significativo para generar un conjunto robusto y estandarizado. Esto a su vez requiere colaboración entre distintos tipos de expertos e instituciones. La autora plantea que los bancos centrales deben ser más proactivos en la recopilación y estandarización de datos climáticos, además de asegurar la transparencia en su uso y la supervisión humana.

También reflexiona sobre datos y métricas **Luis Ángel Maza**, director del Departamento de Estadística del Banco de España, que repasa la experiencia del banco en este aspecto, y presenta algunas iniciativas de gran interés, como la base de microdatos ESG de empresas españolas (CBS), el visualizador de empresas con múltiples localizaciones (ViME), la base de datos europea ERICA o la contribución del Banco de España a los indicadores climáticos del Banco Central Europeo. El autor también presenta proyectos en marcha en biodiversidad, datos geoespaciales, estándares estadísticos internacionales o la aplicación de la inteligencia artificial

a las estadísticas climáticas. Maza concluye ofreciendo algunas lecciones aprendidas: es importante tener claro el objetivo institucional; hacen falta capacidades nuevas, y colaboración; es esencial el punto de vista del usuario potencial; y hay que mantener un balance adecuado entre acceso a los datos y calidad de estos.

Carmen Nuzzo, profesora y directora del TPI Global Climate Transition Centre de la LSE, considera, sin embargo, que el problema principal no reside en la disponibilidad de los datos climáticos, sino en su comparabilidad, en la capacidad para evaluarlos —en particular respecto a la adaptación— a los riesgos basados en la naturaleza y al creciente volumen de actividad empresarial que se sitúa fuera del perímetro de la transparencia. También es fundamental incorporar la visión a futuro. Además, el mantenimiento del bien público que esta información supone es difícil cuando depende de entidades filantrópicas.

Agnieszka Trzcinska, del Banco Central Europeo, y responsable del equipo de escenarios de NGFS, presenta los últimos escenarios elaborados por esta red, creada en 2017 como una coalición de bancos centrales y supervisores comprometidos con la incorporación de los riesgos climáticos y las finanzas sostenibles. Los escenarios de NGFS están específicamente diseñados para facilitar los ensayos de estrés y evaluar las consecuencias económicas y financieras de los riesgos climáticos, con dos horizontes temporales: 2030 y 2050. Estos escenarios permiten además a los responsables entender las vulnerabilidades de la economía y diseñar políticas efectivas. Los escenarios de corto plazo, presentados por primera vez en 2025, ofrecen algunas conclusiones de gran interés: la importancia de una transición ordenada, la relevancia de los eventos meteorológicos extremos en el corto plazo o la interrelación entre los costes de transición y eventos extremos. NGFS sigue trabajando para mejorar estos análisis.

Finalmente, **Yann Marin**, secretario general de NGFS y subdirector para estabilidad financiera del Banco de Francia, propone ir más allá de los datos climáticos, e incorporar otros recursos también de gran importancia en nuestras regiones, como el agua. El agua es un recurso crítico y una fuente material de riesgo financiero a nivel internacional, y no local como se había considerado habitualmente. El agua, además, conecta el cambio climático con la degradación de los ecosistemas y la economía. Las sequías, inundaciones, o contaminación pueden crear riesgos financieros sistémicos, y, por tanto, deben ser incorporadas a la supervisión bancaria dentro de los marcos prudenciales establecidos, con el objetivo último de no solo medir el riesgo, sino también la resiliencia.

Agradeciendo una vez más al Banco de España su disponibilidad para realizar esta publicación conjunta, animo a todos los lectores a profundizar en este asunto de tanta relevancia actual y futura, mediante la lectura de todos los artículos de este número.

High Level Conference Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice

*Soledad Núñez**

Good morning, distinguished guests,

It is a pleasure to *welcome you to the Banco de España for this High-Level Conference on* "Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice". A joint conference with the Network for Greening the Financial System (NGFS), the Centre for Economic Transition Expertise (CETEx), and the TPI Global Climate Transition Centre, both at London School of Economics. We sincerely thank these institutions for their valuable collaboration and contribution.

And I would like to thank all participants, in person and online from central banks, supervisors, academics, policy-makers and practitioners, for joining us today. Your commitment and expertise make gatherings like this not only possible, but truly meaningful.

We meet at a time when the global context makes our work more urgent than ever. Climate change is no longer a distant or theoretical threat—it is a present and accelerating force shaping global economic and financial conditions. We are witnessing a sharp increase in physical risks with remarkable consequences from extreme weather events. At the same time, transition risks are becoming more complex, driven by rapidly evolving regulation, technological shifts, and rising expectations on transparency and accountability.

In today's increasingly complex geopolitical landscape, we are reminded of how deeply interconnected our world has become. These challenges underscore an urgent truth: the climate crisis does not pause political tensions, nor does it respect borders. More than ever, we must remain committed to advancing climate action, strengthening international cooperation, and accelerating the transition to a resilient, sustainable future. This requires embracing a long term vision, as Mark Carney, former Governor of the Bank of England, reminded us with his idea of the "tragedy of the horizon," ensuring that today's decisions reflect the risks and opportunities that will unfold over the coming decades.

Extreme weather events are generating mounting economic and financial costs. These impacts translate into growing financial sector vulnerabilities: higher credit risk in affected industries,

* Subgobernadora del Banco de España.

increased insurance liabilities, and fiscal pressures that can weaken sovereign creditworthiness—all of which heighten systemic risk and challenge financial stability frameworks.

At the same time *extreme weather events do not affect all regions or countries in the same way,* and their economic and financial consequences vary widely depending on geographic exposure, structural vulnerabilities, and levels of development.

Moreover, the distinction between local and national impacts is crucial: while a flood or storm may devastate a specific region's productive capacity, employment, or credit conditions, the aggregate national effect may appear smaller—masking deep localized damage and financial sector stress concentrated in the affected areas. For example, the October 2024 DANA in Valencia Spain, caused economically severe local losses for households and firms in the affected areas, though its overall impact on Spain's broader economy remained limited. From a financial stability perspective, the Banco de España concludes that, despite causing severe local damage and some deterioration in credit quality in the affected areas, had a non systemic impact thanks to the relatively small share of exposed credit and the mitigating measures implemented by public authorities.

Recognizing this heterogeneity is essential for designing targeted adaptation policies and financial stability frameworks that account for regional disparities and country specific vulnerabilities.

In this context, strengthening our climate agenda is essential for boosting competitiveness and building greater resilience across our economies. Competitiveness and resilience are mutually reinforcing: the more resilient we become to environmental, energy, and geopolitical disruptions, the more competitive we are; and the more competitive we are, the better equipped we become to sustain long term climate roadmap.

And *for central banks and supervisors, this reality poses a fundamental challenge*: we must ensure that the financial system remains resilient in the face of climate-related shocks. And to do so, we must deepen our understanding of how these risks propagate, how they interact with macroeconomic trends, and how they can impact financial stability. In this sense, advancing the knowledge, data, and analytical tools needed to assess climate risk is not optional—it is essential for fulfilling our mandates. And taking into account that today's challenges extend far beyond climate change alone, encompassing the accelerating loss of nature and biodiversity—crises that are deeply interconnected and must be addressed together.

Today's agenda reflects this imperative. Throughout the day, we will hear several presentations addressing both climate change mitigation and adaptation. While mitigation remains essential to reducing future risks, today's discussions will place particular emphasis on adaptation. This

is a dimension that has become crucial for strengthening resilience, protecting vulnerable communities, and ensuring the stability of our economic and financial systems in the face of increasingly frequent and severe climate related events.

In this regard, reliable, comparable, and sufficiently granular climate data is the foundation of any rigorous climate assessment. Without it, neither policy-makers nor supervisors can fully anticipate the risks ahead or design credible, effective responses. Strengthening our analytical capacity is therefore essential to improving the quality and precision of our decisions. For that reason, exploring how better data and methodologies can support more informed and forward looking policymaking.

At the same time, a key part of this effort involves deepening our understanding of how physical climate risks will shape economic activity in the years to come and evaluating the credibility of transition plans. These dimensions are central to ensuring that financial institutions properly integrate climate related risks into their strategies and operations.

And central banks themselves have an important role to play in the way we manage our own portfolios. Integrating climate considerations into portfolio management—while remaining fully aligned with our mandates—offers a concrete opportunity to lead by example.

Across all the sessions runs a common leitmotif: collaboration. No single institution, no single country, can address these challenges alone. We must strengthen the bridges between research and policy, between public and private sectors, and across jurisdictions. Only through coordinated efforts—rooted in sound science, rigorous analysis, and a long-term perspective—can we ensure that the financial system supports a sustainable and orderly transition. As the Network for Greening the Financial System has stressed, the cost of inaction far exceeds the cost of an orderly transition: delaying climate measures not only raises transition costs but also amplifies the economic and financial risks posed by increasingly severe climate related shocks.

Let me close by expressing my gratitude once again for your presence and engagement. I am confident that today's discussions will not only deepen our understanding but also inspire concrete progress in the months ahead.

Thank you very much.

Adapting to Physical Climate Risk: Evidence, Decisions and the Missing Bridge to Finance

Iñigo J. Losada *

Abstract

Physical climate risk has crossed from projection to observation. 2024 was the first calendar year more than 1.5°C above pre-industrial levels, 2015–2025 were the eleven warmest years on record, and the rate of global sea-level rise has doubled since satellite measurements began. Yet the argument of this paper, developed from the author's participation in the panel "Transition Plans and Adaptation to Physical Risk" at the Banco de España High-Level Conference on Climate Risk and Sustainable Finance (Madrid, 25 March 2026), is that physical climate risk is now as much a matter of decisions as of evidence. The hazard is measured and rising; how much of it becomes risk depends on adaptation, that is, on choices about what to protect, how much, for whom and when. Those choices are taken at local scale, under deep uncertainty and against multiple criteria, and the financial system has yet to internalize any of the three.

Four messages follow. First, what matters for risk is the shift in extremes, their sequencing and compounding, and the erosion of resilience, the function a system keeps and the speed at which it recovers, when events arrive faster than recovery allows; the transmission from hazard to sectoral damage to macro-financial impact remains the weakest link in the chain. Second, risk is in part a construct of choices (what to protect, how much, for whom and over what horizon), which is why adaptation has no equivalent of the 1.5°C target and must instead be governed through tolerable residual risk and flexible adaptation pathways set at local scale. Third, the implementation gap is a gap of governance and of funding permeability across central administration, regional, municipal and private levels, not a knowledge gap alone. Fourth, "optimal" adaptation cannot be reduced to minimizing the public cost or achieving insurability, these are constraints on a multi-criteria decision, not its objective, and the adaptation effort itself, if compressed in time or concentrated in indebted territories, is a source of financial risk in its own right. The paper closes with what physical-risk science can and cannot yet deliver to prudential transition plans, stress tests and the forthcoming European climate-resilience framework. Adaptation must become legible to finance, through physically consistent scenarios calibrated on well-documented local events; and finance would do well to stop treating it as an exogenous parameter.

Keywords: physical climate risk, adaptation, adaptation pathways, coastal risk, financial stability, transition plans.

1. INTRODUCTION: CONTEXT AND SCOPE

On 25 March 2026 the Banco de España hosted, with the Network for Greening the Financial System (NGFS), the Centre for Economic Transition Expertise (CETEx) and the TPI Global Climate Transition Centre at the London School of Economics, the High-Level Conference "Climate Risk and Sustainable Finance: Bridging Policy, Research and

* Distinguished Researcher. Instituto de Hidráulica Ambiental-IHCantabria, Universidad de Cantabria.

Practice". Its three sessions (climate data and analytical tools, transition plans and adaptation to physical risk, and the greening of central-bank portfolios) were framed by an explicit choice: while mitigation remains essential, the day would place particular emphasis on adaptation, as the dimension now critical for protecting communities and for the stability of economic and financial systems. The conference thus marked a visible shift in the central-banking climate agenda, from transition risk, where the analytical machinery has a decade of development behind it, to physical risk and adaptation, where it is still being built.

This paper takes up one strand of that agenda. It is written from the author's participation in the panel on transition plans and adaptation to physical risk and is organized around the three questions the panel was asked to address. What does the evidence say about the impacts of physical risk, and where is adaptation most useful and most implementable now? Is an overarching adaptation target conceivable, as the temperature goal is for mitigation, and where are the largest gaps between what could be done and what is being done? And, from the floor, can the optimal level of adaptation be defined as the level that minimizes the cost to government and makes the residual risk insurable? A fourth theme runs beneath all three and is taken up in Section 6: the difference between the partial-equilibrium view of an institution assessing its own exposures and the general-equilibrium view that a public authority must hold, between private cost and social cost.

This paper takes the adaptation strand and tries to turn the panel's insights into a structured argument. Its spine is a single claim: physical climate risk is now as much a matter of decisions as of evidence. The hazard is measured and rising, and the evidence on that is settled; how much of it becomes risk depends on adaptation, that is, on choices about what to protect, how much, for whom and when. Those choices have three features that distinguish them from mitigation and that the financial system has yet to internalize: they are taken at local scale, under deep uncertainty and against multiple criteria. Adaptation is likely to remain the least developed part of climate policy, and the least legible to finance, until its governance and its metrics reflect those three features. Section 2 sets out the evidence and why the signal lives in the extremes. Section 3 presents the adaptation cycle as a sequence of decisions rather than a modelling exercise. Section 4 explains why adaptation has no 1.5°C and what governs it instead. Section 5 addresses the question of optimal adaptation and insurability. Section 6 draws the bridge to the supervisory and financial agenda, and Section 7 concludes.

2. THE EVIDENCE: FROM MEANS TO EXTREMES, FROM EVENTS TO SEQUENCES

The scientific evidence on physical climate risk is now overwhelming, and the signal that matters for risk does not live in the means. It lives in the extremes, in their sequencing, and

in their compounding across hazards and regions. Decades of improved observation converge on one conclusion: hazards are increasing in severity and in frequency, in their averages and in their tails, for almost every climate variable one chooses to examine.

2.1. The observed record

The World Meteorological Organization's State of the Global Climate 2024 confirmed that 2024 was the warmest year in the 175-year observational record, at 1.55 ± 0.13°C above the 1850–1900 average, and likely the first calendar year above 1.5°C (WMO, 2025). One year above the threshold does not mean the Paris goal has been breached (the long-term warming level was estimated at 1.34–1.41°C) but the direction is unambiguous. The 2025 edition, released on 23 March 2026, two days before the conference, added that 2015–2025 were the eleven warmest years on record, that 2025 was the second or third warmest at about 1.43°C, that the ocean continues to absorb around 90% of the excess heat, and that the Earth's energy imbalance, tracked as a headline indicator for the first time, reached a record high (WMO, 2026).

For a coastal scientist, like this author, the single most consequential number in these reports is the rate of sea-level rise. Global mean sea level rose at 2.1 mm per year over 1993–2002 and at 4.7 mm per year over 2015–2024: the rate has doubled within the satellite era (WMO, 2025). Sea level is now about 11 cm above its 1993 level, and the rate since 2012 exceeds that of 1993–2011 (WMO, 2026). Sea level is the baseline against which every coastal return period is computed. Shift the baseline and the whole distribution of extreme water levels shifts with it: the IPCC's Sixth Assessment projects that extreme sea-level events that occurred once per century in the recent past will occur at least annually at more than half of the world's tide-gauge locations by 2100 (IPCC, 2021). In plain terms, under some scenarios the event that engineers designed against as the hundred-year storm becomes an annual occurrence. A design standard becomes a season.

The year in which this paper is written has extended the record rather than interrupted it. August 2026 was the warmest August in the ERA5 dataset (Hersbach et al., 2020) and, tied with July 2023, the joint warmest month ever recorded, at 1.65°C above pre-industrial levels; it was the first month above 1.5°C since November 2025, and June–August 2026 was the joint warmest boreal summer on record, level with 2024. Sea-surface temperature over the extra-polar ocean reached an August record of 21.07°C, the joint highest for any calendar month, with strong El Niño conditions developing in the equatorial Pacific (C3S, 2026a). For western Europe the summer of 2026 was the warmest on record, surpassing 2003, at 21.69°C, 2.54°C above the 1991–2020 average, marked by a succession of exceptionally early, persistent and intense heat waves from the second half of May, widespread drought, and exceptionally low flows on the Rhine and the Danube (C3S, 2026b; C3S, 2026c).

Spain sits at the center of that anomaly. AEMET's summer balance, published on 22 September 2026, records the warmest summer since the official series began in 1961 and, on a reconstructed series, since at least 1869, with a peninsular mean of 24.5°C, 2.4°C above the 1991–2020 reference and 0.3°C above the previous record, set only a year earlier. Sixty-one days were spent under heat-wave conditions, against the previous record of 41 in 2022; July, at 25.7°C, tied July 2022 as the warmest month of the series; summer rainfall was 39.6 mm, 56% of normal and the third lowest since 1961; and fully summer conditions extended over four months, from an episode 5°C above normal in the second half of May to a fifth heat wave in the first week of September (AEMET, 2026a; AEMET, 2026b). The ten warmest summers of the Spanish series all belong to this century, and seven of the eight warmest to the years since 2015. Heat and drought translated into fire: by early September close to 296,000 hectares had burned in Spain according to the European Forest Fire Information System, following the 393,000 hectares of 2025, the worst year in the recent record (EFFIS, 2026). None of these numbers is a projection. They are the observed record of the year in which this paper was written, and they sit where the trend would have placed them.

2.2. Frequency, sequencing and the erosion of resilience

It is tempting to read the evidence as a story about intensity. The story that matters more for risk is about frequency and sequencing, and the concept that captures it is resilience. In the IPCC's definition, resilience is the capacity of a system (social, economic or ecological, and usually all three at once) to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain its essential function, identity and structure while retaining the capacity for adaptation (IPCC, 2022). Engineers make the idea operational as a curve: the function lost when the event strikes and the time taken to recover it (Bruneau et al., 2003). Seen that way, resilience has three components that the adaptation cycle of Section 3 must treat separately: the capacity to absorb a shock, the capacity to recover from it, and the capacity to adapt so that the next shock does less harm. Adaptive capacity is the third of these, the forward-looking one; it is a component of resilience, not a synonym for it.

Every extreme event consumes part of all three. Physical defenses are damaged, budgets are drawn down, institutions are exhausted, households and firms lose reserves, and the attention that adaptation requires goes to reconstruction instead. Recovery takes time. If the next event arrives before recovery is complete, the risk it poses is higher than the hazard alone would suggest, because the system is still weakened. Its vulnerability has risen and its resilience has fallen in the interval. Risk increases not because the storm is stronger but because the system has not yet recovered from the last one.

The 2017 Atlantic hurricane season was the first in which the United States and its territories were struck by three Category 4 landfalls (Harvey, Irma and Maria) in a single season. Puerto

Rico, weakened by Irma, was devastated by Maria two weeks later; the second event did far more harm than it would have done to an intact system. We now observe the same pattern across heat waves, droughts, wildfires, extreme precipitation, river flooding and coastal flooding. Southern Europe's summers since 2022 have been a sequence of this kind.

The Iberian winter of 2026 supplied a textbook case of sequencing weeks before the conference. Between 22 January and 14 February, seven named Atlantic storms (Ingrid, Joseph, Kristin, Leonardo, Marta, Nils and Oriana) crossed the peninsula in succession with no recovery periods between episodes; soils saturated progressively and the hydrological response intensified with each storm. Leonardo, fed by a subtropical atmospheric river, left 577 mm in 24 hours at Grazalema (Cádiz), a national record, and more than 2,500 mm fell there in little over three weeks; AEMET ranks the sequence among the most significant since at least 1961 and among the three largest of this century for accumulations over periods of two weeks to a month (AEMET, 2026c). The same storm train struck Portugal and Morocco, and a rapid attribution study concluded that climate change had made the rainfall more intense. The Consorcio de Compensación de Seguros treated the period 20 January to 20 February as a single episode of atypical cyclonic storm comprising eight storms, and activated its claims-management agreement with the insurers' association on account of the episode's intensity, duration and territorial extent (CCS, 2026a). The damage done by the eighth storm was damage to a system whose resilience the seventh had already spent.

A second feature is compounding: events that combine across hazards (drought followed by flood), across regions (the same storm system hitting several countries), or across time (back-to-back seasons). Italy's recent record makes the statistical point (figures from Battiston, 2026). Direct costs of climate-related disasters average about €3 billion per year, but the average is made up of many years near €1 billion and a few years at €10 billion or more; a handful of events account for 60–80% of cumulative damage. The 2022 drought in the Po valley, at roughly €6 billion, was followed within a year by the 2023 floods in Emilia-Romagna at roughly €10 billion. The distribution of losses is not Gaussian; it is closer to a generalized Pareto, and its tail is where the decision-relevant information sits. Please note that the generalized Pareto distribution (GPD) is a family of continuous probability distributions used mainly to model the data points that exceed a high threshold. Spain's 2026, a record storm train in winter, a record heat and fire season in summer, is compounding across time within a single year.

2.3. Southern Europe and Spain as a hotspot

The projections are as clear as the observations, and for Spain, though one could say the same of Portugal, Greece or Italy, they are unfavorable. The IPCC's Sixth Assessment Report identifies the western Mediterranean as a hotspot in which water scarcity, more frequent hydroclimatic drought, intensifying wildfire and the growing vulnerability of densely populated

coasts coincide (IPCC, 2022). Spain's first integrated national assessment, the *Evaluación de Riesgos e Impactos derivados del Cambio Climático en España* (ERICC-2025), mandated by Law 7/2021, characterized those risks sector by sector, including, for the first time, the financial and insurance sector and the cascading effects that originate in the direct impacts on other sectors, and concluded that, for all the regulatory and analytical progress made, the tools available remain insufficient to represent the complexity of physical risks and their interaction with macroeconomic and financial risk (Losada et al., 2025). The first European Climate Risk Assessment (EEA, 2024), which identified 36 major climate risks and singled out southern Europe as a hotspot, reached the same conclusion at continental scale. Physical risk is material now and will become more so; how much of it becomes financial risk is the question the rest of this paper addresses.

2.4. The weakest link

What the evidence does not yet give us is the chain that connects a physical event to a balance sheet. Between a hazard and a financial exposure lie several links: physical damage to assets, disruption of sectoral activity, macroeconomic shock, transmission to credit, market and operational risk. Each with its own data, models and uncertainties, and each studied by a different community. The climate stress tests run so far have, understandably, bridged that chain by assumption. The shocks applied to the macroeconomic models (i.e. to total factor productivity, sectoral output, relative prices or sectoral income) are specified consistently with NGFS or ECB scenarios, but, to the author's knowledge, they are not derived from any physical reconstruction of a plausible event. Such exercises give a valuable first view of financial vulnerability, but their limits should be stated plainly. They cannot distinguish a severe coastal flood from a prolonged drought, they do not reproduce the intensity or duration of the phenomenon, they offer no test of coherence between the shock applied and the physical damage that could plausibly produce it, and they leave the transmission mechanisms uncalibrated against evidence. Building the link *physical event → sectoral damage → macroeconomic shock → financial impact* on physical rather than assumed foundations is the frontier on which physical scientists and financial economists have to meet. The rest of this paper is about what the physical-risk side can bring to that meeting, and what it cannot yet.

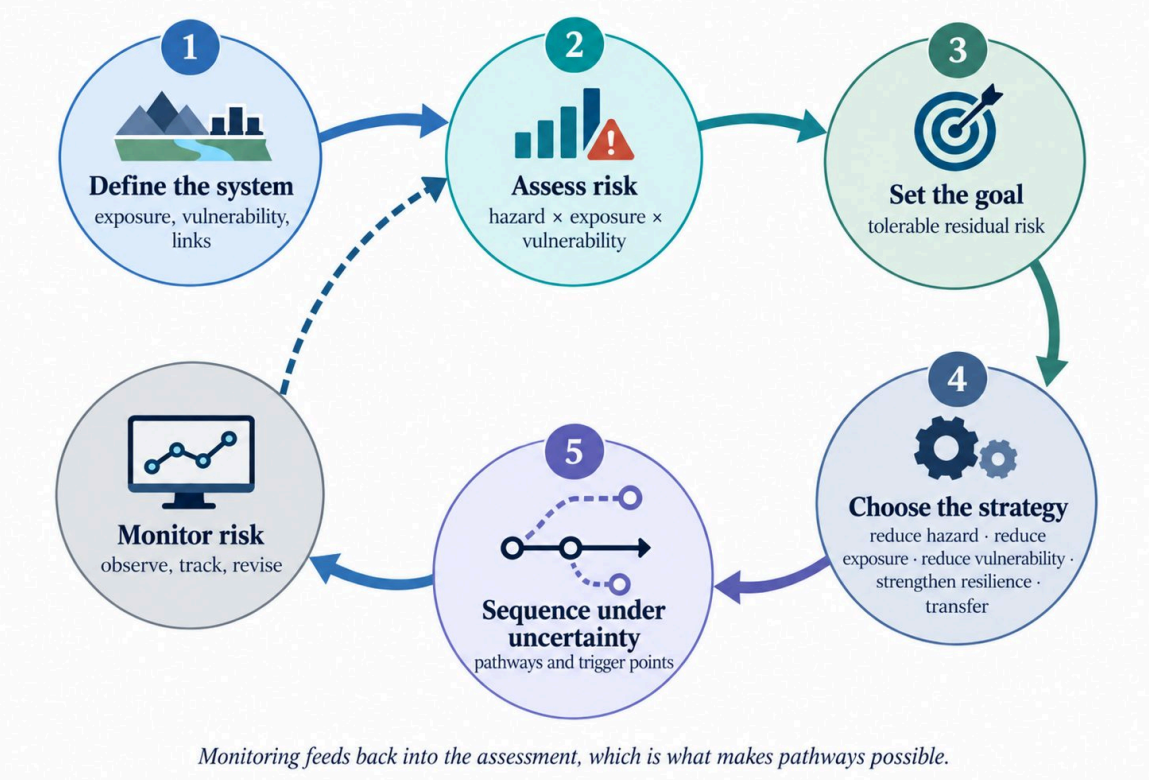
3. RISK IS A DECISION: THE ADAPTATION CYCLE

Adaptation is arguably the least developed part of climate policy, in part because it forces a sequence of decisions that mitigation does not. Mitigation has one metric, one direction and, in principle, one global objective. Adaptation asks, before any measure is built: what system, what risk, what goal, what residual risk, what strategy, and when. The adaptation cycle is usually drawn as a loop of assessment, planning, implementation and monitoring. In this

context the author prefers to present it as five decisions, because that is what it amounts to in practice, and because each decision is a place where the physical-risk community and the financial community still tend to talk past each other.

Figure 1

The adaptation cycle as five decisions



Fuente: Elaboración propia.

3.1. Decision one: define the system

The first decision is what we are adapting. Risk, in the IPCC's formulation, is a function of hazard, exposure and vulnerability. Hazard is what the climate does; exposure is what stands in its way; vulnerability is how badly what stands there is hurt. Before any of these can be quantified one must draw a boundary: which elements are exposed, what their vulnerability is, and, the part most often neglected, which processes connect them. A port, the road that serves it, the industrial estate behind it and the housing on the reclaimed marsh are one system, not four assets. The boundary determines every number downstream, and it is a choice. Resilience is a property of that system, not of any of its assets; the port with a second road recovers in days; the port without it recovers when the road does.

3.2. Decision two: assess risk honestly

The second decision is how to assess risk, and here the physical-risk community owes the financial community some candor about its own products. Take flood modelling, since flooding (i.e. river, pluvial and coastal) is the hazard most often mapped and most often bought. A flood map depends on the model that produced it. A process-based hydrodynamic model and a simplified planar-surface model can give very different inundation extents for the same event. It depends on the topography beneath it: a coarse or inaccurate digital elevation model will overestimate flooding. And it depends on whether existing protection and existing resilience (i.e. the dike that is already there, the drainage that was upgraded in 2015, the early-warning system that empties the ground floor before the surge arrives, the recovery capacity of the institutions and the economy behind them) have been taken into account. Leave them out and the map will overstate risk, often by a large margin.

The consequence is that risk assessments are not comparable unless the approach is coherent across the whole chain. Two hazard providers can return different exposures for the same mortgage book, and both can be internally consistent. Establishing the protection and the resilience that already exist, up front, is a precondition for knowing where risk actually stands today, and today's risk is the reference point for every adaptation goal.

3.3. Decision three: set the goal

The third decision is the one that has no analogue in mitigation. We know what we want from mitigation: net-zero emissions on a given date, consistent with a temperature limit. What do we want from adaptation? One must decide what to adapt, how much, for what time horizon and for what climate scenario. Each of these is a choice, and the choices differ from one location to the next, because adaptation is implemented at local scale. The variable that ultimately must be fixed is the level of residual risk a community is willing to tolerate; the risk that remains after the measures are in place. Every adaptation plan the author has been involved in has reached the point where this question had to be put to the people who would have to answer for it, and every time it has been the hardest decision on the table. It is also the decision that a bank, an insurer or a supervisor most needs to know, because tolerable residual risk is, in financial language, the risk appetite of the territory in which the asset sits. Increasingly the goal is also stated in terms of resilience: how much function a system must keep during the event and how quickly it must recover (hours for a hospital, days for a port, a season for a beach). The two formulations are complementary. Residual risk bounds the loss, resilience bounds the disruption, and a lender or an insurer needs both.

3.4. Decision four: choose the strategy

The fourth decision is the strategy. Whatever the hazard, an adaptation measure can act on one of five things: 1) the hazard that reaches the asset, 2) the exposure that stands in its way, 3) the vulnerability of what is exposed, 4) the resilience with which the system keeps and recovers its function, or 5) the allocation of the residual risk. Coastal planners know the first four as protect, retreat, accommodate and prepare, and the fifth as insurance; the same logic governs river floods, drought, heat and fire, and it maps onto the vocabulary supervisors are beginning to use (i.e. invest, avoid, accept, transfer) a correspondence the author returns to in Section 6. Each strategy can be delivered by very different combinations of measures, grey and green, structural and operational, and the combination is itself a design choice.

Table 1

The strategy space across hazards and its risk-management analogue

Strategy	What it changes	Examples across hazards	Risk-management analogue
Reduce the hazard	The event that reaches the asset.	Dikes, dunes and wetlands against flooding; storage and reuse against drought; urban shade and green cover against heat; fuel management against fire.	Invest: lowers the probability of loss.
Reduce exposure	What stands in the way.	Setback lines and managed retreat; land-use planning in floodplains; crop and land-use change in water-stressed basins; relocation of activity.	Avoid: lowers the exposure at loss.
Reduce vulnerability	The damage per unit of hazard.	Flood-proofing and elevation; early warning; irrigation modernization and efficiency; building design and heat-health plans.	Invest: lowers the loss given event; the asset stays, its damageability falls.
Strengthen resilience	The function kept during the event and the speed of recovery.	Redundancy in transport, power and water networks; emergency response and business-continuity planning; contingency finance and social protection; ecosystem restoration.	Invest: shortens the duration of loss (business interruption, recovery time).
Transfer the residual	Who pays.	Insurance and public compensation schemes; agricultural insurance; parametric covers.	Transfer: moves what remains to a carrier able to hold it.

Note: "accept" is not a lever. It is the tolerable residual risk of Section 3.3 that remains once the other five have been applied.

3.5. Decision five: sequence under deep uncertainty

The fifth decision is when to act, and it is governed by uncertainty. The modelling chain runs from emissions scenarios, whose probabilities we do not know, through the downscaling of

global climate projections to regional and local hazard, to exposure, to vulnerability, to risk. At every link uncertainty enters and must be tracked, not averaged away. For some links the uncertainty is deep. The IPCC's Sixth Assessment could not rule out global mean sea-level rise approaching 2 m by 2100 under a very high emissions scenario, because of ice-sheet processes whose physics remain poorly constrained (IPCC, 2021). No single design horizon can accommodate that spread.

The sensible answer is not to pick the solution we believe will hold forever. It is to combine implementation with observation: to define a set of actions, each with the conditions under which it stops being adequate (i.e. its adaptation tipping point) and to monitor how risk evolves so that the next intervention is triggered when the observed system, not the projected one, requires it. Recovery times after each event are the most direct evidence of where a system stands on its pathway; resilience is not only a design objective but the variable being monitored. This is the logic of dynamic adaptive policy pathways (Haasnoot et al., 2013; Fernandez-Perez et al. 2025), which has become the standard framing for long-horizon adaptation planning, from estuaries and deltas to urban water supply. Pathways buy flexibility and avoid lock-in, at the cost of an institutional obligation that few administrations have so far taken on: someone has to keep watching. The moment one tries to connect this decision structure to economic and financial impacts, things become harder still, because the financial system prices assets against a fixed horizon while the physical system is being managed against a moving one.

4. WHY ADAPTATION HAS NO 1.5°C: GOALS, SCALE AND GOVERNANCE

There is no global adaptation target comparable to 1.5°C, and it is hard to see how there could be one. What exists instead is an indicator framework, a finance pledge, and a widening gap between the assessments we have produced and the adaptation we have implemented. That is the answer to the panel's second question, and the months since the conference have, if anything, sharpened it.

4.1. The global stocktake and Belém

The global stocktake concluded at COP28 (2023) in Dubai and the process that followed under the Global Goal on Adaptation taught us something uncomfortable: the world has produced a great many climate risk assessments (one can argue about their quality, but not about their number) and, measured against stated objectives, has implemented very little adaptation (see for example, Magnan et al., 2023). COP30 in Belém (November 2025) was billed as the adaptation COP. Its outcome was a list of 59 voluntary indicators, the Belém Adaptation Indicators, covering the eleven targets of the UAE Framework for Global Climate

Resilience and reduced from an initial pool of roughly ten thousand candidates. On finance, the decision calls on parties to at least triple adaptation finance by 2035, without a reference year Against that pledge stands the arithmetic of the UNEP Adaptation Gap Report 2025: developing countries will need $310–365 billion a year by 2035, while developed countries provided $26 billion in 2023, down from $28 billion the year before, a gap of twelve to fourteen times current flows, with the Glasgow goal of doubling adaptation finance by 2025 on course to be missed (UNEP, 2025).

An indicator framework is not a target. Fifty-nine indicators describe progress; they do not say how much progress is enough, because that question can only be answered system by system, community by community. This is less a failure of negotiation than the nature of the problem.

4.2. Local risk, national plans

The deepest reason there is no 1.5°C for adaptation is scale. Adaptation is implemented locally, but adaptation planning is national. A national plan can set direction, allocate resources and define methods; it cannot decide the residual risk that a particular estuary town, irrigation district or heat-exposed city will tolerate. Spain's coastal adaptation strategy, mandated by Law 2/2013 and approved on 24 July 2017 on the basis of the national risk assessments produced from 2014 (MITECO,2017 and Losada et al., 2019), illustrates the tension. Its overarching objective, to keep coastal risk at the level assessed at the time, under rising hazard, is a legitimate and communicable national goal; operationalizing it means going stretch by stretch, equipping each with a defensible risk metric and a portfolio of measures that keeps risk below the threshold as sea level and storminess rise. Drought plans, flood-risk management plans and heat-health plans face the same arithmetic: the national goal is one sentence, the local plans are thousands of decisions, most of them still to be taken.

4.3. The two gaps

Two gaps stand out between what could be done and what is being done.

The first is methodological and institutional at once. We do not yet know how to build the flexible adaptation pathways of Section 3.5 as living instruments. We know how to draw them; we do not know how to fund, staff and govern the monitoring that gives them meaning. A pathway without a monitoring programme is a plan with an expiry date that no one is watching.

The second is governance and the permeability of funding. National funds may exist, but the channels through which they reach a municipal drainage scheme or a regional dune-restoration

programme are narrow and slow. In Spain the chain runs from the central administration to the autonomous communities to the municipalities, and from there to the private owners of most of the exposed assets, and each level may set its adaptation goals differently and hold interests that do not align. Every measure implemented at one level interacts with the system in which it is embedded: a seawall built by one municipality changes erosion in the next; a retreat decided by a regional plan changes the value of assets financed by a national bank. Adaptation governance is therefore not a matter of assigning responsibility but of managing interactions, and this, at least as much as the science, is where implementation tends to stall.

4.4. The European turn

The European Union is now attempting what national plans have so far struggled to achieve: to move adaptation from strategy to obligation. The first European Climate Risk Assessment (March 2024) concluded that the Union is not sufficiently prepared and that some risks are already at critical levels, and the European Court of Auditors reached similar conclusions in 2024. The Commission is preparing the European Climate Resilience and Risk Management Integrated Framework, the package announced in the 2024 political guidelines as the European Climate Adaptation Plan, with legislative and non-legislative elements, expected in the second half of 2026 (European Commission). The consultation that preceded it called for resilience-by-design in investment, harmonised climate risk assessments and stable long-term adaptation financing. If the framework delivers harmonised assessment methods and binding resilience requirements for climate-vulnerable investment, it will for the first time give supervisors a policy anchor for adaptation comparable to those they have for mitigation. Whether it does is, at the time of writing, open.

Seen from the balance sheet, the same problem appears in a different vocabulary. The supervisory diagnosis presented in the panel is that prudential transition plans remain mitigation-centric, that the systematic integration of adaptation is limited, and that the lack of relevant metrics and targets is the binding constraint, because adaptation is local and context-specific, without a single global quantified objective, and because quantitative policy anchors are few (Casillas, 2026).

5. BEYOND COST: MULTI-CRITERIA DECISIONS, RESIDUAL RISK AND INSURABILITY

The optimal level of adaptation should not be defined as the level that minimizes the cost to government and makes the residual risk insurable. Cost and insurability are constraints on the decision; they are not its objective function. The question was put from the floor, and it deserves more space than the panel could give it, because the proposition is understandably attractive to the audience this paper is written for.

5.1. Why the proposition is tempting, and where it falls short

The proposition is tempting because it would close the problem. If adaptation is the quantity that minimizes public expenditure subject to the constraint that what remains can be priced and transferred to an insurance market, then the goal of Section 3.3 has a formula, the governance problem of Section 4.3 reduces to budgeting, and the financial system knows where it stands. However, it runs into three difficulties.

First, adaptation is not only a cost. It has social and environmental implications, co-benefits and collateral effects, and all of them have to be accounted for. A dune-restoration programme protects a beach and also restores a habitat, sustains a tourism economy and changes who can live where; a seawall protects assets and also may contribute to destroying a beach, alters sediment transport downstream and can lock a community into a defended position it may later regret. This is why adaptation plans generally select their measures through multi-criteria analysis rather than through cost-benefit analysis alone.

Second, the criterion that decides is frequently not the one the economist expects. After the 2011 tsunami, some communities on the Tōhoku coast rejected the seawall that engineering and cost analysis recommended, while others rejected relocation inland and demanded a seawall in order to stay where their families had lived for centuries. Neither was irrational; both were optimizing an objective function that did not appear in the cost model, and something similar can be expected in many of the floodplains and irrigated districts in Spain from which a plan may propose to withdraw.

Third, insurability is a property of the residual risk, and the residual risk is fixed by the tolerable-risk decision of Section 3.3, which belongs to the community, not to the insurer. Insurability matters, the protection gap is real, and a residual risk that cannot be transferred lands on public budgets, but a plan whose only purpose is to make the leftover risk insurable has inverted the order of decision. One decides what to protect and how much and then asks how the remainder can be shared.

5.2. Scale and who pays

There is a fourth reason, and it concerns scale. Adaptation will require very large investment. The author is entirely in favor of a climate-resilient development policy that combines mitigation and adaptation. But it is reasonably clear in advance that public budgets alone will not protect what is exposed: some 8,000 km of coastline, the floodplains on which much of Spain's industry and housing stands, the irrigated agriculture of the water-stressed south and east, and the cities in which heat now costs lives and productivity. Under current governance the public administration bears most of the responsibility for protection, and the plans are public documents. They will not be implementable without the private sector, i.e. the owners, developers, insurers and lenders whose assets are what is being protected, and who at present

treat protection as something the State provides. The figures presented for the EU in the conference keynote, annual adaptation needs of about €83 billion against current flows of €13 billion, a gap of €70 billion of which roughly €67 billion falls on the public sector, with private finance covering only around 5% of adaptation in high-income countries (Markandya, 2026), describe an arrangement that is unlikely to scale, and point precisely to the fiscal channel through which physical risk reaches sovereign creditworthiness.

5.3. The cost of resilience as a financial risk

That fiscal channel points to a dimension to which the adaptation debate, preoccupied with the cost of inaction, has paid comparatively little attention; the adaptation effort itself can generate macroeconomic and financial risk. Adaptation at the scale the evidence requires means a large volume of investment, concentrated in a few sectors (i.e. health, construction, water, energy, transport and territories) and in some cases needed within short periods. Investment of that kind has the familiar expansionary effects of infrastructure spending; it can also crowd out other uses of capital, generate cost inflation in civil engineering when it is compressed in time, raise public debt precisely at the regional and municipal levels where exposure is greatest and fiscal room smallest, and increase leverage in capital-intensive sectors that must adapt before their investments pay back. The risk is less one of insufficient adaptation than of disordered adaptation. An urgent need to reinforce defenses, modernize urban water systems or adapt critical infrastructure, arriving after the event and financed under pressure, can produce liquidity stress in indebted administrations and transitory deterioration in sectors that need credit at the moment their collateral has lost value.

A financial-stability framework should therefore be able to compare trajectories: one in which adaptation reduces physical risk but generates short-term financial tension; one in which under-investment accumulates physical risk and future losses; and one in which adaptation distributed sensibly over space and time reduces structural risk and stabilizes exposed sectors. The indicators are not exotic. Adaptation investment as a share of GDP, additional indebtedness attributable to adaptation and its sectoral distribution, the absorption thresholds beyond which tension appears, the net financial risk once the costs and the benefits of adaptation are both counted but, to the author's knowledge, no supervisory framework currently produces them. Anticipating the risks of action as well as of inaction is what it would mean to treat adaptation as a financial-stability question.

5.4. Adaptation and mitigation are not substitutes

A related question is how adaptation and mitigation interact, and the answer completes the argument. Mitigation is a global public good, which explains why it is undersupplied. Adaptation is a local public good, which is why it is undersupplied too, only at a smaller

scale. A firm can build a wall around its plant, but unless the municipality has built the dike upstream the wall protects nothing. And there is only so much one can adapt to. In the absence of mitigation, at some point no level of adaptation works; and the less we mitigate, and the later we adapt, the more expensive adaptation becomes. The two are complements in a climate-resilient development path, and a financial framework that treats adaptation as the residual after mitigation has been costed is likely to misprice both.

6. THE MISSING BRIDGE: MAKING ADAPTATION LEGIBLE TO FINANCE

The bridge between physical-risk science and finance is not a better hazard map. It is a shared language about decisions, tails and residual risk and a recognition on the financial side that adaptation is an endogenous variable, set by public decisions at local scale, rather than a parameter to be read off a data vendor's file. This section aims at drawing that bridge from both ends. From the supervisory agenda as it now stands, and from the physical-risk science that has to feed it.

6.1. What the supervisory agenda now requires

The regulatory trajectory is by now well defined. The ECB moved from setting expectations in its November 2020 guide on climate-related and environmental risks, through thematic reviews, to the first supervisory climate stress test in 2022; the banking package (CRR3 and CRD6) introduces a formal definition of ESG risk and requires prudential transition plans (risk-management instruments distinct from the disclosure-oriented plans of the CSRD) and the European Banking Authority's guidelines on the management of ESG risks bring these requirements into the Internal Capital Adequacy Assessment Process (ICAAP), risk appetite and strategy, including the quantification of short-, medium- and long-term financial impacts. The supervisory assessment of progress, as presented in the panel, is that it is real but uneven (Casillas, 2026): the regulatory perimeter has expanded faster than implementation; institutions still struggle with data, with integrating pathways into credit models and stress tests, and with governance; and adaptation in particular has barely entered the frame. The prescription for institutions is pragmatic. Scope and gather data, assess exposure and vulnerability, translate the assessment into a choice among avoid, accept, transfer and invest, and track progress along a maturity pathway without waiting for perfect data. The reader will recognize the first two steps as decisions one and two of Section 3, and the four options as the strategy space of Section 3.4.

6.2. Two conceptual blind spots

Two blind spots remain that no amount of data will remove, because they are conceptual (Battiston, 2026). The first is the reliance on expected values. Public decision-makers, and many financial ones, reason in terms of expected annual loss: a few tenths of a percent of GDP,

small next to a geopolitical shock, and therefore not a priority. But the distribution of climate losses is fat-tailed, a few events carry most of the damage, and the tail events are not one-in-a-million; they are events that will occur within the lifetime of the assets being financed. A decision framework that ignores the tail will, in this domain, produce the wrong decision. The NGFS short-term scenarios are the first set intended for financial use in which extreme events enter as return periods rather than averages, the equivalent of a value-at-risk on the loss distribution, although a 1-in-50 combined hazard is too extreme for some users and not extreme enough for insurers, whose reference is 1-in-100.

The second blind spot is indirect impact. What can be counted after a flood is the direct loss, often proxied by the aid claimed from the central administration. What is not counted, because it is confounded by everything else, is the long-run effect on the attractiveness of the territory for investment, on the confidence of people in staying, on the fabric of the local economy. Taking it into account changes the adaptation decision; ignoring it produces a different one. This is the distinction between partial and general equilibrium, between private and social cost, made concrete. An individual institution will, correctly, assess its own exposure. Someone must hold the general-equilibrium view, the indirect losses, the correlated exposures across institutions, the fiscal backstop and that someone is the public authority. Physical-risk science can supply the hazard and the direct-damage functions; it cannot, at present, supply the indirect-loss function, and it should say so.

On adaptation itself, one point deserves to be repeated to every scenario user. In a model, adaptation is an adjustment to the vulnerability function of the agents that are hit, and data on how much firms are actually adapting on the ground are very scarce. Results without adaptation are an upper bound. Results with adaptation are, at present, an assumption.

6.3. Adaptation as an endogenous variable

The physical risk on a bank's mortgage book in a floodplain, on an insurer's commercial-property portfolio in a water-stressed basin or on critical infrastructure depends on decisions the institution does not take: whether the municipality builds the dike, whether the basin plan restricts abstraction, whether the regional plan permits retreat, whether the national strategy funds the works. For the institution these decisions are externalities. They are, however, observable externalities, and the adaptation pathway of Section 3.5 is exactly the object a supervisor could ask to see (i.e. the sequence of planned actions, the residual risk each is designed to hold, the trigger conditions under which the next action is due, and the monitoring that watches for them). A territory with a published pathway, a stated tolerable residual risk and a functioning monitoring program is a materially different credit from one without, even at identical hazard. Its resilience, the function it keeps during an event and the speed at which it recovers, is the variable through which a physical shock reaches the balance sheets financed on it, and it is observable: recovery times after the events of Section 2 are data, not projections.

Building that bridge means working at two scales at once, because neither suffices alone. Top-down, the shocks that enter macroeconomic and financial models should be derived from physically consistent scenarios (i.e. simulated floods, droughts, heat waves and fire seasons with realistic intensity and duration) and translated into sectoral perturbations through damage functions rather than assumed. The fall in industrial output justified by the physical parameters of the damage, the loss of labor productivity derived from physiological heat indices, the tourism shock from modelled damage to coasts and access, the energy shock from modelled reductions in hydropower inflows. Bottom-up, a small number of well-documented events, studied at the local and regional scale at which their effects are visible and attributable, with damage records such as the ones collected by the Spanish Consorcio de Compensación de Seguros, sectoral data and high-resolution modelling, serve as empirical laboratories in which the full chain from hazard to household and firm to lender can be traced, and in which one can observe which channel dominates (direct damage, operational disruption, productivity loss, cascading effects through supply chains, or prices). The local cases anchor and calibrate the aggregate model; the aggregate model gives the local cases a system in which to matter. In the same loop adaptation stops being an assumption. The physical effect of a measure on the event (i.e. depth, duration, extent, water deficit) is modelled, the residual risk after adaptation is compared with the baseline, and trajectories of risk under different degrees and speeds of implementation can be placed side by side. That is what adaptive trajectories would look like in a supervisory exercise, and it is, in the author's assessment, within reach of existing methods.

The table sets out what physical-risk science can deliver to that end today, and what it cannot yet.

Table 2

What physical-risk science can and cannot yet deliver to the supervisory agenda

Can be delivered now	Cannot yet be delivered reliably
Granular hazard under multiple scenarios and horizons, including compound events and return periods in the tail.	Probabilities of emissions scenarios, and hence of the hazard projections that depend on them.
Asset-level exposure, provided assets are geolocated where they stand rather than at the registered office.	Consistent treatment of existing defenses and resilience across data providers.
Vulnerability and depth-damage functions for the main asset classes.	Calibrated firm-level adaptation and its effect on vulnerability.
Baselines of existing protection, which fix where risk stands today.	Indirect and second-order losses to territories and sectors.
Recovery times and function loss observed in past events, as the measurable resilience of a territory.	The resilience of institutions and governance, which is not a physical quantity and has to be inferred.
Adaptation pathways with tolerable residual risk and trigger conditions, where a plan exists.	The tolerable-risk decision itself, which is political and local.

One item in the left-hand column deserves emphasis. The Banco de España's own statistical work shows that allocating a firm's activity to its production centers rather than to its registered office changed the estimated impact of the DANA in one affected municipality by 17% in sales, employment and assets (Maza, 2026). Geolocation is not a detail; for physical risk it is often the difference between measuring exposure and estimating it.

6.4. The DANA as the worked example

The Valencia DANA of 29 October 2024 is the case against which the argument of this paper can be tested. It was, in the terms of Section 2, a tail event in a fat-tailed distribution, and it was locally catastrophic. By 5 June 2026 the Consorcio de Compensación de Seguros had registered 251,813 claims, 95.4% of them in the province of Valencia, had paid 212,533 of them for a cumulative €4,484 million, and estimated the total cost of the event at around €4,800 million (CCS via SegurosNews, 2026). Estimates of total economic losses have been reported at well above that figure (Zurich, 2025), which is another way of saying that the insured share was a fraction and that the rest fell on households, firms and public budgets. And yet the Banco de España assessed the event as non-systemic for the financial system, because the share of exposed credit was small and public authorities intervened (Núñez, 2026).

Every element of the bridge is present in that sentence. The transfer mechanism, a publicly administered, surcharge-funded scheme with an equalisation reserve, is itself an adaptation measure of the accommodate type, and it worked. It also separates two resiliences that the same word conceals: the territory absorbed the shock with great difficulty and was still recovering eighteen months later, when the Consorcio was still settling claims; the financial system absorbed it well. The second depends on the first only through the share of exposed credit and the speed of local recovery, this time. The public intervention that made the event non-systemic is the general-equilibrium actor doing its job. The small share of exposed credit is a partial-equilibrium fact about one event in one region. The question the DANA does not answer, and that the frequency argument of Section 2.2 forces us to ask, is what happens when the next event arrives before the reserve is rebuilt, or strikes a region where credit is more concentrated, or coincides with a macroeconomic shock. The supervisory statement of the same point, heard in the conference's closing conversation, is that climate does not create a new class of risk but drives the established ones, and that its materiality for financial institutions is amplified by the growing insurance gap. The bridge is needed not because the last event was systemic, but because the next sequence might be.

7. CONCLUSIONS: SIX MESSAGES

The question the panel was set has not been solved here. What this paper has tried to do is to structure it, and the structure yields six messages for the community the conference brought together.

1. The evidence is settled; the signal is in the extremes. Warming, ocean heat and sea-level rise are at record levels, and the rate of sea-level rise has doubled in three decades. What that implies for risk is not a shift in averages but a shift in tails, in frequency, in sequencing and in compounding (Spain's 2026 showed all four) and, through recovery time, in resilience. Analysis built on expected values will systematically understate what is coming.

2. Risk is partly a decision, and the decisions must be made explicit. Where the system boundary is drawn, whether existing protection and resilience are counted, and what residual risk is tolerated determine the number that ends up in a stress test. Users of hazard and risk data should demand to know these choices, and providers should state them.

3. Adaptation has no 1.5°C and should stop waiting for one. It is governed instead by tolerable residual risk and required resilience, how much function a system keeps and how fast it recovers, set system by system, and delivered through flexible pathways with monitored trigger points. The Belém indicators measure progress; they do not define sufficiency. Sufficiency is local.

4. The implementation gap is a governance gap. National plans and local implementation are separated by narrow funding channels and by interactions between levels of government and between public and private actors that no one manages. The European climate-resilience framework expected in late 2026 is the first opportunity to give adaptation a policy anchor that supervisors can use; it should be judged by whether it does.

5. Optimal adaptation is multi-criteria; insurability is a constraint; and the adaptation effort is itself a financial-stability question. Cost minimization and insurability cannot serve as the objective function of an adaptation plan. The scale of exposed assets exceeds what public budgets can protect, the financing structure that brings private owners, lenders and insurers into protection has not been designed, and adaptation investment compressed in time or concentrated in indebted territories generates risks of its own. A framework able to compare trajectories (i.e. inaction, disordered action, well-sequenced action) is needed and does not yet exist.

6. Adaptation is an endogenous variable in financial risk, and it can be made legible. The physical risk on a portfolio depends on public adaptation decisions the institution does not control but can observe, and on a resilience it can measure. Supervisors should ask for pathways, residual-risk statements and monitoring; scientists should deliver physically consistent scenarios, tail return periods, geolocated exposure, baselines of

existing protection and observed recovery times, calibrated on well-documented local events, and be candid about indirect losses and firm-level adaptation, which they cannot yet quantify. The right unit of analysis is the sequence of events, not the event; the right statistic is the tail, not the mean; and the right question is not whether the last event was systemic but whether the next sequence might be.

REFERENCES

AEMET. (2026a). *España registra 61 días bajo ola de calor en 2026, más que en ningún otro año.* Agencia Estatal de Meteorología, 9 September 2026. aemet.es.

AEMET. (2026b). *Un verano de cuatro meses bate récords de calor en, al menos, siglo y medio.* Agencia Estatal de Meteorología, 22 September 2026. aemet.es.

AEMET. (2026c). Informe sobre las borrascas atlánticas y las lluvias persistentes e intensas asociadas de enero y febrero de 2026. Agencia Estatal de Meteorología, 25 April 2026. aemetblog.es. Also published in *Tiempo y Clima* (AME), July 2026.

Banco de España. (2026). *Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice*, High-Level Conference, Madrid, 25 March 2026. Event page; programme; presentations; video playlist.

Battiston, S. (2026). Remarks in Session 2, "Transition Plans and Adaptation to Physical Risk", Banco de España High-Level Conference, 25 March 2026 (video, above).

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., Shinozuka, M., Tierney, K., Wallace, W. A. and von Winterfeldt, D. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra, 19*(4), 733–752.

C3S. (2026a). *Copernicus: August was the world's joint hottest month on record, pushing global temperatures back above 1.5°C above pre-industrial levels.* Copernicus Climate Change Service, 9 September 2026. climate.copernicus.eu.

C3S. (2026b). *Surface air temperature for August 2026.* Copernicus Climate Change Service. climate.copernicus.eu.

C3S. (2026c). *Climate Bulletins*, August 2026 edition. Copernicus Climate Change Service. climate.copernicus.eu.

Casillas, A. (2026). Remarks in Session 2, "Transition Plans and Adaptation to Physical Risk", Banco de España High-Level Conference, 25 March 2026 (video, above).

CETEx. (2026). *Climate risk and sustainable finance: bridging policy, research, and practice* — event commentary, 2 April 2026. cetex.org.

Consorcio de Compensación de Seguros. (2026). Nota informativa sobre las inundaciones extraordinarias producidas por la DANA de octubre de 2024, 5 June 2026. Reported by SegurosNews; see also Gobierno de España, 26 November 2025 and the CCS DANA page.

Consorcio de Compensación de Seguros. (2026a). Nota informativa sobre episodios de tempestad ciclónica atípica producidos entre el 20 de enero y el 20 de febrero de 2026. consorseguros.es; definitive delimitation reported by SegurosNews, 30 June 2026.

European Banking Authority. (2025). *Guidelines on the management of ESG risks.* EBA/GL/2025/01.

European Commission. (2026). *European Climate Resilience and Risk Management – Integrated Framework* (forthcoming). climate.ec.europa.eu; European Parliament Legislative Train).

EEA. (2024). *European Climate Risk Assessment.* EEA Report 01/2024. Copenhagen.

EFFIS. (accessed 28/10/2026). https://forest-fire.emergency.copernicus.eu

Fernandez-Perez, A., Lara, J. L. Losada, I. J. (2025). Flexible adaptation strategies for managing compound climate risks in port infrastructures. *Coastal Engineering*, 104844.

France 24. (2026). *España vivió su verano más cálido desde que hay registros*, 9 September 2026 (EFFIS burned-area figures). france24.com.

Haasnoot, M., Kwakkel, J. H., Walker, W. E. and Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change, 23*(2), 485–498.

Hersbach, H., Bell, B., Berrisford, P., et al. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society,* 146, 1999–2049. https://doi.org/10.1002/qj.3803

IPCC. (2019). *Special Report on the Ocean and Cryosphere in a Changing Climate.* Cambridge University Press.

IPCC. (2021). *Climate Change 2021: The Physical Science Basis. Summary for Policymakers.* Working Group I contribution to the Sixth Assessment Report. Cambridge University Press.

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability.* Working Group II contribution to the Sixth Assessment Report; Cross-Chapter Paper 4, Mediterranean Region. Cambridge University Press.

Losada, I. J., Feliu, E. and Sanz, M. J. (coords.) (2025). *Evaluación de Riesgos e Impactos derivados del Cambio Climático en España (ERICC-2025).* Ministerio para la Transición Ecológica y el Reto Demográfico, Madrid. Executive summary; sectoral chapter on the financial system and insurance

Losada, I. J., Toimil, A., Muñoz, A., Garcia-Fletcher, A. P., Diaz-Simal, P. (2019). A planning strategy for the adaptation of coastal areas to climate change: The Spanish Case. *Ocean & Coastal Management*, 182, 104983.

Magnan, A. K., Bell, R., Duvat, V. K. E, Ford, J. D., Garschagen, M., Haasnoot, M., Lacambra, C., Losada, I. J. (and 10 other authors). (2023). Status of global coastal adaptation. *Nature Climate Change*, 13, 1213-1221.

Markandya, A. (2026). *Climate Risk and Sustainable Finance.* Keynote presentation, Banco de España, 25 March 2026 (in the conference presentations pack, above; figures drawn from Climate Policy Initiative data).

Maza, L. Á. (2026). *Integrating the climate dimension into economic statistics: the experience of the Banco de España.* Presentation, Session 1 (in the presentations pack, above).

MITECO. (2017). *Estrategia de Adaptación al Cambio Climático de la Costa Española.* Dirección General de Sostenibilidad de la Costa y del Mar, approved 24 July 2017. miteco.gob.es.

NGFS. (2025). *NGFS short-term climate scenarios.* Network for Greening the Financial System.

Núñez, S. (2026). *Climate risk and sustainable finance: bridging policy, research and practice.* Opening remarks, Banco de España, 25 March 2026. BIS central bankers' speeches.

UNEP. (2025). *Adaptation Gap Report 2025: Running on Empty.* Nairobi. (summary).

UNFCCC. (2025). Decisions of COP30/CMA7, Belém, November 2025 (Global Goal on Adaptation indicators; adaptation finance). See Carbon Brief and Adaptation Community.

WMO. (2025). *State of the Global Climate 2024.* WMO-No. 1368. Geneva. (summary of findings)

WMO. (2026). *State of the Global Climate 2025.* WMO-No. 1391. Geneva, 23 March 2026. wmo.int.

Zurich Insurance. (2025). *Valencia floods: lessons in claims and recovery, one year on.* zurich.com.

Climate Risk and Sustainable Finance*

*Anil Markandya***

Abstract

The paper reviews the links between climate change and sustainable finance, set within the wider context of the triple planetary crisis of climate change, biodiversity loss and pollution. Treating these challenges as interdependent, it first defines sustainable finance via the environmental, social and governance (ESG) framework used by the European Commission and the OECD. It then compares current financial flows against estimated needs. Globally, at least $6.3 trillion in annual climate finance is required to 2030, against roughly $1.9 trillion currently mobilised — 93% of it for mitigation and only about 3% for adaptation. Adaptation finance, however, shows the largest relative shortfall, at ten to twelve times estimated needs, while biodiversity finance stands at $77–87 billion against a $200 billion target. Pollution prevention lacks any integrated global tracking framework at all. Combining the three areas, financing needs amount to 6.6% of global GDP and the gap to 4.8%, with the shortfall falling disproportionately on the private sector. The review examines instruments for closing these gaps: biodiversity-premium carbon credits, REDD+, GSSS bonds, debt-for-climate and debt-for-nature swaps, blended finance, dual-purpose mitigation—adaptation investments, and climate-related prudential policy for central banks, where stress tests and disclosure requirements show the strongest evidence of effect. A more detailed assessment of the financing gap for each area the planetary crises has been carried out for the EU, where more data are available. As for the global data it shows the largest gap for climate finance but also identifies a significant gap in pollution prevention.

It concludes by identifying gaps in understanding — notably the weak tracking of pollution finance and the insufficient identification of synergies and trade-offs across the three objectives — and the research needed to address them.

Keywords: sustainable finance, climate change, biodiversity, pollution, public, private.

1. INTRODUCTION

The topics in the title of this paper cover a vast literature. What is provided in this review is very much in the nature of an overview of the issues involved in the links between climate change and sustainable finance. These links are explored in the wider context of the planetary crisis in which climate is looked at in conjunction with the challenges of biodiversity loss and pollution because these things are not independent and dealing with one and not taking account of the interactions with the others will result in an incomplete assessment of the problem.

* This paper is based on a talk I gave at the Central Bank of Spain in April 2026. My thanks to participants who provided helpful comments that I have tried to take into account.

** Basque Centre for Climate Change, Leioa, Spain.

We begin by defining sustainable finance and follow that by reviewing the current flows of finance for climate change and related planetary challenges. These are compared with the amounts of finance needed to address climate risk and these related challenges. Given the gap in financing, we explore ways in which more finance can be mobilized and actions that can be taken in financial institutions to make the use of such finance more effective and more sustainable.

Since climate risk is related to the other problems of biodiversity loss and pollution, we look at the synergies and trade-offs between measures that address each of these components.

Finally, the review notes areas where there are gaps in understanding the problem and where further research is needed.

2. WHAT IS SUSTAINABLE FINANCE?

The European Commission[1] views such finance as a process of taking *environmental, social and governance (ESG) considerations* into account when making investment decisions in the financial sector, leading to more long-term investments in sustainable economic activities and projects. *Environmental considerations* include climate change mitigation and adaptation, as well as the environment more broadly, for instance the preservation of biodiversity, pollution prevention and the circular economy. *Social considerations* could refer to issues of inequality, inclusiveness, labour relations, investment in people and their skills and communities, as well as human rights issues. The *governance* of public and private institutions — including management structures, employee relations and executive remuneration — plays a fundamental role in ensuring the inclusion of social and environmental considerations in the decision-making process. The OECD[2] takes a similar approach stating that sustainable finance integrates environmental, social and governance (ESG) information into the decision-making process of companies and financial institutions.

We work within this framework for sustainable finance, especially the links between climate change and other areas. In this context, it is useful to know the magnitude of flows for mitigating climate impacts as well as for adapting to climate change compared to estimates of needs. It is also relevant to track the finance for limiting biodiversity loss relative to the amount needed to reduce such loss. The same applies to finance for actions to reduce pollution.

There are significant links, synergies and trade-offs between finances allocated to each of these objectives. Allocating finance to reducing GHGs will in most cases also result in a decrease

1 https://finance.ec.europa.eu/sustainable-finance/overview-sustainable-finance_en

2 https://www.oecd.org/en/topics/sub-issues/sustainable-finance.html

in local air pollutants from fossil fuel combustion and the health benefits of the reduction in those can often significantly lower the overall costs of making the transition away from fossil fuels (Markandya et al., 2018; Vandyck et al., 2018)).

In terms of biodiversity, climate change could overtake land use change as the leading cause of biodiversity loss by 2070 (Newbold, 2018). Wildfires are increasing as a cause of loss of forests and climate change is affecting and will continue to affect all forests, especially tropical forests.[3] A key indicator of biodiversity is mean species abundance, and this is declining with temperature rise (Dasgupta, 2021). The use of wood for energy is still an important source of deforestation in some hot spots (Bailis et al., 2015). And the change in climate is altering marine biomes including systems such as coral reefs (Hoegh-Guldberg et al., 2007).

Biodiversity also has huge implications for climate change. Enormous amounts of carbon are locked within animal life and vegetation. The Amazon contains carbon equivalent to a decade of global human emissions.[4] Biodiversity loss reduces significantly the capacity of the biosphere to absorb waste (WWF, 2022).

Regarding pollution and its links to climate change and biodiversity, the discharge of pollutants contributes to the degradation of the biosphere. As the pollution damages forests, lakes, rivers, estuaries and coastal waters, coastal waters suffer from eutrophication when subjected to overload of nutrients (Akinnawo, 2023), with consequences for recreation, fisheries etc. One issue which sometimes goes the other way is emissions of sulphur, a pollutant which can reduce the impacts of greenhouse gases and temperature and if it is reduced, may actually increase the temperature.

The OECD projections to 2050 indicate that, under current policies, all three elements of the planetary crises will worsen over that period. Global temperatures will rise from around 1.2°C in 2020 to 2.1°C by 2050. Historical data confirm that Europe is warming faster than any other continent, with temperature increases running about 1°C higher than the global average.[5] The effects of these increases are already being felt. The Summer of 2026 has been marked by extraordinary and record-breaking heat, led by Western Europe recording its hottest June on record at 3.06°C above the recent 1991–2020 average, according to the Copernicus Climate Change Service. Wildfires have raised mass evacuations and national emergencies in France and Spain.

Biodiversity will continue to decline, with mean species abundance (MSA) falling from 59.7 in 2020 to 56.5 in 2050. This reduction may appear modest but is equivalent to the

3 https://gfr.wri.org/latest-analysis-deforestation-trends

4 https://www.worldwildlife.org/places/amazon/

5 https://www.eea.europa.eu/en/topics/at-a-glance/climate

conversion of several million km^2 of pristine habitat into areas where all the original species have been lost.

With respect to pollution, plastic leakage into the environment is expected to increase by 64% between 2020 and 2050, undermining efforts to meet the global ambition to end plastic pollution. The nitrogen surplus indicator shows a smaller but still notable increase, reaching a 32% rise over the same period. A more positive development is the projected global decline of 21% in population weighted $PM_{2.5}$ concentrations by 2050 relative to 2020 (OECD, 2024).

3. FINANCE FOR CLIMATE CHANGE

Finance for climate change is separated into that for mitigation (i.e., reducing GHGs) and adaptation (i.e., adapting to a changing climate). Global Estimates by the CPI (Climate Policy Initiative. 2025) indicate that at least $6.3 trillion in annual climate finance will be needed from 2024 to 2030 to avoid the worst impacts of climate change. Current finance for mitigation and adaptation by CPI is estimated around $1.9 trillion a year, made up 93% for mitigation and about 3% for adaptation. The rest is a mixture of the two.

Mitigation Finance

So, there is a major gap to fill. Climate mitigation finance reached $1.9 trillion in 2023, but it has risen quite sharply — about 134% since 2018. This includes investment in various mitigation programmes involving: energy, transport, buildings, and infrastructure. As noted, most of the total finance has been for mitigation and of that, about one-third has been public and about two-thirds private. Hence for climate mitigation we are seeing a significant amount of expenditure coming from private sources. But mitigation amounts are still far short of needs: the gap is between $4.4 and $8 trillion a year, which equals to between 8 and 18% of all direct investment positions globally.

It is clear that a massive scaling up is needed if the climate finance targets are to be achieved. How can this be done within the framework of sustainable finance? These issues are discussed across the papers in this volume in some detail, but the following key points can be noted here. First, amounts of finance going to fossil fuel production and distribution are still large: they were about $1.2 trillion in 2024. At present, low carbon energy supply accounts for only 4% of global listed equity, compared to 10% for fossil fuel supply. Banks continue to finance fossil fuel supply heavily, with an estimated $1 trillion allocated in 2022, although that is much less than the $7.7 trillion of finance for low-carbon energy (IEA, 2025).

Second, fiscal incentives for switching to low carbon in the form of carbon pricing are still low and regulations for net zero are facing significant pushback. At present, only about 3.2% of emissions are priced at or above the recommended level and only 28% of emissions globally are covered by any pricing.[6]

Third, there are some positive trends as well. Costs of key clean technologies continue to fall rapidly, making them more competitive. The IEA's clean energy equipment price index hit a record low in early 2024, a 60% fall compared to 10 years ago. Solar panels and wind turbine prices have gone down 60% and 50% since 2022 and much more if you go back another decade (IEA, 2025).

A trend against that is the costs of grid materials, which have doubled in the last five years as a result of the demand for cables and transformers, raising infrastructure costs. Intermittency with renewables is an issue, but costs of battery storage are declining fast and declined 93% since 2010. And intermittency can be addressed through better connected grids and through variable electricity pricing. And these tools still have much greater potential than has been realized.

A key role in promoting changes that increase mitigation finance in a sustainable way lies with the central banks, who need to adopt climate-related prudential policies for risk management supervision. The integration of climate change-related risks into prudential policies covers: (a) capital (broadly covering minimum capital requirements); (b) risk management and supervision; (c) market discipline and (d) policies relating to liquidity and large exposures (OECD, 2024). On minimum capital requirements, this can be done through adjusting capital adequacy ratios with so-called green supporting or brown penalising factors, adjusting capital requirements for specific sectors highly exposed to climate-related risks or ones that can benefit from the climate transition, and adjusting counter-cyclical and systemic risk buffers. On risk management and supervision, climate-related measures involve integrating climate risks in stress tests, adjusting requirements for the quality and level of capital, or specifying lending limits. On market discipline integration mainly refers to climate-related disclosure policies for banks. Finally, liquidity requirements can be adjusted to better reflect climate related risks to banks' operations. Policymakers could restrict the share of banks' portfolios that are exposed to particularly high climate-related risks to limit their vulnerability to shocks. Similar exposure restrictions already exist for other risks (OECD, 2024).

In terms of implementation, prudential policies have mostly been implemented for capital-related policies. By 2023, 41 countries and the EU had developed some climate-related capital-related policies. Within climate-related and capital-related prudential policies, climate-related risk management and supervision policies are most common, often combined with

6 Home Page | Carbon Pricing Dashboard

related disclosure policies for financial institutions. Climate stress tests have been, to date, the most common climate-related risk management and supervision policies adopted or piloted.

An evaluation of the different measures is limited by a lack of data. Where attempts have been made, they have often relied on assessments based on theoretical models. Empirical data have been examined, however, for climate-related stress tests and climate-related disclosure requirements. According to the OECD, these two requirements (especially stress tests) are found to have a positive effect on reducing climate-related risks and increasing climate-related finance. Other measures studied through modelling approaches find mixed effects for restrictions on level and quality of capital, but generally positive effects of liquidity and exposure requirements (OECD, 2024).

Adaptation Finance

The amounts available for adaptation are much smaller than mitigation. About $123 billion globally was the figure compared to $1.7- $1.8 trillion for mitigation. The flows for adaptation in developing countries are around $26 billion. Compared to estimated needs, there may be a 10 to 12 times shortfall, according to the UNEP Adaptation Gap Report (UNEP, 2025).

In Western Europe, total investment for adaptation was about €13 billion in 2023 (Climate Policy Initiative, 2025). A European Commission study estimates the needs of the EU (which is not the same as Western Europe, but the difference is small) at around €70 billion a year to 2050.[7] So even in this region there is quite a big gap which needs to be filled.

For adaptation generally, the private sector accounts for very little of the total. It is about 5% in high income countries, while in developing countries adaptation finance is predominantly obtained through public international sources. In 2022, the public share of such finance was almost 100% for least developing countries and for the emerging market economies it was 97%. Furthermore, international public finance has declined since 2022 and further declines are expected, so there will be even bigger gaps to fill.

How can adaptation finance be increased? More private sector investment has been identified as being possible, especially in the areas of agriculture, water use and infrastructure. According to UNEP about 15 or 20 % of adaptation can be met in this way. In developing countries, the public sector's role of de-risking the investment and providing leverage is very important although there is potential for increasing it. The average leverage ratios for adaptation finance are 2:1, considerably lower than mitigation (3.6:1) (UNEP, 2025).

7 EU needs to invest €70 billion per year in climate adaptation up to 2050 - Climate Action

Further, there is need to find more ways of linking finance (i.e., where the funds come) to funding (i.e., who pays for the investments). Without clear and reliable sources of revenue private finance will not be forthcoming. The link could be done by mobilizing the funding sources through measures such as charging for land value enhancement or for the creation of increased resilience to the beneficiaries. Such measures may face opposition on grounds of equity or affordability but there is still some potential for them. At present, a lot of the adaptation finance is funded after the event from public sources.

Lastly, adaptation finance can be increased by supporting dual purpose investments that combine mitigation and adaptation. This is especially in areas of agriculture, forest and land use. Forest, water and waste are key sectors where complementarity exists and where it is playing an increasing role (Climate Policy Initiative, 2025).

4. FINANCE FOR BIODIVERSITY

The second area where sustainable finance to address climate risk needs to engage is biodiversity loss. Here the global biodiversity framework is a central guide.[8] The framework has many targets, but one of the key ones is to halt and reverse biodiversity loss by 2030 and restore 30% of degraded areas. The finance target is to increase finance for biodiversity actions and strategies to about $200 billion by 2030. The OECD estimates current finance from all sources about $77 to $87 billion (OECD, 2020). So again, there is quite a significant gap here.

Biodiversity, like climate change and to some extent pollution, is hard to finance because it is a public good. Hence it is under provided by the market. Furthermore, there is a global subsidy involved because biodiversity rich countries (a large amount of the biodiversity is in the global south) provide conservation benefits to the financially rich in the global north.

Instruments for raising finance for biodiversity conservation that also contribute to reducing climate risk include: (a) carbon credits with a biodiversity premium; (b) public-private sector bonds and public debt conversion and (c) private sector biodiversity markets.

Carbon Credits and Biodiversity

Carbon credits are certificates representing the removal of an amount of CO_2 from the atmosphere. They are purchased by parties on the voluntary carbon market (VCM) who wish to contribute to such reductions for a variety of reasons. Biodiversity-positive carbon credits are carbon credits that include additional and specific management actions linked to the enhancement, conservation, and or restoration of biodiversity. As a result of these

8 https://www.cbd.int/gbf

additional nature benefits, the credits can be sold at a premium, thus providing some finance for biodiversity protection. The VCM has a market valuation approaching US$2 billion (GEF, 2023) and about 10-15% of these have a biodiversity premium status[9].

In addition to the biodiversity-linked credits, there is also the REDD+ framework to bundle carbon reductions, human wellbeing and nature enhancement. Around 50 countries have REDD+ programs at various development phases, and over 350 REDD+ projects have been initiated to date. Project-based REDD+ credits are supplied both to the voluntary carbon market (VCM) and to compliance markets. The annual amount of REDD+ approval, however, in the five years to 2023 was only about $362 million.[10] Problems with the mechanism include: issues around additionality, leakage and permanence and actual and perceived integrity of the credits (GEF, 2023).

Despite the recent growth in biodiversity-linked carbon credits, the supply of such credits from both these sources remains small.

Sustainability Bonds and Debt Relief

A second source of sustainable finance is through sustainable bonds and through the repurposing of sovereign debt relief for environmental purposes. Instruments involving public and some private sources also support nature and climate objectives. One of these is Green, Social, Sustainability and Sustainability-linked (GSSS) bonds, which represent a new asset class across developed markets. GSSS bonds, which grew by $600 billion in 2021 alone, are borrowing instruments where the financial and structured characteristics are based on meeting pre-agreed sustainability criteria measured through key performance indicators (KPIs) (GEF, 2023). For example, nature performance bonds are tied to measurable targets for restoring wetlands, protecting forests, and reducing threats to wildlife and plant species, while still allowing for general use of proceeds (Nature Finance, 2021).

While having considerable potential, GSSS bonds still make up just a fraction of the bond market. The size of this market remains particularly limited in developing countries: Africa, for instance, accounted for only 0.077% of the global green bond market in 2021 (GEF, 2023). The market for GSSS bonds is hampered by several barriers in developing countries, especially least developed countries and small island developing states. Adequate market infrastructure is needed to provide the foundation for capital market depth and liquidity (Markandya, 2025). The share of the funds raised that are used for environmental purposes can also be quite small.

9 https://www.msci.com/research-and-insights/blog-post/the-carbon-credit-market-could-help-solve-the-biodiversity-funding-challenge

10 https://climatefundsupdate.org/wp-content/uploads/2024/04/CFF5-2024-ENG-REDD-DIGITAL.pdf

Debt conversions, often known as "debt for-climate" and "debt-for-nature swaps" are transactions where countries restructure, reprofile, and reduce their debt obligations in exchange for committing some portion of the freed-up financing toward domestic climate and nature projects (IMF, 2022). Debt for climate and nature swaps rely on blended finance, in the form of insurance policies or guarantees to provide below market borrowing rates for the borrower country. Examples include the GEF-supported Seychelles' 2016 debt conversion, which resulted in $22 million of investment in marine conservation (Convergence, 2017). Belize's 2021 debt conversion enabled the issuance of $364 million worth of blue bonds linked to national marine conservation activities (TNC, 2022) (Markandya, 2025). Recently, Portugal agreed to provide debt relief to Cabo Verde on condition the funds are used for climate and nature (Expresso Das Ilhas, 2023).

5. FINANCE FOR POLLUTION PREVENTION

The pollution crisis is the result of the release of various substances into the environment across several media (air, water, and soil). Its impact on both human health and wildlife is significant, with pollution being responsible for an estimated 9 million deaths annually, equivalent to one in six deaths worldwide (Fuller et al., 2022). The main forms of pollution that make up the crisis are particulate matter and ground-level ozone (air pollution), nutrients, chemicals and plastics (OECD, 2025).

As noted earlier, links between air pollutants and the drivers of climate change are strong. The links between pollution and biodiversity loss are also important. OECD (2024) notes that among species at risk of extinction, 18.2% are affected by pollution and that pollution ranks as the third most significant driver of biodiversity loss, up from fourth according to IPBES (IPBES, 2019).

Indicators that track pollution include population-weighted $PM_{2.5}$ concentration for air pollution; leakage of plastic waste into the environment for plastic pollution; area of surface water exceeding critical phosphorus concentration thresholds, and nitrogen surplus from agriculture for nutrient pollution (OECD, 2025).

In the case of pollution prevention, unlike for climate change and biodiversity, there is no integrated planning and reporting framework and no overall estimate of finance. National pollution control and management policy is made up of disparate policies and plans developed in response to different priorities and multilateral environmental agreements. These target various environmental problems such as air and water pollutants and hazardous chemicals, across different life cycle stages.

The OECD has recommended quite recently developing national plans to tackle pollution comparable to those available for climate change and biodiversity (OECD, 2025). This may be conducive to the identification of policy gaps as well as opportunities for synergies and risks of trade-off.

While there are also no global figures for financing pollution like those for climate and biodiversity, some data are available for the EU. Before looking at those, a summary of the known finance gaps at the global level are given. This recaps the discussion and figures presented earlier. It is followed by a more complete set of estimates of the financing gaps for pollution, climate change mitigation and adaptation, and biodiversity conservation for the EU. Through these we see the financing gaps that need to be filled for these three areas across this region.

6. GLOBAL SUSTAINABLE FINANCING GAPS EXCLUDING POLLUTION

Table 1 brings together the information available on finance needs and current expenditures at the global level for climate change and biodiversity. As noted, comparable data are not available for pollution. The finance needs as well as current expenditures are greatest for climate mitigation, followed by climate adaptation. The amounts for biodiversity by comparison are

Table 1
Global finance needs and levels for climate and biodiversity

	USD Billion Unless Otherwise Stated				
	Needs	Current	Gap	Public gap	Private gap
Mitigation	6,200	1,767	4,433	1,478	2,955
Adaptation	1,353	123	1,230	N.A.	N.A.
Pollution Prevention	N.A.	N.A.	N.A.	N.A.	N.A.
Biodiversity	200	82	118	N.A.	N.A.
Total	7,753	1,972	5,663		
As % of:					
Global GDP in 2024	6.6%	1.7%	4.8%		
Global Investment in 2024	27.1%	6.9%	19.8%		

N.A.: Not availale

Notes:

1. Public and private gaps for mitigation assume needs are in the same proportion as current public and private finances.
2. In the case of adaptation about 5% of expenditures in high income countries are private and the rest public. In all other countries, virtually all expenditures are public.
3. In the case of biodiversity, a very high percent is currently public although new instruments involving the private sector are being developed.
4. Global GDP in 2025 is estimated at $117.2 trillion. https://statisticstimes.com/economy/world-gdp.php
5. Global fixed capital formation figure for 2024 was $28.6 trillion. (World Bank Data).

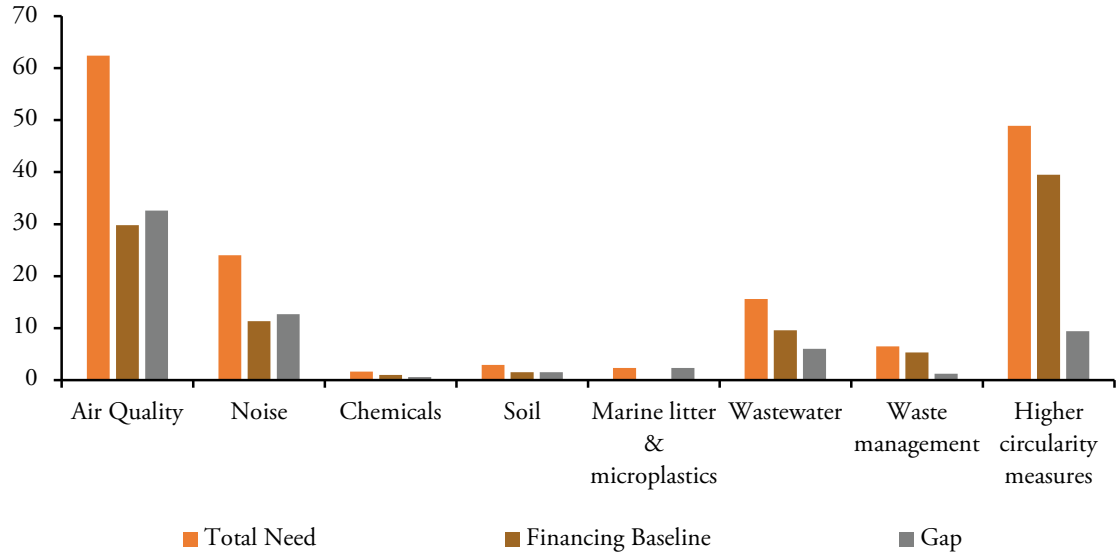
Sources: See Text.

much smaller. The gap for mitigation finance is currently around $4.4 trillion.[11] Based on the current private and public expenditures this would amount to about $1.5 trillion for the public gap and nearly $3 trillion for the private gap. We note in the text, however, there are several initiatives to increase the role of the private sector. Looking at the total (which is incomplete as pollution is not included), financing needs are about 6.6% of global GDP and 27.1% of global fixed capital formation. The corresponding gap is 4.8% of GDP and 19.8% of gross fixed capital formation. These are large amounts to raise between now and 2030.

7. FINANCING GAPS FOR THE EU INCLUDING POLLUTION

The European Environment Agency (EEA) has estimated the levels of finance needed to meet its 2050 zero pollution goals — i.e., to levels of pollution that are considered no longer harmful to the environment and human health.[12] To achieve this goal by 2050, it has set important milestones along the road. By 2030, it will require around €76 billion in EU investments. The significant current investment gap of approximately €40 billion is expected to be filled largely by private investments and additional measures through national energy and climate plans. Figure 1 shows the gap by area of pollution prevention. The biggest needs and gaps are for air

Figure 1
Pollution prevention finance in the EU 2030



Sources: Zero pollution: financing the investment gaps (Signal) | Indicators and signals | European zero pollution dashboards (EEA).

11 Figures are averages over a range.

12 https://www.eea.europa.eu/en/european-zero-pollution-dashboards/indicators/zero-pollution-financing-the-investment-gaps-signal

quality improvement, noise prevention, managing wastewater and circularity measures. The last of these consist of measures to prevent pollution and waste before it arises. They consist of designing and manufacturing goods to eliminate waste creation from the start; creating systems like refill stations or deposit-return programs to keep items in use; inspecting, cleaning, or repairing used products so they can be used again without remanufacturing and removing hazardous chemicals and dangerous materials from products during the design phase.[13]

The data show that around 47% of investment needs for pollution prevention are being met. Private funds are expected to account for a significant share of investments going forward, along with increased efforts by EU member states, partly through in-country resources and partly through EU funding, such as through the National Energy and Climate Plans. The European Commission says general government plus non-profit institutions serving households accounted for 28% of total national expenditure on environmental protection in 2022 (European Commission, 2026). In this context, easily understandable disclosures, well-introduced green bond standards, and incorporation for environmental, social, and governance elements into the ratings of corporations will help increase private finance. Also, reductions of fossil fuel subsidies will act as a means of reducing pollution as well as greenhouse gases.

A review similar to that for pollution was carried out by the European Commission for the finance gaps related to biodiversity conservation. Overall expenditure supporting biodiversity — including the EU budget, Member States' national budgets, and private expenditure — was reported at around €29 billion in 2021.[14] The estimated annual needs across the EU by 2030 are estimated at €48 billion.[15] We do not have an estimate of actual current expenditures but it is unlikely to very different from that in 2021. The current EU budget for biodiversity for example is fixed for the period 2021-2027 at €113 billion, or €16 billion per year.[16] Taking these figures, the financing gap in 2030 for the EU region is likely to be around €19 billion, a figure also calculated by the Institute of European Environment Policy.[17] In the case of biodiversity approximately 80% of biodiversity conservation funding in the EU comes from public sources, while the private sector contributes the remaining 20%.[18]

13 See: https://rethinkplasticalliance.eu/news/the-new-circular-economy-action-plan/; https://watereurope.eu/european-parliament-adopts-resolution-on-the-new-circular-economy-action-plan/; https://ecostandard.org/wp-content/uploads/2019/12/The-Next-Circular-Economy-Action-Plan-Priority-Measures-For-The-European-Commission.pdf

14 https://knowledge4policy.ec.europa.eu/biodiversity/eu-action-biodiversity-financing_en

15 https://wwfeu.awsassets.panda.org/downloads/invest-in-nature-for-people-and-planets-wellbeing_1.pdf

16 https://commission.europa.eu/strategy-and-policy/eu-budget/performance-and-reporting/horizontal-priorities/green-budgeting/biodiversity-mainstreaming_en

17 https://ieep.eu/publications/biodiversity-tracking-in-the-eu-budget-and-financing-the-eu-biodiversity-strategy-2030/

18 https://www.sciencespo.fr/chair-sustainable-development/files/Unlocking-Private-Finance-for-Nature-.pdf

As far as finance for climate mitigation and adaptation is concerned, estimates for 2030 have been made by the Climate Policy Initiative (CPI) for individual member states. They indicate that, based on latest figures, about €13 billion is spent on adaptation and €325 billion on mitigation. The needs by 2030, however, are estimated at €83 billion for adaptation and €718 billion for mitigation, implying financing gaps of €70 billion and €393 billion respectively.

All these figures are collated in Table 2, along with statistics on the share of 2025 GDP and of EU investment they represent. In the case of the public sector financing gap, it is also reported as a percent of EU public expenditures as a whole in 2025.

The table shows that there are significant financing gaps for all areas of sustainable finance, with the largest gap in absolute terms being from climate mitigation, followed by climate adaptation and pollution prevention. Relative to current levels of expenditure, the gap is largest for adaptation, with mitigation and pollution prevention being similar.

The breakdown of the gap between public and private finance indicates that more needs to be raised from private sources (€313 billion) than from public ones (€210 billion). As a percent of total investment by each of these sectors, however, the public gap amounts to around 31%, whereas the private one is much less — at around 8%. Hence, there is a strong need to shift financing further to the private sector. As we have discussed, there are several options for doing this for all three areas, but it needs a major effort and a significant upscaling of the measures currently being implemented.

Table 2
Financing needs and expenditures in the EU

	Euros Billion Unless Otherwise Stated				
	Needs	Current	Gap	Public gap	Private gap
Mitigation	718	325	393	118	275
Adaptation	83	13	70	67	4
Pollution Prevention	76	36	40	9	31
Biodiversity	48	29	19	16	3
Total	925	403	522	210	313
As % of:					
EU GDP	4.7%	2.1%	2.7%	1.1%	1.6%
EU Investment	21.1%	9.2%	11.9%	30.7%	8.4%
EU Public Expenditure				2.2%	

Sources: See Text.

8. CONCLUSIONS

The financing needs for meeting climate change, biodiversity and pollution prevention are significant across all countries. Although amounts being mobilized are rising fast, the gaps that need to be filled are very large. Climate change mitigation has the largest requirements and needs to go up at least threefold. The good news here is that private investment in low carbon is increasing fast. Incentives to reflect risks for fossil fuel investment and support renewables can speed up this process. In this regard, the banking sector has an important role to play. A number of instruments have been introduced recently, and evidence shows that climate-related stress tests and climate-related disclosure requirements (especially stress tests) have a positive effect on reducing climate-related risks and increasing climate-related finance. Increased adoption of these is therefore recommended.

Adaptation to climate change has lower finance requirements but depends significantly on the public sector and the relative gap is greater than for the mitigation, especially in developing countries. Increasing the private sector's role is possible to a limited extent but needs concerted action through blended finance, leveraging scarce public funds to attract private sources and the use of dual-purpose programs.

The needs for biodiversity conservation are more than double the actual flows. The expenditures are needed most in biodiversity rich countries, which are mostly in the global south. Most finance will have to continue to come from public sources, but there is a potential for the private sector through various instruments such as carbon credits with a biodiversity premium, public-private sector bonds and public debt conversion that targets some of the funds realised for biodiversity conservation and private sector biodiversity markets. At present the extent of finance from these sources, however, is small.

Pollution prevention is not tracked globally in an integrated manner, and this gap needs to be addressed. Finance for such prevention is from a mixture of public and private sources, with the adoption of the polluter pays principle (PPP) determining to some extent, who finances the measures to reduce pollution. However, PPP is not universally adopted, partly on distributional grounds, so the public sector bears some of the burden. A more detailed review for the EU revealed that general government plus non-profit institutions serving households account for around 28% of national expenditure on environmental protection. Increasing the role of the non-public sector would involve the use of pollution disclosure requirements, green bonds with strong links to pollution reduction, and the incorporation for environmental, social, and governance elements into the ratings of corporations. Further, as noted, reductions of fossil fuel subsidies will act as a means of reducing pollution as well as greenhouse gases.

There is also a gap in identifying synergies and trade-offs when designing programs. This is also an area where action is needed.

REFERENCES

Akinnawo, S. O. (2023). Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies. *Environmental Challenges*, Volume 12, 100733. ISSN 2667-0100. https://doi.org/10.1016/j.envc.2023.100733. (https://www.sciencedirect.com/science/article/pii/S2667010023000574)

Bailis, R., Drigo, R., Ghilardi, A., and Masera, O. (2015). The carbon footprint of traditional woodfuels. *Nature Climate Change*. doi:10.1038/nclimate2491.

Climate Policy Initiative. (2025). *Global Landscape of Climate Finance 2025.* https://www.climatepolicyinitiative.org/publication/global-landscape-ofclimate-finance-2025/

Dasgupta, P. (2021). *The Economics of Biodiversity: The Dasgupta Review*. London: HM Treasury.

European Commission. (2020). Biodiversity Strategy for 2030: Bringing Nature Back into Our Lives. https://www.arc2020.eu/wp-content/uploads/2020/05/Biodiversity-Strategy_draft_200423_ARC2020.pdf

European Commission. (2026). Fitness Check of the Polluter Pays Principle. {SEC(2026) 404 final} - {SWD(2026) 403 final}. Polluter Pays Principle (PPP) Fitness Check - Environment.

GEF. (2023). *Innovative Finance for Nature and People: Opportunities and Challenges for Biodiversity-Positive Carbon Credits and Nature Certificates.* Washington DC.

Hoegh-Guldberg, O., Mumby, P. J., Hooten, A. J. et al. (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. *Science, 318*(5857), 1737–1742.

International Energy Agency (IEA). (2025). *World Energy Investment.* 10th Edition. Paris: IEA.

IPBES. (2019). *The global assessment report of the intergovernmental science-policy platform on biodiversity and ecosystem services.* IPBES, https://doi.org/10.5281/zenodo.3553579.

Markandya, A. (2025). Mobilising Finance for Global Biodiversity Targets. *Ekonomiaz*, 106, 104-128. https://doi.org/10.69810/ekz.1485

Markandya, A., Sampedro, J., Smith, S. J., Van Dingenen, R., Pizarro-Irizar, C., Arto, I., González-Eguino, M. (2018). Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study. *Lancet Planet. Health,* 2, e126–e133.

Nature Finance. (2021). *Nature Performance Bonds – Frequently Asked Questions* https://www.naturefinance. net/resources-tools/nature-performance-bonds/

OECD. (2020). *A Comprehensive Overview of Global Biodiversity Finance: Initial results*. Thematic Workshop on Resource Mobilisation for the Post-2020 Global Biodiversity Framework, January 14-16 2020.

OECD. (2024). *OECD Review on Aligning Finance with Climate Goals: Assessing Progress to Net Zero and Preventing Greenwashing*, *Green Finance and Investment.* Paris: OECD Publishing. https://doi.org/10.1787/b9b7ce49-

OECD. (2025). *Environmental Outlook on the Triple Planetary Crisis: Stakes, Evolution and Policy Linkages.* Paris: OECD Publishing. https://doi.org/10.1787/257ffbb6-en.

UNEP. (2025). Adaptation Gap Report 2025. Adaptation Gap Report 2025: Running on Empty - The World is Gearing up for Climate Resilience — without the Money to get there

Vandyck, T., Keramidas, K., Kitous, A., Spadaro, J. V., Van Dingenen, R., Holland, M., Saveyn, B. (2018). Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. *Nat. Commun.*, 9. https://doi.org/10. 1038/s41467-018-06885-9.

WWF. (2022). *Living Planet Report 2022 – Building a nature positive society*. Almond, R.E.A., Grooten, M., Juffe Bignoli, D. & Petersen, T. (Eds). Gland, Switzerland: WWF.

Financing the Transition*

From Bridgetown to a new architecture for public and private climate finance: personal reflections

*Avinash Persaud***

Abstract

The debate over climate finance is too often framed as a search for one very large pot of money. That framing obscures the central problem. Different climate and development investments have different economics and as a result require different forms of finance. Activities with capturable revenues can and should attract private capital. Investments in resilience often produce very large social and fiscal savings but little direct revenue, making long-term, low-cost multilateral development bank finance the natural instrument. Climate-related loss and damage impose real costs without an offsetting financial return and therefore require grants and other forms of fiscal transfer. Once these distinctions are made, the apparent financing problem becomes affordable.

But it also exposes a problem in the prevailing response: blended finance has become a default rather than a diagnosis. Guarantees, first-loss capital and concessional finance use scarce public risk-bearing capacity even when they do not require an immediate fiscal outlay. They should be reserved for risks markets cannot efficiently bear, not routinely used to make already-commercial investments acceptable to investors. Sovereign debt must meanwhile become more shock-absorbing through pause clauses, longer maturities, timely restructuring and scalable debt swaps. And private capital mobilisation must move beyond trying to persuade regulated institutional investors to buy risks they are structurally unable to hold. ReInvest+ illustrates an alternative: use the local banking systems that already know how to originate and manage commercial risk, recycle seasoned performing assets into rated hard-currency securities that institutional investors can hold, and require the released capacity to be reinvested in commercially viable national development priorities.

The result is not a call for finance to become less commercial. It is a call for a better division of labour: public finance should bear the risks only public balance sheets can bear, while financial intermediation should give private investors the assets they are institutionally equipped to own.

Keywords: climate finance, development finance, multilateral development banks, private capital mobilisation, financial intermediation.

1. THE PROBLEM IS NOT SIMPLY A SHORTAGE OF MONEY

When I worked on macroprudential regulation after the 2007-2013 global financial crisis, one of the central lessons was a fallacy of composition. Making every individual

* Prepared from remarks delivered at the Banco de España conference, March 2026. This paper contains personal reflections on development and climate finance of the author and does not represent the collective views of the Inter-American Development Bank where he is the Special Advisor to the President.

** Inter-American Development Bank.

bank safer did not necessarily make the financial system safer. If every bank responded to risk by selling the same assets at the same time, individually prudent behaviour could produce systemic instability.

Climate and development finance has its own fallacies of composition. What is sensible for one country in the short run may not be sensible for the planet in the long run. What is commercially rational for an individual investor may leave socially valuable investments unfunded. And the countries bearing the greatest climate losses are often those least responsible for the stock of emissions. We cannot solve these problems simply by exhorting every participant to do more.

There is a great deal to be pessimistic about in the world today. However, I am not pessimistic about our ability to finance the climate transition and climate resilience. The world has the savings, the technology and, increasingly, the institutional capacity. What it lacks is financial architecture that sends the right kind of money to the right kind of investment.

The usual discussion starts with a very large number: the climate-finance gap. It then asks governments, development banks, philanthropies and private investors each to contribute to closing that same gap. This is the horizontal approach. Mitigation receives a layer of grants, a layer of concessional finance, a layer of multilateral development bank finance and a layer of private capital. Adaptation gets another stack. Loss and damage get another. When public budgets tighten, policymakers hope the private layers will somehow thicken to compensate.

This approach will fail. It creates unrealistic expectations of private finance, dissipates scarce grant resources, and uses the risk-bearing capacity of governments and multilateral development banks for activities that private capital could finance if the intermediation problem were solved. It also invites political backlash, because taxpayers are asked to subsidise investments that already have commercial revenues while genuinely non-commercial needs remain unmet. The issue is not simply that public money is scarce and private finance is abundant. Public risk-bearing capacity is scarce too and private finance cannot do everything.

The alternative is a vertical approach: start not with the climate label attached to an investment, but with its underlying economics. Listening to an earlier, more incoherent version of this framework, Ronan Palmer, produced a simple taxonomy of my idea: revenues, savings and costs. Those three words lead to three different financing answers. These categories describe economic functions, not necessarily whole projects. A single investment may contain elements of all three. A resilient power system, for example, may generate commercial revenues, economy-wide savings and uncompensated public benefits. The purpose of the taxonomy is not to force every project into one or another box, but to identify which component should be financed by which instrument.

2. REVENUES, SAVINGS AND COSTS: A FUNCTIONAL TAXONOMY

■ *Revenues: use private capital where private capital works*

Many investments associated with mitigation generate capturable revenues. A solar farm sells electricity at commercial rates, so does a wind farm. A more efficient industrial plant produces goods at lower operating cost. Electric mobility can generate fares or lease payments. They have customers and cash flows.

In advanced economies, private capital already finances most of such investments. That tells us something important. The technology is financeable. The commercial model is financeable. The challenge in emerging and developing economies is not to invent a different economic model for a solar panel. It is to overcome the financial frictions that make an otherwise familiar investment expensive to fund: macroeconomic risk, currency risk, shallow capital markets, regulatory constraints, small transaction sizes and the institutional rules governing the owners of global savings.

If an investment produces commercial revenues, our first question should therefore be: what is preventing commercial finance from reaching it at scale? Public money should be used to remove systemic barriers, create markets or bear risks that private actors cannot efficiently hold. It should not routinely be used to compensate investors for risks that are already commercially manageable merely because the available asset is packaged in the wrong form.

■ *Blended finance: an instrument, not an allocation rule*

Blended finance has an essential role, but in its traditional forms it has gradually become an answer offered before the question has been properly diagnosed. There are investments where social returns exceed private returns, where pioneering investors face costs that later entrants will not, or where a limited public guarantee can create a market that subsequently stands on its own. In those cases, blending can be exactly the right instrument.

But not every gap between the return an investor demands and the return a project offers is evidence of a market failure that the public sector should fill. Sometimes it reflects a currency mismatch. Sometimes it reflects the investor's regulatory mandate. Sometimes the transaction is too small, the asset too unfamiliar or the structure too illiquid. These are intermediation problems. If we respond to each of them with a guarantee, a first-loss tranche or concessional capital, we turn public risk-bearing capacity into a universal subsidy for financial friction.

That capacity is scarce even when no cheque is written on day one. A guarantee uses balance-sheet headroom. A junior tranche commits capital to absorb losses. A concessional loan transfers value. A first-loss facility can tie up public capacity for years. Each has an opportunity cost:

the same capacity cannot simultaneously support a public good, a fragile borrower, a disaster response or a market that genuinely cannot emerge without public risk-taking.

This changes how we should judge mobilisation. The question is not simply how many dollars of private finance appear beside each dollar of public finance. We should ask what risk the public sector is taking, why the private sector cannot efficiently take it, whether the intervention is temporary and market-building, and what alternative public purpose is displaced. Blended finance should be used where it changes the economics of an otherwise underprovided activity, not as the default response to every financing friction. Structural risks such as currency and sovereign risk should not automatically become public risks merely because a particular investor cannot hold them. The first question should be whether they can be diversified, hedged, pooled, priced or transformed before scarce public risk-bearing capacity is deployed.

This suggests a hierarchy. Transform risks first. Socialise them only where necessary. Subsidise them where justified by public goods, externalities or genuine market-creation barriers. The purpose of financial architecture should be to place each risk with the institution best equipped to bear it, rather than to make the public balance sheet the residual holder of every risk private investors would prefer not to own.

- *Savings: finance resilience with long-term development credit*

The economics of much adaptation are different. A seawall does not usually charge every house it protects. Better drainage does not collect a fee from every business that remains open after a storm. A stronger bridge may prevent a region from being cut off, but the avoided economic loss does not automatically appear as revenue to the bridge owner. These are public goods or have large public-good characteristics.

Yet the absence of capturable revenue is not the absence of economic return. Resilient infrastructure can produce extraordinary savings by avoiding future losses, reducing reconstruction costs, preserving tax bases, keeping schools and hospitals functioning and limiting the fiscal shock that follows disasters. The return exists, but it accrues diffusely across society and over long periods. That is precisely why public finance exists.

This is where multilateral development banks should be at their most useful. They can borrow long, lend long and pool risk across countries. They can help governments turn future fiscal savings into affordable investment today. But the instrument must match the asset. Financing infrastructure that lasts fifty years with ten- or fifteen-year money unnecessarily raises annual debt service and can make an economically compelling investment look fiscally impossible. We need much more twenty-five-, thirty-five- and, where appropriate, fifty-year finance for long-lived resilience investments.

The Bridgetown Initiative helped move the debate on the capital adequacy of Multilateral Development Banks (MDBs) narrow concern with preserving capital ratios to a more systemic concern about how to use public balance sheets most effectively. Reforms pushed by the Bridgetown Initiative and others have created substantial additional lending headroom — according to the credit rating agencies, MDB lending headroom has increased by as much as $700bn without new capital. This provides substantially more space for MDBs to pursue those investments most suited to them: those with substantial national savings but limited capturable revenues. And there is more progress to be made on reforming MDBs to expand their impact, through better recognition of callable capital, portfolio guarantees, use of SDRs, risk transfers and other balance-sheet measures. The point of these reforms is not to make MDBs unsafe or even to lose their 'AAA' rating. But it is to recognise that excessive conservatism in a public development institution also has a cost: investments not made, resilience not built and crises made more expensive.

- *Costs: reserve scarce grants for what cannot repay finance*

The third category is cost. When a low-income household's home is destroyed by a hurricane, there is no future revenue stream or fiscal savings big enough to service a loan to rebuild it. The loss is real, and somebody must bear it. If a climate vulnerable country borrows every time homes, crops and public assets are destroyed, it can drown in debt before it is submerged by rising seas.

That is why I resist the proposition that scarce grant money should be spread evenly across mitigation, adaptation and loss and damage. If there were a spare trillion dollars of grants, the allocation problem would be less pressing. There is not. Grants are politically and fiscally scarce. Every grant dollar used to subsidise a revenue-generating project that could have been commercially financed, or a resilience investment that could have been financed on long-term concessional terms, is a grant dollar unavailable for a loss that cannot be financed any other way.

This is not an argument against concessionality. It is an argument for greater precision in mapping resources to purpose. Use the scarcest public resources on those things that cannot be funded any other way. Unavoidable costs call for grants and transfers. Where there are revenues, it calls for facilitating private capital. Savings call for long-term development finance funded at AAA rates. Once we stop treating all climate finance as one thing, the numbers become less impossible.

3. RESILIENCE IS THE BEST FORM OF INSURANCE

There is also a critical distinction between insurance and resilience. Insurance is not magic. It redistributes losses across time; resilience reduces them. Insurance remains valuable because it

pools and transfers risks that households, firms and governments should not bear alone in an instant. But premiums must cover long-term expected losses, administration and the return required by insurers' capital. What you get out is less than what you put in. Resilience investment, by contrast, can reduce the underlying expected loss itself. Research and publications from the Inter-American Development Bank (IDB) and others point to substantial economic returns: the IDB has estimated that every dollar invested in resilient infrastructure can generate up to four dollars in economic benefits, including avoided recovery and reconstruction costs. The precise ratio varies by project and hazard, but the direction is clear: well-chosen resilience investment can pay for itself several times over in avoided losses and preserved services.

There is also a practical feature of insurance that policymakers sometimes overlook: much property and catastrophe insurance is renewed annually. An insurer can cover a risk year after year until repricing along with exclusions make premiums unaffordable precisely when the underlying risk has become greatest. Paying premiums without investing in resilience can therefore leave a country poorer and uninsurable.

The objective of resilience investment is not to abolish insurance. It is to make insurance a solution again by pushing risks back to the tail. Stronger buildings, flood protection, better drainage, resilient power and communications, early-warning systems and anticipatory action reduce expected losses and preserve the insurability of residual risks. Resilience, especially when funded long-term at low-cost MDB borrowing rates is, in that sense, the best form of climate insurance.

4. IF WE USE MORE DEBT FOR RESILIENCE, DEBT ITSELF MUST BECOME MORE RESILIENT

The vertical financing framework has an important implication. If MDBs provide substantially more long-term finance for resilience, public debt architecture must also change. There will be more debt, not less and the answer is not to pretend that debt does not matter. It is to design debt that is better matched to long-lived investments and better able to absorb shocks.

The first reform is the natural disaster pause clause championed through the Bridgetown Initiative. The principle is simple. When a sufficiently severe disaster occurs, verified by an independent trigger, scheduled debt service is paused for a defined period and added back later. Properly designed, the clause can be net-present-value neutral to the creditor. It is not debt forgiveness. It is pre-arranged liquidity precisely at the moment liquidity is most valuable and most costly to arrange.

The scale matters. A country can purchase contingent credit lines or catastrophe insurance, but these instruments normally cover only a fraction of national financing needs after a major

disaster. If pause clauses are embedded across a large share of sovereign debt, the liquidity released can be an order of magnitude larger and arrive without negotiating a new emergency loan in the middle of a disaster. Debt stops being an amplifier of the shock and becomes, at least temporarily, a shock absorber.

Second, maturity should better reflect asset life. A fifty-year resilience asset should not routinely be financed as though it were a short-lived expenditure. Longer maturity reduces the annual fiscal burden and allow the generations benefiting from the assets to share its financing cost.

Third, we need to become less afraid of timely debt restructuring where debt is genuinely unsustainable. National governments often congratulate themselves when they avoid default even if the price is years of compressed public investment, deteriorating services and implausible fiscal adjustment. Delayed restructuring can destroy value for creditors as well as citizens. A better system would combine more predictable restructuring terms with credible safeguards around essential social and development spending. And of course, new efforts to maintain fiscal sustainability into the future.

Fourth, for countries whose debt is high and expensive but not necessarily unsustainable, market-based debt swaps can create fiscal space. Credit enhancement from an 'AAA'-rated institution can allow a country to refinance expensive commercial debt at a much lower rate and longer maturity, with part of the resulting savings committed to resilience, nature or social investment. The Inter-American Development Bank is a leader in debt swaps having done more than any other MDB but the next step is to make these operations less bespoke. Multi-guarantor structures, in which MDBs and bilateral guarantors combine their credit enhancement under common arrangements, can enlarge transactions, diversify guarantor exposure and make the instrument more repeatable. I am pleased to note that the first multi-guarantor structure is being trialed in Barbados in 2026.

Together, pause clauses, longer maturities, timely restructuring and scalable swaps amount to a different conception of sovereign finance. The objective is not simply more debt or less debt. It is debt that is cheaper where it funds high-return public investment, restructured when it is unsustainable, and capable of flexing when disaster strikes.

5. THE PRIVATE-FINANCE PROBLEM IS AN INTERMEDIATION PROBLEM

The other half of the architecture concerns investments with revenues. Here the debate has been dominated by the phrase "mobilising private capital". That is the right ambition but

often instills the wrong mental model. We speak as if trillions of dollars are sitting in a room waiting for a sufficiently persuasive climate project to knock on the door.

The trillions exist, but they are institutional. They sit in pension funds, insurance companies, mutual funds and other regulated portfolios. The clue is in the name: institutional investors are very institutional. They have external regulation, internal risk limits, benchmark constraints, rating requirements, currency mandates, liquidity needs and familiar investment processes. Many cannot hold an unrated project loan, denominated in local currency, in an unfamiliar jurisdiction even when the expected return looks attractive.

This helps explain a persistent puzzle. Emerging and developing economies account for a large share of global growth and an even larger share of future investment needs, yet they remain a very small share of many institutional portfolios. We often diagnose this as excessive risk aversion and respond by trying to change the investor. We organise roadshows, create public databases of returns information, add guarantees and blended-finance layers, and ask for a regulated pension fund to behave more like an emerging-market project-finance bank. The result is either nothing or an extensive use of public risk-bearing capacity to make the investor behave differently. We are not fitting the asset to the investor.

Sometimes that is worthwhile. We do it at the IDB and other MDBs will continue to do so. But it is not a scalable organising principle. If every transaction requires a public guarantee, junior tranche or concessional layer before a private investor can participate, mobilisation remains bounded by the limited size of public balance sheets. Worse, the headline mobilisation ratio can disguise what has happened economically: the public sector has retained or absorbed the difficult risk while the private investor has taken the part it already wanted. That may be justified where there is genuine externality or a temporary market-creation problem. But it is not evidence that a commercial market has been created.

The more promising question is not how much public support is needed to drag an investor into an unfamiliar asset. It is: who already knows how to take the risks we need to take, and how can we connect that risk-taking capacity to deeper pools of funding? In middle-income developing economies the answer is often local banks. They know their clients, their regulations, their collateral regimes, their currencies and their sectors. They already hold vast portfolios of performing corporate loans. Their constraint is not always a shortage of projects or expertise. It may be the cost and availability of balance-sheet capacity, funding and liquidity to originate more of the things the private sector can fund.

ReInvest+, a novel IDB initiative, starts from this institutional reality. Instead of trying to take the global institutional investor directly into a new renewable-energy project in an unfamiliar market, it separates origination from ultimate funding.

In the first step, local financial institutions do what they are good at: originate and manage commercial credit in their own markets. ReInvest+ purchases pools of seasoned, performing local-currency corporate loans from participating banks. These are not speculative start-ups selected because somebody has attached a climate label. They are commercial assets with payment histories, observable performance and credit characteristics that can be analysed and rated.

In the second step, those selected, performing assets are pooled and transformed into rated hard-currency securities designed for the risk, currency and regulatory requirements of mainstream institutional investors. The investor does not have to become a specialist in local project origination. The local bank does not have to become a global asset manager. Financial structuring bridges the two. This is risk transformation rather than indiscriminate risk socialisation: diversification, seasoning, standardisation, currency structuring and tranching are used to create an investable security, rather than assuming that the public sector must simply absorb the risk the investor does not want.

The development additionality comes from what happens next. The originating bank sells performing assets – while keeping a share to avoid adverse selection — receives cash and releases lending capacity. Participation requires that this capacity be redeployed into new commercially viable lending aligned with national development priorities, including NDCs (nationally determined contributions) and other agreed priorities. The system therefore recycles capital: originate, season, sell, reinvest and repeat.

This distinction matters. ReInvest+ is not a climate subsidy programme and it is not built around a permanent public first-loss layer. Its raw material is commercial lending already taking place in developing economies. Its purpose is to connect strong local financial institutions with deep global capital markets, while using the recycling condition to direct newly released lending capacity towards a country's own development priorities including their NDCs, which are often the most detailed of those long-term priorities. Development impact is primarily achieved through the reinvestment and eligibility framework, not by pretending that investors will accept risks their mandates prohibit or by permanently subsidising them to do so. It is also indirectly achieved by lowering the cost of capital through the injections of new, cheaper, overseas capital.

The model also addresses scale differently. The stock of performing assets on bank balance sheets in major emerging markets is measured in trillions of dollars. A programme can therefore begin with an issuance of a few hundred million dollars, establish pricing and investor familiarity, and then become a repeat issuance programme. Scale comes from repetition and standardisation, not from making each individual transaction heroic.

This is the private sector part of the Bridgetown logic. Bridgetown asked how to use the public financial architecture we already have more intelligently for those things that generate fiscal and national savings: MDB balance sheets, callable capital, disaster clauses, concessional resources and guarantees. And it asked to address the obstacles to private sector investment into those things that have capturable revenues. ReInvest+ asks the equivalent question of private finance: how do we use the financial institutions and assets that already exist in developing economies to connect them to the institutional savings that already exist globally? A common principle is that scarce public risk-bearing capacity should not be the universal solvent for every financing friction. Another is the idea that the principal constraint is not an absolute shortage of money but an exercise in financial architecture. The task is to match risk-bearing capacity with the risks that each institution is actually equipped to hold. Public institutions should bear public risks and market failures that cannot sensibly be shifted elsewhere. Commercial institutions should bear commercial risks. And intermediation can transform risks and assets before governments are asked to socialise them.

6. MIDDLE-INCOME COUNTRIES ARE CENTRAL, NOT PERIPHERAL, TO THE TRANSITION

For a start, a large share of the world's poorest people live in middle-income countries. The distribution is changing as extreme poverty becomes increasingly concentrated in fragile low-income countries, but the basic point remains concern for poor people cannot be reduced to concern only for countries currently classified as poor. Moreover, the global energy transition will be won or lost in middle-income countries. Their energy demand, cities, transport systems and industrial capacity are expanding rapidly. If countries such as Brazil, Mexico, India, Indonesia, South Africa and others lock that growth into high-carbon systems, actions elsewhere cannot compensate for the environmental, health and economic harm. Fortunately, these economies also have something that poorer economies may have less of: substantial domestic financial systems, institutional capacity and large pools of commercial assets. That makes capital recycling, like that envisaged by ReInvest+, particularly powerful.

The vertical framework again helps avoid a false argument. Supporting private capital mobilisation in a middle-income country need not mean diverting scarce grants from a low-income country. If the instrument is commercially structured and catalytic rather than subsidised, it can expand the total pool of finance. The objective should be differentiation, not graduation from relevance. Poorer and more vulnerable economies will need more grants and concessional resources. Large middle-income economies need financial intermediation on a scale, lower costs of capital and instruments that mobilise their own banking systems. The architecture should respond to those differences rather than force every country through the same financing window.

7. WHAT SHOULD SHAREHOLDERS AND CENTRAL BANKS ASK OF THE SYSTEM?

This agenda has implications for the shareholders of international financial institutions, including Spain, and for central banks and financial authorities. The first is to stop measuring ambition primarily by the volume of climate-labelled finance or by simple mobilisation ratios. The more useful question is whether the right finance is being helped in the right places to maximise development impact.

For MDB shareholders, that means continuing capital-adequacy reform while giving clearer strategic direction. Additional lending headroom is only valuable if it is used. If resilience is a priority, shareholders should ask why high-return resilience investments are not being financed. They should support more effective use of callable capital and guarantees, and the standardisation of shock clauses and multi-guarantor structures, but should also consider new instruments too, such as those with extra-long maturities.

For private capital mobilisation, shareholders should be wary of mobilisation ratios that reward complex subsidies without establishing a repeatable, deeper domestic market. Every guarantee, junior tranche or concessional layer has an opportunity cost, even when it does not appear as an immediate budgetary expenditure. The test should therefore be additionality, repeatability, the risks the public sector is actually bearing, and whether that support can diminish as the market matures.

Central banks and regulators also matter because institutional investment is shaped by prudential rules. The answer is not to weaken regulation in the name of climate. We learned during the global financial crisis what happens when risk is hidden rather than managed. The better approach is to create instruments whose risk characteristics genuinely fit regulated portfolios: transparent structures, credible ratings, diversified pools, appropriate currency denomination and robust disclosure. Financial innovation should work with prudential reality, not wish it away.

There is also a macroprudential insight. A world in which global savings are concentrated in a narrow set of advanced-economy assets while the fastest-growing economies face structurally high costs of capital is not obviously an efficient allocation of risk. Better diversification can serve investors as well as development. But diversification will not happen at the necessary scale through exhortation. It requires investable instruments and institutions that can perform the transformation between local risks and global mandates.

8. FROM SCARCITY TO ARCHITECTURE

The politics of climate finance has been trapped by scarcity. Developing countries point, correctly, to enormous needs and historical responsibilities. Advanced economies point, also

correctly, to their constrained budgets and competing demands. Each negotiation then becomes a struggle over a number that is simultaneously too large for public budgets in developed countries and too small for the investment need in developing countries.

The way out is not to deny scarcity but to use scarce resources according to function. Do not spend grant money where a commercial revenue stream can pay investors or a resilient investment can repay its financing loan many times over with fiscal savings. Do not use scarce public risk-bearing capacity merely to improve the risk-return profile of investments that could be financed commercially with better intermediation to better manage genuine FX and sovereign credit risks. Do not demand private capital for public goods whose returns only arrive as social and fiscal savings. Do not lend to people who have suffered an uncompensated loss and then call the resulting debt a sustainability problem mismanagement. And do not ask institutional investors to become something they are not when a new financial architecture can give them the assets they are designed to hold.

This is why I remain optimistic. We do not need to choose between prosperity, peace and the planet because the financing problem, properly disaggregated, is manageable. We need grants for costs that cannot be repaid. We need MDB balance sheets for investments whose returns appear as economy-wide savings. We need shock-absorbing sovereign debt. And for revenue-generating investment, we need to connect global savings to local financial systems on a scale.

Revenues, savings, costs. Private capital, development banks, grants. Resilient debt and active intermediation between local expertise and global savings. Blended finance remains an important instrument, but it should be a scalpel, not the whole operating system. Once we put the right money — and the right risk-bearing capacity — against the right problem, financing the transition looks less like an impossible demand on scarce resources and more like what it really is: a solvable problem of financial design. None of this is to deny that climate finance is ultimately political. Those of us trained in finance are perhaps too inclined to believe that better design can solve political problems. It cannot. But better design can change politics. An architecture that requires less of scarce public budgets while delivering more investment is easier to build a coalition around; and successful investment can expand the economic and political space for greater ambition. Financial architecture is therefore not a substitute for political ambition. Done well, it can make greater ambition possible. Ambition can beget ambition.

REFERENCES AND FURTHER READING

Inter-American Development Bank. (2022). 'IDB and IDB Invest Provided $26 Billion in Climate Financing over Five Years', citing estimates that each dollar invested in resilient infrastructure can generate up to four dollars in economic benefits.

Inter-American Development Bank (2025). From Risk to Reliability: Resilient Infrastructure Services to Face Nature's Challenges. Washington, DC: IDB.

Inter-American Development Bank. (2026). Operational Readiness and Early Implementation of ReInvest+ (RG-T5078).

Persaud, A. (2025a). Climate Finance 101. Power and Planet podcast, Inter-American Development Bank.

Persaud, A. (2025b). The Road to $1.3 Trillion. Power and Planet podcast, Inter-American Development Bank.

Persaud, A. (2026a). Oral evidence to the UK Parliament International Development Committee, 3 March 2026.

Persaud, A. (2026b). Challenges of climate mitigation and adaptation for emerging markets, remarks at the Banco de España conference, 25 March 2026.

World Bank. (2023). Most of the world's extreme poor live in middle income countries - but not for long. Data Blog, 21 March 2023.

Climate and Nature-Related Risks: From Awareness to Action*

*Frank Elderson***

Abstract

Climate change and nature degradation are no longer distant risks. They are already affecting economies, societies and financial systems, and they are doing so through several channels. Banks and other financial institutions face both the physical consequences of a changing climate and the transition risks associated with the shift towards a more sustainable economy. These two types of risk are often discussed separately, but in practice they are two sides of the same coin. The more disorderly the transition, the greater the risks for banks. And the longer decisive action is delayed, the more severe the physical impacts will be.Climate and nature-related risks are, fundamentally, financial risks. They are material risk drivers that affect the way banks manage traditional risk categories such as credit risk, market risk and operational risk. Serious risk management must therefore take climate and nature-related risks into account when identifying, measuring, managing and mitigating all material risks.

Keywords: climate risk in banking, ECB climate supervision, sustainable finance.

1. PHYSICAL AND TRANSITION RISKS ARE INTERTWINED

In the financial sector, this issue is sometimes framed as a choice between addressing either transition risk or physical risk. But this is a false dichotomy, because banks and other institutions will be affected by a combination of both. The balance between them will depend, to a large extent, on the decisions that are made — or not made — by policymakers in the years ahead.

The transition is already under way. Yet there are increasing signs that it is becoming progressively more disorderly, meaning that climate action is being taken in a delayed, inconsistent or abrupt manner. Put simply, our planet is warming faster than previously expected, and too little is being done about it. The longer action is postponed, the more severe the physical consequences of climate change will be, increasing losses caused by extreme weather events and other climate-related impacts.

As these physical impacts become more severe, reducing emissions and adapting to a changing climate will require a faster adjustment later on, leading to more abrupt changes in policies,

* Contribution by Frank Elderson to Banco de España–Funcas joint special issue of *Papeles de Energía*.

** Member of the Executive Board and Vice-Chair of the Supervisory Board of the European Central Bank.

technologies and market conditions. This will create a more difficult risk landscape for banks, as households, businesses and financial institutions will ultimately have to adapt more rapidly and with greater uncertainty.

Evidence from the EU-wide climate stress test conducted by the European Central Bank (ECB), as well as from similar exercises conducted by other authorities and by financial institutions themselves, points in the same direction. Timely and orderly action can substantially mitigate physical risks and reduce risks to financial stability more generally. Every delay comes at a cost: the longer action is postponed, the higher the required investment and the more disruptive the eventual adjustment is likely to be.

Every tenth of a degree of warming we can avoid matters: it can reduce the likelihood of disasters, savelives and preserveeconomic activity. The Intergovernmental Panel on Climate Change estimates that the risks, losses and damage caused by climate change escalate with every increment of global warming. These risks will increasingly interact, creating compound and cascading reactions that will become more complex and difficult to manage. For banks, the implications are clear: as physical risks become more material and the transition path becomes more uncertain, risk management practices will need to cover both physical and transition risks more comprehensively. They will need to focus on all material portfolios, all relevant geographical areas and all risk categories.

The reason is straightforward: climate and nature-related risks are not confined to a single part of a bank's risk framework. They do not constitute a new category of financial risk, but are rather horizontal risk drivers that cut across traditional risk categories like market risk, credit risk and operational risk. Like geopolitical developments, demographic change, technological disruption and changes in global trade patterns, they are risk drivers that influence established prudential risk categories. Physical risks such as floods, droughts and forest and city fires can damage companies' production facilities and people's homes. This can affect loan repayment capacity which, in turn, can lead to higher credit risk for the bank that provided the loan. Transition risks — driven by changes in regulation, technology or market preferences — can result in stranded assets and expose banks to litigation or reputational harm. This means that any institution seeking to manage its risks effectively must consider how climate and nature-related risks affect each part of its risk framework.

2. FROM AWARENESS TO ACTION

The financial sector has made considerable progress in tackling these risks in recent years. At the end of 2019, fewer than a quarter of banks under European banking supervision had undertaken any meaningful work on climate and nature-related risks. Even among those that

had started, the analysis they carried out was often limited in scope and depth. Since then, the ECB has pursued a multi-year supervisory strategy aimed at moving banks from awareness to action on this front.

In 2020 the ECB published supervisory expectations on the management of climate-related and environmental risks. Banks were asked to conduct self-assessments and draw up action plans in this area. The ECB subsequently carried out a thematic review covering the 110 banks under its direct supervision, set interim deadlines for implementation and monitored progress in meeting them. Where necessary, it also took enforcement measures, including imposing periodic penalty payments on banks that failed to meet supervisory requirements.

The progress achieved since then is significant. Banks have built internal expertise, conducted materiality assessments and begun integrating these risks into their management frameworks. Today, virtually all banks under ECB supervision have the foundations in place to identify, assess and manage climate and nature-related risks. Almost all banks now explicitly say that they consider climate and nature-related risks to be material to their business. Many have also adopted a number of good practices to address them, from advanced scenario analysis and transition planning to stronger engagement with clients when navigating physical and nature-related risks. That is an important achievement, and it reflects the work of thousands of people across the banking sector.

This progress matters because it shows that the discussion has moved beyond mere awareness. Banks increasingly recognise that climate and nature-related risks are part of the everyday business of risk management. Since the first banks were established centuries ago, sound banking has always required institutions to understand the risks they face. Managing material risks is simply prudent, objective risk management — and climate and nature-related risks are no exception.

3. CLOSING THE REMAINING GAPS

The financial sector has come a long way, and climate and nature-related risks are no longer treated as abstract concepts or niche concerns. The challenge now is to move from partial progress to full integration.

Full integration means ensuring that climate and nature-related risks are considered across all material portfolios, exposures, geographical locations and risk categories. It means translating materiality assessments into concrete action. It means looking beyond the most visible hazards, such as floods, to consider a broader range of risks, such as droughts and wildfires, and embedding these considerations not only into the management of credit

risk, but also of operational risk, market risk and other relevant areas. And it means using transition planning as a prudential tool to test resilience across a range of plausible future scenarios.

To achieve this, banks need to apply sound practices consistently and comprehensively in all their operations. Yet this is precisely where significant gaps remain. Some banks focus only on transition risks but not on physical risks — and vice versa — in certain portfolios. Some prudential transmission channels, such as operational or market risk, receive far less attention than credit risk. Furthermore, not all banks have included all material risk drivers, relevant portfolios or transmission channels in their climate and nature-related risk management processes. As a result, banks' approaches often remain uneven.

No bank is yet applying good practices across the board. Some banks, for instance, look at flood risk but do not comprehensively assess wildfires, droughts or other physical risk drivers that may be just as material for their exposures. Others identify risks in their materiality assessments but do not consistently translate those findings into concrete follow-up measures in their risk management processes. And while some banks have developed sound approaches for certain portfolios or markets, these are not always applied consistently across all relevant material geographical areas.

Identifying a risk is an important first step, but it is only part of the process. This is not about pursuing perfection: risk management is, and always will be, a process of continuous improvement. But it does require consistency, comprehensiveness and commitment. Banks should not treat climate and nature-related risk management as a stand-alone exercise to be completed and set aside, but as part of the day-to-day discipline of sound banking.

The starting point for this is a rigorous materiality assessment. Different banks will, of course, have different exposures, so there is no one-size-fits-all approach. But every bank needs to understand whether it is exposed to climate and nature-related risks, how significant those risks are, where they are concentrated and how they may materialise. Without this kind of knowledge, banks cannot decide where action is needed. A robust materiality assessment therefore provides the foundation for all subsequent risk management decisions.

That is why supervisory teams will continue to track progress closely and urge banks to implement sound practices across all material exposures, portfolios, geographical locations and risk categories, covering both physical and transition risks. The objective is not to create a parallel risk management universe for climate and nature-related risks, but to ensure that these risks are fully integrated into banks' ordinary risk management frameworks.

4. PRUDENTIAL TRANSITION PLANNING

If banks are to manage climate and nature-related risks effectively and continue supporting the green transition, they need to take a forward-looking view of how those risks may evolve. Prudential transition planning provides a framework for doing so.

In simple terms, prudential transition planning means that a bank understands its risk profile across different plausible transition pathways and ensures that it is resilient both today and over the longer term. This is essential because there is no certainty about how transition and physical risks will materialise, in what order or with what magnitude. Banks therefore need to be prepared for a range of possible outcomes rather than relying on a single view of the future.

Climate and nature-related risks are characterised by tipping points, non-linearities and compounding effects. Small changes can sometimes trigger disproportionately large consequences, while different risk drivers can reinforce one another. As a result, these risks can evolve along very different pathways. Rather than trying to predict a single future, banks should test their resilience against a set of credible scenarios, including baseline and adverse outcomes. The European Banking Authority's Guidelines on environmental scenario analysis encourage banks to draw on established scenario frameworks — such as those developed by the Network for Greening the Financial System — to assess how their portfolios, clients and business models would perform under different transition and physical risk outcomes. This helps banks identify vulnerabilities early and strengthen their resilience to future shocks.

Prudential transition planning is not about supervisors telling banks which path they must follow or directing their business decisions. Rather, it is about making sure they think consciously about their strategies across a range of possible future scenarios, test those strategies and take action where vulnerabilities are identified.

Done well, prudential transition planning can help banks become more resilient and more competitive. A bank that understands how different transition scenarios may affect its clients, portfolios and business model is better equipped to make strategic decisions over the long term and is better able to support the real economy through the green transition.

5. THE GROWING IMPORTANCE OF PHYSICAL RISK

Physical risk management is another area where there is room for improvement, as these risks are becoming more visible and more costly. Losses caused by droughts, heatwaves, floods and other extreme weather events are already substantial, while global insured losses have risen rapidly over recent decades. The economic consequences extend far beyond the immediate

damage caused. As physical risks intensify, there are serious implications for insurers and banks alike.

Traditionally, insurance coverage and fiscal support have acted as buffers against losses. Today, however, both are under pressure. Insurers are developing innovative products and incentives that help households and businesses adapt to climate and nature-related risks, for example by requiring them to be more resilient to extreme weather events. This is a positive development, but at the same time insurers are also pulling back from certain higher-risk activities and regions, widening coverage gaps. Fiscal space is also more constrained than in previous decades.

This matters directly for banks because the availability of insurance and public support can affect the size of the losses they ultimately incur. Loss given default, for example, can depend in part on whether borrowers have access to compensation after a damaging event. When these buffers weaken, banks can face bigger losses. What may sound like a technical issue — an insurance coverage gap — has concrete consequences. If a house burns down and there is no coverage, the owner may receive nothing. If a harvest is destroyed and no compensation is available, the loss is borne directly by the farmer. These are real economic impacts. And because they affect the income, balance sheets and resilience of households and businesses, they increasingly translate into financial risks for banks.

This is why cooperation between banks, insurers, supervisors and international organisations is so important. Physical risks cut across sectors, institutions and jurisdictions, making collective action essential. The ECB works closely with the European Insurance and Occupational Pensions Authority, while the Network for Greening the Financial System is well placed to contribute further owing to its global reach and involvement of supervisors with insurance responsibilities. Understanding and managing physical risk requires cooperation across sectors and countries.

6. A PRAGMATIC AND TARGETED SUPERVISORY APPROACH

Supervision has an important role to play in this process. The ECB has used both expectations and enforcement to ensure that banks address climate and nature-related risks appropriately. But effective supervision is not only about setting deadlines and imposing penalties. It is also about helping banks understand what sound climate risk management looks like in practice.

As a supervisor of 110 significant institutions, the ECB benefits from a unique perspective. It has a full view of banks across the euro area that individual institutions do not. This allows supervisors to identify and share practices that may be useful for other institutions, while

preserving confidentiality and competitiveness. To make this knowledge available to the whole sector, the ECB published a compendium of good practices for climate and nature-related risk management in 2022 and has since published an updated good practices report.

Importantly, these good practices are not legally binding — they are intended as practical examples of how a bank could manage climate and nature-related risks. A bank may choose not to use any of them and can still meet supervisory expectations if it manages its material risks effectively. Equally, a bank may develop innovative approaches that are not yet reflected in the existing set of good practices and that could inspire future updates. The purpose of these good practices is to make the knowledge gathered through supervision available, without naming individual institutions, so that banks can learn from one another and accelerate progress towards sound risk management.

This combination of supervisory pressure and practical support is important. Expectations establish the outcomes that banks are expected to achieve. Enforcement ensures that these minimum standards are taken seriously. And good practices help banks understand how they can meet those expectations in a robust and proportionate manner. Together, they help raise standards across the banking sector.

7. MANAGING RISKS AS A COMPETITIVE ADVANTAGE

The benefits of sound climate and nature-related risk management extend well beyond regulatory compliance. Banks that build a deeper understanding of these risks are not only better prepared for an uncertain future; they are also better positioned to support their clients and seize the opportunities created by the green transition.

Managing climate and nature-related risks well is a competitive advantage. This is true for any material risk: banks that understand their exposures, assess them rigorously and manage them effectively are better positioned to serve their clients, protect their balance sheets and remain resilient in a changing economic environment. Sound risk management strengthens the financial system; the opposite is true when material risks are overlooked.

This is particularly important in Europe, where the economy is still largely bank based. Banks play a vital role in financing households and firms, in good times and in bad. To fulfil that role effectively, they need to be able to manage climate and nature-related risks in a sufficiently sophisticated way. If they cannot, banks may resort to blanket approaches, such as reducing lending to whole sectors or regions rather than distinguishing between borrowers with different risk profiles and transition strategies.

But the benefits go beyond risk mitigation. The transition to a more sustainable economy is creating significant financing needs and new business opportunities across sectors. Banks that understand the technological, regulatory and market dynamics shaping their clients' transition can support them more effectively, while also identifying attractive business opportunities for themselves.

For example, some banks are already using their sectoral expertise to develop transition finance solutions for clients in industries such as steel, cement, aviation and energy. Others are expanding advisory services, helping clients navigate decarbonisation pathways and investment decisions. Rather than stepping back from sectors undergoing transition, these banks are building long-term client relationships and diversifying their sources of revenue.

The green transition is not only about financing firms that are already green. It is also, and perhaps most importantly, about financing firms that are on the journey to becoming greener. Banks need to be able to differentiate between the two. They need to understand which firms have credible transition plans, which exposures are most vulnerable and where risks can be mitigated. The banks that can make these distinctions are likely to be better positioned both to manage risk and to capture the business opportunities created by the transition. Sophisticated risk management allows banks to support clients with financing through the transition rather than withdrawing it indiscriminately.

Moreover, in building the capabilities needed to identify, measure and manage climate and nature-related risks, banks also strengthen their ability to assess other complex risk drivers like geopolitical developments, supply chain disruptions and technological change. Many of the tools developed in recent years, such as scenario analysis, materiality assessments and the identification of risk transmission channels, can be applied more broadly to other complex risk drivers. This allows banks to build on existing frameworks and expertise rather than starting from scratch whenever new risks emerge. Banks that can adapt their risk management processes in this way are likely to be more resilient, more agile and ultimately more competitive in an increasingly uncertain world.

8. CONCLUSION

Climate and nature-related risks are already shaping the environment in which banks operate. They affect households, firms, insurers, public finances and financial institutions alike. They can materialise through physical damage, transition dynamics, market adjustments, operational disruptions and changes in borrowers' creditworthiness. They are therefore highly relevant for financial stability and for the safety and soundness of banks.

The key message is simple: banks do not need to manage climate and nature-related risks because supervisors say so. They need to manage them because these risks are material. They are embedded in the economy, in their balance sheets and in the prospects of the households and businesses they serve. Managing them well is not a drag on competitiveness, but a precondition for it.

The transition will continue, and physical risks will continue to grow. Banks that understand this, assess their exposures rigorously and support their clients through the transition will be better placed to remain resilient in an increasingly uncertain environment. Supervisors will continue to play their part by setting expectations, enforcing them where necessary and sharing good practices to help raise standards across the sector.

The objective is not to prescribe the future, but to ensure that banks are prepared for a range of plausible future scenarios. In a world of uncertainty, that is what makes prudential risk management sound.

Incorporating Climate Change into Traditional Supervision

*Kevin Stiroh**

Abstract

This note argues that traditional risk management and supervisory programs should incorporate climate-related risk drivers to the extent that they contribute to material risks for supervised banks. The challenge for bank risk managers and supervisors is that climate-related risk drivers are growing and have distinctive attributes such as wide-spread and secular impacts, deep uncertainty, and the belief that the future is unlikely to look like the past, which suggest a need for additional focus from banks and their supervisors to achieve traditional prudential objectives. The note concludes with observations about how supervisory and regulatory activities can effectively incorporate climate-related risk drivers.

Keywords: financial institutions, risk management, supervision and regulation, climate-related risk drivers.

1. INTRODUCTION

The question of how central banks and supervisory authorities should address the economic and financial impact of climate change has received increasing attention since the well-known "Tragedy of the Horizons" speech by then-Governor of the Bank of England Mark Carney (Carney, 2015). Subsequent work by a wide range of central banks and supervisory authorities and by international groups such as the Basel Committee on Banking Supervision, the Financial Stability Board, and the Network for Greening the Financial System has brought this into the mainstream with respect to monetary policy, financial stability, and prudential supervision and regulation through a combination of policy actions, speeches and moral suasion, and rigorous empirical research. Despite these efforts, some debate remains about whether it is appropriate for central banks and supervisory authorities to consider the financial impact of climate-related risk drivers as part of their traditional responsibilities.

This note discusses conceptual issues related to the specific link between climate-related factors and traditional supervisory programs that are designed to promote the safety and soundness of individual financial institutions. The note also presents observations about how banks and prudential supervisors can effectively incorporate climate-related risk drivers into their existing enterprise risk management frameworks and supervisory programs.

* Senior Fellow, Resources for the Future.

2. TRADITIONAL SUPERVISION

Bank supervisors generally expect banks to manage all material risks regardless of the source, i.e., whether they come from a business cycle, a geopolitical event, a cyber threat, or a climate-related risk driver linked to physical or transition risk. That statutory responsibility reflects the observation that banks (broadly defined to include financial institutions that accept customer deposits, provide credit, and offer related financial services) are critically important for the real economy and that resilient banks can best support those activities. Absent supervisory and regulatory intervention, there are good reasons to believe that market forces alone won't lead to optimal financial outcomes from society's perspective.

The standard rationale for the need for prudential supervision and regulation is that market failures such as information asymmetries, externalities, and the resulting institutional responses such as deposit insurance and lender of last resort responsibilities encourage banks to take excess risks from society's perspective (Mishkin, 2001; Stiroh, 2016). As a result, governments developed regulations such as minimum capital standards or liquidity requirements and supervision such as broad risk management expectations and on-site examinations to curb this excess risk-taking. Financial institutions have a responsibility to all stakeholders to pursue opportunities and manage risks in a manner consistent with their corporate strategy and risk appetite. This requires that banks appropriately manage all material risks through traditional risk management approaches such as risk-based monitoring and pricing, business resilience planning, client engagement, and development of robust business strategies and effective governance and controls. The role of supervision and regulation to ensure those processes are effective and consistent with broader societal goals such as the stable provision of financial services.

The challenge is that climate-related risk drivers are deteriorating and have distinctive attributes. For example, Swiss Re (2026) estimates that insured losses from natural catastrophes are growing around 5-7% per year, and climate-related risk drivers are important determinants for some perils such as severe convective storms and wildfires. In addition, climate-related risk drivers have several distinctive attributes that suggest a need for additional focus from banks and their supervisors and regulators.

First, the impact of climate change is likely to be wide-reaching and secular, rather than narrow and cyclical. This suggests that the business models of some banks could be impacted in both the short-run and the long-run and that shocks can compound and materialize over time in new ways. Second, while the direction of travel is clear, the economic and financial impact remains highly uncertain in terms of both the timing and the allocation of impact across regions and sectors. This suggests the need for banks to develop and maintain robust strategies and risk management tools for financial risks and operational resilience and for supervisors to

consider the necessary attributes of an effective risk management and control framework as part of their oversight framework. Third, the future is unlikely to look like the past, so banks and supervisors need new models, data, and expertise such as those required for forward-looking scenario analysis to appropriately account for the impact of climate-related risk drivers. In the United States, for example, the Federal Reserve's pilot climate scenario analysis (CSA) exercise identified data gaps that hindered effective analysis, e.g., characteristics of physical assets such as location, age, and energy efficiency, insurance such as type of coverage, deductible, and replacement value, and borrower attributes related to emissions and transition risk management (Federal Reserve Board, 2024).

This rationale is entirely motivated by traditional, prudential objectives for supervision to ensure that banks manage all material risks to continue to provide critical financial services to the real economy. While it has sometime been portrayed differently, this rationale does not rely on a need for supervisors to broaden their mandate to include additional societal objectives such as those related to facilitating a transition to a low carbon economy.

The Basel Committee on Banking Supervision (BCBS) took this approach through its Taskforce on Climate-related Financial Risks (TFCR). BCBS (2021) focused on the ways that climate change can acts as a "risk driver" that impacts traditional prudential risks. This is analogous to the way business cycle dynamics can impact credit risk as borrower income fluctuates or a geopolitical event can impact market risk as perceptions of risk evolve. From a climate risk driver perspective, a severe weather event has the potential to impact a wide range of bank risks. For example, a hurricane might raise a bank's credit risk if default rates among borrowers rise. It may increase a bank's operational risk if its branch network or supply chain are disrupted by the storm. The effects of a storm could also ripple through the local economy or through insurance markets, bringing additional indirect impacts as local economic conditions deteriorate or house prices fall. For example, as the price and availability of insurance change in response to rising physical risks, financial losses get reallocated among borrowers, insurers, and creditors in ways that are difficult to predict and hard to price.

3. RECENT DEVELOPMENTS

When thinking about this framing, it is instructive to consider the evolution of financial policy in the United States, where a fundamental tension has emerged (Stiroh, 2025). On the one hand, the risks are growing and there's a compelling case for risk management described above. At the same time, the U.S. financial sector is pulling back.

All three of the U.S. federal banking regulators (the Federal Reserve, the Federal Deposit Insurance Corporation (FDIC), and the Office of the Comptroller of the Currency (OCC))

exited the Network for Greening the Financial System (NGFS) in early 2025. The publicly stated rationales generally reported that the NGFS had broadened its cope of activities, covering a wider range of issues that went beyond their supervisory mandates. Similarly, in October 2025, the federal banking agencies formally withdrew the risk management guidance that was issued in 2023 (FDIC et al., 2025). The explanation for the shift centered on the idea that risk-specific guidance was not necessary and could be distracting large financial institutions from the management of material financial risks. The Securities Exchange Commission (SEC) ended its defense of the rule requiring disclosure of climate-related risks and greenhouse gas emissions in March 2025 (SEC, 2025). Finally, the Financial Stability Oversight Council (FSOC) rescinded the charters of two climate-related committees that had been started just a few years prior — the Climate-Related Financial Risk Committee and the Climate-Related Financial Risk Advisory Committee in September 2025 (U.S. Department of Treasury, 2025).

In the private sector, the picture is somewhat different with more heterogeneity in responses. For the U.S. insurance sector, for example, climate-related risk drivers continue to be a factor in the determination of the pricing and availability of insurance for mortgage on residential real estate in high-risk areas. A large body of academic work has been developed that links the physical risks of climate change to a wide range of insurance outcomes such as insurance premiums and renewal rates and to related financial outcomes such as house prices or mortgage delinquencies. Sastry and Sen (2025) provide an overview of the link between climate-related shocks, household finance, and the macro-finance literature.

As a related point in the world of insurers, several recent papers have highlighted the question "uninsurable" risks related to climate-driven shocks (Glendon et al., 2025; Jones, 2025, and Mitchell, 2025). These papers raise the possibility that the shifting distribution of shocks can impact supply and demand forces in the market for insurance in a way that causes markets not to clear, i.e., some real estate properties become "uninsurable." These papers and the broader literature often conclude that traditional insurance tools such as diversifying and broadening the pool won't be enough to bring the market back to equilibrium. Rather, investment in resilience and adaptation are required as a scalable solution to reduce the underlying risk.

Results for the banking sector are more mixed. In terms of academic research, De Bandt et al. (2025) review over 230 papers and conclude that: "Despite notable progress in terms of the quantity and quality of studies published in recent years, the cumulative impact of physical and transition risks on banks' exposures remains difficult to quantify for several reasons." Conceptually, there are reasonable explanations that suggest that this literature understates the potential future impact for the banking sector. The work is largely backward-looking and, as discussed above, the distribution of shocks is likely to change as climate continues to deteriorate. Similarly, climate and economic tipping points can have large and compounding

non-linear effects on economic and financial outcomes and the impact of these types of tipping points are difficult to capture when using historical data. Indirect effects such as spillovers to the local economy through impacts on economic activity or asset values can bring additional losses that might not be captured in empirical studies of particular events.

From the risk management perspective of large banks, Fulvi and Stiroh (2026) review the public disclosure of six large bank in the U.S. and report that banks continue to invest in risk management capabilities related to governance, strategy, risk management approaches, and risk management tools, even as they reduce their focus on a related set of issues such as net zero commitments or sectoral goals related to financed emissions. For example, large U.S. banks exited the Net Zero Banking Alliance, which subsequently ended, and these banks are focusing less of their disclosure to topics related to net zero goals and more disclosure of core risk management tools and process.

It is important to emphasize two caveats about these conclusions. First, these conclusions are generally based on public disclosures, and it is difficult to know whether large banks are disclosing all relevant information and whether they are acting differently or just talking about climate-related risks in a different manner, i.e., the so-called shift from "greenwashing" to "greenhushing." Second, this type of evaluation has focused on the largest banks in U.S. There is very little systematic information about what small banks are doing.

This is concerning because smaller financial institutions tend to have more concentrated portfolios with lending focused on specific regions and sectors. Moreover, smaller financial institutions tend to have few resources to devote to the development of the new data, models, and expertise that are required to incorporate climate-related risks drivers into existing enterprise risk management frameworks. Of course, financial institutions also benefit from deep knowledge of local economies, e.g., "relationship banking" and "soft information" that can protect them from these types of local hazards. For example, Blickle et al. (2025) report that "local banks avoid mortgage lending where floods are more common than official flood maps would predict, suggesting local knowledge may also mitigate disaster impacts."

Finally, the recent U.S. experience stands in sharp contrast to the developments in other countries. As a few examples:

- The Bank of England (BoE, 2025) issued SS5/25, which has a goal to promote effective risk assessment and risk management capabilities in the banks and insurers under their supervision.

- The European Central Bank (ECB, 2026) issued a document covering "good practices" that outlined a broad set of effective climate and nature risk management practices.

- The Office of the Superintendent of Financial Institutions (OSFI, 2025) published guideline on climate risk management for banks and insurance companies.

This divergence is interesting for two reasons. First, it reflects different assessments of the relative risks associated with climate-related shocks. Ultimately, that is an empirical question, and it would be helpful to understand the different analytical approaches and models that led to such different conclusions about relative risks and policy actions. Second, a common concern expressed by international banking organizations is the desire for harmonization in supervisory approaches and expectations as a way to reduce supervisory burden, reduce the complexity of the international regulatory regime, and improve efficiency. This divergence in how supervisors think about climate-related risk drivers can contribute to differences in approaches that hamper effective risk management and financial intermediation, which are the traditional goals of bank supervisors.

4. LOOKING FORWARD

This evolution and divergence around climate-related risk management practices raises important questions about the best ways to promote effective risk management in world of new risk drivers. This note concludes with a few high-level principles that might help describe how supervisory and regulatory activities can effectively incorporate climate-related risk drivers.

- *Clarity.* Supervisors and regulators need to be clear on what problem they are trying to solve and how it fits into the existing statutory mandate and responsibilities. In the case of climate-related financial risks, for example, traditional supervisors and regulators need to be clear that the goal is effective risk management, and not broader social goals related to things like promoting a transition to a low-carbon economy or the energy transition. This will help avoid the "strawman" argument that supervisors and regulators are expanding supervisory powers to achieve objectives that are outside of their core mandates and responsibilities. For example, the Basel Committee on Banking Supervision (Basel Committee) explicitly focused on traditional prudential goals in its work. From the perspective of a particular bank, this suggests supervisors should be looking within the enterprise risk management functions and not to those related to corporate social responsibility such as a sustainability function (Fulvi and Stiroh, 2026).

- *Risk-Focused.* The critical first step for any risk management exercise is an assessment of the current and potential future materiality of the risk. This requires careful analytical work that relies on forward-looking assessments through tools such as stress testing and scenario analysis. Moreover, because the impact is likely to vary across different types of geographic exposure, sectoral exposure, bank business model, and risk appetite, a proportionate and risk-focused approach that is tied directly to each bank's particular risks is likely most appropriate.

- *Broad-based Approach.* The transmission of climate-related shocks to economic and financial outcomes is complex and difficult to model and would likely be most effectively addressed through a combination of many tools, rather than pushing on a single one. For example, the Basel Committee initially undertook a "holistic approach" that included efforts related to all three pillars of the Basel Framework - supervision, regulation, disclosure. For example, the Basel Committee published work on risk management principles for banks and supervisors (Basel Committee, 2022a), frequently asked questions around regulatory issues (Basel Committee, 2022b), and a voluntary disclosure framework for climate-related financial risks (Basel Committee, 2025).

- *Embedded.* As discussed above, the traditional perspective for climate-related financial risks is through enterprise risk management. This follows from the starting point of climate as a risk driver of traditional prudential risks. As such, it is likely to be more effective when this perspective is integrated into existing, business-as-usual practices, rather than developed separately and managed somewhere else. Fulvi and Stiroh (2026), for example, report that most banks view climate as a cross-cutting risk driver that include multiple prudential risks such as credit, market, and operational risks.

- *Flexible.* A core attribute of climate-related financial risk is the inherent uncertainty related to things like climate sensitivity, the relationship between climate factors and economic ones, the behaviour of consumers and firms, and policy responses. As such, a policy approach that builds in flexibility seems appropriate, rather than one that is based on rigid rules or labels that adjust only slowly. It is important to recognize that much remains unknown about how climate-related risks drivers will materialize and impact the real economy and financial sector, so it seems helpful to avoid hard definitions, specific cutoffs, very precise ex-ante ways to classify things as brown or green or high risk or low risk activities.

- *Engagement.* The unprecedented nature of the evolving climate, large scale shifts in the economy, and policy responses raises challenges for all actors including the private sector and the official sector. This suggests that it would be effective to continue to engage, share best practices, and build capacity. For example, the Federal Reserve's pilot climate scenario analysis exercise was explicitly designed to "enhance the ability of large banking organizations and supervisors to identify, estimate, monitor, and manage climate-related financial risks" (Federal Reserve Board, 2024). Moreover, policy solutions are more likely to be effective and durable if they incorporate a broad range of perspective and insights.

It is also useful to think about this from the perspective of a bank interested in supporting its clients, managing its risk, and meeting the needs of stakeholders. One plausible hypothesis is that identifying, measuring, and managing climate-related risks will prove to be a competitive advantage for commercial banks. If so, banks will have some private incentives to manage these risks. This is true even in a world where there are some market failures that might lead banks

to take excess risk from society's perspective, so supervisors can observe and learn from the risk management approaches pursued across the financial sector.

The discussion of what banks can then do to manage these risks is sometimes framed as choice among two extremes — ignore climate-related risk drivers or completely stop lending and exit the market. This seems extreme, and the reality likely falls in between with a range of actions that banks can take to work with their clients, seek opportunities, and manage the risks that they face.

At one end, it might be perfectly appropriate for a business- as-usual approach for certain risks using the existing data, using the existing approaches for certain risks for certain banks. This depends on the materiality assessment and reflects the underlying heterogeneity of the shocks and the exposures. In other cases, it might be more appropriate for banks to invest in new data, new models, and new expertise to better monitor and understand these risk drivers. Other banks may want to engage with their clients to understand how they are managing their risk, which is ultimately the bank's risk. Banks may want to invest in the business resilience of their own operations, i.e., manage their own operational risk by including different types of physical risk drivers in their business continuity plans to ensure their supply chains, data centers, and branch networks are sufficiently robust. Banks may employ traditional risk management tools that incorporate climate-related factors for things like underwriting decisions and loan pricing, setting concentration limits, or enhanced internal controls. These are all traditional risk management decisions that banks can consider. Finally, in certain circumstances for certain banks, for certain exposures, there might be a strategic solution that involves broader strategic questions such as operating in a particular region, asset class or sector.

5. CONCLUSIONS

This note makes three related points about the link between climate-related risk drivers and traditional prudential supervision that is focused on promoting the safety and soundness of financial institutions.

First, supervisors expect banks to manage all material risks in order to continue to provide critical financial services to the real economy, so the question about climate-related risk drivers is an empirical one and not a conceptual one. If climate-related risks drivers can lead to material risks, then they should be incorporated into banks' existing risk management frameworks and supervisory oversights in a way that is consistent with risks that each bank faces.

Second, it is critical to do the analytical work to make an informed assessment of materiality. It is unlikely to be effective to just assume that past processes and approaches will be sufficient in

a changing world where climate-related risk drivers are evolving. In an environment where the underlying distribution of shocks is shifting, for example, it seems necessary to do a forward-looking empirical assessment of potential materiality in order to make informed judgments about emerging risks and risk management priorities.

Third, both the private sector and official sector need to recognize that the outcome is likely to be heterogeneous across banks depending on their exposures, geographical footprint, sectoral focus, business models, etc. There is no one-size-fits-all solution. The appropriate response, for both financial institutions and for their supervisors and regulators, will depend on the specific bank and its exposure, business model, and risk appetite.

REFERENCES

Bank of England. (2025). SS5/25 - Enhancing banks' and insurers' approaches to managing climate-related risks, Supervisory Statement 5/25, December, 2025. "PS25/25 - Enhancing banks' and insurers' approaches to managing climate-related risks - Update to SS3/19," Policy Statement 25/25, December 2025. "Press Release," December 3, 2025.

Basel Committee on Banking Supervision. (2021). Climate-related risk drivers and their transmission channels. April.

Basel Committee on Banking Supervision. (2022a). Principles for the Effective Management and Supervision of Climate-Related Financial Risks. June 13.

Basel Committee on Banking Supervision. (2022b). Frequently Asked Questions on Climate-Related Financial Risks. December 8.

Basel Committee on Banking Supervision. (2025). A Framework for the Voluntary Disclosure of Climate-Related Financial Risks. June 13.

Blickle, K. S., Hamerling, S. N., Morgan, D. P. (2025). How Bad Are Weather Disasters for Bank? *FRBNY Staff Report,* 990. Revised October 2025.

Carney, M. (2015). B*reaking the Tragedy of the Horizon – Climate Change and Financial Stability.* Bank of England, September 29.

De Bandt, O., Kuntz, L-Ch., Pankratz, N., Pegoraro, F., Solheim, H., Sutton, G., Takeyama, A., and Xia, D. (2024). The Effects of Climate Change-Related Risks on Banks: A Literature Review. *Journal of Economic Surveys, 39*(4), 1553-1594, September 2025.

European Central Bank. (2026). Good Practices for Climate and Nature Risk Management - Observations from the ECB's Five-Year Climate and Nature Risk Programme (2020-25). May.

Federal Deposit Insurance Corporation, Federal Reserve Board, Office of the Comptroller of the Currency. (2025). Agencies Announce Withdrawal of Principles for Climate-Related Financial Risks. October 16.

Federal Reserve Board. (2024). Pilot Climate Scenario Analysis Exercise: Summary of Participants Risk-Management Practices and Estimates. May 9.

Fulvi, Ch., and Stiroh, K. (2026). How Large U.S. Banks Manage Climate-Related Financial Risks. Policy Insight. Center for Economic Transition Expertise, August.

Glendon, S., Kousky, C., and Schauble, B. (2025). Is the Future Insurable? *Probable Futures,* August 13.

Jones, D. (2025). The Uninsurable Future: The Climate Threat to Property Insurance, and How to Stop It. *The Yale Law Journal Forum*, December 3.

Michael, M. (2025). *The Uninsurable Future is Nearly Here - How Climate Change is Pushing the Global Economy into Systemic Risk.* August 18.

Mishkin, F. S. (2001). Prudential Supervision: Why is it Important and What are the Issus? In F. S. Mishkin (ed.), *Prudential Supervision: What Works and What Doesn't.* January.

Office of Superintendent of Financial Institutions. (2025). Climate Risk Management. March 7.

Sastry, P., and Sen, I. (2025). Perspectives on Insurance and Climate Risk. *Journal of Finance: Insights and Perspectives*, forthcoming, December.

Securities Exchange Commission. (2025). SEC Votes to End Defense of Climate Disclosure Rules, 2025-58, March 27.

Stiroh, K. J. (2016). The Theory and Practice of Supervision. April 11.

Stiroh, K. J. (2025). The Evolving View of Climate-Related Financial Risks in the US Financial Sector. *Common Resources*, Resources for the Future Blog, December 15.

Swiss Re. (2026). Natural Catastrophes in 2025: The Persistent Rise of Wildfire and Storm Risk. *Sigma*, No 1/2026, March 16.

U.S. Department of Treasury. (2025). Readout: Financial Stability Oversight Council Meeting on September 10, 2025. September 10.

Climate Risk and Central Bank Operations: Evolving Good Practices and Innovative Approaches

*Rob Patalano**

*Enrique Serrano Rodríguez***

Abstract***

Central banks are increasingly incorporating climate-related considerations into their monetary operations as evidence grows that physical and transition risks can affect financial stability, monetary policy transmission and the value of assets held on central bank balance sheets. This article reviews recent developments in the greening of monetary policy and non-monetary policy portfolios, examining emerging practices across major central banks and drawing on discussions from the Banco de España conference Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice. It analyses the evolution of climate-related tilting of asset purchase programmes, targeted refinancing operations and collateral frameworks, with particular attention to reforms introduced in the latter by the European Central Bank and the Bank of England. This article argues that monetary authorities are gradually moving beyond climate-aligned asset purchases towards the integration of climate considerations into collateral valuation and risk-management frameworks. It finds that further progress could be achieved by extending climate risk methodologies to additional asset classes, strengthening the coherence of existing policy tools, incorporating physical climate risks more systematically and beginning to address material nature-related risks. While important operational and methodological challenges remain, the experience of central banks suggests that climate- and nature-related financial risks can increasingly be incorporated into monetary operations in ways that are consistent with central bank mandates and established risk-management objectives.

Keywords: central banking, monetary operations, climate risk, collateral frameworks, asset purchases, refinancing operations, nature risk, climate factor, ECB, Bank of England.

1. INTRODUCTION

The concept and practice of monetary policy transmission is core to how central banks fulfil their price stability mandate, influencing interest rates and borrowing costs in the

* Is the Executive Director and Professor in Practice of the Centre for Economic Transition Expertise, which cosponsored the Banco de España's conference on "Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice".

** Is a Policy Analyst at the Centre for Economic Transition Expertise. He has experience working at the Directorate General Market Operations of the European Central Bank.

*** They thank CETEx colleagues David Barmes, Harriet Richards and Maria Waaifoort for their review and comments. They also thank staff from the ECB, Bank of England and Bank of Spain for their feedback. Their editorial review does not suggest an endorsement of all the forward-looking policy recommendations.

financial system and throughout the real economy. Monetary operations, including direct lending and repo operations[1] secured by collateral as well as asset purchase facilities, are central to how monetary policy is implemented in practice. These actions, which are governed by risk management frameworks, influence the availability of liquidity in the financial system and, in turn, the borrowing costs that transmit monetary policy to the real economy. Central banks' emergency measures in response to the Global Financial Crisis and the Covid-19 crisis demonstrated the efficacy of more elaborate central bank toolkits. This wider range of tested tools offers opportunities for central banks to contribute to reducing the likelihood of future crises, including those that could result from growing climate transition and physical risks.

As understanding and measurement of physical and transition risks improve, many central banks are considering how to more effectively incorporate climate risk into their monetary operations. In recent years, a number of central banks have introduced climate-related considerations into their balance sheets through risk-management tools that incorporate climate risks into their asset purchase programmes and collateral frameworks. The European Central Bank (ECB) and Bank of England, for example, have incorporated climate-related considerations into their monetary and non-monetary portfolios and integrated climate risks into collateral. Several major Asian central banks have initiated targeted lending operations that support lower-cost financing of the private sector to incentivise the greening of the real economy. In addition, the Bank for International Settlements established dedicated green bond funds to invest central bank reserves in green bonds.

One important aspect of central banks' operations is their collateral framework, which determines the eligibility and valuation of collateral. Accepting a wide range of assets lets central banks supply vital reserves to the banking system. Central banks value collateral below market price (applying a discount known as a "haircut") in their lending operations to financial counterparties in order to absorb sudden drops in asset value. The greater the risk, the higher the haircut. Given that growing evidence of climate risks suggests potential future market and credit losses on a wide range of collateral, central banks are making concerted efforts to understand and effectively assess current and future risks to valuations.

The Network for Greening the Financial System's 2023 membership survey on monetary policy and climate change noted that almost a third of responding central banks had implemented climate-related adjustments to their collateral framework, a majority of which were from the euro area (NGFS, 2023). In 2024, the Bank of England became the first major central bank to formally incorporate climate-related transition and physical risks into collateral haircuts (Bank of England, 2024). The ECB followed in 2025 by announcing a climate factor that adjusts the value of collateral to reflect transition risk (ECB, 2025b). While the climate factor was initially applied

1 Liquidity-providing operations whereby the central bank buys assets, which serve as collateral, in exchange for cash. The assets are then repurchased at a later date.

to corporate bonds, which represent a small portion of eligible collateral, it was nevertheless an important step in signalling to markets that transition risk is material and can be identified and converted into risk metrics. In July 2026, the ECB decided to extend the application of climate factors to certain eligible non-financial corporate credit claims, further broadening the incorporation of climate-related transition risk into its collateral framework (ECB, 2026).

To reflect on central bank practices amid growing evidence of physical and transition risks, in 2026 the Banco de España hosted a conference in collaboration with the NGFS and the London School of Economics, including the Centre for Economic Transition Expertise (CETEx). The conference, titled "Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice", included a session on incorporating climate considerations into monetary operations with a focus on how asset purchase and emerging collateral policies incorporate climate risks.

This article will address approaches and developments with respect to the greening of monetary operations. The second section outlines the key issues raised by practitioners in the market operations session of the Banco de España conference. The third section elaborates on the recent ECB and Bank of England announcements to more thoroughly embed climate risks in their collateral policies, methodological considerations assessed by CETEx in a recent publication and examples of climate-related practices adopted by other central banks. The fourth section discusses opportunities to further embed climate risks in monetary operations.

2. EMBEDDING CLIMATE INTO MONETARY OPERATIONS — INSIGHTS FROM THE BANCO DE ESPAÑA CONFERENCE[2]

The Banco de España's panel on greening central banks' portfolios, held as a session within its conference on bridging policy, research and practice of climate risks, included speakers from the Bank of England, the ECB, and Banco de España, and was moderated by LSE CETEx.[3]

In this session, panelists reflected on how central banks are moving from broad climate commitments to practical changes in central bank operations, including their monetary and own funds as well as their collateral frameworks. They emphasized that implementation must be firmly grounded in central banks' mandates, and that when climate and nature-related risks affect balance sheets, market functioning, monetary policy transmission and price stability, taking action lies within these mandates. Panelists also highlighted the importance of

2 Session 3: Greening central banks' portfolios. Recording of conference session at Climate risk and sustainable finance: bridging policy, research, and practice, Madrid, 25 March. https://www.youtube.com/watch?v=TUqCg6AjZAs

3 James Talbot (Executive Director of the International Directorate, Bank of England; Chair, NGFS Workstream Monetary Policy); Irene Heemskerk (Head of Climate Change Centre, ECB); Juan Ayuso (Director General Operations, Markets and Payment Systems, Banco de España); and Robert Patalano (Professor in Practice, Executive Director, LSE Centre for Economic Transition Expertise — CETEx) moderated the session.

institutional credibility and transparency, and they stressed the need to avoid overly mechanical approaches that penalise credible transition activity, especially where high-emitting firms or public sector issuers are actively trying to move towards lower-carbon pathways.

Key issues emerging from the discussion

First, *articulation of mandate and purpose.* Discussants agreed that central banks need to explain why they are acting, whether for balance-sheet risk management, financial stability, or public-sector leadership to create a conducive environment to accelerate the transition. Communicating the extent to which policy decisions involving climate fall under the primary or secondary mandate helps counterparties and markets understand the context. Regarding monetary operations, this communication should reflect on how the central bank is responding to climate risks that markets may not fully price, while remaining sufficiently aligned with the operating principle of market neutrality.

Second, *central bank operations have undergone an operational shift across both monetary and non-monetary policy portfolios.* As the size of asset-purchase portfolios has declined amid the gradual normalisation of monetary policy, their role in either risk management or the need to incorporate climate risk into portfolio management has become less relevant. Attention is moving towards collateral frameworks and how to embed climate factors in collateral valuations. In addition, central banks are exploring sustainable investment approaches for their non-monetary policy holdings, such as their own funds and foreign reserves portfolios. And, in some jurisdictions, liability-side instruments, such as tiered reserve requirements or climate-differentiated remuneration on bank reserves, are being considered.[4]

- The Bank of England's current focus is on incorporating climate risk into its collateral framework. Since a large share of its collateral is made up of residential mortgage pools, the Bank has incorporated physical and transition risks into haircuts, using scenario analysis for flood risk, subsidence risk and energy-price shocks. It has also restricted eligibility of mortgages non-compliant with energy efficiency standards. The BoE discussant suggested the distinction was between risk management and transition incentives: both are possible, but they require different justification and different tolerance for balance-sheet risk. The large degree of heterogeneity across central banks, not only in terms of mandates but also monetary policy operating frameworks and institutional starting points, will shape how different approaches can be applied across jurisdictions.

4 See NGFS (2026). It notes several types of greening of liabilities, including green reserve requirements, issuing green short-term debt securities (monetary bills) and/or certificates of deposits, and offering central bank accounts to NBFIs involved in sustainable/climate projects. The central banks of Lebanon, Philippines and Indonesia offer concrete examples of green liability policies.

- The ECB discussant traced the ECB's approach back to the 2021 monetary policy strategy review, which recognised climate change as relevant to the ECB's mandate and supported a climate roadmap covering modelling, data, operations and transparency. She explained that the ECB's corporate bond tilting was primarily designed to reduce climate risk exposure, but also contributed, within the primacy of price stability, to wider EU climate objectives.

- The Banco de España discussant highlighted that for non-monetary policy portfolios, sustainable and responsible investment was added as a new investment principle in 2019, alongside efficiency, professionalism, market neutrality and prudence. A dedicated portfolio was made up of green investment funds and direct holdings in green, social and sustainability-related bonds. He highlighted that central banks may not be large enough to move markets through purchases alone but can lead by example through transparent and prudent practice.

Third, *data gaps and methodological challenges.* Discussants agreed that data gaps remain a major obstacle to advancing policies to incorporate climate risk. Key gaps that impede progress include Scope 3 emissions and forward-looking transition metrics, and data gaps regarding climate information with respect to covered bonds and public sector securities.

- The Banco de España discussant highlighted double counting, data lags and the lack of forward-looking public sector transition metrics as unresolved barriers, while arguing that imperfect data should not become an excuse for inaction.

- The ECB discussant suggested to start with what is actionable, rather than focusing on where data and methodologies are missing. Beginning with small, manageable steps can be effective, allowing for gradual improvement through an iterative process. In this way, it is possible to start with available data and test what works, while taking care to avoid instruments that are too blunt. She also noted the potential for spillover effects between initiatives. For example, introducing climate disclosures enabled the ECB to collect insights later used for portfolio tilting. Similarly, the climate factor in the ECB's collateral framework incorporates insights gained from the outcomes of its climate stress testing.

Fourth, *strengthening the enabling environment for transition finance to help scale up clean energy and reduce climate risks over time.* In this respect, taxonomies and collateral rules must be attuned to the credibility of transition plans, not just current emissions intensity metrics.

Central banks have started to incorporate climate-related risks into their monetary operations and are currently widening their approaches. Greening central bank portfolios is no longer only about tilting corporate asset purchases and disclosures. It increasingly concerns collateral policy, taking action to address data challenges, determining appropriate transition metrics and moving beyond corporate bond portfolios to other asset classes. Nature-related topics, too, represent new and important considerations.

To overcome associated challenges, the discussants highlighted the importance of peer learning. Collective analysis and case study development through the NGFS, ongoing Eurosystem cooperation, and common disclosure practices were presented as essential mechanisms for spreading knowledge and good practice. In particular, a highlighted strength of the NGFS has been its emphasis on sharing experiences and practical examples rather than advocating one-size-fits-all solutions

The next phase will depend on better data, iterative processes, more credible forward-looking methods and continued international cooperation. The panel's practical conclusion was clear: central banks already have scope to act and should focus on doing what is feasible and consistent with their mandates.

3. DEVELOPMENTS IN FACTORING CLIMATE RISKS INTO MONETARY OPERATIONS PRACTICES

Over the past decade, central banks have made notable progress in developing and implementing approaches to factor climate risks into monetary operations. These approaches primarily rely on forms of asset purchase facilities, climate-related refinancing or targeted lending operations; and, through the incorporation of climate risks into central banks' collateral valuation practices. While the asset purchase facilities were very active at major central banks during periods of extraordinary monetary policies following crises (e.g. Global Financial Crisis, Covid Crisis), more recently the collateral approaches are being contemplated and utilized by several central banks during normal monetary conditions.

3.1. Greening of asset purchase programmes

Asset purchase programmes are central bank programmes that serve to purchase market securities, such as sovereign or other public sector bonds, corporate bonds, covered bonds, or asset backed securities, to provide liquidity that reduces stress and improves the efficacy of monetary policy transmission across markets. In this regard, the asset purchasing signals higher asset demand and helps lower the yield on eligible assets, which facilitates positive market conditions even for similar securities that are not eligible for purchase.[5] Benefitting from a growing body of research on climate risks, certain central banks sought to apply climate-risk analytical tools to help rebalance asset-purchase portfolios and tilt towards assets that have lower climate-related physical and transition risks.

The Bank of England's climate methodology for its £20bn Corporate Bond Purchase Scheme (CBPS), introduced in 2021, used a climate scorecard to tilt reinvestments toward greener

5 A number of research papers have reviewed the efficacy of central bank asset purchase programmes, with generally positive results in terms of lowering yields and risk premia. See Andrade et al. (2016).

issuers within sectors. This enabled the Bank to reduce exposure to climate transition risks and incentivise the transition to net zero while also maintaining market neutrality. The Bank also set a portfolio-level target to reach net zero by 2050 and excluded purchases of corporates that mine thermal coal. The extent to which purchases were tilted depended upon the strength of corporates' climate performance, assessed against four metrics: their emission intensity; progress in reducing emissions; having published a climate disclosure; and having a verified emissions reduction target (Bank of England, 2021).

The ECB incorporated climate risk methodologies to help tilt its purchases of corporate sector securities within two of its asset purchase portfolios, the Corporate Sector Purchase Programme and the Pandemic Emergency Purchase Programme (ECB, 2022). The ECB employed a multi-pronged methodology composed of backward-looking metrics assessing company emissions, forward-looking metrics of companies' future emissions; and the robustness of climate disclosures. With these measures, the Eurosystem sought to mitigate climate-related financial risks and, without prejudice to the mandate of price stability, gradually decarbonise its corporate bond holdings to improve the weighted average climate score of the holdings over time, thereby aligning the portfolio with the goals of the Paris Agreement (ECB, 2025). In doing so, it also sought to support the green transition of the economy in line with the EU's climate neutrality objectives.

Overall, the greening of central bank portfolios in this manner has three benefits: (i) during the announcement and asset purchasing phase, it shifts the demand and therefore cost of capital to modestly benefit securities with relatively lower transition or physical risk; (ii) during the wind-down, it maintains the positive tilt toward assets with lower climate risk; and (iii) after the wind-down, aspects of the methodologies may continue to be utilised by market participants.[6]

Assessments of the efficacy of climate-aligned asset purchase programmes indicate, to varying degrees, that they contribute to decarbonisation. The ECB's assessment of the decarbonisation in its own climate-aligned asset purchase programmes is that it contributed to about 25% of decarbonisation of the corporate portfolios from 2021-2024, and corporate holdings remain on track to meet their interim decarbonisation targets based on carbon-intensity metrics (ECB, 2025). There is evidence that the ECB's asset purchase programmes contributed to significantly improving financing conditions for eligible green bonds, thereby increasing the attractiveness of these instruments to issuers and of the euro area as a location of issuance (Bremus et al., 2021). However, due to the limited size of ECB holdings relative to the broader corporate debt outstanding and the relatively short time frame, there is little evidence that this

6 Anecdotally, the author received feedback from London-based market participants that the benefits of the Bank of England's climate scoring include better educating market participants of ways to utilise quantitative methodologies to assess climate risk in portfolios in a systematic manner.

alone had a material impact on accelerating decarbonisation. Nevertheless, the combination of these and numerous other central banking, supervisory, and EU green spending programmes is widely credited with the acceleration of financial and corporate sector decarbonisation in the European Union.

3.2. Climate-related refinancing operations

Several central banks have engaged in direct climate-related refinancing or direct lending operations to channel financing to entities that are decarbonising. Unlike asset-purchase programmes that buy securities on the secondary market, these operations are intended to refinance central bank counterparties, such as commercial banks, on preferential terms that incentivise them to extend lower-cost lending to customers that are demonstrating reductions in their emissions.

The Bank of Japan (BOJ) supports green refinancing through its Climate Response Financing Operations, providing low- or zero-interest funds to financial institutions that invest in or lend to projects and firms demonstrating a sufficient level of transitioning to lower their net emissions. For example, the BOJ provides one-year, zero-interest funds to commercial banks matching the volume of their internal green or transition financing lending (Bank of Japan, 2025). One of the eligibility criteria for counterparties is that they disclose particular information about their efforts to address climate change and about the green and sustainability-linked loans, bonds, and transition finance they provide to customers or issue to markets. The outstanding climate-related preferential lending under this program reached roughly US$155 billion in July (Bank of Japan, 2026) which is more than 30% of BOJ lending to counterparties in 2026.[7]

The People's Bank of China (PBOC) also conducts green lending to counterparties, in a similar manner yet with distinct operational features, to encourage decarbonisation of the real economy. In 2021, the PBOC launched a Carbon Emission Reduction Facility, which provides to banks, at a lending rate of 1.75%, 60% of the principal of qualifying loans for clean energy, energy conservation, and carbon reduction activities (Caswell, 2021). At the same time, financial institutions that received the low-cost funds from the PBOC were required to disclose information about the outstanding balance and interest rates of carbon emission reduction loans as well as their effects on carbon emission reduction, and to be subject to verification by independent third-party agencies (Yi, 2023). By mid-2023, over $120bn had been disbursed to carbon reduction projects under the programme, according to the disclosures of 21 major banks in China, driving the reduction of an estimated 215 million tonnes of CO2 (Green Central Banking, 2024). Given its usage and impact, PBOC extended the programme through 2027.

7 Authors' calculations from data on the Bank of Japan Accounts, July 31, 2026.

Overall, the purpose of central bank green lending schemes is to help accelerate decarbonisation through incentives, and in turn to foster a conducive macrofinancial environment over the medium-term by making financial systems and the real economy more resilient to climate. Notwithstanding progress, central banks face a number of operational challenges, including technical expertise, data availability, selection criteria, counterparty practices, etc.

The research on efficacy toward these objectives is mixed. Some research suggests measurable impact on lending volumes, and correlation with reduction in emissions; however, there is some evidence that this is accompanied by higher Non-Performing Loans (NPLs) and weaker bank profitability (Wang et al., 2026). It is not clear, however, whether this relates to green investments, as greater lending volumes and looser lending standards are typically associated with subsequent higher NPLs.[8] Climate-aligned lending facilities are not without criticism, including concern over the extent to which counterparties pass on the rate benefits, and over inadequate disclosure. Nevertheless, these programmes have provided clear evidence that — within their mandates — central banks can provide incentives via advantageous cost-of-capital for counterparties and their borrowers to decarbonise. Looking ahead, there is room for greater application across central banks, and room for improvement in terms of standards of implementation. Doing so within a broader integrated strategy for greening monetary policy and operations would more effectively contribute to shaping financial sector and real economic incentives to accelerate decarbonisation.

3.3. Including climate risks in collateral frameworks

The consideration of embedding climate risk in central bank collateral frameworks gained acceptance over the last decade. This shift in mindset was aided by assessments that such measures could contribute meaningfully within central bank toolkits to help green the financial system, either based on sound risk management or environmental considerations (Grantham Research Institute, 2022). In its 2022 membership survey, the NGFS found that almost a third (mostly from euro area) of responding central banks had taken some steps to introduce climate considerations in their collateral frameworks, including adjustments to haircuts for green assets, as well as limiting eligibility of carbon-intensive collateral NGFS, 2023). Yet, genuine progress has been gradual due in part to operational challenges including data gaps and measurement challenges. Since then, three central banks have made substantial changes to their collateral policies to measure climate transition risks and adjust haircuts accordingly.

8 See Foos et al. (2009). Based on an assessment of 16 countries, it suggests that bank loan growth leads to an increase in loan loss provisions during the subsequent three years, to a decrease in relative interest income, and to lower capital ratios.

Hungary

Hungary's central bank, the Magyar Nemzeti Bank (MNB), issued an innovative sustainability-aligned monetary policy toolkit in 2021, in which it noted that greening of collateral management would be one important step to help encourage sustainability markets. It highlighted that the introduction of a green haircut could effectively contribute to the development of a sustainable bond market through the preferential treatment of green securities (MNB, 2021). As such, in 2021 the MNB introduced a 20 percent discount on green securities' haircuts, with a maximum value of 5 percentage points. To further develop the domestic green securities market, the use of preferential haircuts for green securities has been made conditional on the fulfilment of transparency conditions, and the central bank subsequently introduced preferential haircuts for non-green assets if the issuer publishes relevant climate reports (MNB, 2024). In addition to these collateral measures, the MNB also launched a Green Mortgage Bond Purchase Programme (MNB, 2026a) and a preferential refinancing programme for green homes (ended in 2022) (MNB, 2026b). It also introduced preferential capital requirements for loans financing the construction or renovation of energy-efficient housing. Similar capital requirement discounts are available for qualifying green corporate and municipal loans and bonds (MNB, 206c). These measures show MNB's efforts to promote green financing within its jurisdiction.

European Central Bank

The ECB's consideration of climate risk in its collateral framework evolved substantially. Initially, the central bank considered concentration limits on collateral pools for securities issued by companies exposed to high levels of transition risk (ECB, 2022). However, in 2025 the ECB's Governing Council decided to introduce a climate factor instead, implemented in June 2026, which reduces the value assigned to eligible assets pledged as collateral, depending on the extent to which an asset can be impacted by transition risks (ECB, 2025b). The climate factor applies to individual assets, and its calibration is based on three components: sector-level data on non-financial corporations from the Eurosystem's climate stress test, the issuer's climate score, and the asset's residual maturity (ECB, 2025b). The maximum additional reduction in the final collateral value will be 5% (ECB, 2026).

While this announcement was important to demonstrate the central bank's commitment to sound risk management and to protect the balance sheet against transition risks in the corporate sector, the application of this measure initially focused on collateral issued by non-financial corporations, representing a limited subset of the broader collateral universe.

In July 2026, the ECB announced an extension of this climate factor to non-financial corporate credit claims (non-marketable debt instruments such as bank loans) by end-2027

(ECB, 2026). This announcement was important, both for risk management and as a signal to markets, as it has the potential to affect up to nearly 30% of used collateral at the ECB.

Bank of England

In June 2026, the Bank of England similarly announced that it would update, starting in October 2026, its corporate bond collateral framework to account for climate-related risks. The Bank's new criteria include: (i) bonds issued by companies active in thermal coal mining would no longer be eligible collateral, in line with its previous approach to its Corporate Bond Purchase Scheme; and (ii) new corporate bond haircuts in sectors exposed to risks from the transition to a green economy (Bank of England, 2026a). This adds to the Bank's existing practice of mitigating physical and transition risks to residential mortgage collateral, which represented 60% of all pledged collateral in 2025 (Bank of England, 2026b). In particular, the Bank chose to exclude mortgages, which represent the majority of pledged collateral, that were not compliant with the minimum energy efficiency standards, and to adjust mortgage haircuts based on their energy efficiency label and exposure to flood and subsidence-related risks. According to CETEx calculations, nearly two-thirds of the Bank of England's collateral holdings are now subject to climate-related collateral rules (Serrano, 2026).

A comparison of these approaches offers a range of tools for central bank collateral management:

- Incentives such as a reduction of haircuts on green bonds, based on the premise that green bonds reduce the climate transition risks associated with standard bonds. This approach provides a direct benefit, thereby financially incentivizing markets and entities to issue green or otherwise sustainability-linked bonds.

- Direct disincentives to issuers with higher transition risk, by increasing collateral haircuts, which indirectly raises the cost of financing for the affected issuers.

- Stronger disincentives to issuers, by excluding their collateral from being pledged in central bank operations. This affects the cost of capital and the liquidity of excluded issuers.

These factors, in combination with other measures to embed transition risk into asset purchase schemes, have the potential to shift cost of financing and liquidity over time, to provide material incentives to transition leaders and disincentives to laggards. In this manner, they should materially influence the funding practices of financial institutions as counterparties to central banking operations. As none of the major central banks provide combined climate transition disincentives and incentives in their collateral policies, there is room for improvement to strengthen risk management of transition risks, and to better align central bank policies with transition objectives where doing so is within their primary or secondary mandates.

4. FURTHER CONSIDERATIONS — BUILDING ON GOOD PRACTICES AND ADVANCING NEW PRACTICES

Insights from the Banco de España panel discussion and our review of areas of progress on embedding climate practices into monetary operations suggest that — notwithstanding welcome developments to implement emerging green practices — much more progress can be made. While such progress would need to assess and overcome operational and reputational risks, primary mandates offer ample room for considerably more incorporation of a range of green operations.

An NGFS review of these policy operations provided a comparative assessment of options to green credit operations, asset purchases and collateral frameworks (NGFS, 2021). Based on survey and judgement, the assessment illustrated that its members considered each of the approaches to have a positive to strongly positive impact on climate change mitigation, and generally a minimal to positive effect on risk mitigation. However, at the time, some questions were raised over the impact on monetary policy efficacy, and complexities with respect to the operational feasibility of haircut adjustments, tilting, and aligning collateral pools frameworks (NGFS, 2021). Several of these challenges, such as those related to expertise and data gaps, are being overcome, while others are more reflective of structural operational constraints, and would benefit from additional analysis.

Advancements can come in the forms of: (i) strengthening good practices – including incentives and disincentives — across asset purchase schemes and collateral frameworks; (ii) extending the application of the climate risk input to haircuts of additional asset classes; (iii) capturing physical risks; and, (iv) including nature degradation, which is already acknowledged to have the potential to erode asset valuations under adverse circumstances.

4.1. Strengthening good practices

The good practices outlined across five institutions in this article — ECB, BoE, MNB, BOJ and PBOC— highlight a wealth of operationalised initiatives to better embed climate transition risks into central bank operations. Yet not one of them incorporates all the good practices. This is not because the practices are conflicting; rather, they could be seen to be more coherent and mutually reinforcing. The calibration of haircut reductions for green bonds and loans, haircut increases for higher transition risk, portfolio tilting and exclusion, and targeted lower-cost lending could all be achieved through a common risk management framework. Adverse effects of stricter eligibility criteria and higher haircuts on liquidity and monetary policy transmission could be counterbalanced by parallel haircut discounts and eligibility status for green securities.

Asian central banks appear to have made the most progress in greening their credit operations. In addition to PBOC and BOJ, central banks of India, Malaysia, and Bangladesh have also made considerable progress in implementing various forms of green lending operations. Yet, the ECB, BoE and the Federal Reserve have not done so, even though certain members of the ECB Executive Committee have signalled that green targeted lending operations could be an instrument worth considering (Schnabel, 2023). As the Federal Reserve overcame operational challenges to utilise a wide array of direct credit operations during the Covid crisis (Milstein and Wessel, 2024) (including direct lending to SMEs, non-profits, and state and local governments), equally such operations could be employed during a climate crisis, such as a severe weather event or disorderly climate transition that creates acute liquidity and credit stress and inhibits monetary policy transmission. This would be well within the Federal Reserve's mandate.[9]

If major central banks in advanced and emerging markets were to incorporate transition risks in their collateral frameworks, asset purchasing and targeted refinancing practices, this would send a strong signal to the corporate sector across industries that there would be financial reward for increasing transition ambition and accelerating decarbonisation, while laggards would face measurably higher costs of capital. Such costs, as well as the growing cost differential between fossil fuels and renewable energy, would in turn raise questions of corporate competitiveness, strategy and leadership.[10] These incentives and disincentives would help shape the growing use of sectoral transition plans and financing plans — such as those being developed in the UK through the Net Zero Council— to help bridge the gap between NDCs and corporate transition plans.

4.2. Extending methodologies to additional asset classes

With the extension of the climate factor to credit claims, the ECB has recognised that the risk-based logic underpinning the factor is not limited to corporate bonds. The Bank of England's haircut adjustments for mortgages similarly show how this asset class is vulnerable to transition and physical risks. But the remainder of the collateral pool of both central banks, comprising sovereign bonds, covered bonds and asset-backed securities, is similarly exposed to climate-related financial risks. These three asset classes account for 60% of the total collateral pledged to the Eurosystem in recent periods. Therefore, the natural next step would be to extend existing measures such as the climate factor across these classes to gain comprehensive climate risk coverage (Serrano et al., 2026).

9 The Federal Reserve's dual mandate includes maximum employment and price stability. Note that the Federal Reserve's Financial Stability Report, 2020, highlighted that climate change poses various risks to the stability of the US financial system. See Federal Reserve, "Financial Stability Report", 2020, which can threaten price stability.

10 For example, see Klein et al. (2026). The authors note that stronger alignment between capital expenditure and climate objectives, alongside lower financing costs, is associated with more credible transition strategies.

For the ECB, this requires adapting the climate factor's methodology to the specific features of each asset class. Some components, such as the asset-specific residual maturity of the climate factor, may be easily translatable across different asset classes. Issuer and sector-specific components may require deeper rethinking in each case.

Asset-backed securities, mainly composed of mortgages and vehicle loans, could rely on a pool-level component measuring the exposure of underlying loans to transition-related energy shocks. This exposure could be assessed from data such as energy performance certificates (EPC) or emissions of vehicles. Although data coverage may be patchy and uneven across Eurosystem countries, interim solutions could look at estimating missing energy efficiency data from available information such as property or vehicle characteristics.

Covered bank bonds would need a component assessing the exposure of the issuing bank to climate-related financial risks. Relevant data may be obtained from existing supervisory assessments, which could then be analysed through the many emerging frameworks that are used in financial markets to analyse banks' financed emissions, transition targets and climate governance.[11] Underlying mortgages in the cover pool could follow the treatment suggested for ABS, building on good transparency practices such as the European Covered Bond Council (ECBC)'s Harmonised Transparency Template (HTT), which offers a well-established framework for incorporating GHG emissions, EPC (Energy Performance Certificates) and other climate-related metrics for the underlying mortgage assets. Public exposures in the cover pool, on the other hand, may prove more challenging to include.

Sovereign bonds are a more sensitive case, due to the effects that adjustments could have on the country's borrowing capacity or in the perceived impartiality of the central bank. In addition, climate performance is largely driven by fiscal, regulatory and structural policies, suggesting that fiscal should remain the key instrument for achieving decarbonisation objectives. Where central banks choose to support these objectives, preferential treatment for strong climate performers and green sovereign bonds may prove more feasible than penalties for laggards, drawing on transparent and open-access assessments of countries' emissions trends, targets and policy frameworks, through existing market-based methodologies such as ASCOR.[12]

A careful calibration must be done to preserve risk equivalence across different asset types. A phased approach, beginning with the components where data is strongest and within an architecture designed to absorb later improvements, would allow central banks to act without waiting for full data harmonisation, an approach the NGFS has also identified as a priority for widening the scope of asset-side measures. The ECB's extension of the climate factor to

11 See Net Zero Banking Assessment Framework (NZBAF) and Carbon Performance, TPI Centre.

12 See Assessing Sovereign Climate-related Opportunities and Risks (ASCOR), TPI Centre.

credit claims provides a practical example of this approach, relying on available sector-level information where granular data remains limited.

4.3. Capturing physical risks

Many central banks have started addressing climate-related risks by focusing on the uncertainties of the low-carbon transition. However, transition risk represents only one dimension of climate change. Global warming also generates physical risks through acute natural hazards and chronic shifts in weather patterns, which can damage firms' operations and their capacity to sustain their debt obligations. Floods, wildfires and droughts can also erode the value of collateral, particularly in the case of mortgages and mortgage-backed securities. These effects can create material risks for both the financial system and central bank balance sheets. It is recognised that acute and chronic physical hazards are increasing in frequency and intensity, and that their effects may turn catastrophic beyond geophysical thresholds known as "tipping points" (Broeders and Mongelli, 2026). Excluding physical risks from central bank frameworks may therefore leave a significant gap in climate-related risk coverage.

The Bank of England's approach has shown feasibility in incorporating physical risk into the valuation of collateral, given the predominance of mortgages in posted collateral. Physical risk, in the form of flood and subsidence risk, is calibrated into the haircut adjustments of eligible mortgages using scenario analysis (Bank of England, 2026b). Other central banks can follow this example and model physical risks in their stress test scenarios to assess the vulnerability of collateral. Since the timing and intensity of physical hazards is highly difficult to predict, forward-looking scenarios may rely on a precautionary approach, assuming high tail risks.

Physical risk also raises equity questions that transition risk does not. Exposure may concentrate geographically, often falling on lower-income households and on regions that have contributed least to climate change. Adjusting collateral values on the basis of location could raise the cost of borrowing precisely where adaptation investment is most needed. Fiscal policies can guarantee fairness by redistribution mechanisms, but this type of support lies outside the scope of central banks and may only be achieved with coordinated action with governments (Claeys et al., 2024).

4.4. Including material risks to asset valuations from nature degradation

Central banks increasingly acknowledge the macroeconomic and financial sector impacts of nature-related risks and are striving to better incorporate them into their frameworks. In an ECB-CETEx joint conference in 2026 focused on Climate, Nature and Monetary Policy, President Christine Lagarde highlighted that last year's ECB strategy assessment was a commitment not

only to incorporating climate change considerations systematically into its monetary policy and central banking, but also to extend that commitment to nature (Lagarde, 2026).

Nature degradation is closely interconnected with climate-related risks, with both reinforcing one another through feedback loops. For instance, rising temperatures allow pests and invasive species to survive and spread, degrading the forests and agricultural systems that both sequester carbon and form a natural buffer against extreme weather events (Almeida et al., 2025). Biodiversity and ecosystem services underpin a wide range of economic activities, many of which, such as agriculture and food production, are highly dependent on natural systems. Nature is also inherently multidimensional. Early work in the euro area has concentrated on one of those dimensions: water. It finds that water-related risks are highly material for the euro area economy, with surface water scarcity alone estimated to place up to 15% of the Eurozone's economic output at risk (Elderson, 2025).

Translating this risk into monetary policy frameworks is perceived to be harder than it is for climate (Serrano et al., 2026). There is no single metric capturing nature loss comparable to carbon emissions, ecosystem dependencies or impacts are highly location-specific, and disclosure frameworks remain voluntary and unevenly adopted. While better data, analytical and modelling practices are needed, a realistic route can follow the approach favoured in the conference discussion: begin where action is possible.

Central banks have already begun assessing financial system exposure to nature degradation. The central banks of the Netherlands, France, Malaysia and Mexico, as well as the ECB (Ceglar, 2025), have all published analyses of dependencies of economic activities and financial institutions on ecosystem services. The next step is to translate exposure into measurable financial risk metrics that can identify the most material sources of nature-related risk (Gallet et al., 2024). From there, nature-related considerations could be integrated into existing climate scenarios[13] and stress tests, allowing them to inform existing measures, such as the Eurosystem's climate factor or the Bank of England's collateral haircuts. Building on the architecture of existing climate risk frameworks to pragmatically integrate nature risk would keep the operational burden proportionate while maintaining methodological consistency across risk types.

5. CONCLUSION

Central banks have come a long way over the past decade from concept to practice, and a number of initiatives outlined in this article highlight the efficacy of such good practices.

13 For instance, the NGFS's Nature Taskforce is spearheading the development of nature-related scenarios for central banks and supervisors, and the ECB has conducted an initial integrated climate-nature scenario exercise in collaboration with the Potsdam Institute for Climate Impact Research (PIK).

However, given the extensive assessment by NGFS, central banks and research centres to determine how greening of operations can be developed and implemented, there is clearly room for improvement well within central banks' mandates and operational competencies. Combining such practices — incentives, disincentives, and other risk-based measures— across asset purchase programmes, collateral frameworks, and other aspects of operations, both within and across central banks, could send a powerful signal to financial systems and the real economy of the tangible economic value of climate and nature transitions.

REFERENCES

Almeida, E., Goumet, L., Greenslade, W, Waaifoort, M. (2025). *Understanding the climate–nature nexus and its implications for the economy and financial system.* London: Centre for Economic Transition Expertise (CETEx). https://cetex.org/publications/understanding-the-climate-nature-nexus-and-its-implications-for-the-economy-and-financial-system/

Andrade, P., Breckenfelder, J., De Fiore, F., Karadi, P., Tristani, O. (2016) The ECB's asset purchase programme: an early assessment. *ECB Discussion Paper Series,* No. 1. Frankfurt: European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpdps/ecb.dp1~938b99b1ae.en.pdf

Assessing Sovereign Climate-related Opportunities and Risks (ASCOR). (2026). ASCOR. https://www.ascor.org/

Banco de España. (2026). Session 3: Greening central banks' portfolios. Recording of conference session at *Climate risk and sustainable finance: bridging policy, research, and practice*, Madrid, 25 March. https://www.youtube.com/watch?v=TUqCg6AjZAs

Bank of England. (2021). *Bank of England publishes its approach to greening the Corporate Bond Purchase Scheme.* Press release, 5 November. London: Bank of England. https://www.bankofengland.co.uk/news/2021/november/boe-publishes-its-approach-to-greening-the-corporate-bond-purchase-scheme

Bank of England. (2024). *Updates to eligibility of residential mortgage collateral in the Sterling Monetary Framework to reflect the Domestic Minimum Energy Efficiency Standard (MEES) Regulations.* Market Notice, 23 May. London: Bank of England. https://www.bankofengland.co.uk/markets/market-notices/2024/may/updates-to-eligibility-of-residential-mortgage-collateral-in-the-smf-market-notice

Bank of England. (2026a) *Changes to collateral eligibility in the Sterling Monetary Framework.* Market Notice, 11 June. London: Bank of England. https://www.bankofengland.co.uk/markets/market-notices/2026/june/collateral-eligibility-in-the-smf-11-june-2026

Bank of England. (2026b) *The Bank of England's climate-related financial disclosure 2026.* London: Bank of England. https://www.bankofengland.co.uk/climate-change/the-bank-of-englands-climate-related-financial-disclosure-2026

Bank of Japan (BOJ) (2025). *Outline of transactions for Climate Response Financing Operations.* Web page, as of 7 May. https://www.boj.or.jp/en/mopo/measures/mkt_ope/ope_x/opetori22.htm

Bank of Japan (BOJ). (2026a). *Loan disbursement under the Funds-Supplying Operations to Support Financing for Climate Change Responses.* Web page, 17 July. https://www.boj.or.jp/en/mopo/mpmdeci/mpr_2026/mpr260717a.pdf

Bank of Japan (BOJ). (2026b). Bank of Japan Accounts (July 31, 2026). Web page, 4 August. https://www.boj.or.jp/en/statistics/boj/other/acmai/release/2026/ac260731.htm

Board of Governors of the Federal Reserve System. (2020). *Financial Stability Report: November 2020*. Washington DC: Federal Reserve Board. https://www.federalreserve.gov/publications/files/financial-stability-report-20201109.pdf

Bremus, F., Schütze, F., Zaklan, A. (2021) The Impact of ECB Corporate Sector Purchases on European Green Bonds. *DIW Discussion Papers*, No. 1938. Berlin: German Institute for Economic Research (DIW Berlin). https://www.diw.de/documents/publikationen/73/diw_01.c.813500.de/dp1938.pdf

Broeders, D., Mongelli, F. P. (2026) The Paris Agreement ten years later: Navigating climate uncertainty and tipping points. *ECB Working Paper Series*, No. 3261. Frankfurt: European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp3261~cc4bd5eabc.en.pdf

Caswell, G. (2021). *PBoC launches targeted green lending*. Green Central Banking, 10 November. https://greencentralbanking.com/2021/11/10/pboc-launches-targeted-green-lending/

Ceglar, A., Jwaideh, M., Danieli, F., Pasqua, C., Hutchinson, J., Ranger, N. et al. (2025) Nature at risk: implications for the euro area economy and financial stability. *ECB Occasional Paper Series*, No. 380. Frankfurt: European Central Bank. https://www.ecb.europa.eu/pub/pdf/scpops/ecb.op380.en.pdf

Claeys, I., Suresh Kumar, R. S., Barmes, D. (2024). *Assessing the Bank of England's climate risk collateral reforms for their greening potential.* Commentary, 6 November. London: Centre for Economic Transition Expertise (CETEx). https://cetex.org/news/assessing-the-bank-of-englands-climate-risk-collateral-reforms-for-their-greening-potential/

Dafermos, Y., Gabor, D., Nikolaidi, M., van Lerven, F. (2022). *Greening collateral frameworks.* INSPIRE Sustainable Central Banking Toolbox Policy Briefing Paper 7. London: Grantham Research Institute on Climate Change and the Environment, London School of Economics and Political Science. https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2022/08/INSPIRE-Sustainable-Central-Banking-Toolbox-Policy-Briefing-Paper-7.pdf ; https://www.lse.ac.uk/granthaminstitute/publication/greening-collateral-frameworks/.

Elderson, F. (2025). *Nature's bell tolls for thee, economy!* Keynote speech at the Naturalis Biodiversity Center, Leiden, 22 May. Frankfurt: European Central Bank. https://www.ecb.europa.eu/press/key/date/2025/html/ecb.sp250522~b371549cb6.en.html

European Central Bank (ECB). (2022a). *ECB provides details on how it aims to decarbonise its corporate bond holdings.* Press release, 19 September. Frankfurt: European Central Bank. https://www.ecb.europa.eu/press/pr/date/2022/html/ecb.pr220919~fae53c59bd.en.html

European Central Bank (ECB). (2022b). *ECB takes further steps to incorporate climate change into its monetary policy operations.* Press release, 4 July. Frankfurt: European Central Bank. https://www.ecb.europa.eu/press/pr/date/2022/html/ecb.pr220704~4f48a72462.en.html

European Central Bank (ECB). (2025a). *Climate-related financial disclosures of Eurosystem assets held for monetary policy purposes and of the ECB's foreign reserves.* Frankfurt: European Central Bank. https://www.ecb.europa.eu/ecb/climate/climate-related-financial-disclosures/shared/pdf/ecb.crfd2025_MPPs.en.pdf

European Central Bank. (2025b). *ECB to adapt collateral framework to address climate-related transition risks.* Press release, 29 July. Frankfurt: European Central Bank. https://www.ecb.europa.eu/press/pr/date/2025/html/ecb.pr250729_1~02d753a029.en.html

European Central Bank. (2025c). *Frequently asked questions on incorporating climate change considerations into corporate bond purchases.* Web page, updated 8 January. Frankfurt: European Central Bank. https://www.ecb.europa.eu/mopo/implement/app/html/ecb.faq_cspp_climate_change.en.html

European Central Bank. (2026). *ECB to extend use of climate factors in Eurosystem collateral framework to non-financial corporate credit claims.* Press release, 24 July. Frankfurt.

Foos, D., Norden, L., Weber, M. (2010). Loan growth and riskiness of banks. *Journal of Banking & Finance, 34*(12), 2929–2940. https://ssrn.com/abstract=1045001

Gallet, S., Hendricks, H., Prodani, J. (2024). The ecosystem service degradation sensitivity indicator (EDSI): A new framework for understanding the financial risk repercussions of nature degradation. *Working Paper*, 814. Amsterdam: De Nederlandsche Bank. https://www.dnb.nl/en/publications/research-publications/working-paper-2024/814-the-ecosystem-service-degradation-sensitivity-indicator-edsi-a-new-framework-for-understanding-the-financial-risk-repercussions-of-nature-degradation/

Green Central Banking. (2024). China's central bank extends green lending scheme until 2027, 22 August.

Klein, SMA., Polzin, F., Urbach, X. (2026). Planning to fail? Credibility and financing of corporate transition plans in hard-to-abate sectors. *iScience 29*(6), 116282. https://doi.org/10.1016/j.isci.2026.116282

Lagarde, C. (2026). *Climate, nature and monetary policy.* Introductory remarks at the Climate, Nature and Monetary Policy Conference organised by the ECB, CETEx and Frankfurt School of Finance & Management, Frankfurt am Main, 5 May. Frankfurt: European Central Bank. https://www.ecb.europa.eu/press/key/date/2026/html/ecb.sp260505~936c9c11b5.en.html

Lee, K. (2024). *China's central bank extends green lending scheme until 2027*. Green Central Banking, 22 August. https://greencentralbanking.com/2024/08/22/chinas-central-bank-extends-green-lending-scheme-until-2027/

Magyar Nemzeti Bank (MNB). (2021). *Sustainability and central bank policy – green aspects of the Magyar Nemzeti Bank's monetary policy toolkit.* Budapest: Magyar Nemzeti Bank. https://www.mnb.hu/letoltes/sustainability-and-central-bank-policy-green-aspects-of-the-magyar-nemzeti-bank-s-monetary-policy-toolkit.pdf

Magyar Nemzeti Bank (MNB). (2024). *The Magyar Nemzeti Bank's Climate-Related Financial Disclosure – 2024.* Budapest: Magyar Nemzeti Bank. https://www.mnb.hu/letoltes/tcfd-jelente-s-2024-eng-0508.pdf

Magyar Nemzeti Bank (MNB). (2026a). *Green Home Programme.* Web page. Budapest: Magyar Nemzeti Bank. https://zoldpenzugyek.mnb.hu/monetary-policy-instruments/green-home-programme

Magyar Nemzeti Bank (MNB). (2026b) *Green Mortgage Bond Purchase Programme.* Web page. Budapest: Magyar Nemzeti Bank. https://zoldpenzugyek.mnb.hu/monetary-policy-instruments/green-mortgage-bond-purchase-programme

Magyar Nemzeti Bank (MNB). (2026c) *Green Preferential Capital Requirement Programme.* Web page. Budapest: Magyar Nemzeti Bank. https://zoldpenzugyek.mnb.hu/supervisory-tools/green-preferential-capital-requirement-programme

Milstein, E., Wessel, D. (2024). *What did the Fed do in response to the COVID-19 crisis?* Commentary, 2 January. Washington DC: Brookings Institution. https://www.brookings.edu/articles/fed-response-to-covid19/

Network for Greening the Financial System (NGFS). (2021). *Adapting central bank operations to a hotter world: Reviewing some options.* Paris: Network for Greening the Financial System, March. https://www.ngfs.net/system/files/import/ngfs/media/2021/06/17/ngfs_monetary_policy_operations_final.pdf

NGFS. (2023a). *Monetary policy and climate change: Key takeaways from the membership survey and areas for further analysis.* Paris: Network for Greening the Financial System. https://www.ngfs.net/system/files/import/ngfs/medias/documents/monetary_policy_and_climate_change_-_key_takeaways_from_the_membership_survey.pdf

NGFS. (2023b). *NGFS survey on climate scenarios: key findings.* Paris: Network for Greening the Financial System. https://www.ngfs.net/system/files/import/ngfs/medias/documents/ngfs_survey_results.pdf

NGFS. (2024) *Adapting central bank operations to a hotter world: current progress and insights from practical examples.* Paris: Network for Greening the Financial System. https://www.ngfs.net/sites/default/files/medias/documents/ngfs_adapting_central_bank_operations_to_a_hotter_world_final.pdf

NGFS. (2026a). *Greening monetary policy operations: exploring additional options.* Paris: Network for Greening the Financial System. https://www.ngfs.net/system/files/2026-01/Greening%20Monetary%20Policy%20Operations.pdf

NGFS. (2026b). *Summary Note on the Improvement of Modelling Tools for Nature-related Financial Risk Scenarios.* Paris: Network for Greening the Financial System. https://www.ngfs.net/en/publications-and-statistics/publications/summary-note-improvement-modelling-tools-nature-related-financial-risk-scenarios

Schnabel, I. (2023). *Monetary policy tightening and the green transition.* Speech at the International Symposium on Central Bank Independence, Sveriges Riksbank, Stockholm, 10 January. Frankfurt: European Central Bank. https://www.ecb.europa.eu/press/key/date/2023/html/ecb.sp230110~21c89bef1b.en.html

Serrano Rodriguez, E. (2026). *Climate-related risks and the future of collateral frameworks.* Centre for Economic Transition Expertise (CETEx). Commentary, 4 August. CETEx. https://cetex.org/news/climate-related-risks-and-the-future-of-collateral-frameworks/

Serrano Rodriguez, E., Barmes, D., Niño Corredor, A. (2026). *Climate and collateral: the design and scope of the Eurosystem's climate factor.* London: Centre for Economic Transition Expertise (CETEx). https://doi.org/10.21953/researchonline.lse.ac.uk.00138616

Stevanović, M., Ceglar, A., von Jeetze, P., Costermani Visconti, A., Krisht, S., Johnson, JA., Borrelli, P., Heemskerk, I., Popp, A., Zadek, S. (2024). *Climate-nature scenario development for financial risk assessment: Presentation of Final Results.* Potsdam/Frankfurt: Potsdam Institute for Climate Impact Research (PIK), European Central Bank (ECB) and NatureFinance. https://www.naturefinance.net/wp-content/uploads/2024/11/ECB_PIK-Report-2024-FINAL.pdf

TPI Global Climate Transition Centre. (2026). *Net Zero Banking Assessment Framework and Carbon Performance for Banks data from TPI Global Climate Transition Centre.* Dataset. London School of Economics and Political Science. https://doi.org/10.21953/researchonline.lse.ac.uk.00137775

Wang, JZ., Herwartz, H. (2026). Central bank green policy, emissions reduction, and financial stability. *Energy Economics*, 158, 109378. https://doi.org/10.1016/j.eneco.2026.109378

Yi, G. (2023). *Proactively implementing the philosophy of green development to peak carbon emissions before 2030 and achieve carbon neutrality before 2060.* Keynote speech at the 14th Lujiazui Forum, Shanghai, 8 June. https://www.bis.org/review/r230622h.htm

From Carbon to Collateral: Five Years of Greening the Plumbing of Monetary Policy

*Caspar Siegert and James Talbot**

Abstract

Over the past five years, central banks have moved from debating whether to factor in climate-related considerations in their monetary policy operations to taking tangible actions. These actions are typically designed to manage climate-related financial risks on central banks balance sheets and/or to support the economy-wide transition to net zero (where central banks have a mandate to do so). This article reviews that evolution, drawing on experiences of the Bank of England and other central banks. It traces the expansion of climate-related measures from asset purchase programmes to collateral frameworks, lending operations and liability-side tools. We argue that clearly articulating a central bank's objectives is crucial for selecting appropriate instruments. These instruments must also reflect substantial differences in local market structures and operating frameworks. While improvements in climate data have removed some barriers, translating this data into decision-useful metrics remains challenging and is an area where the NGFS can provide valuable support.

Keywords: central banking, monetary policy operations, climate change, climate risk, physical risk, transition risk, sustainable finance.

The impact of climate change is intensifying. Rising temperatures have increased the frequency and intensity of extreme weather events and their economic impact is increasing. While the policies needed to mitigate climate change are for governments to decide, central banks need to understand the impact of climate change on the economy, the financial system and their own balance sheet. In 2021, an NGFS report titled 'Adapting central bank operations to a hotter world' (NGFS, 2021) discussed how central banks might need to factor in climate-related considerations in their monetary policy operations.

We can distinguish two distinct reasons why central banks might need to consider climate change as part of the financial operations that they use to implement monetary policy. First, all central banks will want to ensure that they are managing the climate-related financial risks on their own balance sheet, even if the materiality of these risks differs across countries. Second, some central banks may have a mandate to actively support the economy-wide transition to net zero. For example, they could use their monetary policy operations to try to reduce the relative cost of funding environmentally friendly vs polluting businesses. Traditionally, most central banks do not try to affect relative funding costs via their

* Bank of England. Caspar was the co-lead of the monetary policy operations workstream in the NGFS from 2022-2026 and James was the Chair of the NGFS monetary policy workstream from 2022-2026. We would both like to thank the NGFS membership for their engagement in tackling the issues referred to in this article.

operations. But they may choose to do so to the extent their legal mandates ask them to in the context of climate change.

Central banks have several levers at their disposal to reflect climate considerations in their operations. For example, they might adjust asset purchase schemes to overweight certain types of issuers. They might also adjust the pricing of their lending operations or refine collateral requirements in relation to such lending. Or they might want to reflect climate considerations in the amount of central bank reserves that commercial banks are required to hold (where such requirements exist). Some of these levers will help manage financial risks to central banks' balance sheets. Other levers will help support a transition to net zero. And some will do both.

Below, we set out key areas in which central banks — including the Bank of England — have made progress in terms of turning these conceptual considerations into practice. Subsequently we will touch on some of the challenges that central banks had to overcome, before concluding with some overarching remarks.

1. PROGRESS CENTRAL BANKS HAVE MADE OVER THE PAST 5 YEARS

Since the NGFS report on monetary policy operations was published in March 2021, central banks have made a huge amount of progress to put these policy actions into practice. The measures that have successfully been implemented include tilting asset purchases towards greener issuers, adjusting "haircuts" on various types of collateral, as well as adjusting the terms of long-term refinancing operations to provide banks with incentives to lend to "green" activities.[1] Crucially, progress has been made both across a wide range of measures and a wide range of jurisdictions, including at the Bank of Japan, the Central Bank of the United Arab Emirates, the European Central Bank, the Magyar Nemzeti Bank and the People's Bank of China. A useful stocktake of these measures is included in the NGFS's 2024 publication "Adapting central bank operations to a hotter world: current progress and insights from practical examples" (NGFS, 2024).

Below, we step through the journey so far using the Bank of England as an example — while acknowledging the progress that has been made by other central banks, too.

Stage 1: greening asset purchase schemes

At the Bank of England our journey started with the greening of our Corporate Bond Purchase Program. The Corporate Bond Purchase Scheme (CBPS) was launched in August

1 A collateral haircut determines how much a central bank will lend against an asset. For example, a 5% haircut means lending 95 cents against a bond worth $1. This provides a buffer against losses: if the counterparty defaults, the bond's value can fall by up to 5% before the central bank incurs a loss.

2016 and expanded in 2020 in response to the Covid-19 pandemic. It purchased investment-grade sterling corporate bonds issued by non-financial corporates judged to make a material contribution to the UK's economic activity. The scheme was a monetary policy tool. Its size was therefore determined by the Monetary Policy Committee (MPC) as part of its monetary policy decision-making in order to achieve its inflation target. At its peak, the CBPS held GBP20bn of corporate bonds — estimated to be around 6.5% of the Sterling corporate bond market (UK Finance, 2021).

In November 2021, the Bank of England announced that it would 'green' this asset purchase portfolio. It decided to do so by regularly reinvesting the proceeds from maturing bonds into bonds issued by more climate-friendly issuers in each sector, and by making bonds by issuers that derive revenue from thermal coal mining ineligible altogether. The target was to achieve net zero in the portfolio by 2050 — something that could support an orderly transition to net zero (Bank of England, 2021). The announcement followed an update to the MPC's remit in which the Chancellor confirmed that the economic strategy of the Government which the MPC is expected to support as a "secondary objective" included supporting the "*transition to an environmentally sustainable and resilient net zero economy"* (HM Treasury, 2021). In addition to supporting the orderly transition to net zero, the changes to the asset purchase scheme also reduced the CBPS's exposure to transition risks (Monnin, 2018). The first reinvestments using this new approach were made in November 2021.

This change made the Bank of England the first major central bank in the world to "tilt" asset purchases towards greener assets. In July 2022, the European Central Bank announced that it would start "tilting" its corporate bond purchases under the corporate sector purchase programme (CSPP) and pandemic emergency purchase programme (PEPP) towards issuers with a better climate performance (ECB, 2022). This came at a time where, in light of the different monetary policy outlook, the ECB was still conducting net corporate bond purchases rather than simply reinvesting the proceeds from maturing bonds. The Magyar Nemzeti Bank announced in August 2021 that it would launch a dedicated Green Mortgage Bond Purchase Programme (Magyar Nemzeti Bank, 2021). Central banks have not yet adjusted their (often bigger) sovereign bond purchase schemes to reflect climate considerations given that there is significantly less scope to adjust the composition of these schemes.

Subsequent changes in the monetary policy environment made changes to asset purchase programs less relevant. As the post-Covid economic recovery began and interest rates moved away from the zero lower bound, central banks stopped expanding their asset purchase schemes, stopped reinvesting the proceeds of maturing bonds, and actively sold assets. This included the UK, where the MPC decided in February 2022 to reduce the size of the CBPS by a combination of ceasing to reinvest maturing assets and actively selling longer-dated bonds. The end of reinvestments meant that the previous approach to "tilting" was no longer applicable.

Instead, the Bank of England considered climate factors as part of the active sales process. This approach was designed to sell bonds issued by climate-friendly issuers less quickly than others. By June 2023 the active sales had concluded, with the last remaining bonds maturing shortly afterwards. This marked the end of the Bank of England's experience with "greening" its CBPS: portfolios that no longer exist cannot be greened.

The experiences with greening asset purchases still provide lasting lessons though. We developed important capabilities in terms of assessing the climate characteristics and associated transition risk for a broad range of non-financial corporates. And we learned how to tilt portfolios in a way that reflects this information without jeopardizing the primary purpose of these asset purchase programs. Some of the learnings from tilting the CBPS are also summarized in the Bank of England's 2025 Climate Disclosures, which show that our actions lead to a material change in the composition of the CBPS (Bank of England, 2025).[2]

The fact that asset purchases were wound down soon after we started to tilt our asset purchases is an example of the primacy of monetary policy objectives. The size of the CBPS was fully determined by the monetary stance required to achieve the UK's inflation target. The exact composition of the CBPS was not pinned down by monetary policy considerations — which allowed us to tilt the portfolio towards greener issuers as part of the Bank's "secondary objective". But as monetary policy required the portfolio to be wound down, that scope to make adjustments to meet the 'secondary objective' eventually disappeared, too.

Stage 2: greening collateral frameworks

Over the past three years, the Bank of England has turned its attention to greening the collateral underpinning our collateralized lending and "repo" operations.[3] These operations are used to implement monetary policy. Central banks lend against suitable collateral, applying conservative haircuts (i.e. lending somewhat less than the market value ot the collateral they take) in order to protect themselves against financial losses. These collateral policies will become increasingly important in the UK and elsewhere, as we transition away from asset purchase programs and towards a repo-led framework for monetary policy implementation (Saporta, 2024; Rodriguez et al, 2026). By accurately reflecting climate-related financial risks in our collateral eligibility and haircut methodologies, the Bank of England aims to ensure that its risk frameworks appropriately capture physical as well as transition risks connected to climate change — in the same way that they would do for any other risks.

2 There are also lessons from the tilting of corporate bond purchase schemes for incorporating environmental factors into international reserve management frameworks (see e.g. BIS, 2022).

3 A repurchase agreement (repo) is a short-term agreement under which the central bank's counterparty agrees to sell securities and repurchase them later at a slightly higher price. This is economically equivalent to a secured lending operation where the price difference is equivalent to the interest rate the central bank would otherwise charge.

In 2024, the Bank of England started incorporating climate considerations into the haircuts and eligibility criteria for residential mortgage collateral. As of July 2026, raw (i.e. non-securitised) pools of residential mortgages accounted for over 60% of all collateral posted with the Bank. The value of these mortgages can be subject to both transition and physical risks. Transition risks include the risk that sharp increases in energy prices reduces the ability of households in difficult-to-heat properties to continue making their mortgage payments. Physical risks include the risk that more frequent flooding or subsidence could reduce the value of the property securing a mortgage. Climate change is expected to lead to more frequent and severe flooding in much of the UK. This can drive up the cost of insuring flood-prone properties or make the properties entirely uninsurable. This in turn can affect property values, for example because uninsurable properties cannot be mortgaged and can only be sold to a much smaller pool of cash-buyers. Similarly, climate change can increase the risk of subsidence. Subsidence occurs due to the expansion and contraction of the clay soil that many buildings in south-east England are built on. As climate change leads to more frequent periods of heavy rain as well as droughts, such contractions and expansions become more pronounced. This can damage properties, affect the cost of insurance, and ultimately reduce the value of a property. We amended data templates, worked with specialist analytics providers, and conducted detailed scenario analysis to quantify these risks and translate them into haircut adjustments. In addition, we also tightened eligibility criteria to ensure we only accept buy-to-let mortgages on properties that comply with the UK's minimum energy efficiency standards for rental properties.

In June 2026 we also announced changes to haircuts and eligibility criteria for corporate bonds. Issuers of the corporate bonds that we accept as collateral can be exposed to potential financial risks connected to the adjustment of the economy towards net zero. To reflect this, the Bank of England decided to apply haircut add-ons to bonds from issuers in relevant sectors to protect the Bank against financial risks. Consistent with the approach taken in the CBPS, it also announced that, from 31 October 2026, bonds issued by corporates that derive revenue from thermal coal mining and that are exposed to particularly material transition risks will not be eligible as collateral (Bank of England, 2026). While corporate bonds are not commonly used as collateral in the UK right now, these measures were announced alongside other changes that might change banks' incentives to use such collateral in the future. As such, they are important for future-proofing our risk management framework.

This shift of focus away from asset purchase schemes towards collateral measures is something we also see in other central banks. For example, the European Central Bank started applying similar haircut add-ons for corporate bond collateral in June 2026 (ECB, 2025). The Magyar Nemzeti Bank took a slightly different approach, and in September 2021 introduced lower haircuts for certain green securities rather than using add-ons for the least green assets.

Other central banks opted to adjust the pricing rather than the collateral policies of their lending schemes. For example, the People's Bank of China (PBOC, 2021) and the Bank of Japan (Bank of Japan, 2021) both rolled out programs that lend to banks at preferential prices, as long as that funding is used to support certain environmentally friendly activities. While the Bank of England's and European Central Bank's changes to collateral policies were motivated by the need to manage risks to central banks' balance sheets, such preferential pricing can support broader environmental objectives of the government.

Stage 3: liability-side tools

Work on the other side of central banks' balance sheet is more nascent. This includes measures such as central banks issuing green monetary bills or adjusting the amount of central bank reserves that commercial banks are required to hold in a way that reflects climate-related factors.

The NGFS's recent work demonstrates that such tools can be useful additions to central bank's toolkits, where central banks conduct these operations to meet their mandate (NGFS, 2026). Liability-side tools do not typically reduce direct financial risks that central banks are exposed to. But they can be effective in terms of supporting a broader, economy-wide transition to net zero. For example, commercial banks may be willing to lend to green projects at advantageous conditions if doing so reduces any reserve requirements they are subject to. And if central banks channel the proceeds of green monetary bill issuances into greener parts of the financial system, then this could support the development of a wider sustainable finance ecosystem.

How applicable such liability-side tools are depends on central banks' mandates as well as their broader operating frameworks. Liability-side tools are most relevant in markets where central banks regularly issue monetary bills, and/or impose reserve requirements that could be relaxed. While this is not the case for the Bank of England, some central banks — such as in the United Arab Emirates — have successfully launched work on schemes like this, demonstrating the diverse approaches taken to greening monetary operations across the NGFS's global membership (CBUAE, 2025).

2. OVERCOMING PRACTICAL CHALLENGES

There are now many successful examples of central banks having incorporated climate change-related considerations into their monetary policy operations. But it's important to acknowledge that central banks had to overcome a range of practical challenges to get there. We are not yet at the point where reflecting climate risks in monetary policy operations is as common and unremarkable as managing other risks. Nevertheless, knowledge sharing and dialogue in fora

like the NGFS are helping to broaden the range of central banks implementing these types of operations. There are three challenges in particular:

Challenge 1: articulating objectives

The first challenge is to clearly articulate what a central bank is trying to achieve by integrating climate considerations into its monetary operations. As mentioned above, some central banks integrate climate factors into their monetary policy operations to reduce risks to their own balance sheet, while others try to support an economy-wide transition that addresses the broader economic and societal risks liked to climate change. These differences reflect different central bank mandates, so there is no right or wrong answer. However, not distinguishing between these distinct objectives is a frequent source of confusion (Sachs et al., 2026).

This is because which objectives a central bank pursues determines which tools to prioritize. There are no "one size fits all" solutions. For example, increasing haircuts on assets exposed to climate risks can be important to protect central banks' balance sheets. But recent analysis by Bank of England staff (Somaiya et al., 2025) has shown that it is unlikely to materially support the transition to net zero. Conversely, long-term refinancing operations that provide cheap funding for green projects could be helpful to support the transition. But providing cheap funding for certain activities will not typically reduce direct financial risks to a central bank. Instead, it could erode central bank income, thereby reducing a central bank's financial resilience.[4]

The NGFS's work acknowledges the importance of matching tools and objectives and provides helpful guidance in this area. For example, the NGFS's 2021 report on monetary policy operations provides an indicative assessment of which tools may be most relevant in the context of reducing risks to central bank balance sheets vs. supporting the transition to net zero. And the NGFS's 2024 report that took stock of progress so far demonstrated that this had been reflected in the tools that different central banks had chosen to deploy in practice. Specifically, changes to the pricing of lending operations always reflected an objective to support the transition, while changes to haircut policies and asset purchase programs would often (also) reflect an objective to manage risks to the central bank's balance sheet.[5] The fact that the NGFS's work can support central banks irrespective of what they are trying to archive is one of the great strengths of the network.

4 Such lending schemes may reduce risks indirectly by supporting a global transition to net zero and reducing physical risks a central bank is exposed to. However, it is not clear that an individual central bank can shape the global transition in a way that would lead to a measurable reduction in physical risks to its balance sheet.

5 According to the 2024 report overall, more measures had been motivated by an objective of supporting the transition rather than managing risks to central banks' balance sheets. However, this could simply be a result of central banks being less likely to talk about their risk management practices in public.

Challenge 2: tailoring solutions to local frameworks

The second challenge is that monetary policy operations differ significantly across countries. Even when abstracting from differences in mandates with respect to climate change, there are big differences in the way different central banks go about their monetary policy operations. This is another reason why there are no one-size-fits all solutions.

At the most basic level this includes the fact that some central banks target inflation while others target exchange rates. Differences between inflation and exchange rate targeting do not only affect the formulation of monetary policy, but also the financial operations that are being used to implement monetary policy. For example, a central bank that targets exchange rates is more likely to intervene in foreign exchange markets or to issue monetary bills, while a central bank that targets inflation is more likely to adjust the terms of its collateralized lending programs or to buy and sell assets denominated in its own currency.

But even amongst inflation targeting central banks there is plenty of heterogeneity. For example, some central banks use reserve requirements while others don't. Some central banks have used large-scale asset purchase programs while others haven't. And some central banks have a history of providing various long-term refinancing operations while others don't. In addition, there is significant heterogeneity in the composition of the collateral that underpins central banks' secured lending operations. For example, some central banks primarily accept traded securities as collateral in their routine operations, while other central banks regularly accept credit claims such as residential mortgages or loans to non-financial corporates. And even where eligibility criteria are aligned in theory, commercial banks may deliver very different collateral mixes in practice. Often, this reflects the nature of different financial systems and the type of assets that commercial banks carry on their balance sheets. For example, in the UK, the biggest class of collateral that banks post with the central bank are residential mortgages, while in the Eurosystem covered bank bonds are the most frequently used type of collateral.

This means that it is not usually possible for central banks to simply copy approaches taken by their peers. Given the many dimensions along which central banks' operating frameworks and the financial systems that central banks operate in differ, it is unlikely that central banks find precedents in other countries that they can exactly replicate in their country without making adjustments.

The NGFS work on monetary policy operations helps address this challenge. Over the past years, the NGFS has organized numerous knowledge-sharing seminars and collated case studies that document measures implemented by a wide range of central banks. Crucially, it has focussed on those common building blocks that other central banks may be able to draw on, even if it does not make sense for them to follow the exact same approach. For example,

this includes sharing experiences on how to best assess transition risks that certain types of assets are exposed to. As usual, the NGFS doesn't try to come up with one-size-fits-all solutions but shares specific insights and experiences with its members. This allows central banks to learn about ways of addressing specific challenges that are relevant to them.

Challenge 3: data and metrics

For a long time, the lack of reliable asset-specific data was another factor that has held back some central banks. Depending on the assets they are trying to assess, central banks may have felt that they did not have the information that would be necessary to assess climate risks that specific assets are exposed to and/or the contribution to the transition to net zero that they could be making.

Fortunately, the availability of relevant information has increased materially over the past years. For example, the share of listed corporates worldwide that disclose Scope 1 and 2 carbon emissions increased from 28% in 2015 to 76% in 2023 (MSCI, 2025). Disclosure rates in developed markets and amongst large firms are even higher and often around 90% (Dalmas et al., 2025). While there continue to be challenges for some other types of assets, data availability has increased for many of these asset classes too.

In light of this progress, the focus has shifted from identifying raw data to developing simple, decision-useful metrics. In many cases, the challenge is not so much to identify raw information, but to make sense of it. For example, the greenhouse gas emissions of a company in isolation will not tell us much about the transition risks the company is exposed to. To understand these risks, we need to also consider the company's revenues, its ability to reduce emissions in a cost-effective way, its ability to pass higher regulatory costs on to its customers, etc. Decision-useful metrics consider all this information and express it in simple summary statistics such as "climate-adjusted probabilities of default", "climate value at risk", etc.

The Bank of England's work on integrating climate considerations into its monetary policy operations demonstrated that this is not always easy — but that central banks can draw on a range of useful tools to overcome these challenges. For example, the Bank of England has used extensive scenario analysis to quantify the physical risks to residential mortgage collateral. This draws on raw data such as a property's location, forward-looking climate projections at a post code level to assess physical hazards that the property might be exposed to across various climate scenarios, and financial modelling to translate this into potential impacts on the value of properties and mortgages. As part of its annual climate disclosures (Bank of England, 2026a), the Bank of England also publishes extensive scenario analysis for sovereign bonds that translates climate factors into potential mark-to-market losses. The NGFS's work

on scenarios, data and metrics can provide extremely useful tools in this context. But making sense of all this information in the context of specific monetary policy portfolios will always require a significant amount of analysis and judgement by individual central banks.

3. CONCLUDING REMARKS

Over the past five years, the debate about climate change and monetary policy operations has moved from theory to practice. What began as a largely conceptual discussion has evolved into a broad range of concrete policy measures that different central banks have implemented. Central banks have demonstrated how to reflect climate considerations in the context of asset purchases, collateral frameworks and lending operations. And we have seen the emergence of interesting work on reserve requirements and green monetary bills. We are moving towards a situation where managing climate-related risks is becoming part of business as usual for central banks.

At the Bank of England, we have moved from greening our Corporate Bond Purchase Scheme to integrating climate risks into the treatment of residential mortgages and corporate bonds used as collateral. These measures have been rooted in our statutory objectives and have been informed by clear-eyed quantitative risk assessments. Climate risk is no longer something that is hypothetical or special. Instead, we quantify and manage it in the same way in that we would treat any other financial risk.

That said, incorporating climate considerations into monetary policy operations is not straightforward. Central banks operate under different mandates, pursue different policy objectives and work within very different operational frameworks. There is no single model that can simply be copied from one jurisdiction to another. Success depends on clearly identifying objectives, selecting tools that are consistent with those objectives, and developing the analytical capabilities needed to turn increasingly rich "raw" climate data into decision-useful insights.

The NGFS has played a central role in overcoming these challenges. By bringing together central banks with diverse mandates, operating frameworks and experiences, it has created a forum in which practical lessons can be shared and new ideas can be tested. As climate-related risks continue to evolve and as central banks' operating frameworks change over time, that collaborative approach will remain invaluable and help us build on the progress we have seen so far.

REFERENCES

Bank for International Settlements (BIS). (2022). Incorporating climate related risks into international reserve management frameworks - by the Consultative Group on Risk Management, BIS Representative Office for the Americas.

Bank of England. (2021). Greening our Corporate Bond Purchase Scheme (CBPS).

Bank of England. (2025). The Bank of England's 2025 climate-related financial disclosures.

Bank of England. (2026a). Changes to collateral eligibility in the Sterling Monetary Framework - Market Notice 11 June 2026.

Bank of England. (2026b). The Bank of England's climate-related financial disclosures 2026.

Bank of Japan (2021). Fund – Provisioning Measure to Support Efforts on Climate Change.

Central Bank of the UAE (CBUAE). (2025). Annual Report 2024.

European Central Bank (ECB). (2022). ECB takes further steps to incorporate climate change into its monetary policy operations (Press Release).

European Central Bank (ECB). (2025). ECB to adapt collateral framework to address climate-related transition risks (Press Release).

HM Treasury. (2021). Remit for the Monetary Policy Committee (MPC).

Magyar Nemzeti Bank. (2021). The MNB takes a further step towards a green economy and a modern real estate market.

Monnin, P. (2018). Integrating Climate Risks into Credit Risk Assessment Current Methodologies and the Case of Central Banks Corporate Bond Purchases. CEP Discussion Note, 2018/4

MSCI. (2025). Material, But Missing: Gaps in Scope 3 Reporting Persist.

NGFS. (2021). Adapting central bank operations to a hotter world - Reviewing some options.

NGFS. (2024). Adapting central bank operations to a hotter world: current progress and insights from practical examples.

NGFS. (2026). Greening Monetary Policy Operations: Exploring Additional Options.

People's Bank of China (PBOC). (2021). The People's Bank of China Launches the Carbon Emission Reduction Facility.

Rodriguez, E., Barmes, D., and Nino Corredor, A. (2026). Climate and collateral: the design and scope of the Eurosystem's climate factor. CETEx Policy report, May.

Sachs, L., Fujimoto, D., and Harel, Q. (2026). From Planetary Hazard to Financial Stability: Disentangling Climate Risk and Institutional Responsibility. Columbia Center on Sustainable Investment Paper

Saporta, V. (2024). Let's get ready to repo! – speech.

Somaiya, U., Siegert, C., and Kingsmore, B. (2025). The right tools for the job? How effectively can central banks support the transition to net zero? Bank Underground Blog.

UK Finance. (2021). Options for greening the Bank of England's Corporate Bond Purchase Scheme - UK Finance response to the Bank discussion paper.

Central Bank Portfolios and the Climate Transition: From Market Neutrality to Leadership Through Transparency

An analysis based on the Banco de España's experience and the climate-related disclosure of its investment portfolios*

*Juan Ayuso***

Abstract

Central banks have gradually brought climate change into the core of their institutional agendas, extending the discussion beyond financial stability and supervision to the management of their own investment portfolios. This article examines the Banco de España's approach to integrating sustainable and responsible investment criteria into non-monetary policy portfolios. Drawing on the Banco's climate-related disclosures and on the broader Eurosystem framework, it argues that the most important contribution of central banks like the Banco de España does not lie on the ability to move market prices through portfolio rebalancing, but on its capacity to lead by example through the creation of standards, transparency, methodological discipline and institutional credibility. The article reviews the guiding principles, the specific constraints, the difficulties of data and metrics—particularly in portfolios dominated by SSA (Sovereign, Supranational and Agency) issuers—and the role of climate disclosure in the strategy of a central bank to improve the quality of the financial debate on the climate transition.

Keywords: central bank investment policies, sustainable and responsible investment, climate-related metrics.

1. INTRODUCTION: A NEW DIMENSION FOR OWN INVESTMENT PORTFOLIOS

For decades, the management of central banks' own investment portfolios rested on a relatively stable set of principles: safety, liquidity, efficiency, prudence and, in many cases, market neutrality. The emergence of climate change as a source of financial risk has challenged this framework. The question is no longer simply how climate change and the entailed risks affect the balance of the central bank; accumulated evidence has shifted the debate towards how those risks should be measured, managed and disclosed without exceeding institutional mandates.

* This article reflects my own views, not necessarily those of the Banco de España. It offers an expanded version of my intervention at the the conference *Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice*.

** Banco de España.

The case of the Banco de España is particularly instructive. Since 2019, sustainable and responsible investment (SRI) principles have formed part of the investment policy for its own portfolios —that is, those portfolios that are not related to monetary policy (see Table 1). This decision preceded the common stance adopted by the Eurosystem in 2021 to apply SRI principles to these portfolios (see ECB, 2021). Following up on this Eurosystem common approach, since 2023, the Banco de España also publishes an annual report specifically devoted to the climate-related aspects of its non-monetary investment portfolios, structured around five blocks: governance, strategy, risk management, metrics and targets.

Table 1

Investment principles, management implications and associated climate challenges

Principle	Management implication	Associated climate challenge
Efficiency	Optimise risk-adjusted return within the mandate.	Integrate climate metrics without unnecessarily weakening financial efficiency.
Professionalism	Apply robust, documented and comparable processes.	Use verifiable data and transparent methodologies.
Market neutrality	Avoid distorting price formation.	Reconcile gradual decarbonisation with market depth and liquidity.
Prudence	Preserve a conservative risk profile.	Assess physical and transition risks without assuming exposures inconsistent with the mandate.
Sustainability/ SRI	Incorporate environmental, social and governance criteria.	Define eligible assets and measure their climate contribution.

This experience reveals an underlying tension. On the one hand, a central bank must act prudently, avoiding market distortions and preserving its primary objectives. On the other, it cannot ignore the fact that climate change affects credit, market stability and liquidity and entails reputational risks. The Banco de España's response has been gradual, transparent and methodologically disciplined: creating a dedicated SRI portfolio, participating in specialised funds, increasing direct investment in green, social and sustainability bonds where taxonomies allow, and disclosing climate indicators in coordination with the Eurosystem.

This experience places investment practice at the centre of the climate-finance debate. Central banks are not ordinary asset managers. They operate under public mandates, are accountable to society and influence financial markets through credibility more than through their transactions. For this reason, the way a central bank designs and explains the climate profile of its own portfolios can become a benchmark for market participants, public issuers and other official institutions. Climate-related disclosure is therefore not a peripheral communication exercise; it is part of a wider institutional discipline through which risks are identified, assumptions are made explicit and progress can be assessed over time.

This article adopts a deliberately pragmatic view of sustainable investment. Climate alignment is not treated as a single number to be maximised in isolation. In central bank portfolios, climate indicators must coexist with liquidity needs, credit-quality constraints, reserve-management considerations and operational requirements. This is what makes the Banco de España's approach relevant: it shows how climate objectives can be embedded in an investment framework without presenting them as a substitute for the core duties of any institution.

2. MANDATE, NEUTRALITY AND LEADERSHIP BY EXAMPLE

The starting point is the distinction between monetary policy portfolios and own non-monetary portfolios. The former serves the primary objective of monetary policy. As part of the Eurosystem, the Banco de España builds and manage these portfolios according to the Eurosystem decisions on the appropriate stance of the single monetary policy of the Euro Area. Non-monetary policy portfolios perform, however, own investment, reserve or asset-management functions, always subject to the limits set in its mandate and/or related to potential interference with monetary policy. In these portfolios, the integration of climate criteria benefits from more direct operational room to apply sustainable investment principles without changing the stance of monetary policy. This room is anyway limited by the other investment principles commented above.

Market neutrality remains an important constraint. Unlike monetary policy operations, where the impact on financial conditions is part of the transmission mechanism, own portfolios must be managed in a way that does not distort price formation. This limits any ambition to "move the market" through purchases or sales. However, it does not prevent any central bank from improving information standards, validating measurement practices and reinforcing long-term signals. In this sense, leadership by example matters more than the relative size of the portfolio (see figure 1).

The Banco de España's practice shows that institutional leadership cannot be reduced to a statement of intent. It requires practical developments in terms of governance, data, methodologies, traceability and accountability. Annual disclosure of climate indicators makes it possible to compare portfolio developments over time, recognise methodological limitations

Figure 1
Institutional impact chain

and make visible the progress towards objectives compatible with the Paris Agreement and European climate legislation.

Leadership by example is especially relevant where market conventions are still evolving. Climate disclosure remains affected by heterogeneous definitions, uneven data availability and competing views on how different emissions should be treated. When a central bank publishes its assumptions, even with caveats, it contributes to standard-setting. It also signals that imperfect information is not a reason for silence, but a reason for transparency. Otherwise, uncertainty can easily become an obstacle to action: if market participants wait for perfect taxonomies, complete datasets or universal methodologies before changing behaviour, they are very likely to react too late. Central banks can help to break that deadlock by showing a credible path of gradual improvement.

At the same time, the concept of leadership must be interpreted carefully. A central bank should not use portfolio management to pursue policy objectives that belong to elected governments. Nor should it imply that the management of its own portfolios can compensate for delayed fiscal, regulatory or energy-policy decisions. The appropriate contribution lies elsewhere: in risk awareness, analytical capacity, transparency and consistency. By applying these principles to its own balance sheet, the central bank strengthens the credibility of its broader messages on climate-related financial risk.

3. THE BANCO DE ESPAÑA SRI STRATEGY

The strategy can be summarised in three lines of action. First, sustainable and responsible investment was incorporated as a formal principle of investment policy (see table 1). Second, a separate thematic portfolio was created for assets that meet SRI criteria, mainly fed by specialised investment funds in a first moment. Third, direct investment in assets that meet the criteria has progressively gained momentum as taxonomies, data providers and classification methodologies have become more robust and comparable.

In the early years, participation in specialised funds was particularly useful. It made it possible to benefit from external selection and verification processes at a time when the boundary between eligible and non-eligible assets was still uncertain and the central bank had not had time to build expertise. Over time, the development of taxonomies, green bond standards and private data providers jointly with the knowledge accumulated by the Banco de España have facilitated an increase in direct investment. This development matters because it reduces dependence on intermediary vehicles, strengthens internal analytical capacity and reinforces institutional learning.

Disclosure adds several important details to this picture. Since 2023, the Banco de España has published an annual climate-related financial disclosure report on its non-monetary policy investment portfolios, as part of a common Eurosystem strategy. This coordinated disclosure facilitates comparability across central banks thus reinforcing the power of the exercise. The reports initially followed the *Task Force on Climate-related Financial Disclosures* (TFCD) framework (see TFCD 2017); since 2024, those recommendations have been embedded in the *International Sustainability Standards Board* (ISSB) standards. This evolution underlines the Banco de España and Eurosystem commitment to climate transparency and to continuous improvement in data quality, disclosure methods and climate-risk management, within the limits of currently available information.

Since 2023 the coverage of the exercise has been extended in several dimensions including asset composition and methodology. The reports always include a careful analysis of the changes in the indicators, which helps to enrich the debate and prevents misleading interpretations of the data. An example can help to illustrate this point. The last report (Banco de España, 2026) showed a coverage ratio of 57% (that is, 57% of the total non-monetary portfolios were covered by the analysis). This meant 5 percentage points less than the previous year. Yet the report emphasises that in the same period gold (a non-financial asset excluded from the analysis because there is no commonly accepted methodology to measure its related emissions) increased from roughly 17% to 24% of the portfolio due to a revaluation effect, not to any change in holdings. This illustrates a point that is often overlooked: changes in indicators sometimes reflect changes in variables that have little to do with portfolio management decisions.

Reports have also refined the treatment of metrics. In 2026, for instance, relative metrics for scope 3 emissions of non-sovereign issuers were added. Also, it was removed the government approach for sovereign issuers and there was a harmonisation of the wording of objectives. These changes may appear technical, but they are analytically important. Climate disclosure is not simply about publishing numbers; it is about publishing numbers that are meaningful, comparable and not misleading. Reducing the number of approaches used for sovereign issuers, for instance, can improve clarity if it eliminates indicators that are difficult to interpret or that generate inconsistent readings across portfolios.

As commented above, the reports dedicate a full section to governance. The governance architecture is more sophisticated than a simple investment rule. It brings together investment policy, financial investment guidelines, risk committees, operational departments, risk-control functions and, in our case, the ESG office. This integrated model is preferable to treating climate as an overlay applied at the end of the investment process. If climate risk is a financial risk, it should be embedded in the ordinary risk-management cycle. If sustainable investment is part of institutional strategy, it should be reflected in governance, reporting lines and periodic review.

4. DATA, METRICS AND THE PROBLEM OF SSA DOMINATED PORTFOLIOS

The greatest practical difficulty for a central bank to materialise its strategic decisions on the climate aspects of its non-monetary portfolios lies, still, in the availability and quality of data. Central bank portfolios are often concentrated in sovereign, supranational and agency assets. This feature distinguishes them from other portfolios where equities or corporate bonds have usually a greater weight. Most, if not all, climate metrics were initially designed for non-financial companies, where it is more straightforward to attribute emissions to a specific productive activity. Measuring the climate characteristics of public issuers, by contrast, requires solving more complex conceptual problems (see table 2).

Table 2
Methodological challenges to measure the climate risk of SSA assets

Methodological challenge	Why it matters	Practical response
Double counting	May overstate the aggregate carbon footprint when sovereign, sub-sovereign and agency issuers are combined.	Separate production-, consumption- and government-based approaches; document the chosen criterion.
Data lag	Reduces timely monitoring capacity and weakens market signalling.	Use prudent estimates and update series when definitive data become available.
Forward-looking indicators	Paris alignment requires the assessment of future pathways, not only past emissions.	Incorporate scenarios, national targets and transition plans when they are verifiable.

A first problem is double counting. If a portfolio includes sovereign debt and, at the same time, regional or agency debt from the same country, territorial emissions may be counted more than once unless consistent criteria are applied. A second problem is the time lag in public-sector emissions data, which are often published later than data for private issuers. A third problem is the forward-looking dimension: it is easier to assess corporate transition plans than to translate national pathways, public policies and climate commitments into homogeneous portfolio metrics.

The challenge of developing forward-looking indicators is likely to become even more relevant as the climate assessment of SSA holdings expands beyond historical emissions. Assessing Paris alignment requires not only measuring past performance but also evaluating the future direction and resilience of public issuers. Transition plans are a central element of this assessment, as they provide information on national targets, policy commitments and

expected emissions pathways. Forward-looking analysis may also need to consider how issuers' exposure and vulnerability to physical and nature-related risks could evolve under different climate and socioeconomic scenarios. These dimensions are also reflected in the ECB's climate and nature strategy, which identifies the green transition, the increasing physical impacts of climate change and nature-related risks as priority areas for further work.

Translating these dimensions into comparable forward-looking indicators will, however, be difficult. National transition plans may differ in scope, legal status and implementation capacity, while projections of physical and nature-related risks are highly location-specific and sensitive to modelling assumptions. Their assessment may therefore require a combination of projected emissions, policy scenarios and geographic exposure measures, complemented by qualitative judgements on policy credibility, adaptation capacity and financing needs. Against this background, indicators matter, but methodological notes and annexes matter as well. Without them, a climate metric can easily be misinterpreted. Any improvement in emissions intensity does not automatically mean that a portfolio is aligned with a net-zero pathway. Conversely, a temporary deterioration does not necessarily imply a failure of strategy if it results from an exchange-rate movement, a change in market values or the inclusion of more complete data. Climate indicators should therefore be treated as diagnostic tools rather than mechanical performance scores. And need to be accompanied always by a careful assessment.

5. A PRACTICAL EXAMPLE: WHAT THE 2026 BANCO DE ESPAÑA'S PORTFOLIO CLIMATE REPORTS SHOW

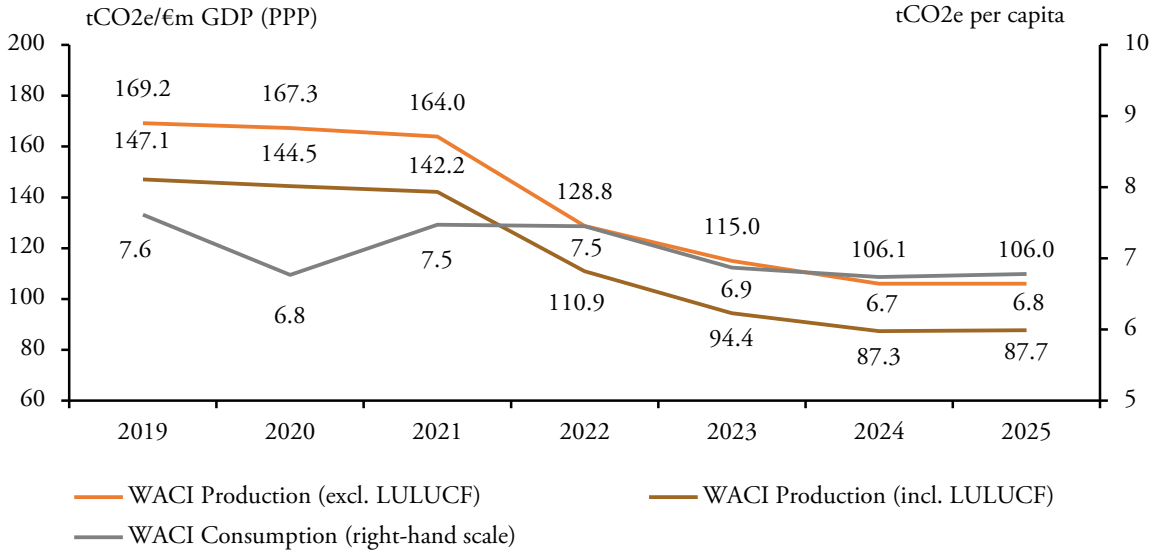
The 2026 edition, published on 2 June 2026, follows the logic of previous editions and its structure reflects the five standard dimensions of climate disclosure agreed by the Eurosystem: governance, strategy, risk management, metrics and targets. In this section the focus is on metrics and targets, where the evolution of the main indicators is analysed.[1]

While the report includes a wide range of indicators, Weighted Average Carbon Intensity, or WACI, may be considered as one of the most well-known standard indicators for portfolio climate content. For sovereign-dominated portfolios, WACI is often expressed in tonnes of carbon-dioxide equivalent per unit of GDP, adjusted for purchasing power parity. According to this indicator, the report shows a marked decline in the WACI of euro-denominated sovereign portfolios. The series falls from around 147 tCO2e per million euro of GDP in 2019 to around 87 in 2024, equivalent to a reduction of approximately 41% over the period and an annual geometric reduction close to 10% (see figure 2).

1 Just a summary of the main results of the report is offered here. For more detailed information, including on the definitions of indicators and the data sources, please refer to the report Banco de España (2026).

Figure 2

WACI according to different approaches: sovereign bonds in euro-denominated portfolios, 2019-2025



Note: LULUCF emissions refer to emissions from land use, land-use change and forestry.

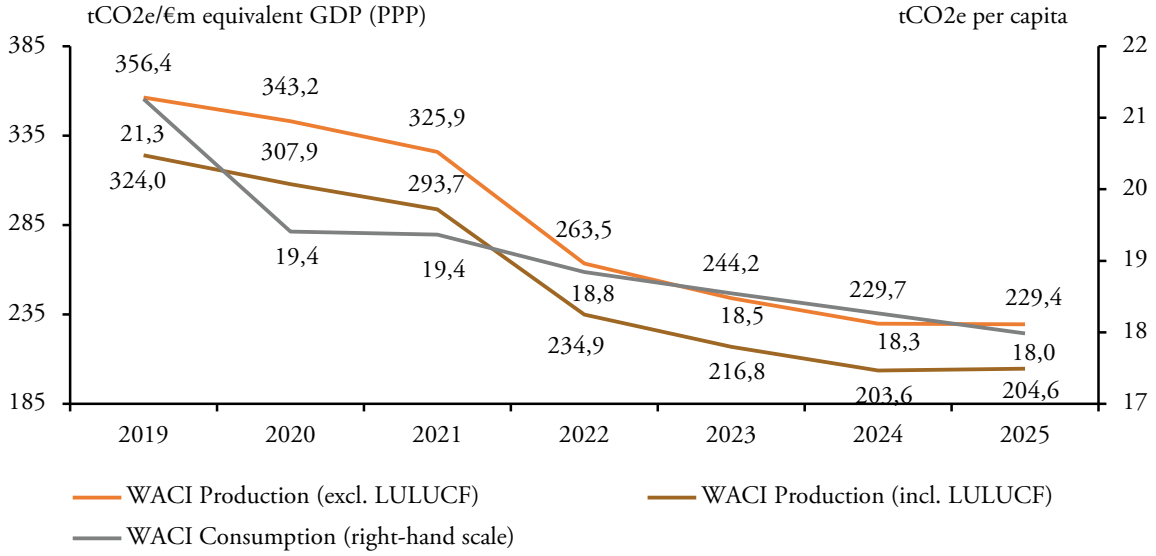
Source: Banco de España (2026).

For foreign-currency portfolios, the same approach shows a reduction from around 324 tCO2e per million-euro equivalent of GDP in 2019 to around 204 in 2024, a decline of roughly 33% using the latest greenhouse-gas data available in the exercise (see figure 3). The level remains higher than for euro-denominated portfolios, which is consistent with differences in issuer composition and currency allocation. From a portfolio-management perspective, however, the level of the indicator is only part of the story. The trend, the quality of coverage and the reasons behind changes are equally important. A fall in WACI may reflect decarbonisation by issuers, portfolio reallocation, valuation effects or changes in data sources. A proper assessment therefore requires all these channels to be considered.

Another relevant indicator to assess the Banco de España's SRI strategy is the investment in green bonds. As can be seen in figures 4 and 5 this indicator shows an upward trend: in 2019, green bonds accounted for less than 1% of total investment portfolios. In 2025 the total share had jumped to 6.7% in 2025, with 9.4% in euro-denominated portfolios and 5.1% in non-euro portfolios. These figures suggest gradual progress, consistent with a prudent approach and with the liquidity and eligibility constraints typical of a central bank. Green bonds tend to be less liquid in secondary markets, partly because many investors hold them to maturity owing to mandate requirements. At the same time, central banks' own legal and operational constraints may limit their ability to participate in primary issuances.

Figure 3

WACI according to different approaches: sovereign bonds in non-euro-denominated portfolios, 2019-2025

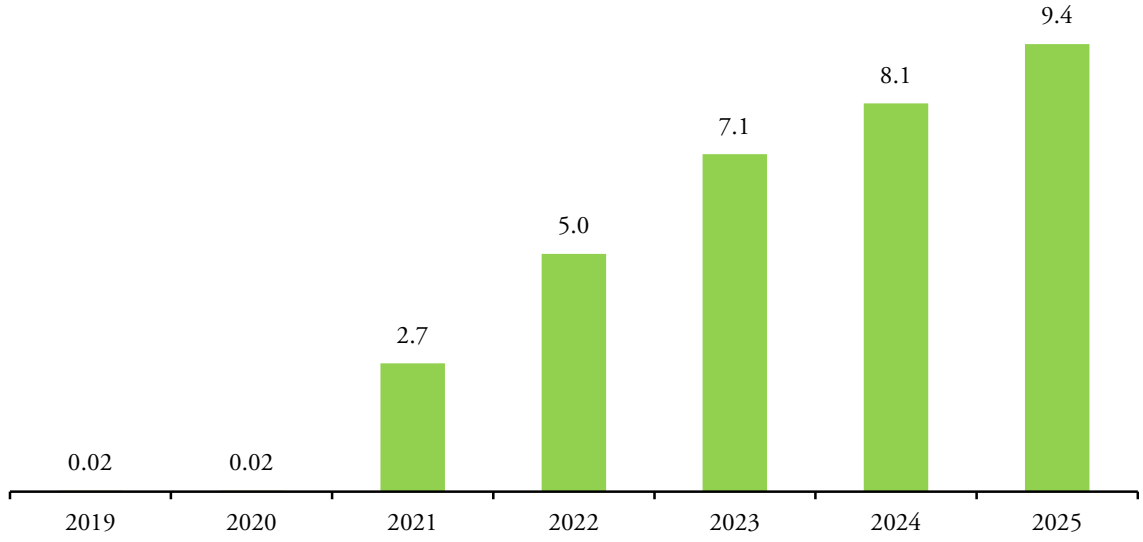


Note: LULUCF emissions refer to emissions from land use, land-use change and forestry.

Source: Banco de España (2026).

Figure 4

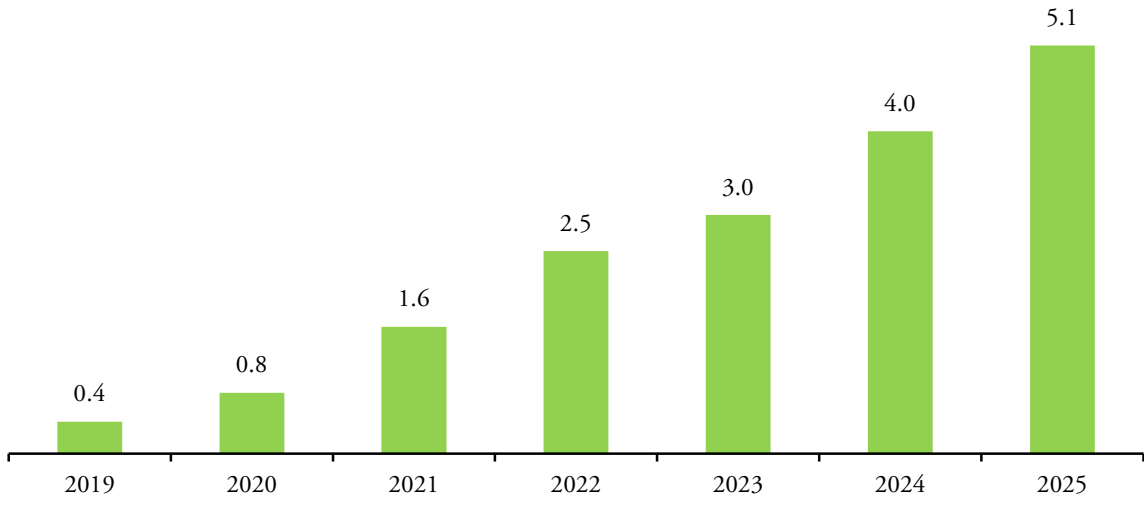
Green investment as a percentage of the holdings in euro-denominated investment portfolios (%)



Source: Banco de España (2026).

Figure 5

Green investment as a percentage of the holdings in non-euro-denominated investment portfolios



Source: Banco de España (2026).

Avoided emissions are also relevant for understanding the practical contribution of green investments. The 2026 report estimates avoided emissions for Bank for International Settlements (BIS) Investment Pool (BISIP) funds and for direct green-bond holdings (see tables 3 and 4). For the euro-denominated BISIP, estimated avoided emissions stood at

Table 3

Additional metrics relating to indirect holdings of euro and US dollar-denominated green bonds

	2021	2022	2023	2024	2025
Avoided emissions euro-denominated BISIP fund (a) (tCO2e)	151,437	393,594	299,670	205,800	205,335
(b)(%)	95	96	84	90	97

	2020	2021	2022	2023	2024	2025
Avoided emissions US dollar-denominated BISIP fund (a) (tCO2e)	69,856	65,175	43,286	48,307	46,628	47,568
(b) (%)	100	94	95	83	81	85

Notes: (a) Annual avoided emissions estimated for each fund, attributed based on the holding therein. Data at end-September each year. (b) The percentages in italics beneath the metrics denote the level of data availability. Previous years' figures have been updated per the data revisions.

Sources: Banco de España (2026).

Table 4
Additional metrics relating to direct investment in green bonds (a)

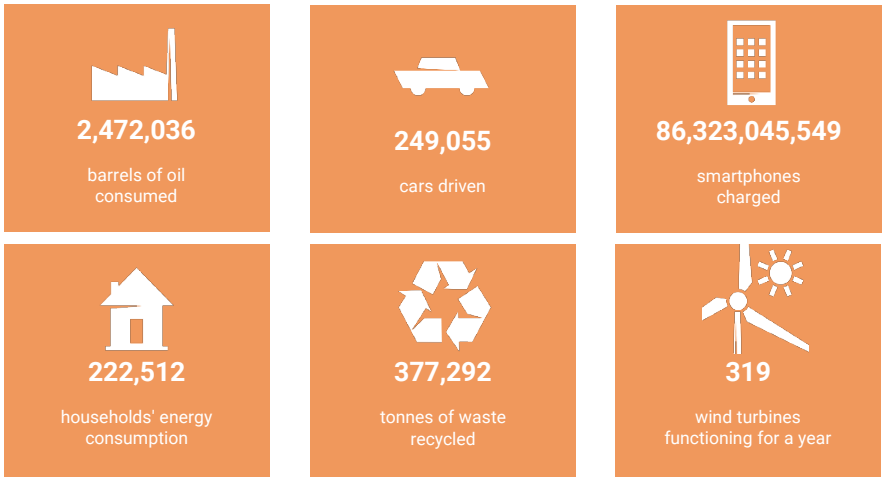
	2024	2025
Avoided emissions of direct investment in green bonds (a) (tCO2e)	1,234,417	1,176,978
(b) (%)	71	91

Notes: : (a) Data at end-March each year. (b) The percentages in italics beneath the metrics denote the level of data availability.
Sources: Banco de España (2026).

approximately 205,335 tCO2e in 2025, with data coverage of 97%. For the US-dollar BISIP, the corresponding figure was approximately 47,568 tCO2e, with coverage of 85%. Direct green-bond holdings were associated with estimated avoided emissions of around 1,176,978 tCO2e in 2025, while data coverage improved to 91% from 71% in the previous year.

The scale of this environmental impact is sizeable. As shown in figure 6, these estimated avoided emissions are equivalent to the annual greenhouse-gas emissions of almost 250,000 cars. They are also comparable to the CO2 emissions from roughly 2.5 million barrels of oil consumed, the charging of more than 85 billion smartphones, or the annual electricity use of over 215,000 households. To put this in perspective, the impact is equivalent to recycling more than 375,000 tonnes of waste or operating more than 300 wind turbines for

Figure 6
Equivalencies of the environmental impact of estimated avoided GHG emissions. Direct investment in green bonds (2025)



Sources: Banco de España (2026).

an entire year. These green-bond-financed projects also contribute to the UN Sustainable Development Goals.

However, these avoided-emissions figures should be read with caution. They are not the same as the carbon footprint of a portfolio, and they depend on project-level assumptions about what would have happened in the absence of the financed activity. Even so, they are useful when analysing labelled bonds whose proceeds are directed to green projects. They connect the financial instrument to a real-world environmental outcome and provide an additional perspective lens alongside portfolio carbon intensity. For professional investors, the combination of portfolio-level metrics and project-level impact indicators is increasingly important.

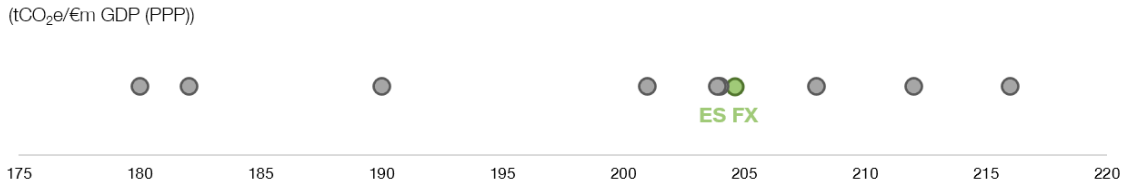
As the report only covers the Banco de España's portfolios, the analysis follows a "time-series" approach, that is, it focuses on the evolution of the different indicators along the time. However, one of the main advantages of the coordination and harmonization between the National Central Banks (NCB) of the Eurosystem is that the time series approach can be complemented by a "cross-section" one. From this perspective, figures 7 and 8 show the same WACI indicators showed above but for the different NCBs and the Eurosystem.

Figure 7

WACI (production approach including LULUCF). Comparison across the Eurosystem. EUR-denominated sovereign bonds

Figure 8

WACI (production approach including LULUCF). Comparison across the Eurosystem. FX-denominated sovereign bonds



Note: LULUCF emissions refer to emissions from land use, land-use change and forestry. Green dots represent other NCBs indicators.

Source: Eurosystem Climate-related financial disclosures (2026).

As can be seen, Banco de España's euro-denominated sovereign bond holdings have the lowest production-based WACI including LULUCF emissions among the comparable portfolios of other Eurosystem central banks. As to the WACI of its non-euro holdings, the relative position is worse, but it is worth noting that in this case the different indicators are more homogeneously distributed across NCBs. This latter result partly reflects the relatively similar currency composition of NCB's foreign-exchange portfolios and, consequently, their exposure to a comparable set of sovereign issuers.

6. SOME LESSONS LEARNED

The Banco de España experience may offer several lessons. The first one is that integrating climate considerations does not require waiting for perfect data. The absence of complete information should not become an excuse for inaction; rather, it requires assumptions to be documented, limitations to be acknowledged and methods to be improved gradually. The second lesson is that the any approach must be adapted to the nature of the portfolios. Portfolios dominated by public issuers require metrics that differ from those used for corporate portfolios. The third lesson is that international coordination is essential: the value of disclosure increases when methodologies are comparable and when different agents send a common signal to the market.

There is also a caveat worth emphasising —or a lesson in realism. Central banks cannot replace governments in climate policy. Taxes, sectoral regulation, public investment, energy planning or territorial adaptation, inter alia, belong to the broader domain of economic policy. They belong to areas outside the reach of central banks. Central banks can only contribute within their mandates: by increasing awareness of the risks leveraging on the management of their balance sheets, incorporating prudent sustainability criteria in this management and raising the standard of financial transparency.

A further implication concerns communication. Climate disclosure is often technically dense, but public institutions must make it intelligible to readers who are not climate-data specialists. A professional article can help bridge that gap by translating methodology into institutional meaning. The key message is that sustainable investment by a central bank is neither symbolic activism nor a mechanical compliance exercise. Rather, it is a disciplined way of recognising that climate change affects financial risk, that central bank portfolios should not ignore this reality and that transparency can improve market practices.

For central banks operating in smaller or less liquid markets, these lessons are particularly relevant. The availability of eligible green assets may be limited, and concentration risk can

arise quickly if sustainability criteria are applied too narrowly. In such contexts, the objective should not be to maximise a single green-bond share at any cost, but to establish a credible process: define eligibility, measure exposures, disclose limitations, engage with common standards and review the strategy periodically. The Banco de España gradual increase in green-bond holdings illustrates this balance between ambition and prudence.

7. CONCLUSIONS

The incorporation of climate considerations into central banks' portfolios represents an important development in public asset management. It does not mean abandoning the classic principles of prudence, efficiency or neutrality, but rather reinterpreting them considering financial risks that materialise over long horizons, with imperfect information and systemic effects. The Banco de España has chosen a gradual and transparent path: formalising SRI principles, creating a thematic portfolio, increasing investment in green assets and disclosing climate metrics annually and in a coordinated manner.

The value of this strategy can hardly be assessed by measuring the share of green bonds in the portfolio or by following the evolution of the aggregate carbon footprint shown by a particular indicator. Its deeper contribution is institutional: creating habits of measurement, recognising limitations, improving data, making practices comparable and demonstrating that sustainability can be incorporated without sacrificing financial rigour. In a context in which markets need credible signals and robust methodologies, leadership by example becomes a powerful form of public intervention.

The 2026 disclosure exercise strengthens that conclusion. It certainly shows progress in the share of green bonds and reductions in key indicators. But also shows improvements in data analysis coverage and refinements in methodology. Climate reporting is a living process. Scope, metrics and assumptions evolve as data improve and as international standards mature. That evolution should not be interpreted as instability; rather, it is a sign that disclosure is becoming more rigorous.

The broader policy lesson is that climate-related financial work should be judged by its contribution to better decisions. In central bank portfolios, better decisions mean identifying relevant risks, avoiding hidden concentrations, improving the quality of information, preserving the integrity of the mandate and supporting more transparent markets. The Banco de España experience shows that these objectives can be pursued together. It is not a model of rapid transformation through large-scale reallocations, but a model of institutional credibility built through method, disclosure and consistency.

REFERENCES

Banco de España. (2023 to 2026). *Climate-related aspects of the Banco de España's investment portfolios*. https://www.bde.es/wbe/en/publicaciones/informes-memorias-anuales/memoria-sobre-informacion-climatica-de-las-carteras-propias-del-bde/

European Central Bank. (2021). *Eurosystem agrees on common stance for climate change-related sustainable investments in non-monetary policy portfolios* [Press release 04.02.2021]

Network for Greening the Financial System. (2024). *Sustainable and responsible investment in central banks' portfolio management. Practices and recommendations.*

Task Force on Climate-related Financial Disclosures. (2017). *Recommendations of the Task Force on Climate-related Financial Disclosures.*

Climate Data and Analytical Tools — the Role of Innovation

*Elena Triebskorn**

Abstract

Climate and sustainability indicators are increasingly vital for monetary policy, financial stability, supervision, regulation, reserve management, and payment oversight due to the risks posed by climate change. However, current climate-related data is often incomplete, inconsistent, and difficult to compare, with notable gaps in regional, sectoral, household, real estate, and non-bank financial institution information, as well as insufficient forward-looking and nature-related indicators and incomplete corporate disclosures.

No single data source can address all these shortcomings, so institutions must rely on multiple sources, which improve robustness but increases costs and complexity. Innovative technologies like machine learning and artificial intelligence can help fill data gaps by extracting information, reducing delays, and generating new indicators, but they require human oversight to ensure transparency, quality, and interpretability, as they may introduce new risks such as model errors and greenwashing.

Effective use of these tools demands clear objectives, high-quality datasets, standardization, validation, and collaboration between technical and subject-matter experts. Cooperation among institutions, including international networks, is essential to harmonize standards, share expertise, and expand public access to climate data, which enhances transparency and supports research.

Central banks should transition from fragmented, reactive data collection to coordinated, standardized, and forward-looking climate statistics. The optimal approach combines international collaboration, diverse data sources, centralized management, public dissemination, and validated analytical technologies, ensuring innovative tools are used transparently and with strong human oversight.

Keywords: data gaps, sustainable finance data, climate data, sustainability reports, natural language processing, large language models.

1. INTRODUCTION

As sustainability issues become more important at the national and global levels, demand has grown for reliable data and measurement frameworks. Central banks' interest in sustainability

* Deutsche Bundesbank. The views expressed in this report are personal views of the author and do not necessarily reflect the views of Deutsche Bundesbank or the Eurosystem.

indicators has grown because they support a range of tasks, including monetary policy, financial stability analysis, statistics, supervision, regulation, reserve management and payment oversight. As data users, central banks often use available information, particularly environmental, social and governance (ESG) metrics, to guide their policies. As data producers, they increasingly develop new or experimental sustainability indicators. Central banks have focused on sustainable finance — financial activities that improve environmental or social conditions or governance practices — and green finance, which focuses specifically on environmental aspects.

This article discusses three avenues to help bridge climate-related data gaps. First, international dialogue among stakeholders can foster the exchange of knowledge and experience. The Banco de España conference on "Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice" established a forum for such an exchange with its session on climate data and analytical tools. Secondly, a growing range of innovative analytical approaches can provide more timely data and fill data gaps. Thirdly, the paper examines how the Deutsche Bundesbank has responded to shortages in climate-related data and identifies lessons for developing climate statistics.

2. TAKEAWAYS FROM THE BANCO DE ESPAÑA CONFERENCE ON "CLIMATE RISK AND SUSTAINABLE FINANCE: BRIDGING POLICY, RESEARCH AND PRACTICE"

Despite strong policy demand for better and more detailed insights into sustainability, important information gaps persist. The first session, "Climate Data and Analytical Tools," showed why reliable, decision-useful climate data are important for financial analysis, risk assessment and policy development. The session featured presentations from representatives of the Network for Greening the Financial System (NGFS), the TPI Global Climate Transition Centre at the London School of Economics and the Banco de España. Participants then discussed climate scenarios, transition assessments, statistical production and data gaps.

Agnieszka Trzcinska presented the NGFS climate scenarios, which help financial institutions and policymakers assess the potential economic and financial effects of climate change. She explained that the NGFS provides both long-term and short-term scenarios. The long-term scenarios extend to 2050 and explore different combinations of transition and physical risks. The recently introduced short-term scenarios focus on effects up to 2030, including rapid or delayed transitions, severe physical hazards and combined transition and physical risks. These scenarios combine climate policy, extreme weather events, macroeconomic trends, sectoral dynamics and emerging transmission channels, such as critical mineral supply bottlenecks.

A key message was that climate risks are not just a distant "tragedy of the horizon." Severe physical-risk scenarios suggest that economic losses could approach the scale of the global

financial crisis. Under particularly adverse conditions, European gross domestic product could decline by as much as 5% by 2030. Future NGFS work will explore more plausible acute physical-risk shocks, adaptation, geopolitical developments, nature-related risks and interactions with broader macroeconomic shocks. Important challenges remain, particularly the lack of sufficiently granular subnational data and the limited ability to model effects on households and real estate markets.

Carmen Nuzzo introduced the TPI Global Transition Centre, an independent academic organisation that assesses the progress of companies, banks and sovereigns towards a low-carbon economy. The Centre develops transparent, sector-specific methodologies based mainly on publicly available information. Investors use the data for risk assessment, portfolio alignment, screening, product development, reporting, active ownership and proxy voting. The Centre is increasingly moving beyond assessing climate ambition to evaluating actual implementation, capital spending, sectoral conditions and regional policy environments. Nuzzo emphasised that climate data must be rigorous, comparable, independent and transparent. She also stressed the need for a system-wide perspective across companies, banks and sovereigns.

Luis Ángel Maza discussed the Banco de España's experience of including climate considerations in official economic statistics. The Bank has developed databases on corporate environmental, social and governance indicators, economic activity locations, financial exposures, carbon footprints and physical risks. It uses sustainability reports, administrative data, commercial sources, machine learning and data science techniques to create granular information for internal analysis and external researchers. Collaboration with the European Central Bank, national statistical institutes, international organisations and accounting bodies has been essential. Future priorities include adding climate variables to national accounts, developing biodiversity and water-stress indicators, improving forward-looking measures and using artificial intelligence to create more efficient "climate intelligence".

The discussion highlighted the need to assess interactions between climate shocks and financial crises, improve consistency between short- and long-term scenarios, account for adaptation and analyse overlapping portfolios in the non-bank financial sector. Participants also stressed the importance of data sharing, harmonised standards, confidentiality solutions and using climate data to inform regulation and investment decisions.

3. FILLING CLIMATE-RELATED DATA GAPS: LEVERAGING INNOVATIVE APPROACHES

Central banks and supervisory authorities have started to integrate climate-related information into instruments such as stress testing (EBA, 2024) and collateral frameworks (ECB, 2026).

However, developing and implementing these instruments requires high-quality data. A lack of structured and complete issuer-level datasets can create significant data gaps and require analysts to spend considerable time collecting data. Generative artificial intelligence can help address these shortcomings, particularly by improving the availability and quality of issuer-level data. While modern artificial intelligence methods can extract and process un-structured data at scale, substantial challenges remain in validating, standardising and post-processing the data.

A growing range of innovative analytical approaches, including machine learning, can provide more timely data and fill data gaps. Like other statistics, climate risk and sustainability statistics are often published with a delay. This limits the ability to monitor risks in real time. Innovative analytical methods can reduce reporting delays and identify early signals. Effective monitoring of climate performance, risks and opportunities across financial asset classes, portfolios and institutions require credible metrics and robust data. This information is critical for informing investment decisions and designing effective policies, including policies to achieve the goals of the Paris Agreement. However, current disclosure initiatives are often too qualitative and incomplete. Access to high-quality publicly available climate data also remains fragmented, limiting the comparability and scalability of assessments. Innovative data solutions that use new technologies and techniques are emerging to help fill these gaps. While promising, they may create new transparency challenges and risks of greenwashing that need to be better understood. Addressing these trade-offs is critical to building trust and ensuring that these solutions are taken up credibly.

To examine the potential of innovative analytical tools and draw on experiences from various central banks, the Network for Greening the Financial System (NGFS) set up an exchange to share knowledge and experience on this topic through its Expert Network on Data. Central banks worldwide face similar difficulties in obtaining climate-related information. Cooperation can help them avoid duplicating work, pool expertise and use their comparative strengths. However, many initiatives are currently being developed independently, so stronger coordination is needed. The findings of the Expert Network on Data are summarised below.

3.1. The use of natural language processing for climate data

Climate reporting is mainly based on text. It covers documents such as scientific reports, policy papers, corporate disclosures and news articles. Central banks and supervisors need to process and analyse large volumes of this information to assess climate-related risks and opportunities. Natural language processing (NLP) can help address this challenge by extracting relevant information from unstructured text. NLP can automate the extraction and analysis of data from different sources. This can help institutions process large volumes of information, identify potential risks and make informed decisions.

NLP can support a wide range of tasks. Its most immediate use is to analyse companies' or financial institutions' disclosures of climate-related risks and impacts. It can also support more specific tasks, such as analysing how central banks and other supervisory authorities communicate about climate change. Different NLP techniques can significantly improve the analysis of climate-related text data.

A key challenge is the need for high-quality datasets with labelled data. Adapting models to specific tasks can be complex and resource-intensive. Integrating climate-specific data into existing models is also challenging. Performance and reliability can improve through comprehensive datasets, better model adaptation and a wider range of applications. Reducing costs and complexity can also make these tools more effective.

The first step in using NLP is to define clear objectives that can be put into practice. These objectives determine the overall design, data organisation and analytical methods needed. Clear objectives also ensure that work reflects institutional priorities and available resources. Common objectives include searching texts by meaning, retrieving climate-related information, analysing sentiment and classifying topics. These objectives provide a framework for using NLP or large language models (LLMs) to monitor climate-related discussions, analyse compliance with regulations and assess climate-related risks.

Setting realistic objectives requires an understanding of what NLP and LLMs can and cannot achieve, and where human expertise is needed. Institutions should therefore define objectives and develop a modelling approach in an iterative process that draws on subject matter expertise and technical knowledge.

3.2. Opportunities and challenges of machine learning applications for nature-related data

Nature-related data vary significantly in quality, coverage and consistency. Collecting these data is particularly constrained by geography because it often requires physical sampling. Assessing cascading effects requires more detailed geospatial data and data on interdependencies for many ecosystem services. Financial risk assessments are also hampered by the lack of standardised reporting frameworks. Machine learning offers opportunities but also poses challenges. It can identify statistical relationships between input and output data without knowing the underlying physical processes. However, it may overlook complex interactions and produce misleading assessments.

Machine learning (ML) models can generate data by classifying and predicting environmental parameters. This can provide useful insights for developing metrics and indicators. However, using ML to generate nature-related data may oversimplify environmental processes. It may

overlook complex interactions between parameters or undetected spatial patterns, leading to incomplete or misleading assessments. Furthermore, artificial intelligence (AI) can support the development and analysis of biodiversity data. Biodiversity data are essential for AI models and innovation. Companies whose long-term innovation strategies depend on AI and biodiversity may have an incentive to support biodiversity conservation. This could preserve existing biodiversity data and enable future discoveries that generate further data. AI can also support effective and efficient conservation by enabling complex, targeted responses to ecosystem degradation or biodiversity loss. It can provide accurate and reliable data for monitoring, reporting and verification by investors and financial institutions. Making this information available should ultimately help direct more funding towards biodiversity protection across industry sectors as links with biodiversity become more visible.

4. CENTRAL BANK STEPS — THE CASE OF THE DEUTSCHE BUNDESBANK

The Deutsche Bundesbank has responded to shortages in climate-related data and identified lessons learned for developing climate statistics. Climate change has become increasingly relevant to central banks because it creates both physical and transition risks. Physical risks result from events such as floods, heatwaves and other extreme weather events, while transition risks arise from political, technological and economic changes associated with the move towards a low-carbon economy. These risks affect central banks' responsibilities, including financial stability, monetary policy, banking supervision, market analysis and risk management. As a result, several divisions within the Bundesbank require reliable climate-related information.

A major challenge is that climate-related statistics and sustainable-finance data are relatively new. When Bundesbank analysts first needed these data, the institution lacked established internal sources and comprehensive statistical systems. Individual users therefore had to search for relevant information at public institutions or private providers and arrange procurement independently. Although this approach could meet immediate needs, it was inefficient, costly and likely to result in duplicated work. It also made it difficult to coordinate data requirements, compare information across departments and ensure consistent quality.

To address these problems, the Bundesbank established the Sustainable Finance Data Hub within its statistics department in early 2020. The hub centrally coordinates the supply of and demand for climate-related data. It identifies common and ongoing data needs through regular communication with internal users, examines available products on the market and procures data from external providers. It also serves as a central point of contact for questions about data sources, definitions and methodology, connecting Bundesbank users with data providers.

The hub is involved in nearly every stage of the data provision process. Its responsibilities include surveying the market, contacting providers, obtaining trial datasets, supporting procurement staff during contract negotiations and cleaning and processing the data once acquired. Data preparation can be technically difficult and time-consuming because providers often use different formats and structures. By centralising these tasks, the hub reduces duplication, creates economies of scale and allows individual departments to focus on their analytical responsibilities. The hub also contributes its experience to international statistical and sustainable-finance groups. This allows the Bundesbank to share its practical knowledge and learn from other institutions.

4.1. A multi-source approach to climate data

Experience has shown that a multi-source approach is necessary because climate-related data are subject to significant uncertainty and there is no universally accepted framework. Third-party providers often use different definitions, methodologies and estimation techniques. They may also cover different regions, markets, sectors or types of financial instruments. Consequently, no single provider can satisfy all potential users or provide a complete and fully reliable picture.

The Bundesbank obtains data from several providers for three main reasons. First, different departments have different analytical needs. Second, providers differ in the scope and geographical coverage of their datasets. Third, climate-related measurements may be uncertain, particularly when information is estimated or based on incomplete corporate disclosures. Comparing data from multiple providers allows analysts to perform robustness checks and identify differences in methodologies or results. A Bundesbank survey confirmed the value of this strategy: more than 70% of respondents who used climate-related data obtained information from two providers. Using multiple sources therefore improves confidence in analyses, even though it can increase procurement and data-management costs.

4.2. Improving public access to climate data

Another important element of the Bundesbank's response is improving public access to climate-related information. Public data remains scarce and is often dispersed among different institutions. By collecting, processing and presenting these data in a single location, the Bundesbank can support both its own analysts and the wider public. Greater accessibility improves transparency and helps raise awareness of climate change and its financial and economic consequences, including those of the transition to a more sustainable economy.

For this purpose, the Bundesbank created a public dashboard containing a selected group of climate-related macroeconomic and financial indicators. The dashboard presents the

information in charts and offers an accessible overview of developments in Germany and the European Union. Its indicators cover three broad areas. Financial indicators include green bonds, environmental tax revenues and fossil-fuel subsidies. Real-economy indicators include greenhouse-gas emissions and energy consumption. Climate indicators include measures such as average air temperature and the number of days with heavy rainfall. Together, these data illustrate both physical risks and transition-related developments.

The Bundesbank publishes the underlying data and sources alongside the dashboard. This strengthens transparency and allows users to understand how the indicators were compiled. The dashboard is updated annually and relies mainly on publicly available, free-of-charge data. However, information on certain sustainable financial products, such as green bonds, is not generally available from public sources. To address this gap, the Bundesbank reached an agreement with a private data provider that permits the publication of aggregated information on sustainable bonds. Although such arrangements are useful in the short term, the long-term objective should be to create publicly available datasets that comply with recognised statistical standards. Cooperation with private providers can temporarily bridge gaps while more permanent public systems are developed.

5. CONCLUSION

Climate and sustainability indicators help inform monetary policy, financial stability assessments, supervision, regulation, reserve management and payment oversight. Their importance is growing because climate change creates physical and transition risks for the economy and financial system. However, significant gaps in climate-related data remain. Available data are often incomplete, delayed, fragmented, qualitative or difficult to compare.

Important shortcomings include:

- insufficiently detailed regional and sectoral data;
- limited information on households, real estate and non-bank financial institutions;
- inconsistent definitions and methods among data providers;
- insufficient forward-looking indicators;
- limited data on biodiversity, water stress and nature-related risks;
- incomplete corporate disclosures.

No single climate data source can address these shortcomings. Differences in coverage, quality, definitions and estimation methods mean that institutions need to use several sources. Comparing data from different providers makes assessments more robust and helps identify methodological inconsistencies. However, it also increases procurement and data management costs.

Innovative technologies can also help close data gaps. Machine learning, natural language processing, generative artificial intelligence and other data science methods can:

- extract information from unstructured reports and news;
- reduce reporting delays;
- identify emerging risks;
- generate environmental and biodiversity indicators;
- improve monitoring, reporting and verification.

However, these tools do not eliminate the need for human expertise. Their outputs may be difficult to validate, reproduce or interpret. Machine-learning models may also overlook complex ecological or economic relationships. Therefore, transparency and quality control are essential when using artificial intelligence. Data generated or extracted by artificial intelligence can create new risks, including model errors, limited explainability and greenwashing. To use these tools effectively, institutions need clear objectives, high-quality labelled datasets, standardization, validation and an iterative process involving technical specialists and subject-matter experts.

Cooperation among institutions is also necessary. Central banks and other authorities face similar data problems. International dialogue and networks such as the Network for Greening the Financial System can reduce duplicated work, share expertise, harmonize standards and improve coordination. Public access to climate data should also be expanded. Dashboards and publicly available datasets improve transparency, support research and help the public understand the economic and financial consequences of climate change.

Central banks need to move from collecting fragmented climate information in response to immediate needs towards coordinated, standardized and forward-looking climate statistics. The most effective strategy combines international cooperation, multiple data sources, centralized data management, public dissemination and carefully validated analytical technologies. Although innovative tools can significantly improve the timeliness and coverage of sustainability data, they must be used transparently with strong human oversight and recognized statistical standards.

REFERENCES

Alonso-Robisco, A., Carbo, J. M., Kormanyos, E., & Triebskorn, E. (2024). Houston, we have a problem: Can satellite information bridge the climate-related data gap? *Deutsche Bundes-bank Technical Report*, 2024-02.

Araujo, D., Bruno, G., Cap, A., Marcucci, J., Schmidt, R., Sirello, O., and Tissot, B. (2026). Generative artificial intelligence in central banking. *IFC Bulletin*, no 67.

Arslanalp, S., Kostial, K., and Quirós-Romero, G. (eds.). (2023). *Data for a greener world: a guide for practitioners and policymakers.* IMF.

Barnava, A., Duijm, P., Noels, J., Schmieder, C., Seven, Ü, Seyhun, Ö, Tissot, B., Triebskorn, E. (2026). The quest for policy-relevant sustainability data in central banking. *IFC Bulletin*, no 68.

Bolton, P., Després, M., Pereira da Silva, L., Samama, F., Svartzman, R. (2020). *The green swan – central banking and financial stability in the age of climate change.* BIS.

Bundesbank. (2023). *Climate-related disclosures by the deutsche bundesbank.* DeutscheBundes bank.

Campiglio, E., Deyris, J., Romelli, D., & Scalisi, G. (2025). Warning words in a warming world: Central bank communication and climate change. *Grantham Research Institute on Climate Change and the Environment Working Paper,* 418

Doll, H., Kormanyos, E., Walter, S., and Alves Werb, G. (2026). The climate data iceberg – a depth of information to integrate. *IFC Bulletin*, no 66.

European Banking Authority. (2024). Annual Report.

European Central Bank (ECB). (2025). *Climate-related financial disclosures of the ECB's non-monetary portfolios.*

European Central Bank (ECB). (2026). ECB to extend use of climate factors in Eurosystem collateral framework to non-financial corporate credit claims. ECB Press Release. July 24th.

Fehr, M., Triebskorn, E., and Mehrhoff, J. (2022). Constructing forward-looking climate relat-ed physical risk indicators. *11th Biennial IFC Conference on Post-pandemic landscape for central bank statistics, BIS Basel, August 2022.*

Gonzalez, C. I., and Triebskorn, E. (2023). The road to net zero: the role of transition plans and forward-looking indicators in portfolio management. *Economic Bulletin, Banco de España,* issue 2023/Q3.

Gonzalez, C. I., and Triebskorn, E., and Félez de Torres, I. (2025). The Puzzle of Forward-Looking Climate Transition Risk Metrics (2025). *Banco de España Occasional Paper No.*, 2515.

Nefzi, D., Noels, J., Peronaci, R., Schmieder, C., Seven, Ü, Seyhun, Ö, Tissot, B., and Triebskorn, E. (2025a). Addressing climate change data needs: the global debate and central banks' contribution. *IFC Bulletin*, no 63.

Network for Greening the Financial System (NGFS). (2022). Final report on bridging data gaps. *NGFS technical document.*

Network for Greening the Financial System (NGFS). (2026b). Navigating nature-related data: metrics, sources and uses. *NGFS Technical document.*

Organisation for Economic Co-operation and Development (OECD). (2022). ESG ratings and climate transition: an assessment of the alignment of E pillar scores and metrics. *OECD business and finance policy papers,* no 6.

Organisation for Economic Co-operation and Development (OECD). (2025). *Behind ESG ratings: unpacking sustainability metrics.*

Park, T.-J. (2025). *Quantifying Material Risks from Textual Disclosures in Financial State-ments using LLM Agents – A Case Study on Physical Risks.* IFC.

Taskforce on Nature-related Financial Disclosures (TNFD). (2023). Recommendations of the Taskforce on Nature-related Financial Disclosures.

Integrating the Climate Dimension into Economic Statistics: The Experience of the Banco de España*

*Luis Ángel Maza***

Abstract

Climate change has become a key concern for central banks due to its implications for economic activity, price stability and financial stability. This paper reviews the experience of the Statistics Department of the Banco de España in integrating climate considerations into its statistical production, covering the rationale, methodologies and data products developed over the past decade. It presents major initiatives such as the ESG microdata database for Spanish firms (CBS), the Multi-location Business Visualiser (ViME), the European ERICA database and the Banco de España's contribution to the ECB climate indicators. The paper also discusses ongoing work on biodiversity, geospatial data, international statistical standards and the application of artificial intelligence to climate statistics. The experience highlights the importance of data access, new analytical capabilities, international collaboration and user-oriented statistical development in supporting sustainable finance and climate-related policymaking.

Keywords: climate statistics, sustainability statistics, ESG indicators, artificial intelligence, biodiversity.

1. INTRODUCTION

Climate change is one of the most complex and far-reaching challenges facing the global economy today. Its impact extends well beyond the environmental sphere, touching the very variables that central banks are mandated to monitor and safeguard: economic activity, price stability and long-term growth. Against this backdrop, the availability of rigorous, comparable and timely climate statistics has shifted from an academic aspiration to an operational necessity for central banks and supervisory authorities.

This contribution summarises the presentation delivered at the international forum "Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice", held on 25 March 2026. It sets out, in a structured manner, the journey undertaken by the Statistics Department of the Banco de España to integrate the climate dimension into official statistical production, the projects that now form part of its regular catalogue of products, and the challenges and opportunities that will shape the agenda for the years ahead.

* Contribution to the forum *Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice.*

* Director, Statistics Department Banco de España.

The presentation was organised around three temporal axes that serve as the thread running through the narrative: the past — what we have done so far; the present — where we stand today; and the future — what challenges and opportunities lie ahead. This structure allows to understand not only the statistical products developed, but also the institutional, methodological and collaborative logic that underpins them.

2. THE STARTING POINT: WHY THE BANCO DE ESPAÑA VENTURED INTO CLIMATE STATISTICS

2.1. The institutional rationale

When the Statistics Department of the Banco de España launched this project approximately eight years ago, the first question that had to be answered was not technical, but fundamental: why are climate statistics relevant for a central bank? The answer, far from self-evident at the time, was built around three arguments that now form the conceptual foundation of all the work carried out.

First, climate change is the most significant global challenge facing humanity, with effects that extend well beyond the environment into the core macroeconomic variables that central banks track: growth, prices and long-term financial stability. A central bank that ignores the climate dimension in its economic analysis risks basing its decisions on an incomplete diagnosis.

Second, the financial sector plays a strategic role in the transition to a more sustainable economy. Banks, capital markets and institutional investors are the channels through which savings flow into productive investment; without adequate information on climate-related risks and opportunities, they can neither efficiently finance the transition nor properly value the exposure of their portfolios to physical and transition risks.

Third, central banks have both the mandate and the capacity to manage high-quality data. They possess experienced statistical infrastructures, privileged access to granular microdata from the financial system, and the institutional credibility needed to lead or co-lead the production of comparable and harmonised statistics. These assets place them in a unique position to tackle the challenge of climate statistics.

2.2. The initial diagnosis: identifying data gaps

Once the institutional rationale was established, the next step was to carry out a systematic assessment of the available data landscape. This analysis revealed that producing relevant

climate statistics required covering four fundamental dimensions, each characterised by significant gaps:

- Economic agents: information on firms and households was needed to assess their exposure and vulnerability to climate change, as well as their contribution to greenhouse gas emissions.
- Financial sector: banks and financial markets required indicators reflecting their exposure to climate-related risks and their contribution to sustainable finance.
- Location data: the geographic distribution of economic activities and assets is essential for assessing exposure to physical risks, which are inherently local in nature.
- Climate-related risks: both transition risks (arising from the decarbonisation of the economy) and physical risks (associated with extreme weather events and gradual climate shifts) required specific measurement frameworks.

A common feature of all these datasets was their non-conventional nature. Unlike traditional statistics (based on structured administrative sources, standardised questionnaires and well-established methodological frameworks) the new climate data posed significant technical challenges: it often originated from unstructured sources, there was little prior experience in handling it within the official statistics domain, and the treatment methodologies were still being developed at the international level.

2.3. Early in-house projects and new capabilities

Faced with these gaps, the Statistics Department launched a series of pioneering projects to explore new data sources and develop the capabilities needed to exploit them. In the initial phase, the focus was on the non-financial corporate sector, examining the potential of sources such as corporate sustainability reports (CSR/ESG reports), bond prospectuses, administrative sources for pollutant emissions, and commercial databases from specialised ESG and climate data providers.

The first concrete product of this phase was the construction of an Environmental, Social and Governance (ESG) microdata database for Spanish non-financial corporations, marking the first systematic attempt to introduce sustainable finance indicators into the Banco de España's statistical production. This pilot project demonstrated both the feasibility of the approach and the need to invest in new competencies: efficient management of granular microdata, record linkage across heterogeneous databases, text extraction from unstructured documents, and the application of machine learning algorithms to ensure scale and data quality.

2.4. The collaborative dimension: a shared journey

One of the most important messages from this initial phase is that the Banco de España did not walk this path alone. Producing meaningful climate statistics requires, by its very nature, a collective effort that transcends institutional and national boundaries. In this regard, collaboration with the European Central Bank and with the Eurosystem's climate statistics expert group proved fundamental to advancing towards the objectives defined at the national level.

At the national level, collaboration with the National Statistics Institute (INE) and with the Spanish accounting profession (including the bodies responsible for the Mercantile Register) was equally essential for precisely defining the required variables and ensuring consistency between the new climate indicators and existing statistical frameworks. At the international level, participation in initiatives such as the G20 Data Gaps Initiative broadened the methodological horizon and reinforced the legitimacy of the projects undertaken.

A further element worth highlighting is the role of user feedback. Researchers and other users of the early statistical products provided highly valuable input that helped reorient priorities, improve indicator quality and ensure the analytical relevance of the data produced. This two-way interaction between producers and users of statistics is one of the hallmarks of the working model adopted. It also reinforced a conviction that grew stronger over the years: climate change is a global challenge, and so is the production of climate statistics. The exclusively national perspective that had dominated traditional statistical production is no longer sufficient. International harmonisation of definitions, methodologies and indicators is not a methodological luxury, it is an indispensable condition for ensuring that climate statistics are comparable and credible.

3. THE CURRENT STATE: STATISTICAL PRODUCTS IN OPERATION

Following the exploratory projects of the first phase, the Statistics Department of the Banco de España now has a set of climate statistical products that form part of its regular production. The most significant of these are described below.

3.1. The ESG microdata database for Spanish non-financial corporations (CBS)

The first operational product is the database of sustainability indicators (CBS, the Spanish acronym for *Central de Balances sobre Sostenibilidad*) for Spanish non-financial corporations. It addresses a fundamental practical challenge: developing a systematic and scalable framework to monitor and analyse the sustainability information disclosed by firms in their sustainability statements.

The solution adopted involves building an in-house database of ESG indicators extracted from the sustainability reports of major Spanish non-financial firms, using advanced natural language processing (NLP) and machine learning techniques to automate the extraction, classification and validation of information. The pipeline covers everything from the identification and download of reports to the publication of clean, structured data.

A particularly noteworthy aspect of this project is its commitment to data accessibility. Beyond their use by researchers at the Banco de España, the CBS[1] is disseminated through the Banco de España's Research Data Center (BELab), enabling external researchers to link it with other microdata sources and generate new evidence on sustainability-related challenges and opportunities in the Spanish corporate sector.

3.2. The Multi-location Business Visualiser (ViME)

The second project highlighted in the presentation is the Multi-location Business Visualiser (ViME)[2], developed in close collaboration with the INE. This tool addresses a methodological limitation that is particularly relevant for climate statistics: geolocating companies based solely on their registered headquarters produces a distorted picture of the actual distribution of economic activity across the territory.

ViME enables a move from headquarters-based geolocation towards a multi-establishment approach, identifying productive facilities beyond firms' registered addresses. This has direct implications for the assessment of physical risks from climate change: knowing where a company's productive installations, employees and assets are located is indispensable for accurately estimating its exposure to floods, droughts, heatwaves and other extreme climate events.

The practical value of ViME was clearly demonstrated in the analysis of the impact of the DANA storm that struck the province of Valencia in 2024. When the estimated impact derived from headquarters-based geolocation is compared with that obtained using the multi-establishment approach, the difference amounts to 17% more in terms of sales, employment and assets in the affected municipality. This figure eloquently illustrates the systematic error introduced in any physical risk analysis that fails to account for the actual distribution of firms' operating centres.

1 Further information and access to the dataset are available on the following webpage: link

2 For further information on the Multi-location Business Visualiser (ViME), see the Banco de España's online visualisation tool available at link.

3.3 The ERICA database: a European ESG corporate project

The third project presented is the ERICA database (European Reporting of Integrated Company Accounts with ESG data), developed under the umbrella of the European Committee of Central Balance Sheet Data Offices[3] (ECCBSO) through the JECED Task Force (Joint ECCBSO-CMFB[4] on Environmental Data). It is a joint initiative of national central banks and national statistical institutes from nine European countries, coordinated by the Banco de España, compiling harmonised ESG indicators for large listed European corporate groups.

The database covers approximately 1,000 corporate groups per year, with 95% coverage in terms of turnover, over the period 2005-2024. Its primary added value lies in the combination, within a single database, of consolidated financial information and ESG data, enabling integrated analyses of the relationship between corporate sustainability and financial performance.

The Banco de España leads this project, assuming responsibility for coordinating the JECED Task Force, hosting the database, designing the methodological framework and harmonising indicators across countries. This leadership position strengthens the Banco de España's presence in the European climate statistics ecosystem and allows it to contribute actively to the definition of common standards.

3.4. ECB climate indicators: sustainable finance, carbon footprint and physical risk

The fourth set of projects in which the Banco de España participates[5] concerns the development of climate statistical indicators by the European Central Bank (ECB), structured around three broad categories: sustainable finance indicators, carbon footprint indicators and physical risk indicators.

The Banco de España's contribution within this framework goes beyond the supply of granular national microdata. Over the years, the Statistics Department has actively participated in the international methodological debate, putting forward proposals for improvement in areas such as estimating the carbon footprint of corporate loan portfolios, linking mortgage loans to energy performance indicators of underlying properties, and developing forward-looking indicators that allow future climate exposure to be anticipated beyond historical data.

3 European Committee of Central Balance Sheet Data Offices (ECCBSO): Official website.

4 Committee on Monetary, Financial and Balance of Payments Statistics (CMFB): link.

5 Further information on the initiative and its main findings is available in the Banco de España press release, accessible through the following webpage: link.

This work has given rise to several published research contributions, illustrating how statistical production and methodological innovation can reinforce each other: data generates analytical questions, and the answers to those questions improve statistical production processes.[6]

4. WORK IN PROGRESS: THE OPEN AGENDA

Alongside the consolidated statistical products, the Statistics Department of the Banco de España has several active workstreams that represent both the natural continuation of existing projects and the opening of new lines of statistical research and development.

In the area of the G20 Data Gaps Initiative (DGI), the Banco de España is working on implementing the DGI-3[7] recommendations on climate statistics, which include the carbon footprint of foreign direct investment, the development of harmonised forward-looking indicators, and climate statistics for the public sector.

On spatial harmonisation, work is under way to integrate geolocation projects with satellite and remote-sensing data, which offer unprecedented possibilities for improving the precision with which the geographic exposure of economic activities and financial assets to physical climate risks is estimated.

A particularly significant line of work is that related to biodiversity and nature, which broadens the focus beyond climate change in the strict sense. Indicators of water use and water stress, species conservation, and the protection of natural ecosystems and habitats are dimensions that are beginning to be incorporated into the official climate statistics agenda, anticipating the growing prominence they will hold in regulatory and reporting frameworks in the years ahead.

Finally, a strategic priority of the highest importance is the incorporation of climate and sustainability considerations into international statistical standards, notably the System of National Accounts (SNA) and the Balance of Payments Manual (BPM). The revisions currently under way will introduce new sustainability-related concepts and classifications that will fundamentally reshape the production of official economic statistics. The implementation of these requirements and the dissemination of the resulting statistical outputs are expected to be completed around 2030. Preparing the Banco de España for this transformation is therefore one of the department's key strategic priorities. For further information on the

6 See, among others, Estimating the Carbon Footprint of Spanish Credit Institutions' Corporate Loan Portfolios (Banco de España Occasional Paper); Green Mortgage Loans in Spain: An Administrative Data Approach; and Carbon Disclosures from Spanish Non-Financial Corporations: Comparing Data Sources and Analysing Historical Reporting Trends. These studies illustrate how granular climate-related datasets can support both policy-relevant research and improvements in statistical production.

7 International Monetary Fund (IMF), G20 Data Gaps Initiative (DGI-3) Recommendations: link.

ongoing revisions of international statistical standards and their implications for economic measurement, see the Banco de España blog article "How do we measure and compare economies? New developments in 2025".[8]

5. CHALLENGES AND OPPORTUNITIES: LOOKING AHEAD

5.1. Data access in a changing reporting landscape

One of the most immediate and complex challenges identified concerns the management of the shift taking place in the European data landscape. The coming months and years will bring significant changes to data access, driven by new European directives on corporate sustainability reporting.[9] In particular, the need to strike the right balance between reducing reporting burdens on companies, a legitimate and necessary objective, and maintaining adequate access to quality, comparable and decision-useful data represents a dilemma that is genuinely difficult to resolve.

The argument put forward in this contribution is that it is not coherent to simultaneously reduce access to data and demand higher quality climate statistics. Both objectives are in tension and resolving that tension requires a data governance architecture that enables information to be shared between public administrations, statistical institutions and the private sector in a fluid, efficient and appropriately secure manner. Data spaces are emerging as a promising environment for structuring this exchange, but their effective development requires institutional and technical agreements that are still being shaped.

Comparability of standards is another central element of this challenge. If each jurisdiction or institution defines key concepts differently (carbon emissions, exposed assets, sustainable finance) the result will be a patchwork of incomparable data that hampers both economic analysis and financial supervision. Aligning the supply of data with the actual demand from users (central banks, supervisors, investors, researchers) is ultimately the criterion that should guide decisions on what data to produce and how to share it.

5.2. Climate intelligence: the convergence of artificial intelligence and climate statistics

The second major future vector is the transformative potential of artificial intelligence applied to the production of climate statistics. Under the concept of *climate intelligence*

8 Banco de España, How do we measure and compare economies? New developments in 2025, available at the Banco de España website: Banco de España blog article.

9 Central Balance Sheet Data Office Annual Publication 2024, available in Spanish only at the Banco de España website.

(sustainable), the Statistics Department conceptualises the synergistic combination of the analytical capabilities of artificial intelligence, including large language models (LLMs), and the production of sustainability statistics.

This convergence has the potential to transform statistical production processes along three main dimensions:

- Granularity and quality: the use of AI makes it possible to process massive volumes of unstructured data (corporate reports, regulatory documents, satellite images) with a level of granularity and precision that would be impossible to achieve with conventional methods. This translates into more detailed, more accurate and more traceable indicators.

- Efficiency and scalability: the automation of statistical processes through AI techniques reduces production costs and allows the scope of statistical projects to be expanded without a proportional increase in resources. Natural language processing, in particular, opens the door to extracting information from textual sources systematically and reproducibly.

- Uncertainty and decision-usefulness: incorporating scenario-based information and explicitly treating uncertainty in statistical indicators are conditions for climate statistics to be genuinely useful for economic and financial decision-making. AI can contribute to developing more sophisticated and better-calibrated forward-looking indicators.

The vision underlying the concept of climate intelligence is that AI is not simply an efficiency tool, but an enabler of new statistical capabilities that previously did not exist: processing texts in multiple languages and formats, automatically cross-referencing information from multiple sources, generating dynamic calibrations, and producing statistics at very fine geographic scales are examples of what this convergence can deliver.

6. CONCLUDING REFLECTIONS: LESSONS LEARNED AND PERSPECTIVES

The experience of the Banco de España in integrating the climate dimension into its economic statistics offers a set of lessons that may be of value to other institutions at earlier stages of this process.

First lesson: the rationale matters. Before investing resources in the production of climate statistics, it is necessary to have clarity about why they are relevant to the institutional mission. In the case of the Banco de España, the answer was articulated around three arguments: the impact of climate change on macroeconomic variables, the role of the financial sector in the sustainable transition, and the central bank's capacity to manage high-quality data.

This conceptual clarity facilitated the obtaining of institutional support and the alignment of projects with the institution's strategic priorities.

Second lesson: new data sources require new capabilities. Climate-related and sustainability data do not fit the conventional statistical paradigm. Their effective use demands skills that were not systematically present in statistical departments just a decade ago, including the management of unstructured data, data science and machine learning techniques, and the integration of information across heterogeneous data sources. Building these capabilities, through both investment in human capital and the development of technological infrastructure, has been a critical enabler of the projects' success.

Third lesson: collaboration is structural, not optional. The development of climate and sustainability statistics at the Banco de España has relied heavily on cooperation with a broad range of partners, including the ECB, the INE, private-sector stakeholders, and international fora such as the G20. These partnerships have been essential to ensuring methodological robustness, international comparability, and analytical relevance. Indeed, the collaborative dimension is not merely a feature of the production process; it is an intrinsic characteristic of climate statistics, which by their nature require the integration of expertise, data sources, and perspectives across institutions and disciplines.

Fourth lesson: users as compass. Feedback from researchers and other data users has played a key role in steering the development of projects towards where they are most needed. A statistical system that produces data without listening to its users risks generating information of limited analytical value. Opening data to external researchers (through the Banco de España's Data Laboratory, BELab) is a concrete embodiment of this principle.

Fifth lesson: the balance between access and quality is a policy challenge, not merely a technical one. The tension between reducing reporting burdens and maintaining a sufficient flow of quality data cannot be resolved through technical solutions alone. It requires public policy decisions on data governance models, reporting standards and information-sharing mechanisms between institutions. Central banks and statistical institutes have an important role to play in these debates, contributing their perspective on the analytical needs of official statistics.

Taken together, the experience of the Banco de España illustrates that integrating the climate dimension into official economic statistics is a long, demanding and multifaceted process, but also an extremely necessary and, ultimately, achievable one. The statistical products developed to date demonstrate that central banks can make a substantive and distinctive contribution to the climate statistics agenda, provided they are willing to invest in new capabilities, collaborate with a broad network of institutional partners, and orient their work towards the real needs of users.

The horizon ahead, with climate intelligence as a new technological driver, the implementation of the revised international statistical manuals as a renewed conceptual framework, and biodiversity as an emerging frontier, suggests that the next phase of this journey will be every bit as demanding, and as rewarding, as the first.

Comparable, Forward-Looking, Independent Climate Data as a Public Good

Lessons from the TPI Global Climate Transition Centre at the London School of Economics and Political Science

*Carmen Nuzzo**

Abstract

Climate data serve different users, for different purposes and at different levels of aggregation. Their value to markets and to policy nonetheless depends on a common set of properties: comparability, a forward-looking dimension, independent production, methodological rigour and public accessibility. Drawing on the experience of the TPI Global Climate Transition Centre at the London School of Economics and Political Science, this article argues that the binding constraint on climate-related financial analysis has shifted over the past decade: no longer the scarcity of data, but the difficulty of comparing them. It sets out what each of these properties requires in practice, how independent assessments are used by investors and policymakers, and where the limits of assessment now lie, namely in the measurement of adaptation and nature-related risk and in the growing share of corporate activity falling outside the disclosure perimeter. It concludes that sustaining these data as a public good is difficult where it depends only on philanthropic funding, and that the principal constraints today are not methodological but informational: what is not disclosed cannot be assessed, however good the method. Nor does better evidence resolve the separate question of climate action: data inform decisions, they do not make them.

Keywords: climate data, sustainable finance, net zero, transition risk, public goods.

1. INTRODUCTION

Climate data serve different purposes, different audiences, and different use cases. Whatever the application, however, their value to markets and to policy depends not only on their volume but also, crucially, on properties that are difficult to achieve: the data must be comparable, forward-looking, independently produced, rigorously constructed and, ideally, publicly accessible.

This article draws on the experience of the TPI Global Climate Transition Centre (TPI Centre) at the London School of Economics and Political Science (LSE). The Centre, established in 2022 and part of LSE's Global School of Sustainability, is an independent source of research

* Professor in Practice – Executive Director, TPI Global Climate Transition Centre at the London School of Economics and Political Science.

and data on the progress of listed companies, banks and sovereigns[1] in the transition to a low-carbon economy, and serves as the academic partner of the Transition Pathway Initiative (TPI), an initiative led by asset owners and supported by asset managers, which was launched in 2017.[2] Its assessments are published annually, with all methodologies and results made openly available and free to use for non-commercial purposes.

The article also draws on the debate that informed the first panel session of the high-level conference that the Banco de España hosted on 26 March 2026, titled "Climate Risk and Sustainable Finance: Bridging Policy, Research and Practice." The conference brought together central bankers, statisticians, academics and market practitioners to take stock of how far the analytical infrastructure for climate risk has developed, and how much further it still needs to progress.

The session theme, "Climate Data and Analytical Tools," established the framing for the discussion that followed during the day. Its premise was simple but consequential: none of the actions that follow climate ambitions (e.g. climate stress-testing, transition planning, prudential supervision, capital allocation) can be built on a foundation of data that is patchy, incomparable or limited by commercial interests. The session reflected the plurality of needs described above, with contributions from practitioners working on the design of globally consistent climate scenarios for financial sector stress-testing, on the experience of building official climate statistics inside a central bank, and on the work of an academic centre with a primary focus on investors' needs.

The constituencies represented came to climate data with different problems to solve. For investors the question is one of fiduciary duty and risk management: whether the businesses they hold on to behalf of their beneficiaries are viable in a low-carbon economy, and whether to retain, engage with, or exit a given company. Answering this question requires a view on individual issuers, namely their emissions trajectories, their governance, and whether their stated ambitions are matched by plan implementation. Central banks, supervisors and other policymakers face a different set of questions: whether climate-related risks are material to the soundness of individual institutions and to financial stability more broadly, through which channels those risks are transmitted, and whether the financial system is capitalised and prepared accordingly, alongside, for some, the implications for monetary policy, for their own balance sheets, and for the design of regulation. That requires a view of exposures in aggregate, across institutions, sectors and jurisdictions.

1 The term sovereigns refers to national governments in their capacity as issuers of debt.

2 As of March 2026, 155 investors representing around US$80 trillion in combined assets under management (AuM) and advice had pledged support for TPI. AuM are subject to market-price and foreign-exchange fluctuations. As the sum of self-reported data by TPI supporters, they may double-count assets.

These are different questions, and the data they require take very different forms. An analyst's benchmark of steel producers and a supervisory scenario carrying output, inflation and sectoral prices are not interchangeable outputs. But the properties each depends on are the same. Neither is usable if the underlying measurements are not comparable across the entities or jurisdictions assessed; neither is decision-relevant if it captures only past performance; and neither can be relied upon if its construction methodology cannot be scrutinised. This convergence is why these properties are worth treating as general requirements rather than the preferences of any one class of user.

2. THE NEED FOR COMPARABLE DATA

Reliable, comparable data constitute a precondition for sound decision-making by investors and policymakers alike, and for the redirection of capital towards sustainable ends. In the case of investors specifically, they provide a consistent starting point for the analysis of individual holding, make peer benchmarking possible, and allow the replicability of beneficial investment projects and solutions. The cumulative effect is on confidence: investors who can test the claims that their investee entities make are more willing to commit capital to those that are seriously engaged in the transition.

When the Paris Agreement was signed, the prevailing assumption was that the binding constraint was scarcity. The reasoning ran along these lines: companies did not disclose enough; if they did, transparency would improve, analysis would follow, and capital allocation would shift in ways that reflected climate-related risks and opportunities. Disclosure was the bottleneck, and disclosure requirements were seen as the remedy.

That diagnosis proved incomplete, for two reasons. The first is that the gap was never a shortage of climate science. The material available a decade ago was substantial and, on its own terms, of high quality, but it had been produced to answer different questions, for different users. Scenarios from the Intergovernmental Panel on Climate Change (IPCC) and from integrated assessment models are designed to inform climate policy: they extend to 2100, are organised around emissions and temperature outcomes. While they are linked to economic variables such as output and energy prices, they do not produce the monetary and financial ones (inflation, policy rates, asset prices) needed to translate a climate pathway into credit losses or a capital position, and they typically report results for broad world regions rather than for individual countries.

A similar mismatch applied to the underlying datasets. Emissions data assembled for national inventories are retrospective, and although they carry considerable sectoral detail, that detail does not follow the industrial classifications investors work with. More fundamentally, the

accounting is territorial: emissions are attributed to countries rather than to the entities that generate them, which makes the data better suited to tracking progress against national commitments but not to assessing an individual issuer. What was missing was a bridge between this material and the variables that influence financial decisions.

The second reason concerns what occurred when disclosure did expand. Data volumes rose significantly (for example, corporate emissions inventories, sustainability reports, climate risk disclosures, net zero target announcements) but without necessarily producing information that could be used comparatively. Disclosures adopted different metrics, different baselines, different boundaries for what counted as an emission, different time horizons, and different implicit assumptions about future policy. Two companies in the same sector could each disclose extensively and still leave an investor with no reliable means of setting one against the other. What had changed was the nature of the constraint: it no longer lay in the absence of data, but in the difficulty of comparing them.

In practice, comparability requires the consistent application of a single measurement framework across a defined universe of entities. To assess companies, methodologies have to be sector specific. Similarly, sovereigns have to be assessed within similar income brackets, so that differences in wealth and development do not distort the comparison. Comparability also requires an evidence base that can be traced back to source. TPI Centre assessments are built exclusively on publicly available information (e.g. annual reports, sustainability disclosures) rather than on questionnaires or private submissions from the entities assessed. Because the inputs are public, any third party can in principle consult the same material. This methodological design principle aims to promote accountability and transparency. It also means the exercise reinforces rather than substitutes for existing disclosure obligations: entities are not asked to undertake additional reporting but are held accountable for what they have already chosen, or been required, to publish.

Comparability also requires clarity as to what is being compared. Different data capture different aspects of the climate challenge, and no single indicator captures them all. For example, the TPI Centre assesses companies' progress in the transition to a low-carbon economy along two dimensions. Management Quality examines how a company manages its emissions and whether it has established the governance necessary to pursue its targets, scored on a progression from Level 0 (meaning no evident awareness of climate-related risks and opportunities) to Level 5 (where a company discloses quantitative metrics relating to the implementation of its transition plan). Carbon Performance is a quantitative, sector-specific exercise that takes a company's emissions-intensity track record and compares its trajectory against benchmark pathways aligned to the Paris Agreement: national pledges, below 2°C, and 1.5°C.

More recently, the Centre has begun piloting a third strand of research, examining companies' transition plans with a specific focus on implementation, thus adding a third dimension to the analysis. Separate frameworks apply to banks and to sovereigns, reflecting the differing ways in which the transition bears upon a lender and upon a government. What this share with the corporate framework is the underlying architecture: public information as the sole input, and assessment organised around ambition, governance, policy and disclosure.

3. THE FORWARD-LOOKING DIMENSION

Comparability alone is not sufficient for data to be decision useful. A consistently constructed record of historical data documents past performance; it provides considerably weaker evidence on whether an entity is positioned in relation to future climate risks and opportunities, which is the question that concerns investors and supervisors alike.

This is not a marginal distinction. Conventional approaches to financial risk assessment are calibrated on historical observation, and that record was generated under conditions unlike those the transition and a warming climate will produce. Backward-looking data can of course be extrapolated; the difficulty is that the uncertainty attaching to such extrapolation is not easy to characterise, since the structural relationships on which it depends are precisely those that climate change may alter. This is why scenario analysis has become central to supervisory practice: not because scenarios are predictions, but because they are a structured way of reasoning about a range of possible futures.

At the entity level, the same problem takes a different form. Assessing preparedness requires a prospective dimension, with attention not only to whether an entity has set targets but to the scenarios under which those targets would be realised. This is why the Centre assesses net-zero target alignment against three benchmarks rather than a single one. It requires attention, further, to whether the entity possesses the governance arrangements necessary to pursue those targets, and, increasingly the decisive question, to whether its capital allocation is consistent with their delivery. It is for this reason that the Centre's focus is moving beyond alignment towards implementation. A company may announce a net-zero commitment; the commitment of capital expenditure to that end constitutes a materially different signal. Distinguishing between the two represents a considerably more demanding evidentiary exercise than the measurement of past emissions, and much current disclosure is not designed to support it.

The distinction between ambition and implementation has become the central methodological problem in this field. In the years immediately following the Paris Agreement, the analytical task was largely one of establishing whether companies had committed to the transition at

all: whether they had quantified their emissions, set a target, and had adequate governance practices in place to reach those targets (such as assigned board-level responsibility). These questions can now be answered from disclosure documents. However, as target-setting has become more widespread, establishing that a company has announced a net-zero target no longer distinguishes it from its peers in most sectors: what is now more informative is whether the company is doing what delivery of that commitment would require.

That question is considerably harder to answer from published sources. It requires evidence about capital expenditure and its allocation across assets and technologies, about the operational lifetime of existing plant, about planned additions and retirements, and about whether the company's assumptions concerning technology cost and policy support are plausible. Some of this is disclosed; much of it is not, at times for competitive reasons, or is disclosed at a level of aggregation that makes assessment very difficult. It is for this reason that work at the asset level, i.e. building up from individual production facilities rather than down from corporate-level statements, has become a methodological priority. An asset-level view allows a top-line commitment to be tested against what is physically being built, extended or closed, which is a more robust basis for judgement, in addition to the comparison of stated intentions.

A related requirement, less often discussed, is that forward-looking assessment must be situated in the policy environment the entity actually faces. A company's decarbonisation options are shaped substantially by circumstances beyond its control: the carbon price in the jurisdictions where it operates, the availability of low-carbon inputs, the state of the electricity grid, the existence or absence of support for emerging technologies. Comparing companies without reference to those circumstances' risks producing an incomplete, and at times misleading, picture. Contextualising assessments by jurisdiction, without abandoning the sectoral comparability that makes them useful, is a genuine methodological tension rather than a solved problem.

4. INDEPENDENCE AND PUBLIC ACCESSIBILITY

The third requirement concerns not what is measured but who does the measuring, and on what terms.

As demand for climate assessments has increased, a commercial industry has emerged in response. Within parts of that industry, the entities producing assessments of climate alignment may maintain commercial relationships with the entities being assessed or protect their methodologies as proprietary intellectual property. Neither feature is disqualifying in itself, and a number of commercial providers undertake rigorous work. Both, however, render independence more difficult to establish from the outside. A user cannot scrutinise

a methodology that is not visible and has no means of determining whether a commercial relationship has shaped what is presented.

These concerns are no longer confined to academic commentary. Regulators have reached a similar diagnosis, largely along lines set out by the International Organisation of Securities Commissions (IOSCO) in 2021, and binding regimes and voluntary codes have since emerged in several jurisdictions. In Europe, ESG rating providers came under supervision at EU level in July 2026, with a comparable United Kingdom regime due in 2028. Both address transparency of methodology and the management of conflicts of interest.

For a provider outside that commercial model, independence must therefore be structural. In the case of the TPI Centre, this takes several concrete forms. The entities assessed are selected by the Centre itself, on the basis of size (for instance, measured by market capitalisation in the case of listed companies) and level of emissions. No assessed entity pays for its assessment. Methodologies are publicly available, published in the first instance as discussion papers inviting feedback, clearly versioned as they evolve, and subject to public consultation whenever substantive changes are made. Following standard academic practice, and exposing methods to scrutiny and challenge, is precisely what makes the resulting TPI Centre's data valuable.

The value of such openness is evident in the range of users who have adopted the data. The Centre's primary audience consists of investors, and the frameworks were originally conceived to support them in their investee entity evaluations. The user base has nonetheless broadened well beyond that constituency. Academics increasingly employ the datasets on account of their coverage; the material features in professional education, including the Chartered Financial Analyst (CFA) Institute's ESG certificate; and the assessments have been cited by policymakers and standard setters, among them the European Commission, the OECD and the UK's Transition Plan Taskforce. A further cohort has emerged among climate litigants. The breadth of that uptake is itself an argument for open publication.

These characteristics give the data the character of a public good. Information is inherently non-rival: one user's access does not diminish that of another. But it can easily be made exclusive, through subscription or licensing. Free availability is therefore a choice, and one that has so far been underwritten by philanthropy. The TPI Centre's work benefits from charitable funding, and the NGFS scenarios, freely available to any user, have likewise been supported by philanthropic grants. Investors, supervisors and researchers now rely on this infrastructure as a matter of routine. Yet, philanthropic priorities shift, and grants of this kind are typically designed to seed new work rather than to sustain recurring assessment. If comparable, forward-looking and independently produced data are to remain publicly available, the question of who sustains them cannot rest with philanthropy indefinitely.

5. FROM ASSESSMENT TO DATA USE

An argument about the properties of data is only as good as the evidence that those properties change what users do. It is worth setting out, therefore, how the TPI Centre's entity assessments are used, and how that use has altered over the past several years, because the pattern is instructive about what comparable, independent data are and are not good for.

In the years immediately after the Paris Agreement, the dominant investor use was negative screening. Investors used comparative assessments to identify laggards within a sector or operating in carbon-intensive sectors and exclude them from portfolios designed to meet climate or sustainability objectives. That use persists, but others have developed as well.

For instance, screening is now also positive, when investing in high-emitting companies that show decarbonisation progress. Investors use the data for net zero portfolio alignment. Net-zero commitments at the portfolio level require a consistent basis for assessing whether their holdings are collectively consistent with those commitments, which is not possible without entity-level assessments constructed on a common basis. In addition, as regulatory reporting obligations have expanded, institutions have started using data for reporting and compliance, as they are in need of a trusted basis for statements about the climate characteristics of what they hold. Comparative carbon performance and management quality assessments have also been used as the reference for index construction, with substantial assets tracking indices built on this basis[3] (an application that depends entirely on the underlying assessments being methodologically stable, transparently documented and independent of the issuers being assessed).

Perhaps the most consequential investor use is active ownership: engagement with company management and, for equity holders, the exercise of voting rights. This deserves emphasis because it illustrates something important about what these datasets do. A single score is, by construction, a simplification. It cannot capture the specific circumstances of an individual company, and it is not intended to. What a comparable, independently produced assessment provides is a common reference point that investors and their investee entities can accept as a reasonable basis for discussion, precisely because neither commissioned it and both can inspect how it was constructed. The assessment is the opening of the engagement exchange, not its conclusion. Investors who use these frameworks would treat a low score as a question to be put to management, rather than as a finding to be acted upon without further interrogation.

For investors, it is not only financial and non-financial corporate assessments that matter but also sovereign data, for two distinct reasons. The first concerns sovereign bondholders directly: lending to a government means taking a position on the sustainability of its fiscal path,

3 See, for example FTSE TPI Climate Transition Index Series.

and climate change bears on that path from both directions, through the expenditure that mitigation and adaptation require, and through the effect of physical damage and transition-related disruption on the public accounts. The second applies to corporate investors, who may hold no sovereign debt at all. Government policy shapes the environment within which companies operate (the carbon price, the pace of grid decarbonisation, the availability of support for emerging technologies) and therefore determines much of what is feasible for any given firm. Corporate assessments are therefore more informative when read alongside an understanding of the jurisdictions in which the company operates.

TPI Centre's sovereign framework, Assessing Sovereign Climate-related Opportunities and Risks (ASCOR)[4], was designed to support a dialogue between investors and governments rather than simply to supply investors with a score. It serves three functions accordingly. It gives investors a structured basis on which to frame climate considerations in their assessment of sovereign issuers, dividing countries by income brackets to avoid introducing an income bias. It also gives governments a means of demonstrating progress to the market, and, because the relevant evidence is drawn from publications by several government ministries and departments, an occasion for improving coordination among them. Finally, it gives both parties a common reference point for engagement, with debt management offices typically the first point of contact for investors.

The ASCOR uses are increasingly visible in practice, and the Centre has documented them directly, publishing a compilation of investor and issuer cases. For example, in 2025, Slovenia became the first European country to issue a sustainability-linked bond (SLB), and its framework referenced its total Greenhouse Gas Emissions Sustainability Performance Targets (1.1. and 1.2) as being aligned with ASCOR's 1.5°C fair share scenario in 2030. ASCOR has also been adopted into practical financial market applications through the launch of an exchange-traded fund (ETF)[5] tracking a sovereign climate index that relies on ASCOR data. The index, developed by FTSE Russell[6], uses ASCOR assessments and green bond issuance to select euro-area sovereign bonds and re-weight them according to their climate commitments and progress: countries that improve their climate performance are rewarded with a higher weight in the index, and therefore with higher demand for their government bonds.

Bank assessments occupy a third position, and a distinctive one. They matter to investors as issuers in their own right, but they matter more as the channel through which capital reaches the rest of the economy: lending and underwriting decisions shape what gets financed and what does not. The Centre assesses the largest global banks on the same design principles applied to corporates and sovereigns (public information only, with attention to ambition,

4 See ASCOR webpage and the TPI Centre ASCOR country results.

5 See 'Introducing Robeco's Climate Euro Government Bond ETF' (11 September 2025).

6 See The FTSE Climate Collective Transition EMU Broad Government Bond Index.

governance, policy and disclosure). The assessment focuses on which business activities banks' decarbonisation targets actually cover and how far those targets align with low-carbon benchmarks, supplemented in successive years by closer examination of regional particular segments, including selected emerging-market institutions and, most recently, European banks.

What distinguishes the banking assessments is that a bank's climate position is largely derivative. Because banks are multifaceted businesses operating across many sectors, it is not possible to construct a single bank-wide emissions pathway in the way that can be done for a real-economy company operating principally in one high-emission sector. Financed emissions are a function of which companies a bank lends to; its transition risk is a function of the sectors and jurisdictions concentrated in its book. A bank cannot report reliably on either unless the companies it finances disclose reliably themselves, which makes the quality of any banking assessment dependent on a chain that begins outside the financial sector altogether.

The substance of what the annual assessment cycles reveal is the subject of the Centre's regular "State of Transition" reports across the three asset classes, which take stock of developments and address selected themes in detail. Connecting the three types of assessments, so that exposure can be traced across categories rather than examined within each in isolation, is the direction in which the Centre's work is now developing.

The three different entity assessments point towards each other. A company's position cannot be read without reference to the jurisdiction whose policy shapes what is feasible for it. A sovereign's climate performance is realised, or not, through the companies operating within its borders. And a bank's exposure is the aggregate of the corporates and sovereigns on its balance sheet. The implication for policymakers is that evidence gathered on any single front will give an incomplete reading of where the transition stands. Assessing whether a financial system is exposed, or whether a decarbonisation policy is working, requires a joint diagnosis: one that traces the connections between what governments legislate, what companies do in response, and what banks finance as a result.

6. THE LIMITS OF ASSESSMENT: MEASUREMENT AND DISCLOSURE

Mitigation remains the focus of the Centre's assessments. Adaptation, however, has risen rapidly up the investor agenda over recent years, partly because it is less politically contested than mitigation in several jurisdictions, and partly because the physical materialisation of climate hazards has made the issue tangible for portfolios with direct exposure. Assets whose output depends on water availability, for example in the mining sector, offer an obvious illustration.

The difficulty is that adaptation and nature-related risk are substantially harder to measure than emissions. A tonne of carbon dioxide is the same quantity wherever it is emitted, which is what makes emissions data comparable across companies and countries in the first place. No comparable unit has emerged for biodiversity loss, water stress or physical resilience. The relevant metrics are inherently local, sector-specific and dependent on the hazard in question, which means the comparability that mitigation assessment achieved through a single common unit has to be constructed differently. This is where investor demand for methodological development is currently greatest.

It would be a mistake, however, to treat adaptation and mitigation as alternatives. The two are sometimes discussed as though they competed for the same capital. They address different parts of the same problem. Mitigation investment targets the cause: while a substantial part of the requirement is now bankable, notably in renewable generation, the financing gap remains concentrated in many hard-to-abate sectors where the necessary technology is either immature or not yet commercially viable without policy support. Adaptation investment addresses consequences that are, to a significant extent, already determined by past emissions. The financing gap is larger on the mitigation side, by a considerable margin, because the industrial transformation required is capital-intensive, and in many cases not yet bankable on commercial terms. That does not make adaptation finance less necessary. It means the two agendas have to be pursued in parallel, and that data infrastructure has to support both.

In both cases the same combination of approaches is probably the way forward, namely bottom-up evidence at entity and sector level, assessed against a consistent framework, combined with top-down analysis of exposure at the macro level and regional level. In the case of the TPI Centre, this collaboration has already begun, with the Centre for Economic Transition Expertise on the macro dimension and with colleagues at LSE working specifically on adaptation, nature and biodiversity.

A further limit, of a different character, warrants explicit statement. Mandatory climate-related disclosure generally applies above a company size threshold, and most consistently to listed issuers, though the extent to which large private companies are captured varies by jurisdiction. Some have begun to disclose voluntarily, but the majority do not, and this is in the nature of private markets. The constraint is therefore one of disclosure rather than of analytics.

This matters increasingly for policymakers, because the share of corporate activity sitting outside the disclosure perimeter has been growing. More than 35,000 companies have delisted from public markets globally since 2005, around 12,000 of them in Europe, and in both Europe and the United States delistings have outpaced new listings for most of that period, producing a sustained net decline in the number of listed companies. The assessable universe is therefore contracting relative to the economy it is meant to represent, and it does so precisely where

climate-related exposures are least visible. To the extent that those exposures go undisclosed and unassessed, valuations are less likely to have accounted for them.

This is, however, a domain in which investors hold considerable power. What a listed company may be required to publish, a private company can be asked to provide. Investors in private markets negotiate terms directly with the entities they fund, and private capital can also be more patient than its listed equivalent, which makes it well suited to funding structured with conditionality, tied to demonstrable progress against climate or sustainability objectives.

Nothing in the design of the TPI Centre's frameworks confines them to listed companies. What limits their application is the availability of the underlying information, which in private markets may be secured through the terms of investment rather than through regulatory requirement. Such information nonetheless remains private to the parties that negotiate it, and while it serves the investor who obtains it, it does not add to the stock of comparable data on which the market as a whole depends.

7. FROM DATA TO NARRATIVE AND COMMUNICATION

A final requirement is readily overlooked in discussions of data infrastructure, concerning not the construction of datasets but the terms in which they are discussed. For data to enter decision-making, they must be rendered into the conceptual vocabulary of the stakeholders expected to act on them, and different constituencies may not share a single vocabulary. The same underlying evidence concerning a company's decarbonisation trajectory is understood by investors in terms of net-zero commitments, alignment with a benchmark pathway, portfolio decarbonisation and stewardship obligations. The company itself frames identical evidence in terms of business strategy, capital allocation, competitive positioning and operational feasibility. A prudential supervisor approaches it through exposures, materiality, transmission channels and capital adequacy. A statistician is concerned with coverage, classification and the integrity of a series over time.

Each framing reflects a distinct institutional mandate and a distinct decision to be taken. It follows that information framed for one type of stakeholder may be of limited use to another, since relevance depends on the connection between the information and a decision the recipient is responsible for taking.

The risk of mistranslation is greater where terminology appears to be shared. The term "transition plan" carries a different meaning for a corporate strategist, for whom it constitutes a forward business proposition, than for a supervisor, for whom it is evidence on which to judge whether

an institution's exposures have been appropriately assessed and provisioned. "Alignment" is meaningless absent specification of the benchmark against which alignment is measured, and different user communities hold differing default assumptions as to what that benchmark comprises. Apparent agreement on terms may therefore conceal substantive disagreement as to what is being measured. This is a difficulty that comparability of the underlying data does not of itself resolve.

There are also cases in which the requirement is not translation but different data altogether. An investor assessing a single issuer, a supervisor assessing a portfolio of exposures, and a statistician constructing a national aggregate require information at different levels of granularity, at different frequencies, and over different horizons. Ultimately, comparability, a forward-looking orientation and independent data provision are required by all three. However, whether a given user needs the same data explained differently or different data altogether is a question to be resolved analytically.

Investors, for example, require complex qualitative and quantitative evidence to be converted into metrics that are readily interpretable. This is why the TPI Centre's frameworks distil such evidence into indicators that take the form of "yes" or "no" answers, which serve investors better than more elaborate formulations that require interpretation before they can be acted on. The simplification entails a genuine loss of nuance, which is absorbed by the analysts who scrutinise thousands of documents to produce the entity assessments. It is a defensible compromise only where the underlying detail remains published and accessible to any user seeking it, or can be pursued further in the course of engagement.

For institutions producing climate data as a public good, this carries a practical implication. Public availability is a necessary condition of accessibility but not a sufficient one. Making data genuinely usable requires sustained engagement with each stakeholder constituency, and increasingly the connection of those stakeholders to one another: explaining what a metric does and does not establish, situating results within the decisions each group confronts, and accepting the challenge to method that follows. This is a substantial undertaking, and one to which policymakers and academic institutions are well placed to contribute through their convening power. The conference at which this discussion took place is itself an example.

8. CONCLUSION

The past decade has brought a marked improvement in the availability of climate-related data. Disclosure has expanded, methodologies have evolved, and assessments that are more comparable across entities are now available in a way they were not ten years ago, as well forward-looking metrics. Where such data are independently produced and publicly

accessible, that has depended largely on philanthropic funding, which raises a question about how sustainable the model is.

Two further implications follow from the argument set out in this article. The first is that the remaining constraints are no longer primarily analytical. The measurement problems in adaptation and nature are real and unresolved, and no improvement in methodology will resolve them without prior agreement on what is to be measured. The disclosure gap is of a different character: in listed markets the question is whether existing requirements produce information that is usable, and in private markets it is one that investors are themselves well placed to address through the terms on which capital is provided. In neither case is better analytics the binding constraint. Nor, it should be said, is the evidence base the only thing that determines what happens next: data inform decisions, they do not make them.

The second concerns how the demands on the data infrastructure are changing. As the constituencies using climate data have grown more familiar with the subject, their questions have become more precise, and with that has come an expectation of more granular and more frequent information than annual assessment provides, particularly by investors.

The expectation is understandable, but it has to contend with the pace at which the underlying changes actually occur. Corporate transformation is slow: business models, capital stock and growth strategies change over years rather than months, and the capital expenditure decisions that determine a company's trajectory take longer still to become visible in its emissions. The same is true of government policies. The effect of a carbon price, a subsidy regime or a grid investment programme registers over years, and often only once firms have adjusted to it.

Artificial Intelligence (AI) is widely expected to make more frequent data updating possible. The Centre's own experience suggests that AI may to an extent assist with the most time-consuming part of the work, namely the extraction of structured information from large volumes of unstructured disclosure. However, the more demanding part is judgement: establishing whether what an entity has disclosed actually satisfies a given criterion, in a context where language is frequently ambiguous and where the absence of a statement may itself be informative. That judgement is not yet something the technology can be relied upon to supply, and it is what the reliability of an assessment ultimately rests on. Reliability here is not merely a technical property: an independent assessment carries weight only for as long as those assessed, and those relying on it, have reason to trust that it has been done carefully.

For a readership concerned specifically with the energy transition, the practical conclusion is narrower. What the sector continues to lack is shared infrastructure allowing the same underlying evidence to be used by an investor engaging with a portfolio company, a supervisor assessing systemic exposure, a researcher testing a hypothesis, and a citizen seeking to

understand what the transition will require. Building it involves genuine trade-offs: national detail against international comparability, breadth of coverage against depth of assessment, speed against rigour. These are trade-offs to be made explicitly, a point the Madrid discussion helped to bring out by setting supervisory, statistical and academic perspectives alongside one another. Occasions of that kind are valuable and would bear repeating.

REFERENCES

European Union (EU) regulation (2024() 2024/3005 of the European Parliament and of the Council of 27 November 2024 on the transparency and integrity of Environmental, Social and Governance (ESG) rating activities, and amending Regulations (EU) 2019/2088 and (EU) 2023/2859 .https://eur-lex.europa.eu/eli/reg/2024/3005/oj/eng

IOSCO. (2021). Environmental, Social and Governance (ESG) Ratings and Data Products Providers, Final Report. https://www.iosco.org/Library/Pubdocs/Pdf/IOSCOPD690.Pdf

NGFS. (2024). NGFS Climate Scenarios, Network for Greening the Financial System. ngfs.net/ngfs-scenarios-portal

OECD. (2025). Global public markets and corporate ownership. In *OECD Corporate Governance Factbook 2025*, Chapter 1.

Republic of Slovenia. (2025). Sustainability-Linked Bond Framework Version 1.0.

TPI Global Climate Transition Centre. (2023). Management Quality and Carbon Performance methodology.

TPI Global Climate Transition Centre. (2025a). ASCOR framework: methodology note. Version 1.2

TPI Global Climate Transition Centre (2025b) Net Zero Banking Assessment Framework: methodology note Version 1.1.

TPI Global Climate Transition Centre - State of the Corporate Transition 2025

TPI Global Climate Transition Centre - State of the Sovereign Transition 2025

TPI Global Climate Transition Centre - State of the Banking Transition 2025

UK the Financial Services and Markets Act 2000 (Regulated Activities) (ESG Ratings) Order 2025, and the FCA's consultation of December 2025, with the regime taking effect 29 June 2028.

NGFS Climate Scenarios: Bridging Climate Realities with Policy Action*

*Agnieszka Trzcinska***

Abstract

The Network for Greening the Financial System (NGFS) was established in 2017 as a coalition of central banks and supervisors committed to addressing climate-related financial risks and advancing sustainable finance practices. A cornerstone of the NGFS's work is the development of climate scenarios, which serve as vital tools for translating the complex realities of climate risks into macro-financial assessments. First launched in 2020, the NGFS scenarios are uniquely designed to facilitate climate stress testing and assess the economic and financial implications of climate risks. The NGFS scenarios are structured around two complementary time horizons: long-term scenarios (to 2050) and short-term scenarios (to 2030). The long-term scenarios, now in their sixth iteration, provide strategic insights into the interplay between transition and physical risks over extended timeframes. Meanwhile, the short-term scenarios, introduced in 2025, offer a novel approach to assessing the immediate macro-financial consequences of climate risks, focusing on four distinct pathways that explore transition and physical risks.

As public goods, NGFS scenarios provide a globally consistent framework for climate scenario analysis, complete with comprehensive guidance and technical documentation to ensure accessibility and transparency. By bridging the gap between climate realities and macro-financial assessments, the NGFS climate scenarios empower central banks, policymakers, and financial institutions to better understand vulnerabilities, assess risks, and design effective policy responses. As climate change increasingly impacts economies and financial systems, the NGFS scenarios remain an indispensable resource for fostering resilience and advancing global efforts to address the challenges of a warming world.

Keywords: NGFS climate scenarios, climate risk assessment, macro-financial impacts, transition and physical risks, climate stress testing, financial stability, financial sector toolkit.

1. INTRODUCTION

The Network for Greening the Financial System (NGFS) was established in 2017 as a voluntary coalition of central banks and supervisors aimed at addressing analytical challenges and exchanging best practices in sustainable finance. Initially launched by eight founding central banks and supervisory authorities, the NGFS has grown rapidly. By 2026, its membership has expanded to over 150 members and 20 observers, reflecting its global reach and influence. Over

* This paper does not represent the official views of the European Central Bank (ECB) or the Network for Greening the Financial System (NGFS). The opinions expressed herein are solely those of the author.

** NGFS Workstream on Scenario Design and Analysis, European Central Bank.

nearly a decade, the NGFS has evolved into a geographically diverse network, incorporating climate and financial risk perspectives from a wide array of jurisdictions.

In its early years, the NGFS focused on building awareness by enhancing the understanding of climate-related financial risks, sharing supervisory and central banking practices, and analysing the implications of climate risks on financial stability. A significant turning point came with the shift from raising awareness to developing quantitative tools for measuring and analysing climate risks. A key milestone in this journey was the launch of the inaugural NGFS climate scenarios in 2020. Importantly, the NGFS prioritises analytical work and the provision of free tools to support the advancement of the climate agenda among central banks and supervisors, rather than participating in policy discussions.

*Over time, the NGFS has substantially broadened its thematic focus***.** Its work now encompasses a wide range of topics related to climate and nature-related financial risks, including adaptation. This expanded scope underscores the NGFS's commitment to advancing the integration of sustainability considerations into financial systems worldwide.

Climate scenarios represent a flagship product of the NGFS. Much like the evolution of the NGFS itself, these scenarios have progressively advanced over the past few years. Initially focused on mapping long-term climate pathways, they have since evolved to provide a deeper understanding of climate change as a source of macro-financial risk across various time horizons. They are other global climate scenarios, such as the pathways offered by the IPCC or the International Energy Agency. However, what sets the NGFS scenarios apart is their unique design, specifically tailored to meet the needs of the financial sector, with a particular emphasis on enabling climate stress testing.

The NGFS climate scenarios provide an analytical bridge to translate the reality of climate risks into macro-financial assessments. By transforming observed climate events into robust, data-driven frameworks, NGFS scenarios enable users — central banks, policymakers, and financial institutions — to assess the wide-ranging implications of climate risks. These scenarios are not forecasts or predictions but represent a subset of plausible pathways defined by narratives that are intended to be policy relevant at the time of their development.

The NGFS climate scenarios are more than just analytical tools — they are a public good. Accessible to all, they provide global consistency, offering a common reference point for climate scenario analysis. The scenarios are delivered as part of a comprehensive toolkit that includes technical documentation, explanatory notes, and a user guide to ensure that they are practical, transparent, and easily applicable.

A dual horizon approach: long-term and short-term perspectives

The NGFS scenarios are structured across two complementary time horizons: the long-term (spanning to 2050) and the short-term (spanning to 2030). Together, these horizons provide a comprehensive framework for both strategic planning and climate stress testing.

NGFS long-term scenarios

The long-term scenarios are a well-established element of the NGFS framework, with five vintages already released and a sixth in development. These scenarios explore the interplay between transition and physical risks under varying levels of climate policy ambition and physical risk. They are primarily designed for strategic planning, offering insights into structural trends and transformations that shape economies over decades.

NGFS short-term scenarios

First released in May 2025, the short-term scenarios represent a novel addition to the NGFS climate scenario analysis toolkit. These scenarios focus on four distinct pathways through 2030, providing a more immediate perspective that aligns with actionable policy horizons. Their primary value lies in their ability to quantify the macro-financial consequences of climate risks within a nearer-term timeframe.

The short-term scenarios are particularly well-suited for carrying out climate stress tests. By operating within a "what if?" framework, they help users assess vulnerabilities and resilience in the face of immediate climate risks. This perspective is critical in the face of increasingly frequent climate shocks.

2. INNOVATIONS IN CLIMATE RISK MODELLING

The NGFS short-term scenarios represent a significant advancement in climate risk assessment. They incorporate several innovative features that enhance their analytical depth and usability.

1. Integration of multiple dimensions

The scenarios combine climate policies, extreme weather events, macroeconomic developments, and sectoral dynamics into a unified framework. This multidimensional approach provides a comprehensive view of climate risk impacts, capturing both direct effects (e.g., physical damage) and indirect consequences (e.g., financial spillovers).

2. Compound physical risk modelling

Recognizing the increasing frequency and severity of extreme weather events, the scenarios account for sequences of shocks. These compounded events — such as consecutive simultaneous heatwaves, droughts, and wildfires or storms and floods — amplify the economic and financial disruptions, creating cascading effects across regions and sectors.

3. New climate-to-macro transmission channels

The scenarios introduce critical-mineral supply bottlenecks as a new transmission channel. As the global economy transitions toward net-zero pathways, the demand for minerals like lithium, cobalt, and rare earths increases. Bottlenecks in mineral supply chains could exacerbate transition costs and destabilise sectors reliant on clean energy technologies.

4. Baseline alignment with IMF forecasts

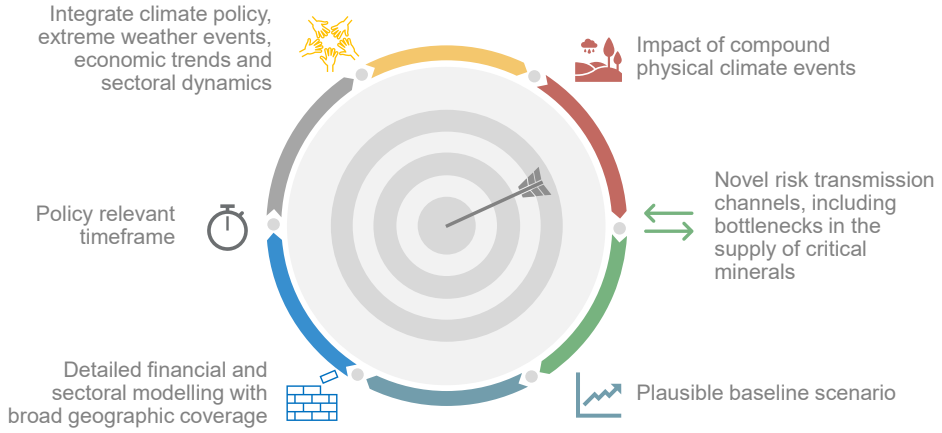
By anchoring the scenarios in globally recognized macroeconomic outlooks, such as those provided by the International Monetary Fund (IMF), they enhance their credibility and relevance. This alignment ensures that the scenarios reflect real-world economic conditions and policy commitments, making them more applicable for practical decision-making.

5. Detailed sectoral and geographical modelling

The scenarios offer granular insights into financial and sectoral impacts, with broad geographical coverage. This level of detail allows policymakers and institutions to assess localized risks while understanding their global implications.

Figure 1

Key innovative features of Phase I of NGFS short-term scenarios released in May 2025



Source: NGFS.

2.1. A broad spectrum of climate risk assessment

The first generation of the NGFS short-term scenarios examined four distinct narratives, divided into two categories: transition risks and physical risks. Each scenario offers unique insights into the economic and financial consequences of different climate trajectories.

Transition risks

- *Highway to Paris*: This scenario envisions a smooth, technology-driven, and globally coordinated transition to net-zero emissions. Carbon tax revenues are efficiently allocated to finance green research and development, enabling gradual emissions reductions with minimal economic disruption. By 2030, global GDP loss is limited to 0.5%, and unemployment rises by just 0.7 pp. Some regions like Europe benefit from the transition due to its ambitious starting climate policies in place, serving as an example of how early action can yield positive outcomes.

- *Sudden wake-up call*: A delayed and abrupt policy shift in 2027 leads to a disorderly transition. Inefficient use of carbon tax revenues and surging carbon prices create inflationary pressures, financial strain, and heightened risks for unprepared carbon-intensive industries. By 2030, global GDP drops by 1.3%, while unemployment increases by 1.3pp.

Physical risks

- *Disasters and policy stagnation*: Severe weather events disrupt affected economies and cause spillovers through trade and finance. Regional GDP losses peak at 12.5% in Africa and over 7% in South America. Even regions not directly impacted experience reduced trade, investment, and financial spillovers, particularly in capital-intensive sectors like agriculture and energy.

- *Diverging realities*: This mixed scenario combines physical and transition risks. Advanced economies (North America, Europe, Oceania, and parts of Asia) remain on track with ambitious climate policies, while other regions face extreme weather events and fail to implement further climate policies. Global supply chains suffer disruptions, mineral shortages drive up transition costs, and recurring disasters lead to global GDP losses exceeding 2.8%, with unemployment rising by up to 1.7pp.

2.2. Key economic takeaways from NGFS short-term scenarios

The NGFS scenarios yield several key insights into the economic trade-offs associated with climate risks and policy actions:

- Orderly transitions reduce costs

Early and coordinated policies, as seen in the Highway to Paris scenario, minimize economic disruption and financial risks through efficient capital reallocation. This scenario demonstrates the benefits of proactive climate action and global cooperation.

- Disorderly transitions amplify risks

The Sudden Wake-Up Call scenario underscores the risks of delayed action. Abrupt policy shifts lead to inflation, financial strain, and unemployment, particularly in high-emission industries that are unprepared for rapid adjustments.

- Extreme weather events cause substantial losses in the near-term

Extreme weather events may lead to substantial GDP losses and strongly affect some economic sectors. Furthermore, the Disasters and Policy Stagnation scenario illustrates how localised shocks can ripple through interconnected economies.

- Transition costs may increase due to severe weather event materialising elsewhere

In the Diverging Realities scenario, advanced economies face higher costs due to mineral shortages and supply chain disruptions, while less developed regions struggle with extreme weather. This dynamic widens economic gaps and creates asymmetrical outcomes.

Figure 2

Key results of phase I of NGFS short-term climate scenarios

Source: NGFS.

2.3. Physical risks materializing in the short-term

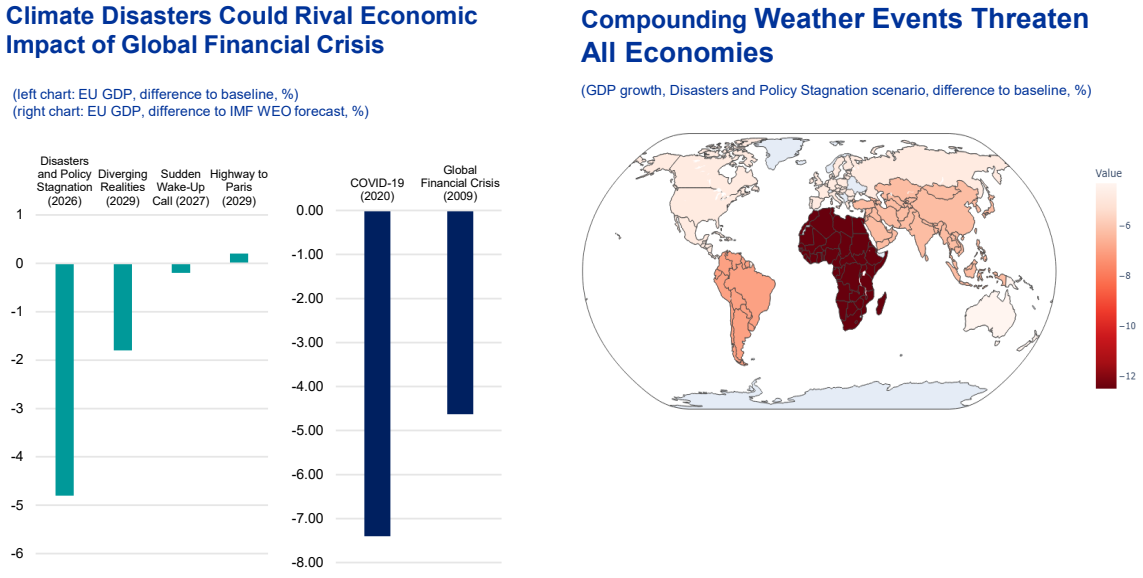
One of the critical contributions of the NGFS short-term scenarios lies in their ability to quantify the macroeconomic impacts of simultaneous, very severe physical climate risks. These scenarios leverage a storyline-based approach to address a fundamental challenge in modelling the joint occurrence of extreme weather hazards which are plausible but for which historical data is scarce or insufficient.

By relying on a storyline approach, the NGFS short-term scenarios overcome modelling challenges and combine individual extreme weather hazards into a coherent sequence. The storyline approach does not claim that the specified sequence of disasters represents the most likely outcome. Instead, it offers a plausible and internally consistent stress scenario designed to explore vulnerabilities and transmission mechanisms within the economy and financial system. This approach is designed for stress testing, where the objective is not to predict the most probable future but to assess how resilient economies and financial systems would be in the face of severe yet plausible climate shocks.

The storyline approach becomes even more relevant as extreme weather events grow in frequency and severity due to the accelerating impacts of climate change. Climate risk is increasingly recognized not as a distant environmental concern but as an immediate financial risk with tangible macroeconomic consequences. For instance, Europe — the fastest-warming region globally — faces significant exposure to physical climate risks despite its commitment to ambitious

Figure 3

Impact of physical risk in the phase I of NGFS short-term scenarios



Source: NGFS.

mitigation policies. Economic losses in the region could amount to 5% of GDP by 2030 due to severe weather events, including heatwaves, droughts, wildfires, storms and flooding.

3. ENHANCING THE NEXT GENERATION OF SHORT-TERM SCENARIOS

The short-term scenarios developed by the NGFS during Phase I were a significant milestone in assessing the macroeconomic and financial impacts of near-term climate risks. However, since the conceptual note underpinning these Phase I narratives was finalized in autumn 2023, the world has significantly changed. To ensure continued relevance, these narratives must be updated to fit the current geopolitical landscape.

Moreover, Phase I was primarily an experimental exercise, and the NGFS is committed to leveraging user feedback to improve the next iteration of its scenarios. Users have identified areas for enhancement, notably pointing out that some scenarios—such as "Disasters and Policy Stagnation," which depicts an extreme physical risk scenario—lacked statistical plausibility due to the unrealistic stacking of severe shocks within compressed timeframes. Similarly, other scenarios, like the smooth transition narrative "Highway to Paris," have grown increasingly disconnected from today's fragmented geopolitical reality.

To address these concerns, the NGFS aims to develop a revised set of narratives that enhance realism, policy relevance, and applicability across diverse contexts. Guided by user feedback, the updated scenarios will focus on the following objectives:

- Reflecting intensifying weather hazards: Future narratives will reflect the growing frequency and severity of climate-related events, ensuring alignment with the current climate realities.
- Adapting to shifting geopolitical dynamics: Scenarios will account for evolving geopolitical conditions and the reduced momentum of climate policies in some regions.
- Expanding applicability through recurring but less extreme shocks: By examining the cumulative impacts of recurrent physical shocks-such as those driven by El Niño and La Niña cycles-scenarios will offer a more comprehensive understanding of climate risks that unfold progressively over time.
- Exploring risk amplification mechanisms: Scenarios will delve into how climate risks intersect with adverse macro-financial conditions, highlighting systemic vulnerabilities and cascading effects that amplify risks.
- Enhancing usability and accessibility for stakeholders: Improved transparency, tailored guidance, and capacity-building initiatives will make the scenarios more actionable and user-friendly for a wide range of stakeholders.

Building on these objectives, the NGFS intends to explore four revised narratives in its second vintage. These narratives aim to provide a comprehensive demonstration of macro-financial impacts:

i. Localised climate events: A scenario focused on acute climate shocks geographically concentrated, offering insights into their immediate economic consequences at local level.

ii. Cumulative impacts across regions: A scenario examining the broader, less severe physical shocks that unfold gradually across multiple economies.

iii. Transition risk with macro-financial amplification: This scenario moves beyond stylised climate policy shocks to include adverse macroeconomic conditions and financial stress, presenting a new perspective on stress dynamics.

iv. Combined transition and physical risks: A scenario that explores diverging climate policy ambitions, integrating the interplay between physical and transition risks alongside financial and supply chain disruptions.

Figure 4

Proposed narratives for exploration in Phase II of NGFS short-term climate scenarios

Source: Own elaboration.

4. APPLYING THE NGFS SCENARIOS

The NGFS scenarios are designed as a starting point for climate scenario analysis. Their users are expected to adapt them to their specific needs. While the scenarios provide consistency and comparability, users shall make sure that the scenarios reflect local circumstances.

Despite their strengths, significant data and modelling gaps remain. For example, more granular subnational projections of physical risks are needed for localized risk assessments. Additionally, there is insufficient data to evaluate the impacts of climate risks on households and real estate in a globally consistent framework. Yet, these are critical sectors for financial stability. Addressing these gaps will be key to enhancing the relevance and utility of future generations of NGFS scenarios.

5. CONCLUSION: TURNING CLIMATE SCENARIOS INTO POLICY ACTION

The NGFS climate scenarios are an indispensable tool for translating the complex realities of climate change into actionable insights. By providing a structured, globally consistent framework, these scenarios bridge the gap between observed climate risks and effective policy responses.

The NGFS short-term scenarios offer a valuable tool for understanding vulnerabilities, exploring transmission mechanisms, and designing policy responses to emerging risks to better prepare for the immediate economic impacts that a warming world may bring. As the NGFS continues to refine and expand its scenarios—addressing data gaps, enhancing plausibility, and incorporating broader risk dynamics—they will become even more essential for tackling the macro-financial challenges posed by climate change.

Ultimately, the NGFS scenarios emphasize the urgent need to treat climate risk not as a distant environmental concern but as an immediate and pressing macro-financial stability issue. In a world increasingly shaped by climate change, the NGFS scenarios are an essential resource of the financial sector's toolkit.

Clear Waters and Financial Stability: From Risk Recognition to Economic Resilience

*Yann Marin**

Abstract

Water has emerged as a macro-critical resource and a material source of financial risk at the international level, where it was considered a local issue before. Droughts, floods, scarcity, pollution and the degradation of freshwater ecosystems may disrupt production, affect inflation, impair assets, weaken borrowers and generate losses across the financial system. These developments are relevant to central banks and supervisory authorities as they may threaten monetary and financial stability as well as the safety and soundness of financial institutions.

Recent research by the Bank for International Settlements (Frost et al., 2025) finds that higher water scarcity is associated with weaker economic growth and lower investment, as well as higher inflation, while greater water-use efficiency is associated with stronger growth and lower inflation. The Network for Greening the Financial System (NGFS) has developed a conceptual framework (NGFS, 2024) through which nature degradation can be translated into conventional categories of financial risk, including credit, market, insurance, liquidity, operational and legal risk.

This article develops five core messages. First, water-related risks fall within the mandates of central banks and supervisors as they affect monetary and financial stability. Second, water is a key transmission channel connecting climate change, nature degradation and the real economy. Third, the materiality of these risks must be assessed through location-specific, forward-looking and system-wide analysis. Fourth, supervisors should integrate water and broader nature-related risks into established prudential frameworks rather than create parallel systems. Fifth, the ultimate objective must be to move from risk measurement to resilience, including by mobilising private capital and strengthening international coordination.

Water is not to be treated as one additional item on an expanding environmental risk register. It is an essential ecosystem service, a factor of production and a potential source of systemic vulnerability. Integrating it into macroeconomic analysis, financial supervision and investment planning is becoming a necessary component of sound central banking and financial governance.

Keywords: water risk, nature-related financial risk, financial stability, price stability, central banks, prudential supervision, ecosystem services, resilience, sustainable finance.

1. INTRODUCTION

Central banks and financial supervisors are being confronted with a widening range of risk drivers. Many institutions already devote substantial resources to monitoring inflation,

* NGFS Secretary General; Deputy Director for Financial Stability, Banque de France.

financial leverage, geopolitical uncertainty, cyber threats, technological transformation and the consequences of climate change. Against that background, calls to examine biodiversity loss, water scarcity, soil degradation and other forms of nature degradation may be perceived as attempts to add further responsibilities to already demanding mandates. This is understandable but ultimately misguided: central banks cannot ignore material threats to financial stability.

Water and broader nature-related risks are not separate from the traditional concerns of central banks and supervisors. They are potential drivers of the conventional risks that monetary and prudential authorities already monitor. When water scarcity reduces agricultural or industrial output, it may affect prices, productivity and economic growth. When floods damage buildings and infrastructure, they can reduce collateral values and increase credit and insurance losses, as well as fostering defaults in corporates and households. When water pollution interrupts production or creates legal liabilities, it can weaken corporate balance sheets. When ecosystem degradation reduces the capacity of land, rivers and wetlands to regulate water flows, it can increase the frequency and severity of water-related events.

Environmental policy remains principally the responsibility of governments and parliaments. The relevant question for central banks is not whether they should pursue environmental objectives independently of elected governments. The appropriate question is whether environmental degradation can materially affect the achievement of central bank and supervisory mandates.

Available evidence increasingly suggests that it can. Many central bankers have accordingly emphasised that considering climate and nature-related risks is not a discretionary extension of their mission. It is a response to material risks that can affect the stability of economies and the robustness of financial systems. At the same time, central banks must remain attentive to the boundaries of their mandates.

This mandate-based approach is particularly important for water. Water is a critical resource for food production, energy, manufacturing, transport, mining, public health, urban development and digital infrastructure. Yet its economic value and the financial consequences of its deterioration are not fully reflected in prices, corporate accounts and standard risk models.

The challenge does not lie in any lack of awareness. It is also an analytical and operational conundrum. Central banks and supervisors must determine how water-related shocks transmit to inflation and financial stability, how material exposures can be identified, how institutions should manage them and how uncertainty should be addressed without either overstating the evidence or waiting for perfect information.

More work is needed to strengthen our capacities in that field and to achieve our objectives. Five foundational pillars can however be considered.

2. PILLAR 1. WATER-RELATED RISKS ARE RELEVANT TO THE CORE MANDATES OF CENTRAL BANKS AND SUPERVISORS

Central banks do not need a specific environmental mandate to examine water-related financial risks. Their responsibility arises when those risks affect monetary and financial stability, channels of transmission for the monetary policy signals or the safety and soundness of supervised financial institutions.

This distinction is major. Governments are responsible for setting environmental objectives, allocating water rights, regulating pollution, financing public infrastructure and determining the distributional choices associated with the transition. Central banks and supervisors are not to decide how society ought to value nature or how water could be allocated among households, agriculture, industry and ecosystems. They must nevertheless assess the consequences of policy decisions or the lack thereof, and the physical degradation occurring, for the economy and the financial system.

The mandates of central banks may vary across jurisdictions, but price stability and financial stability are generally their core responsibilities. Water-related shocks can affect both.

2.1. Water and price stability

Water scarcity can constrain agricultural, industrial and energy production. Flooding can interrupt transport and damage productive capacity. Pollution can increase treatment costs or render existing water sources unusable. These effects can reduce aggregate supply and increase the prices of food, energy, manufactured goods and essential services.

Recent BIS research provides empirical support for this macroeconomic relevance. Using panel data covering 169 countries from 1990 to 2020, the authors find that higher water scarcity is associated with lower gross domestic product growth, weaker investment and higher inflation. They also find that greater water-use efficiency is associated with stronger growth and lower inflation. The paper concludes that water availability and efficiency may become relevant considerations for economic forecasting and monetary-policy analysis.

The monetary-policy implications need to be interpreted with caution. Central banks are not capable of eliminating a drought or restoring water storage through changes in interest rates. Temporary movement in food prices should not always be treated as a source of persistent inflation.

However, the conventional distinction between a temporary supply shock and a persistent inflationary process becomes less clear when physical shocks occur repeatedly, with heightened frequency and severity, affect multiple regions, modify expectations and disrupt price formation. Recurrent water shortages can raise production costs, alter investment decisions and weaken potential output. If businesses conclude that water-related disruption is no longer exceptional, higher expected costs may become embedded in prices and supply-chain strategies.

Water-related inflation can also have distribution effects. Food, water and energy represent a larger share of expenditure for lower-income households. Even when the impact on aggregate inflation is moderate, the social and political consequences may be material.

Central banks therefore need to understand the nature and persistence of water-related supply shocks, their interaction with inflation expectations, and their implications for the balance between inflation and economic activity.

2.2. Water and financial stability

The financial-stability implications of water shocks extend across established categories of risk.

Credit risk can increase when firms lose revenue, face interruptions or incur additional costs because of water scarcity, flooding or pollution. Borrowers may be directly dependent on water or indirectly exposed through suppliers, customers, energy systems and transport networks.

Market risk can arise when investors reprice companies, sectors, sovereigns or regions in response to new information about water exposure. Assets that appear valuable under assumptions of stable access to water may become impaired when physical constraints, regulation or social opposition are recognised.

Insurance risk can increase through flood claims, business interruption and the deterioration of insurability in repeatedly affected areas. If insurers raise premiums, restrict coverage or withdraw from certain markets, risk is transferred to households, businesses, banks and, in some cases, governments with consequences for public finances.

Operational risk may also arise. Financial institutions depend on buildings, electricity, telecommunications, data centres and service providers that can be affected by flooding or water shortages.

Legal and reputational risks are becoming more important. Firms may face litigation, penalties or loss of public trust when their operations contribute to pollution, ecosystem degradation or conflicts with community water needs. The financial institutions that lend to or invest in those

firms may face secondary exposure. Central bank analysis has emphasised that nature-related risks are material financial risks that should be assessed, analysed and managed in the same way as other potentially significant risks.

The critical point is that the environmental driver of a risk does not place it outside a central bank's mandate. A drought is a physical event, but its financial consequences may appear as credit losses, market repricing or inflation. Pollution is an environmental problem, but it can generate operational, legal and reputational risk. Nature degradation may begin outside the financial system yet enter it through familiar balance-sheet channels.

Mandate relevance should therefore be determined by the economic and financial consequences of the risk, not by the disciplinary label attached to its origin.

3. PILLAR 2. WATER IS A KEY TRANSMISSION CHANNEL BETWEEN CLIMATE CHANGE, NATURE DEGRADATION AND THE FINANCIAL SYSTEM

Water occupies a distinctive position in the emerging analysis of nature-related financial risks. It is simultaneously a natural asset, an essential ecosystem service, a factor of production and a channel through which climate change could become economically visible.

Water is indeed one of the clearest examples of the climate-nature-economy nexus.

3.1. From ecosystem degradation to economic disruption

Economies depend on nature through provisioning, regulating and supporting ecosystem services. These include the provision of food, water, timber and biological materials, as well as pollination, water filtration, climate regulation, flood protection, soil formation and disease control.

These services do not always have explicit market prices, but their absence can generate substantial economic costs. Wetlands can absorb excess water and reduce flooding. Forests and healthy soils can regulate the timing and quality of water flows. Aquifers can provide buffers during dry periods. When these ecosystems are degraded, the economy may lose forms of natural infrastructure that were previously available at little or no direct financial cost.

Research and policy work presented by central banks increasingly recognise that economic activity depends on natural resources such as water and on the wider services provided by nature. The NGFS Conceptual Framework (NGFS, 2024) was developed in part to establish a

common language for translating these dependencies and impacts into economic and financial risks.

Water helps make this relationship tangible. The degradation of a wetland can increase flood losses. Deforestation can affect water retention and sedimentation. Soil degradation can reduce agricultural productivity and increase irrigation needs. Pollution can convert physical water availability into economic scarcity by making water unsafe or too costly to use.

Nature-related financial risk does not mean biodiversity risk in a narrow sense. It encompasses the economic consequences of changes in the status of ecosystems and the services they provide to the economy.

3.2. The importance of dependencies and impacts

The NGFS framework distinguishes between an economy's dependencies on nature and its impacts on nature.

A dependency exists when an economic activity relies on an ecosystem service. Agriculture depends on water availability, soil quality and pollination. Hydroelectric production depends on river flows. Industrial facilities may depend on water for cooling, cleaning or processing.

An impact arises when an economic activity changes the state of nature. A company may pollute a river, deplete groundwater or alter an ecosystem through land occupation.

Dependencies and impacts are interconnected. An economic activity may degrade the ecosystem service on which it relies. The financial consequences can emerge immediately through physical disruption or later through regulation, litigation, changing consumer preferences or social conflict.

This feedback effect distinguishes nature-related financial risk from a simpler model of external shocks. The economy is affected by nature degradation, but economic and financial decisions can contribute to that degradation, which can in turn increase future financial risks.

3.3. Physical and transition risks

Nature-related physical risks arise from the degradation of ecosystems and their services. For water, these include shortages, deteriorating quality, altered flows, flooding and the loss of natural water regulation.

Transition risks arise from the responses of governments, markets, firms and society to nature degradation. New pollution standards, restrictions on extraction, changes in water tariffs, restoration requirements, liability regimes or shifts in consumer behaviour can affect company costs and asset values.

The distinction is analytically useful but should not imply that the two forms of risks are independent. Delayed policy action may increase physical damage and eventually require a more abrupt transition. Conversely, poorly designed policies can create unnecessary economic disruption without adequately reducing physical vulnerability.

Uncertainty about future policy can itself become a source of risk. If firms do not know whether water restrictions, pollution standards or restoration obligations will be introduced, they may delay investment. When policy ultimately changes, adjustment may be more sudden and costly.

3.4. Modelling effects of nature degradation

Nature-related risks are difficult to model because ecosystems can respond nonlinearly. A gradual increase in pressure may produce limited observable effects until a threshold is crossed, after which ecosystem services deteriorate rapidly.

Water shocks can also be combined with other risks or happen in a sequence. Drought may increase wildfire risk. Wildfire may damage soils and vegetation. Subsequent rainfall may then produce erosion, pollution and flooding. Low river levels may simultaneously constrain transport, power generation and industrial cooling.

These interactions matter for financial stability because they increase the possibility of correlated losses. A drought affecting a region may impair farms, food processors, energy companies, industrial firms, households and local authorities at the same time. The resulting losses may appear across loans, bonds, equities and insurance claims.

The NGFS stresses that climate change and broader nature degradation should not be analysed in isolation. Its conceptual framework is intended as a first step towards an integrated assessment of climate and nature-related risks, reflecting the scientific evidence that the two crises are deeply interconnected.

For central banks, the implication is clear. Water should not be treated as a narrowly environmental variable. It is a transmission mechanism connecting climatic conditions, ecosystem health, economic production and financial balance sheets.

4. PILLAR 3. MATERIALITY MUST BE ASSESSED THROUGH LOCATION-SPECIFIC, FORWARD-LOOKING AND SYSTEM-WIDE ANALYSIS

The recognition that water matters does not mean that all water-related risks are material for financial institutions. Prudential action should be grounded in a detailed assessment of exposures, vulnerabilities and transmission channels.

Formalising materiality is therefore a major task for central banks and supervisors.

4.1. From environmental indicators to financial variables

A financial institution does not need only to know whether a borrower uses water. It needs to understand whether access to water is critical to that borrower's operations, whether alternatives exist, how exposed the relevant location is, and how a disruption would affect cash flow, asset value and debt-servicing capacity.

This requires a sequence of analysis:

1. identify the economic activity's dependencies and impacts;
2. locate the relevant assets, facilities and supply chains;
3. assess the condition and likely evolution of the relevant ecosystems;
4. translate environmental disruption into economic effects;
5. translate those economic effects into financial risk;
6. examine whether exposures are concentrated or correlated across the financial system.

The NGFS Conceptual Framework follows this logic. It connects sources of physical and transition risk with impacts on the economy and then with conventional financial-risk categories. It includes two illustrative applications to freshwater and forest ecosystems, demonstrating how the framework can be applied to specific forms of nature dependence. Additional illustrations are to be published in a compendium in October 2026.

4.2. Location is key

Water is highly location-specific. A litre of water used where abundant does not create the same dependency or impact as a litre used where severely stressed.

Company-level averages can consequently be misleading. A diversified corporation may report a moderate global water footprint while operating one strategically important facility in a highly vulnerable area. A bank may appear to have limited exposure to water-intensive sectors while holding substantial credit concentrations in a region exposed to drought or flooding.

Geospatial information is therefore essential. Financial exposures should, where possible, be linked to the locations of borrowers' assets, operations, major suppliers and collateral. This is more demanding than conventional sectoral analysis, but without such information material risks may remain hidden.

4.3. Forward-looking analysis is required

Data is incomplete not provide a sufficient guide to future risk. Climate change, ecosystem thresholds, infrastructure deterioration, population growth, technological development and regulatory responses may alter the frequency and scale of events.

Scenario analysis can help institutions explore plausible futures without requiring precise forecasts. Scenarios may examine prolonged drought, severe flooding, restrictions on extraction, pollution-related closures, changes in water costs or the deterioration of ecosystem services.

Scenarios need also to consider interactions. For example, a drought may reduce agricultural production and hydropower at the same time, while low river levels disrupt transport. The aggregate effect may be larger than the sum of shocks modelled independently.

The NGFS is tentatively developing scenarios and modelling tools for nature-related financial risks, but the field remains less mature than climate-risk analysis. Its 2026 package provides work on nature-related data, modelling tools and supervisory practices (NGFS, 2026a), while explicitly acknowledging the challenges created by data gaps, complexity and the absence of universally applicable metrics.

4.4. A system-wide perspective

Microprudential analysis asks whether an individual institution is resilient and able to face stressed situations by itself to a high extent. Macroprudential analysis considers whether common exposures, interconnections or responses could destabilise the financial system.

This distinction matters for water. An individual bank may diversify its exposure by reducing lending to water-intensive sectors. If many institutions respond in the same way, however, vulnerable but economically essential sectors may lose access to the funding required for adaptation.

Similarly, insurers may protect their solvency by withdrawing coverage from flood-prone areas. At the level of each firm, that response may be rational. However, at the system level, it may weaken collateral values, raise bank losses and transfer liabilities to the public sector.

Central banks therefore need to analyse not only first-round losses but also amplification channels, including:

- common portfolio exposures;
- geographical concentration;
- insurance withdrawal;
- falling collateral values;
- fire sales and market repricing;
- the migration of losses to sovereign balance sheets;
- feedback between reduced investment and greater physical vulnerability.

Materiality is not determined solely by the aggregate value of an exposure. It also depends on concentration, substitutability, timing and the existence of thresholds. A relatively small sector can be systemically important if it supplies a critical input to many other sectors.

4.5. Acting in an uncertain world

Nature-related analysis is affected by significant data and modelling limitations. Yet uncertainty cannot justify postponing necessary action. Prudential supervision routinely addresses risks for which probabilities of occurrence and consequence upon materialisation are difficult to estimate.

The appropriate response is proportionate and iterative. Authorities can begin with qualitative assessments, exposure mapping, targeted reviews and exploratory scenarios. Methods can become more sophisticated as information improves.

The NGFS has explicitly concluded that the lack of absolute certainty or perfect knowledge should not prevent action, particularly when delay could produce a "too little, too late" outcome.

The standard should therefore not be perfect quantification. It should be decision-useful analysis that is transparent about assumptions, limitations and uncertainty.

5. PILLAR 4. NATURE-RELATED RISKS SHOULD BE INTEGRATED INTO EXISTING PRUDENTIAL FRAMEWORKS

Central banks and supervisors rightfully resist the creation of an entirely separate prudential architecture for every environmental issue. Nature-related risks are drivers of conventional risks and should therefore be incorporated into established frameworks whenever they prove material. This approach is both conceptually sound and operationally efficient.

A water-related shock may manifest as credit risk, market risk, insurance risk, liquidity risk, operational risk or legal risk. The supervisory question is therefore whether institutions identify, assess and manage these risks appropriately.

5.1. Governance and strategy

Boards and senior management need to understand their institution's material dependencies on climate and nature-related factors. Responsibilities need to be clearly allocated, and relevant considerations must be included in strategy, risk appetite and internal controls in an effective way.

Financial institutions are to be able to explain where material exposures are concentrated and how they influence business decisions. Governance cannot be limited to policy statements. It should affect credit standards, portfolio management, client engagement, capital planning and operational-resilience arrangements.

5.2. Risk identification and monitoring

Banks may need to incorporate location, sector, water dependency and adaptive capacity into borrower assessments. Insurers may need to examine the implications of repeated flooding for pricing and insurability. Asset managers may need to consider whether valuations adequately reflect exposure to scarcity, regulation, litigation and ecosystem decline.

A proportionate approach remains essential. Not every small financial institution requires an advanced global nature model. However, a small institution concentrated in an exposed agricultural or coastal region may face substantial risk and should not be exempt merely because of its size.

5.3. Supervisory assessment

Supervisors can use a range of tools, including thematic reviews, questionnaires, portfolio analysis, scenario exercises, on-site inspections and discussions with boards.

The NGFS's 2026 note on nature-related supervision (NGFS, 2026a) proposes a pragmatic four-step approach that builds on existing climate supervision. Supervisory practices are emerging across advanced, emerging and developing economies, ranging from awareness-raising to requirements for concrete improvements in financial institutions' risk-management practices.

The NGFS's updated 2026 guide for supervisors (NGFS, 2026b) goes further by integrating climate and nature-related risks into a common prudential framework. It covers mandates, governance, organisational arrangements, exposure assessment, qualitative and quantitative analysis, scenarios, supervisory expectations and microprudential and macroprudential tools.

This integrated approach is preferable to regulatory fragmentation. Financial institutions should not be required to operate separate systems for climate, biodiversity, water and pollution when these risks are interconnected and transmitted through the same balance-sheet channels.

5.4. Data and disclosure

Supervisory effectiveness depends on decision-useful information. Companies and financial institutions need to disclose enough information to facilitate the assessment of material dependencies, impacts and exposures.

For water, relevant information may include:

- the location of significant facilities;
- dependency on water availability and quality;
- exposure to stressed basins;
- major sources of pollution or ecosystem impact;

- vulnerability of critical suppliers;
- adaptation and contingency plans;
- financial implications of restrictions or physical disruption.

Standardisation improves comparability and reduces reporting costs. Yet the value of common standards should not lead to excessive simplification. Because water is local, globally standardised metrics must be accompanied by geographically specific information.

The climate-disclosure work of the Basel Committee illustrates the direction of travel. Proposed disclosures have included sectoral exposures and exposures subject to physical risk by geographical area. While designed for climate-related risks, the underlying logic is also relevant to nature and water: risk assessment requires information about both economic activity and location.

5.5. Legal and reputational risks

Supervisors also consider nature-related litigation and conduct risk. Legal claims may concern pollution, corporate responsibility, misleading sustainability statements or failures to manage foreseeable environmental harm. Financial institutions need to identify plausible legal exposures and assess whether governance, due diligence and disclosures are adequate.

The expansion of nature-related litigation can create direct financial costs and accelerate the repricing of assets. It can also affect the responsibilities of central banks and supervisors themselves when the financial implications of nature degradation become increasingly established.

The objective of supervision is not to penalise exposure to environmentally sensitive sectors as such. It is to ensure that material risks are understood, governed and managed, and that the financial system remains resilient and able to perform its service to the real economy at all times.

6. PILLAR 5. POLICY OBJECTIVES TO SHIFT FROM MEASURING RISKS TO BUILDING RESILIENCE

Risk measurement is necessary, but not sufficient.

A financial institution may reduce its exposure to water risk by selling assets, restricting lending or withdrawing insurance. Such actions may improve its individual risk indicators while

leaving the underlying economic vulnerability unchanged. In some cases, they may make that vulnerability worse by reducing access to the capital needed for adaptation.

The strategic objective should therefore be to move from risk recognition to resilience.

6.1. What resilience means

Economic resilience is the capacity to absorb shocks, adapt to changing conditions and continue providing essential functions. In the context of water, it may involve:

- maintaining and modernising water infrastructure;
- reducing leakage and inefficient consumption;
- improving wastewater treatment and reuse;
- adapting agricultural and industrial processes;
- protecting buildings and transport networks against flooding;
- restoring wetlands, forests, soils and river systems;
- improving emergency planning and business continuity;
- diversifying supply chains and sources of water.

Some measures reduce immediate financial exposure. Others strengthen the underlying ecosystems on which economic activity depends.

The two dimensions are connected. Engineered infrastructure can be indispensable, but nature-based solutions may provide complementary protection. Wetland restoration, improved soil management and forest protection can contribute to water retention, filtration and flood attenuation while producing wider environmental benefits.

6.2. The private sector's role

Public finance alone is not sufficient to meet the scale of investment required. Private companies and financial institutions must also play an active role.

Companies need to identify not only their water consumption but also their critical dependencies, local impacts and exposure through supply chains. They are to develop credible adaptation plans and incorporate water constraints into investment decisions.

Banks can support resilience through lending, client engagement and the assessment of adaptation plans. Investors can distinguish between firms that are merely exposed and those that are actively reducing vulnerability. Insurers can provide risk expertise and incentives for prevention, if coverage remains appropriately designed and priced.

Public authorities can help mobilise capital through clear regulation, project preparation, guarantees, blended finance and reliable information. Public intervention may be particularly important where projects generate substantial public benefits that cannot be fully captured by private investors.

The purpose is not to protect every existing activity regardless of its environmental impact. Some activities may be incompatible with sustainable water conditions in specific locations. Financial institutions will need to distinguish between credible adaptation, the transfer of impacts to others and business models that are no longer viable or will cease to be.

6.3. Avoiding maladaptation

Resilience investments need to be carefully evaluated. A project that secures water for one industrial user may reduce access for competitors, households, agriculture or ecosystems. New infrastructure may create environmental damage or lock economies into unsustainable patterns of consumption.

This is why basin-level governance and engagement with affected communities are important. Water resilience cannot be assessed solely at the level of an individual asset or company.

Central banks and supervisors are not responsible for selecting individual projects. They can nevertheless encourage financial institutions to consider whether adaptation plans are credible, comprehensive and consistent with long-term physical constraints.

6.4. International coordination

Water risks are local in their physical manifestation but global in their economic transmission. Food markets, supply chains, migration, trade and financial portfolios connect water-stressed regions with the rest of the world.

International coordination is therefore essential. The NGFS contributes by developing common concepts, supervisory practices, scenarios and analytical tools. It has established nature-related risk as a dedicated area of work, with priorities including scenario development, practical implementation of its conceptual framework and the integration of nature considerations across its wider activities.

Coordination should aim to prevent unnecessary fragmentation. Common principles, terminology and baseline expectations would improve comparability. At the same time, national implementation must reflect differences in ecosystems, financial systems, institutional mandates and levels of development.

6.5. Building conviction

None of this can progress without sustained political and institutional conviction.

Within specialised communities, the financial relevance of water and nature degradation is increasingly recognised. Outside them, the agenda competes with many urgent economic, social and geopolitical concerns and may lose momentum.

The call for action must therefore be expressed clearly, and rely on evidence rather than principles or general statements. It should explain for example how water-related risks affect prices, production, employment, public finances, borrowers and financial institutions. It should also distinguish between the responsibilities of the various stakeholders, those of governments and those of central banks.

Communication should make risk tangible. Visible cases of water pollution, flooding or competition between households and industrial facilities can help demonstrate the economic and social significance of the issue. They should be connected to robust analysis of materiality and transmission.

Central banks have a particular responsibility to communicate with precision. Their credibility depends on the remit of their mandates and on recognising uncertainty. At the same time, their credibility would be weakened if they ignored risks that are becoming increasingly relevant to price and financial stability.

7. CONCLUSION

Water is becoming a central macrofinancial issue. It is a fundamental input into production, a critical ecosystem service and a transmission channel linking climate change, nature degradation and the economy. Its scarcity, excess or pollution can reduce output, raise prices, impair assets and weaken borrowers. These effects can appear in the financial system as credit, market, insurance, liquidity, operational, legal and reputational risks.

The relevance to central banks and supervisors follows from these transmission channels. It does not depend on expanding their mandates into environmental policymaking. Governments

must continue to lead on environmental objectives, infrastructure, taxation, regulation and distributional choices. Central banks and supervisors must act where environmental developments affect monetary and financial stability.

The analytical agenda remains demanding. Data are incomplete, modelling is still at an early stage of development and ecosystem responses are complex. There is no single metric comparable to greenhouse-gas emissions, and no universal transition pathway can capture the diversity of water systems and local ecological conditions. The NGFS recognises these limitations while encouraging central banks and supervisors to advance through pragmatic, proportionate and iterative action.

Action must be now. Waiting for perfect information would be neither realistic nor prudent. Central banks are used to making decisions in an uncertain environment. The appropriate response is to improve data and methods while acting on risks that are already sufficiently visible and potentially material.

Water should therefore not be presented as another burden imposed on institutions already working on climate risk. It is one of the principal channels through which climate and nature-related pressures become economically and financially relevant. Integrating it into forecasting, financial-stability analysis, supervision and investment planning will improve, rather than dilute, existing risk frameworks.

The strategic direction can be summarised in a straight-forward manner: central banks and supervisors need to help move the financial system from risk recognition to resilience. That transition will require analytical rigour, supervisory clarity, international coordination, private-sector mobilisation and credible public policies.

Above all, it will require conviction work. The financial implications of water and nature degradation are to be communicated beyond the specialist community, supported by evidence and in line with mandates: stable prices, sound financial institutions and resilient economies.

REFERENCES

Basel Committee on Banking Supervision. (2023). *Disclosure of Climate-related Financial Risks.* Consultative document, November. https://www.bis.org/publications/202311-consultation-disclosure-climate-related-financial-risks.pdf

Elderson, F. (2024). *Nature-related Risk: Legal Implications for Central Banks, Supervisors and Financial Institutions,* September. https://www.ecb.europa.eu/press/key/date/2024/html/ecb.sp240906~54436f6891.en.html

Frost, J., Madeira, C., and Martínez-Jaramillo, S. (2025). The economics of water scarcity. BIS *Working Papers,* No. 1314. Basel: Bank for International Settlements. https://www.bis.org/publ/work1314.htm

Network for Greening the Financial System (NGFS). (2024). *Nature-related Financial Risks: a Conceptual Framework to guide Action by Central Banks and Supervisors.* Paris: NGFS. https://www.ngfs.net

Network for Greening the Financial System (NGFS). (2026a). *Nature package*. Paris: NGFS. https://www.ngfs.net/en/publications-and-statistics/publications/ngfs-2026-nature-package

Network for Greening the Financial System (NGFS). (2026b). *Guide for Supervisors: Integrating Climate and Nature-related Risks into Prudential Supervision.* Paris: NGFS. https://www.ngfs.net/en/publications-and-statistics/publications/guide-supervisors-integrating-climate-and-nature-related-risks-prudential-supervision

Villeroy de Galhau, F. (2023). *Launch of the NGFS Conceptual Framework for Nature-related Financial Risks,* September. https://www.banque-france.fr/en/governors-interventions/launch-ngfs-conceptual-framework-guide-action-central-banks-and-supervisors-nature-related-risks

Información Publicaciones / Publications Information:

Funcas
Caballero de Gracia, 28
28013 Madrid
España / Spain
Tfno. / Phone: +34 91 596 54 81
publica@funcas.es

P.V.P.: Suscripción anual papel, 25 € (IVA incluido)
Edición digital, gratuita

ISSN: 2445-2726
Depósito Legal: M-7537-2016