



Emerging Analysis

The treatment of physical climate risks by central banks

Insights for the Reserve Bank of India

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December 2023

Key messages

Increasing global recognition of climate change impacts has led central banks, financial authorities and their associations to set out principles, guidelines and methodological approaches on assessing physical climate risk exposure of regulated entities (REs).

Practical experience from selected central banks suggests a phased approach with clear timelines to implement physical climate risk assessment policies. Such an approach allows for pro-active awareness-raising on climate issues, laying out regulatory expectations and scoping technical capacities and data availability among REs at the early stages of policy development. During the implementation phase, most emerging market central banks find it appropriate to adopt the principle of proportionality, in recognition of variations in technical capacities and the systemic importance of REs.

Central banks pointed to serious challenges in terms of data availability, modelling risks and varied capacities of REs. In this context, current policy efforts aim at enhancing REs' capabilities to manage physical climate risks, rather than modifying capital requirements.

The RBI has taken critical steps to raise awareness among REs on climate issues, and it is important not to lose this momentum. This paper offers a stylised roadmap based on a phased approach with practical steps that RBI may consider as it develops policies with ambitious timelines on climate scenario analysis, stress testing and disclosure requirements.

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How to cite: Raga, S., Vaze, P., Tan, E. and Gilmour, A. (2023) The treatment of physical climate risks by central banks – insights for the Reserve Bank of India. ODI Report. London: ODI.

Acknowledgements

About this publication

This paper is part of a project that aims to help unlock finance for India's transition to a resilient and low-carbon economy. This paper benefited from interviews/written feedback from officials of Banco Central do Brasil, the Bank of England, the Hong Kong Monetary Authority, Bank Negara Malaysia, Bangko Sentral ng Pilipinas and South African Reserve Bank. The findings in this paper will form part of a more comprehensive report to be published in 2024.

The authors would like to thank Sarah Colenbrander for feedback on an earlier draft. We are also grateful to reviewers from Auctus ESG (Smitha Hari, Sudha Meiyappan and Namita Vikas), Climate Bonds Initiative (Lily Burge) and SOAS University (Yannis Dafermos).

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Acronyms

BCB	Banco Central do Brasil
BCBS	Basel Committee on Banking Supervision
BIS	Bank for International Settlements
BNM	Bank Negara Malaysia
BoE	Bank of England
BSP	Bangko Sentral ng Pilipinas
FCA	Financial Conduct Authority (UK)
FSB	Financial Stability Board
CRST	Climate Risk Stress Test
GFANZ	Glasgow Financial Alliance for Net Zero
HKMA	Hong Kong Monetary Authority
IIASA	International Institute for Applied Systems Analysis
NGFS	(Central Banks and Supervisors) Network for Greening the Financial System
PRA	Prudential Regulatory Authority (UK)
RBI	Reserve Bank of India
RE	Regulated entity
SARB	South African Reserve Bank
WB	World Bank
WMO	World Meteorological Organisation

Executive summary

Central banks, financial authorities and their associations – the Network for Greening the Financial System (NGFS), the Financial Stability Board (FSB) and the Basel Committee on Banking Supervision (BCBS) – have set out principles, guidelines and methodological approaches for assessing climate risk exposure of regulated entities¹ (REs) and the financial sector as a whole. These broadly recommend that REs have board-level management oversight of climate risks, collect data on their exposure to climate risks, undertake internal stress tests to ensure these risks are being suitably managed, and disclose material climate risks to shareholders and other stakeholders.

The Reserve Bank of India (RBI) recognises the climate challenge and is engaged with Indian REs on this agenda. This paper aims to contribute to these efforts. It draws on structured interviews with officials of selected central banks in June–August 2023 and review of selected central bank reports to understand their physical climate risk assessment and disclosure regimes. Separate forthcoming papers are being undertaken focusing on issues on transition risk assessment and disclosure in the Indian context.

For this paper, case studies cover the Banco Central do Brasil (BCB), the Bank of England (BoE), the Hong Kong Monetary Authority (HKMA), Bank Negara Malaysia (BNM), Bangko Sentral ng Pilipinas (BSP) and the South African Reserve Bank (SARB). The practical experiences of these six central banks and the literature review (NGFS, 2023; FSB and NGFS, 2022) highlight some common challenges:

- The lack of technical skills in REs on climate risk assessment and significant variations in resources among REs.
- Concerns about available data, especially granular counterparty exposure to physical climate risks and location of at-risk assets.
- The sensitivity of assumptions used in different climate and financial modelling techniques.

In view of the above challenges, most emerging market central banks indicated that the main objective of ongoing policy efforts is to enhance the capabilities of banks to understand and manage exposure to physical climate risks, rather than to compare banks or modify regulatory capital requirements.

In addition, interviewees from central banks underscored the advantages of undertaking a phased approach, allowing for pro-active awareness-raising on climate issues, laying out regulatory expectations and scoping technical capacities and data availability among REs at the early stages

¹ For consistency, regulated entities (REs) in this paper broadly refer to financial institutions under the supervision of central banks/monetary authorities.

of policy development. However, to ensure REs upgrade internal capabilities in a timely fashion, an ambitious but realistic roadmap needs to be established at the outset. The approach gives room for cross-learning among REs and feedback between central banks and REs, providing important inputs for designing and implementing guidelines and targeted capacity-building support for REs. A phased approach also provides room for domestic regulators to consider developments in international standards on climate-related assessments and disclosure (NGFS, 2020; BIS, 2022a; TFCO, 2017).

Interviewees from central banks mentioned a number of other specific initiatives they undertook to guide REs in the conduct of their physical climate (and transition) risks, management and disclosure:

- Establishing working groups with leading REs to debate insights and find solutions to industry concerns regarding handling climate risks (HKMA, BNM, BoE).
- Leveraging existing climate risk assessment frameworks by banking associations (BCB), international knowledge sharing platforms such as NGFS (SARB), and international development partners (e.g. IMF, World Bank) (BSP).
- Preparing datasets of publicly available and locally applicable economic and physical data to supplement REs' own data (BNM).
- Adopting a pragmatic approach in the face of data or capacity limitations, such as conducting pilot climate stress-testing exercises on a sample of volunteer banks (HKMA, SARB) or reducing the complexity of regulatory requirements for smaller REs (BSP, BCB).
- Tailoring scenarios for national climate hazards and economic structures, providing a specific scenario (e.g. most significant physical climate hazard) (BoE, BNM, SARB) and narrow scope of analysis (e.g. credit and operational risks) (HKMA, SARB, BCB), or focusing on specific vulnerable sectors (HKMA) and geographical areas (BCB) at an earlier stage.
- Institutionalising inter-agency collaboration to ensure harmonised terminologies/taxonomies and data disclosure requirements by different financial regulators (e.g. covering banks, insurance firms and other non-banking financial institutions). Examples are the BoE-Financial Conduct Authority Climate Financial Risk Forum and the Philippines' Inter-Agency Technical Working Group on Sustainable Finance.

Based on the lessons from the literature and the practical experience of six central banks, Table ES1 provides a stylised roadmap with practical steps that central banks might adopt to implement climate risk assessment and disclosure within their jurisdictions.

Table ES1 Stylised roadmap for establishing physical climate risk assessment and disclosure regimes

Phase	Suggested action points
Phase I Raising awareness of REs on climate-related issues	1. Central bank senior staff communication on the importance of climate change, and introducing climate change issues in central bank mandates/objectives 2. Identifying data availability and technical capabilities of REs through consultations (e.g. via a working group), ad hoc surveys, stock-taking exercises
Phase II Developing policy guidance on physical climate risk assessment and disclosure requirements	3. Issuing regulatory expectations on REs' physical climate risk assessment, management and disclosure, in consultation with REs and leveraging global practice and guidance by international standard-setting bodies 4. Some central banks might undertake top-down assessment of exposure or stress tests with internal data and models 5. Solicit feedback and co-develop detailed policy guidance with REs and stakeholders
Phase III Understanding and implementing measures on physical climate risk assessment and disclosure requirements	6. Provide guidelines and conduct a pilot climate scenario analysis and stress-testing, allowing for flexible and narrower scope in earlier stages when there are major data limitations and variation in technical capacities among participating REs 7. Enhance climate scenario analysis and stress-testing guidance based on disclosed results and lessons learned from pilot exercises
Phase IV Continuous refinement of policies and capacity-building on climate risk management and disclosure	8. Amend or issue new regulations to mainstream climate risk assessment and disclosure in supervisory processes. Consider implementing compliance under the principle of proportionality, or providing room for transition plans to help REs build data and technical capacities 9. Provide targeted support for capacity-building efforts based on stakeholder feedback, as well as local and international policy developments

The RBI is at an important juncture in issuing regulatory guidelines specifically on climate risk assessment and disclosure. If situated in the above roadmap, the RBI has already conducted Phase I activities, including central bank communications recognising the importance of climate risk on financial sector stability, conducted stocktaking exercises on REs' technical capacities and preparedness for climate risk assessment, and undertaken studies on macroeconomic implications of physical and transition risks. It is important not to lose this momentum by setting clear and ambitious timelines on the next policy steps.

The RBI is yet to issue specific policy guidance on climate scenario analysis, stress-testing and disclosure frameworks. Once policies are in place, RBI should conduct intensive and patient engagement with REs, assess the scope for mandatory requirements and application of the principle of proportionality, and keep abreast of international technical and policy developments on climate-related issues.

1 Introduction

1.1 Physical climate risks and banking supervision

The 2023 hot season came early in India. In April, 11 people died from heat stroke at a rally in Maharashtra (Shiraz, 2023). That same week, many cities endured noon temperatures greater than 40°C, obliging schools to adjust their lesson times or bring forward their summer breaks (Indian Express, 2023).

Emerging market economies, especially those in the tropics like India, are highly vulnerable to physical climate risks (CEEW, 2020). A high proportion of GDP is earned from climate-sensitive sectors such as agriculture; households have lower levels of savings to cushion against climatic shocks and climate change – especially higher temperatures and more uncertain rainfall – has more serious and more negative consequences in tropical countries.

The physical effects of climate change have economic ramifications through various transmission channels (BIS, 2021a; NGFS 2022b, 2022c). For example, parents stay home to look after children, and large public gatherings have to be rescheduled or held indoors. These impact household budgets and business profits, which in turn has implications for credit extended by banks to economic actors.

Central banks have made great strides in detailing the interactions between climate change, credit risk and bank exposure (NGFS, 2019). Since 2017, they have coordinated their efforts on research and shared best practice through the NGFS. The RBI joined NGFS in April 2021. In November 2022, the FSB and NGFS published a survey of the analysis of climate scenarios undertaken by central banks (see Section 3). NGFS is also surveying network members' views on data quality and availability – a recognised challenge in operationalising climate physical risk analysis (NGFS, 2022a).

Central banks also coordinate through the BCBS to create common rules that all major economies' central banks and supervisors incorporate into regulation. In June 2022, the BCBS published a set of principles for managing and supervising financial risks from climate change (BIS, 2022a). Under the heading 'risk management', principle 6 asks banks to 'identify, monitor and manage all climate-related financial risks that could materially impair their financial condition ... and establish a reliable approach to identifying, measuring, monitoring and managing those risks'.

The RBI recognises that the financial sector is impacted by climate change, and the role it needs to play. On 8 February 2023, at the monthly Monetary Policy Committee meeting, RBI Governor Shaktikanta Das set out RBI's intention to publish guidance on:

1. A broad framework for acceptance of green deposits.
2. A disclosure framework on climate-related financial risks.
3. Guidance on climate scenario analysis and stress testing (RBI, 2023c).

This announcement builds on RBI's July 2022 discussion paper on climate risk and sustainable finance (RBI, 2022b). The paper sought stakeholder views on two important new supervisory themes: exploring how forward-looking tools like stress testing and climate scenario analysis could be used to identify and assess vulnerabilities in REs; and practical challenges from climate risk-related financial disclosure and reporting for REs. Recent policy and research efforts by RBI on climate-related issues are discussed in Section 3.

1.2 Purpose and structure of this paper

This paper is intended to assist the RBI in its efforts to produce guidance on identifying, standardising, measuring, stress testing, managing and disclosing REs' exposure to financial risks from likely physical climate change. This aim echoes the objectives set out by BCBS and the RBI. There are numerous challenges in producing such analysis: the extent of likely climate change, the modelling of the financial risks arising from physical climate change, locating and assembling data on individual banks' exposure, and lack of capacities within REs, especially smaller players. Data on exposure will often be geographically localised, vary with lenders' efforts to climate-proof their operations and be subject to huge uncertainty about likely climate change.

No country has resolved these issues. But important advances are being made, and it is instructive to learn from other countries' experiences, especially other emerging markets. This paper draws on international best practice and supplements this with interviews with central banks in selected emerging markets and advanced economies to assess the feasibility of approaches on physical climate risk assessment and disclosure within India.

The report does not consider climate transition risks associated with policies to curb greenhouse gas emissions. These are discussed in an accompanying report. The focus is on microprudential regulation of individual REs rather than systemic risks, which are the domain of macroprudential regulation.

The paper is structured as follows.

Section 2 discusses physical climate risks and the financial sector, and sets out the key concepts/definitions used – chronic and acute physical climate risks; transmission mechanisms for physical climate change impacting on the bank balance sheet; the key economic sectors being impacted. The section also includes stylised pathways that central banks commonly use in developing their physical climate risk assessment and disclosure regimes.

Section 3 surveys approaches and methodologies for physical climate risk assessment used in selected (mainly emerging market) countries in terms of scenario-building, stress testing and disclosure. Recent policy efforts by RBI are also discussed.

Section 4 provides conclusions and options for RBI's consideration, and a practical roadmap that RBI and other central banks may consider in establishing physical climate risk assessment and disclosure regimes.

2 Physical climate risks and the financial sector

This section presents the key concepts/definitions, parameters and frameworks used in this paper. The channels of impact from climate-related physical risks are next outlined. Third, the section provides stylised pathways that central banks commonly use as they develop their climate-related physical risk assessment and disclosure regimes, drawing on existing literature and practice in the case study examples (details are presented in Section 3).

2.1 Concepts and definitions

Adverse climate change effects can be a source of financial risks to banks. The Intergovernmental Panel on Climate Change (IPCC, 2020) uses the term ‘risks’ when referring to potential adverse consequences and uncertainty related to those consequences. BIS (2021) describe physical climate risks as ‘economic costs and financial losses’ arising from increasing severity and frequency of:

- **Acute physical risks:** extreme climate change-related weather events such as lethal heatwaves, landslides, floods, wildfires and storms.
- **Chronic physical risks:** longer-term gradual shifts in climate such as changes in precipitation, extreme weather variability, ocean acidification and rising sea levels and average temperatures.

There are further indirect effects of climate change, such as through desertification, water shortage and the degradation of soil quality or marine ecology.

Physical climate risks may manifest as financial risks for banks. BIS reports describe the main risks as follows:

- **Credit risk:** the potential that a bank borrower or counterparty will fail to meet its obligations in accordance with agreed terms (BIS, 1997). One aspect of this relates to ‘credit concentration risk’ wherein a bank’s single exposure or group of exposures may potentially produce large losses that threaten the bank’s health or ability to maintain its operations (BIS, 2023a).
- **Market risk:** the risk of losses arising from movement in market prices (e.g. risks around defaults, interest rates, credit, equity or foreign exchange) (BIS, 2023b).
- **Liquidity risk:** risk to the ability of a bank to fund increases in assets and meet obligations as they come due, without incurring unacceptable losses (BIS, 2008).
- **Operational risk:** risk of loss resulting from inadequate or failed internal processes, people and systems or from external events (BIS, 2022b).

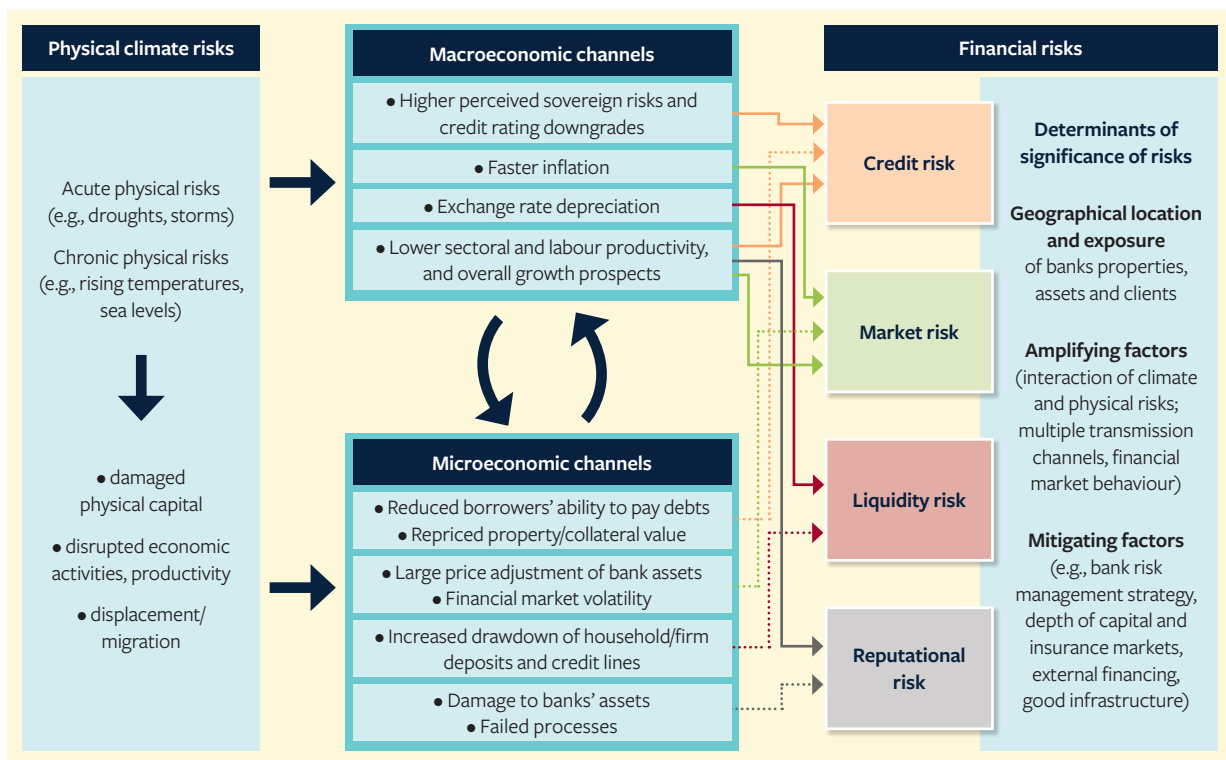
- **Reputational risk:** risk arising from negative perceptions on the part of customers, counterparties, shareholders, investors, debt-holders, market analysts or other relevant parties that can adversely affect a bank’s ability to maintain existing, or establish new, business relationships and continued access to sources of funding (BIS, 2019).

Transmission channels refer to the causal chains tracing how physical climate risk events directly and indirectly affect REs’ financial risks through their counterparties (e.g. households, firms, non-banking REs), assets and the financial system and economy in which they operate (BIS, 2021a).

2.2 Transmission of physical climate risks to financial risks

Figure 1 illustrates pathways through which physical climate risks translate to increased financial risks for REs. Banks’ financial risks may arise from the impact of physical climate risks through two main routes. The first is through *macroeconomic* channels like growth, labour productivity, interest rates, inflation, commodities and foreign exchange rates. For example, Buhr et al (2018) find an increase in climate vulnerability (e.g. propensity to be affected by rising sea levels, floods and droughts) increases developing countries’ borrowing costs by 117 basis points. Higher public borrowing costs and future debt servicing may increase the risk of public debt distress or default, which may increase the credit risks of REs with large lending exposures to governments.

Figure 1 Transmission channels of physical climate risks to banks’ financial risks



Source: Authors, modified graph based on BIS (2021a), NGFS (2022b, 2022c).

The second route is through microeconomic channels in which physical climate events may directly affect bank clients, individual bank operations and financial assets, and the financial system through which REs source their funds (e.g. interbank linkages) (BIS, 2021a). For example, empirical evidence suggests that weather-related disasters associated with extreme rainfall are associated with higher non-performing loan (NPL) ratios of banks in the Philippines (Bayangos et al., 2021) and the US (Noth and Schüwer, 2023).

The ultimate impact of physical climate events for REs' balance sheets may be mitigated or amplified by several factors. One major consideration is the geographical exposure of bank properties, assets and clients in locations vulnerable to physical climate change (e.g. near coastal areas, urban areas with poor drainage systems for flooding).

Another amplifying factor would be the feedback effects between macroeconomic and microeconomic channels. For instance, extreme droughts may affect agricultural production and increase food prices, pushing up inflation. Fast acceleration of inflation affects microeconomic agents through eroded purchasing power of households and firms, reducing the capacity of these agents to repay debts owed to REs, in turn increasing REs' credit risks. Interaction between physical climate risks (e.g. extreme rainfall and rising sea levels) may also amplify effects through the supply chain, for instance floods causing structural damage and disruption in logistics chains.

Meanwhile, there are mitigating factors that may help reduce REs' financial risks from physical climate events – including their risk management strategy, such as reducing loan exposures to or allocating capital buffers for climate change-sensitive portfolios, or putting in place business continuity plans. One climate stress exercise in Hong Kong suggests that, while annual physical climate scenario losses through credit risks may reach HK\$17.3 billion, expected operational losses are estimated to be much smaller (HK\$2.2 billion) in view of banks' business continuity plans (e.g. technology solutions, flexible work arrangements).

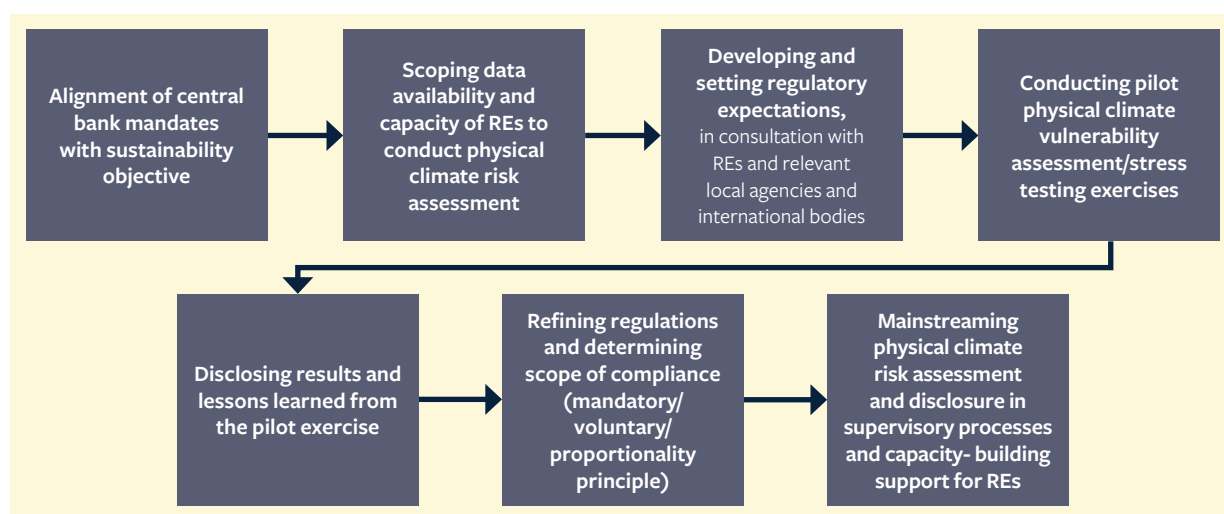
Assessing the financial exposure of banks stemming from physical climate risks is a complex exercise. It requires data or assumptions at each node of the pathways (e.g. the probability and magnitude of climate risk, hence the impact on macroeconomic and microeconomic agents, thence the impact on REs based on RE-level exposure to transmission channels and contagion between REs), which may interact and create non-linear effects.

As of November 2022, the FSB and NGFS had surveyed 53 financial authorities and identified 67 climate scenario analysis exercises among them. Of these, 35 had been completed. Two-thirds of the exercises considered physical climate risks, 33 of which focused on acute physical climate risks (FSB and NGFS, 2022). Section 2.3 presents the common practical steps taken by central banks in establishing and implementing their physical climate risk assessment and disclosure regime.

2.3 Climate risk assessment and disclosure regimes

Identifying the channels and quantifying the potential impact of physical climate events on REs is critical so that risk mitigation measures may be put in place. Figure 2 provides an overview of the practical steps taken by central banks in designing and implementing policies on physical climate risk assessment and disclosure, based on the review of literature and case studies (discussed in detail in Section 3).

Figure 2 Stylised pathway used by central banks in developing physical climate risk assessment and disclosure policies



Source: Authors

The first step often involves situating the relevance of climate change to central bank mandates. While environmental sustainability aspects are not explicitly included in central banks' primary mandates (NGFS, 2020; Dikau and Volz, 2019), for the majority of surveyed central banks there is scope within their operational frameworks to consider climate-related issues in the implementation of monetary policy (NGFS, 2020) and monitoring of financial stability (FSB, 2020). In addition, more than half of surveyed central banks that have some sort of financial inclusion mandate (Tissot and Gadanez, 2017) considered that it might be important to design and implement financial inclusion policies and regulations that focus on individuals, communities and MSMEs most vulnerable to climate change.

In the case studies of central banks examined in Section 3, early efforts include messaging to raise awareness on the increasing relevance of climate change impacts on central bank mandates (e.g. price stability, financial stability, financial inclusion, economic development), as well as the role, plans and vision (e.g. roadmap overview) of the central bank in the context of climate change. Central banks may also communicate their alignment with national plans (e.g. national targets to reduce greenhouse gas emissions), as well as regional and international central bank efforts (e.g. NGFS membership) on climate finance and risk management.

The next stages would usually involve early scoping of available data and modelling tools and the technical capacities of REs to conduct physical climate risk assessments. The latter is typically conducted through ad hoc surveys, targeted information requests from selected REs and stocktaking exercises (see FSB, 2022). Such scoping exercises help a central bank determine its approach to assessing the vulnerability of REs to physical climate change events. Physical climate risk assessment may be led by the central bank (a top-down approach), conducted by REs with central bank guidance on parameters (a bottom-up approach) or a combination. Each approach has its advantages and disadvantages (Table 1).

Table 1 Physical climate risk assessment/stress test approaches

Approach	Description	Pros	Cons
Top-down	Central banks apply their own calculations, assumptions on physical climate risk on REs' regulatory filings on their sectoral lending.	<ul style="list-style-type: none"> • Easier to plan and execute • Greater consistency in methodology, assumptions on risk metrics, and data sources • Allows comparability of results 	<ul style="list-style-type: none"> • Relatively limited data available to authorities on individual banks' exposures • May overlook idiosyncratic characteristics of REs' portfolio
Bottom-up	Central banks determine the scenarios and variables, and ask REs to perform their own assessment/ stress test (based on their own data, models, analytics) of how such scenarios will impact their balance sheet. This includes supporting REs to integrate climate risk models into their own risk frameworks.	<ul style="list-style-type: none"> • Greater depth of analysis from granular data available to REs (beyond what is reported to central banks) • Useful for raising awareness, building capabilities and sharing good practices among REs 	<ul style="list-style-type: none"> • Disparities in tools, capacity and expert judgement across REs, raising issues around comparability of results or whether aggregated results can be adopted for financial sector-level assessment

Source: Authors' compilation based on NGFS (2020); BIS (2021a); FSB (2022)

After considering data sources and technical capabilities, central banks issue policy guidance on how banks are expected to integrate climate risks in their operations, activities and risk management. Based on case studies conducted for this paper, policy guidance related to climate change often benefits from central banks' engagement with domestic REs, and collaboration with climate agencies and experts and regional and international knowledge-sharing platforms (e.g. NGFS). Information received via technical assistance from development partners (e.g. IMF, World Bank) and guidance from international standard-setting bodies (e.g. BCBS, FSB Task Force on Climate-Related Financial Disclosures, International Financial Reporting Standards (IFRS) International Sustainability Standards Board, among others) also provides useful inputs during the policy development stage.

Policy guidance would usually begin with regulatory expectations, with a focus on raising awareness and senior management buy-in. It usually entails qualitative expectations regarding REs' climate risk management, governance and strategies, aligned with recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD). Policy guidance for bottom-up climate scenario analyses and stress-testing exercises may entail specific guidance on the following elements:

- Scope of physical climate risks (e.g. acute and chronic events, or specific hazard with higher materiality in the country context).
- Types and time horizons of scenarios of physical climate change events/pathways.
- Use of backward-looking (historical) data and forward-looking data in scenario analysis.
- Balance sheet assumptions – *static*, where balance sheet composition is assumed to remain unchanged over time; or *dynamic*, where management actions in response to climate change developments may change balance sheet composition.
- Assumptions/information on transmission channels of physical climate risks (e.g. macro, micro, sectoral) to financial risks.
- Qualitative and/or quantitative methodologies to assess financial risk exposure (e.g. by specific risk category – credit, market, operational) at the counterparty and/or portfolio level.
- Disclosure of data, assessment methodologies and results.

These guidance documents often include localised and global data sources, as well available methodological references (in the public domain and through third-party services) that banks may utilise in their assessment exercises. For example, the BNM provides a Data Catalogue Report with accompanying excel spreadsheet of 82 local and international data sources, half of which are related to physical climate vulnerability and impact, which REs may explore when undertaking climate stress-testing (more on this in Section 3.1.4).

Appendix 1 provides a list of public and commercial sources of physical risk assessment methodologies that may be relevant to the Indian context. Methodologies are reviewed by type of physical risk (acute, chronic), level of analysis (asset, firm, sector, country and portfolio), impact channels, methodologies for assessing risk and data requirements. Given the range of data and methodologies available publicly or commercially, policy guidance or regulatory expectations from central banks on the scope and variables to consider during REs' physical climate risk assessment is warranted.

Once regulatory expectations are in place, most of the central banks in this study conducted pilot exercises for climate risk assessment, scenario analysis and stress-testing. These exercises are mostly designed to raise awareness and increase understanding of the capacities of and challenges faced by REs in implementing central bank guidance. Box 1 provides an overview of some methodological/modelling approaches to estimating the macroeconomic/financial impact of physical climate risks.

Box 1 Broad methodological approaches to a physical climate financial exposure and risk assessment

- 1. Exposure mapping and measurement of climate risks.** Involves identification indicators or metrics that can be mapped and monitored to indicate geographical risk concentrations and type of hazards and their corresponding probability and potential severity. For example, banks (and supervisors) may conduct geospatial mapping of bank portfolios (banking sector assets) in regions at high risk of flooding to identify bank exposure to elevated flood levels. Climate risk areas are usually identified based on historical data, publicly available information from government agencies or climate risk scores by commercial vendors. Exposure mapping may be portrayed qualitatively or quantitatively, such as through heatmaps and climate risk scores or ratings.
- 2. Models to translate climate risks to economic impacts.** To quantify climate-related financial risks, banks and supervisors need to identify the paths through which climate affects economic variables, which in turn affect the performance of bank assets. Some modelling techniques include: i) integrated assessment models (IAMs) linking climate risk drivers to economic growth impacts; ii) input-output models quantifying static economic linkages among sectors and geographic areas to trace impacts of climate shocks to a given industry or region; and iii) general equilibrium models capturing interactions between sectors and agents in the economy. These models have strengths and weaknesses in terms of complexity, assumption validity, transparency, data availability and computational burden (see BIS, 2021b). Nevertheless, the results of these models are utilised as inputs to scenario analysis, linking economic damage from climate events to risk in bank portfolios.
- 3. Climate scenario analysis** is a forward-looking projection of financial risk outcomes through the following steps: i) identifying physical risk scenarios; ii) linking the impacts of scenarios to banks' financial risks and strategies; iii) assessing counterparty and/or sector sensitivities to those risks; and iv) extrapolating the impacts of those sensitivities to calculate an aggregate measure of exposure and potential losses. Physical risk scenario analysis may be conducted at different levels of granularity and a wide range of plausible scenarios. For instance, the scope of scenario analysis may focus on a specific hazard (e.g. droughts), assess the potential economic impacts of physical climate events under an extreme scenario (e.g. RCP 8.5), and evaluate the implication of these impacts on specific financial exposure of the bank (e.g. credit risk at the portfolio level) over a given time horizon.
- 4. Climate stress testing** is a sub-set of scenario analysis wherein the resilience of banks or the financial system against severe but plausible shock scenarios is assessed through capital or liquidity targets. Given climate data and modelling limitations, stress-testing exercises are typically exploratory rather than serving as a basis for policy changes (e.g. capital adequacy requirements).
- 5. Sensitivity analysis** is another a sub-set of scenario analysis. It is used to assess the impact of a specific variable on outcomes – for instance, by observing changes in scenario outputs if one parameter is altered across multiple scenarios.

Source: Compiled based on BIS (2021b)

Pilot climate stress-testing exercises are often conducted among volunteer participating banks or banks identified as systemically important domestically, but in most cases the sample comprises a good representation of total banking sector assets. In pilot exercises using the bottom-up approach, central banks typically provide a narrow scope for assessment by setting parameters. These exercises may focus on a specific peril (e.g. droughts or floods), time horizon (e.g. short- to medium term), sector (e.g. real estate, agriculture), and financial risks to be assessed (e.g. credit and market risks). Engagement between supervisors and REs during pilot exercises often provides a useful learning platform, especially from foreign banks that already typically adopt international climate standards and sophisticated methodologies based on internal policies from headquarters.

Initial results from bottom-up pilot climate stress-testing exercises provide lessons critical for refining policy regulations and designing targeted capacity-building support for REs, including data and technical capacity limitations and challenges around the comparability and robustness of methodologies across different REs.

Whether central banks' policy guidance translates into mandatory regulations or voluntary compliance depends on several factors, including capacity constraints, data gaps and developments in methodological tools and international standards.

Global initiatives remain largely voluntary – the NGFS, Basel Committee and TFCDD encourage effective climate-related risk management and supervision and promote principle-based disclosure, rather than setting thresholds and disclosure standards (NGFS, 2020; BIS, 2022a; TFCDD, 2017). Even the ISSB standards on sustainability and climate-related disclosures (IFRS S1 and IFRS S2) released in June 2023 are designed for 'proportionality'² and phased requirements, depending on company circumstances. All else being equal, efforts expected on implementing assessment and climate-scenario analysis are likely to be less from companies with limited resources than well-resourced companies (IFRS, 2023a).

In the case studies, central banks implemented different levels of compliance requirements. For example, the BSP implements mandatory regulations on integration of ESG-related issues in banks' risk management and disclosure, but does so under the principle of proportionality and provides room for banks to submit transition plans if they are not able to comply within the set timeline. For BCB, disclosure requirements are more rigorous for REs holding larger assets. For the BNM, ongoing climate stress testing is mandatory for all banks, investment banks and insurers, including professional reinsurers (more details in Section 3).

The next section looks in more detail at the selected case studies of central banks (BCB, BoE, BNM, BSP, HKMA and SARB), and their physical climate risk assessment and disclosure regimes.

2 Proportionality refers to application of requirements that are 'proportionate' to the range of capabilities and preparedness of companies (IFRS, 2023a). Based on IFRS (2023b), mechanisms to address proportionality include: a) the use of reasonable and supportable information that is available without undue cost or effort; and b) consideration of an entity's skills, capabilities and resources.

3 Physical climate risk assessment and disclosure in practice

This section features six case studies of approaches central banks have adopted to including physical climate risks in their supervision of REs and provides an overview of the latest initiatives by the RBI on its physical climate risk assessment. The selection of case studies was informed by the FSB and NGFS (2022) survey reviewing climate scenario analyses of 53 institutions in 36 jurisdictions.

The criteria for selection were that a physical climate risk assessment had been conducted, and that the results of the exercise had been published. The first filter yielded 13 central banks, mainly from high-income countries and emerging markets. The list was further narrowed for relevance to the Indian context (e.g. considering income level, geographical location, level of financial development, scope of physical climate risk assessment).

Using these filters produced the list of six case studies: Banco Central do Brasil (BCB), Hong Kong Monetary Authority (HKMA), Bank Negara Malaysia (BNM), Bangko Sentral ng Pilipinas (BSP), and South African Reserve Bank (SARB). The Bank of England (BoE) was also included to illustrate policy efforts at a relatively advanced stage. The case study analysis is largely based on review of published central bank statements and reports, complemented by interviews with central bank officials. Interview guide questions are in Appendix 3.

An overview of the main characteristics of the case studies is in Table 2. ‘Top down’ refers to an internal assessment of climate risk undertaken by the central bank. ‘Bottom up’ refers to physical risk assessments REs have been asked to undertake by the central bank. ‘Scenarios’ refers to any scenario for stress testing the central bank has supplied, for example drawing from NGFS and IPCC scenarios. ‘Data supplied’ refers to any assistance the central bank has provided in assembling and sharing of physical climate risk data to REs.

Table 2 Physical risk assessment* approaches by selected central banks

	BCB	BoE	BNM	BSP (policy guidance)	HKMA	SARB
Top-down	Yes		Yes (2019)			Yes (2021 – to validate and benchmark bottom-up results)
Bottom-up		Yes (2021)	Yes (2024)	Yes	Yes	Yes (2021 – scenario provided)
Sector focus/ scope	All sectors in high-risk areas to droughts and heavy rains	All	All	All	Mortgages, property-related lending, bank operational losses	Drought-sensitive sectors
Banking and insurance sector coverage	Banking sector	Both	Both	Banking sector	Banking sector	Banking sector
Scenarios supplied	Yes (consistent with IPCC RCP 8.5 scenario)	Yes (NGFS scenario)	Yes (NGFS scenario)	Yes (suggests NGFS scenarios)	Yes (consistent with IPCC RCP 8.5 scenario)	Yes (drought scenario based on NGFS)
Climate data supplied to REs (for bottom-up approach)	No	No	Yes	Yes (online sources of local hazard maps)	No	Yes (rainfall data for drought scenario)

Note: *Physical risk assessment broadly refers to exposure assessment, scenario analysis and stress-testing exercises or policy guidance provided by selected central banks.

Source: Authors

3.1 Banco Central do Brazil (BCB)

Background

Brazil's economy is highly susceptible to climate risks because of the major role played by export-oriented agriculture and climate-sensitive renewable energy (hydroelectricity and biofuels) in its economy. Parts of the country have long been exposed to physical risks – especially drought – that will likely become more frequent and severe with climate change.

The BCB has been encouraging Brazilian banks to support the government's Social and Environmental (S&E) agenda. Key developments in the last 10 years include:

- Since 2014, REs licensed by the BCB have had to develop S&E risk management workplans and Policies for Socio-Environmental Responsibility (PRSA).
- Since 2017, REs must devise a risk management structure and governance to mitigate S&E and other risks, and disclose S&E risks and include them in their capital adequacy considerations.
- In 2019, the Federation of Brazilian Banks (FEBRABAN) published simplified guidance for estimating exposure to climate risk, providing banks with a starting point to voluntarily disclose their climate risk.
- In 2021, the BCB laid out disclosure requirements for Social, Environmental and Climate-related Risks and Opportunities (GRSAC) (BCB, 2021). Climate risks were also integrated into the 2014 PRSA and the 2017 risk management requirements.
- In 2022, the BCB undertook a top-down stress test of banks to assess vulnerability to two drought scenarios, using in-house data.
- In 2023, the BCB undertook a second top-down stress test of banks, this time assessing vulnerability to two heavy rain scenarios, using in-house data.

The following discussion focuses on BCB's climate stress-testing exercises and policies related to climate-related disclosure for banks.

Scope of stress-testing exercise and data availability

BCB has undertaken exploratory top-down stress-testing exercises using internal data and models, with the aim of promoting better understanding of climate risks in the financial system.

In cooperation with government agencies, the exercises considered the impacts of extreme climate scenarios not only on the financial sector, but also on energy, food and health security. Impacts under different climate scenarios were estimated at the municipality level. The exercises focused only on the exposure of loans in medium- and high-risk areas; they did not attempt a projection of financial losses to climate risks.

Data on bank credit distributions between sectors and locations was drawn from the BCB Credit Bureau (SCR) (BCB, 2022). Drought and rain projections are based on data from AdaptaBrasil, a portal developed by the Ministry of Science, Technology and Innovation. AdaptaBrasil consolidates climate impact data across two time horizons (2030 and 2050), in line with IPCC scenarios Representative Concentration Pathway of greenhouse gases (RCP) 4.5 and RCP 8.5.

Scenario-building

BCB's stress-testing considered drought scenarios for the exercise in 2022, and heavy rain scenarios for the exercise in 2023. Meteorological projections used were based on data from AdaptaBrasil, which is consistent with the IPCC RCP 8.5 scenario for 2030 and 2050. This is the most pessimistic IPCC scenario, as the goal of the exercises was to evaluate the financial system's exposure to extreme drought and heavy rains.

Transmission channels were identified for the stress-testing exercises. To assess the potential impacts of drought, the stress-testing exercise covered economic activities that make intense use of water. For the exercise with heavy rain scenarios, it is presumed that heavy rains can damage or destroy buildings and facilities, and cause inventory contamination and degradation of logistics infrastructure. Threat levels were based on the maximum annual rainfall over five days, and on the total annual rainfall of days above the 95th percentile (to gauge one-day intensity). The exercises were conducted with static balance sheet assumptions.

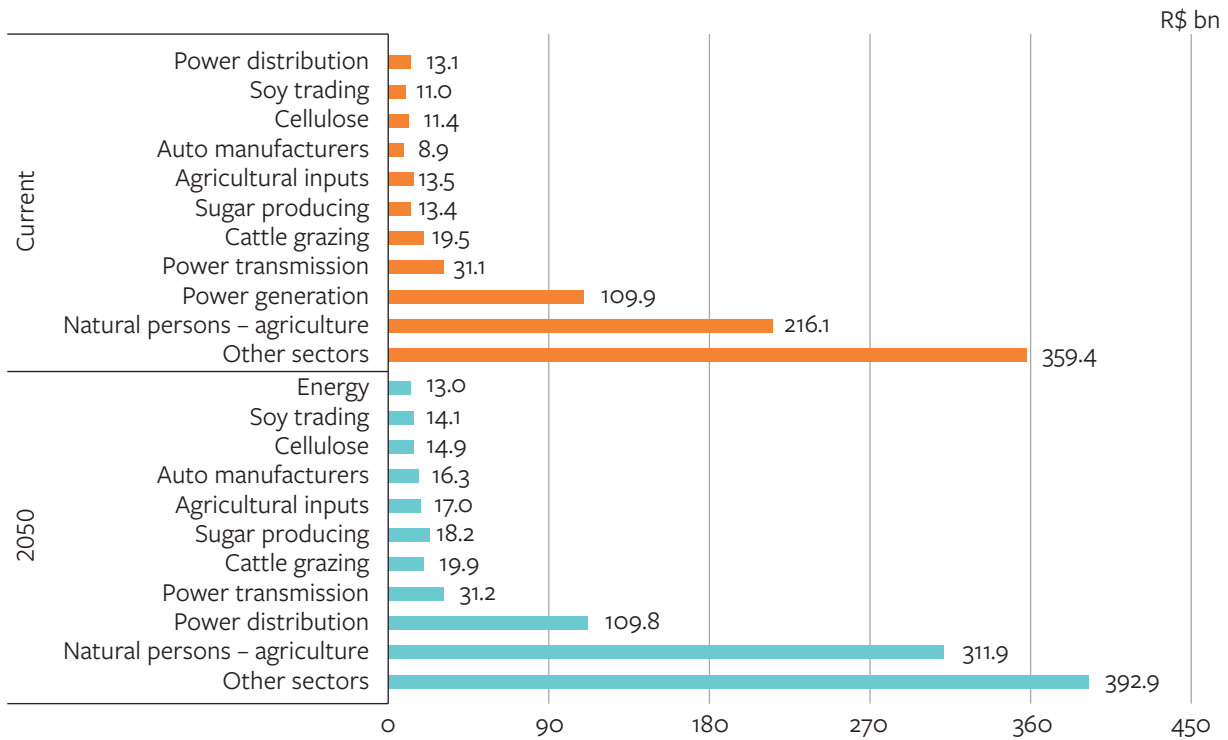
Stress-testing results

In the first exercise, BCB finds that 16% of current loans are in municipalities with high or medium drought risks and to debtors engaged in activities requiring intensive water usage. This ratio rises to 19% in both 2030 and 2050 scenarios. Some municipalities that are currently at low or medium risk of drought would be exposed to high risk of drought in the 2030 and 2050 scenarios, which would further increase the banking system's credit exposure. Loans to individual farmers ('natural persons – agriculture') and the energy sector have the highest concentrations of risk (Figure 3). Drops in profitability can also be a transmission channel of impacts, since up to 15% of the interest income of the financial system could be impacted in medium- and high-risk drought areas.

In the second stress-testing exercise, focusing on heavy rains, no municipality was assessed to be at high risk of heavy rains, so no current loans (baseline) are considered exposed. Under the 2030 scenario, however, 15.5% of credit portfolios are projected to be exposed, rising to 32.9% by 2050. In the latter case, exposure is spread across 281 banks which together represent almost 90% of total credit in the financial system.

The exercise was accompanied by a survey of REs on climate risks. Survey responses suggest that drought and floods were considered to be the biggest physical risks to REs, both in the short term (the next five years) and the long term (BCB, 2023).

Figure 3 Exposure to extreme physical risk (drought) in activities with intensive water usage, current loans in R\$bn



Source: BCB November 2022 Financial Stability Report

Policies for climate-related disclosures for banks

BCB regulations on climate-related disclosures are broadly applied in proportion to risk profile and bank segments based on the size of total assets, where S1 are the largest and S4 and S5 the smallest institutions.³

The 2021 GRSAC reporting requires most banks (S1–S4) to disclose climate risks on a consolidated basis. Disclosure of metrics is voluntary, as is disclosure of climate-related opportunities. Templates are provided covering how to report on governance, strategy and impacts, and management processes for social, environmental and climate-related risks. Templates are also provided for reporting quantitative indicators utilised in risk management and identified business opportunities related to social, environmental and climate issues. These reporting requirements adopt a proportional approach and draw on TCFD and BCBS frameworks and NGFS work.

3 S1 institutions are those with total assets equal to or greater than 10% of Brazilian GDP, or with relevant international activity. The total assets of S2 institutions are between 1% and 10% of Brazil’s GDP, S3 between 0.1% and 1%, S4 smaller than 0.1%. S5 institutions are also smaller than 0.1% but additionally use a simplified methodology to calculate minimum requirements of regulatory capital (BCB Resolution 4553, 2017).

BCB expects that banks consider the actual and potential impacts of climate risks on business strategies and capital adequacy. Climate-related risks should be included in financial institutions' Risk Appetite Statement (RAS) and in their stress-testing programmes – for S1 and S2 – using different scenarios and over different time frames. It is up to the REs to design appropriate scenarios themselves; while BCB has the discretion to require inclusion of particular scenarios, none have yet been proposed. BCB points to a FEBRABAN tool (see Box 2) as a starting point, but stresses that it is imperative that REs conduct their own assessments.

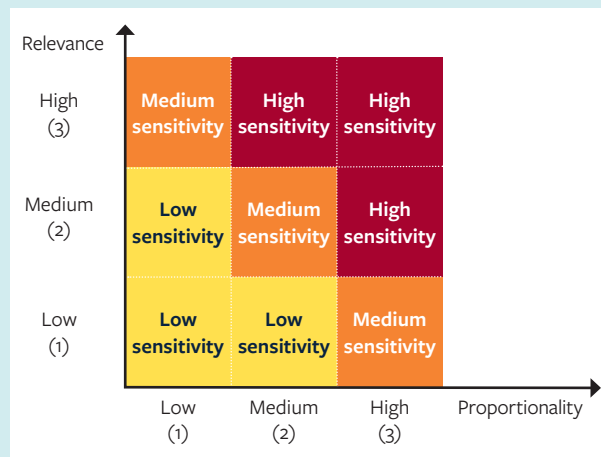
The first round of GRSAC disclosures is currently being assessed, and this will determine whether BCB supervision needs any standardisation.

Box 2 FEBRABAN's Climate Risk Sensitivity Assessment Tool

In 2019, FEBRABAN published a simple assessment tool for REs to estimate their exposure to climate and environmental risk. The tool is based on data that banks submit to BCB as part of their Credit Information System returns.

The assessment combines relevance (exposure to climate risk – is the bank invested in an exposed sector?) and proportionality (how much of a bank's portfolio is exposed to those sectors?). Assessments are then categorised into low, medium and high sensitivity to risks.

This sensitivity analysis is repeated at three levels: by sector, by client and by client operations. Sector and client levels of analysis yield useful information to the financial institution about the breadth of its exposure. Analysis at the level of client operations, however, still requires data on clients' assets by location. BCB considers this a useful start, but it requires additional refinement because it does not differentiate between transition and physical risks and does not sufficiently consider location data.



Source: FEBRABAN (2019) and written feedback from BCB officials received in August 2023

Key lessons and future plans

On the stress-testing exercise, BCB recognises data and modelling limitations. While AdaptaBrasil was found to be helpful as a source of data for climate impacts on water risk and Brazil's rural credit scheme has accurate location data on loans to agriculture, there were substantial data gaps on non-agricultural asset locations.

There were two main limitations to the modelling approach. First, the static balance sheet assumption may be unrealistic for scenarios that capture long-term climate impacts. Second, the use of historic data to build the stress-testing models may not capture the inherent uncertainty in long-term climate impacts and the possibility that these impacts will deviate from historical patterns.

To help the banking sector respond to climate risk, the BCB is establishing a coordination mechanism with other domestic financial regulators, and regularly consulting with regulated entities and interested partners. BCB officials indicated that the next phase of disclosure requirements, informed by the first round of disclosures currently under review, will be proportional – applying the segmentation system of REs – and informed by IFRS Sustainability Disclosure Standards released in June 2023. There are no current plans to conduct a bottom-up stress test.⁴

3.2 Bank of England (BoE)

Background

The BoE supervises UK-registered banks and insurers. It represents the UK in NGFS and is at the forefront of the Network's efforts to incorporate climate risks into bank supervision. It commenced work on climate change in 2016 under the leadership of former Governor Mark Carney, who helped establish both the NGFS and the TCFD (via the FSB). Since then, initiatives undertaken by the BoE related to physical climate risks include:

- Publication of a set of climate-related supervisory expectations for banks and insurers in April 2019, which were embedded by 2021 (BoE, 2019).
- Establishment of the Joint BoE-Financial Conduct Authority (FCA) Climate Financial Risk Forum (CFRF) convening senior financial sector representatives established in 2019.
- Publication of the second Climate Change Adaptation report in 2021 (BoE, 2021b).
- Addition of climate change as a secondary objective in the remits of the BoE's monetary and financial committees in March 2021 (BoE, 2022).
- Launch of the first round of Climate Biennial Exploratory Scenarios (CBES) in June 2021 (BoE, 2021a; 2022).
- Launch of the second round of CBES in February 2022 to explore in greater depth banks' and insurers' prospective responses to climate risks. The results were published in May 2022 (BoE, 2022).

4 Based on written interview response of BCB officials received in August 2023.

The BoE and the FCA (responsible for micro-prudential regulation) co-chair the CFRF. The CFRF meets every quarter and consists of 20 banks, insurers, asset owners and other interested parties representing a cross-section of the finance industry. It produces reports, guidance and best practice ‘by industry for industry’, available on the FCA website. These include practitioners’ experiences with implementing climate scenarios and stress tests. Sub-groups led by industry appointees convene taskforces comprising working-level practitioners.

The succeeding discussion lays out BoE’s experience and lessons learned in conducting the CBES. The first round of CBES was run by seven banks and 11 insurers, with the results published in June 2023. A second round was run in February 2022.

Scope of climate scenario analysis

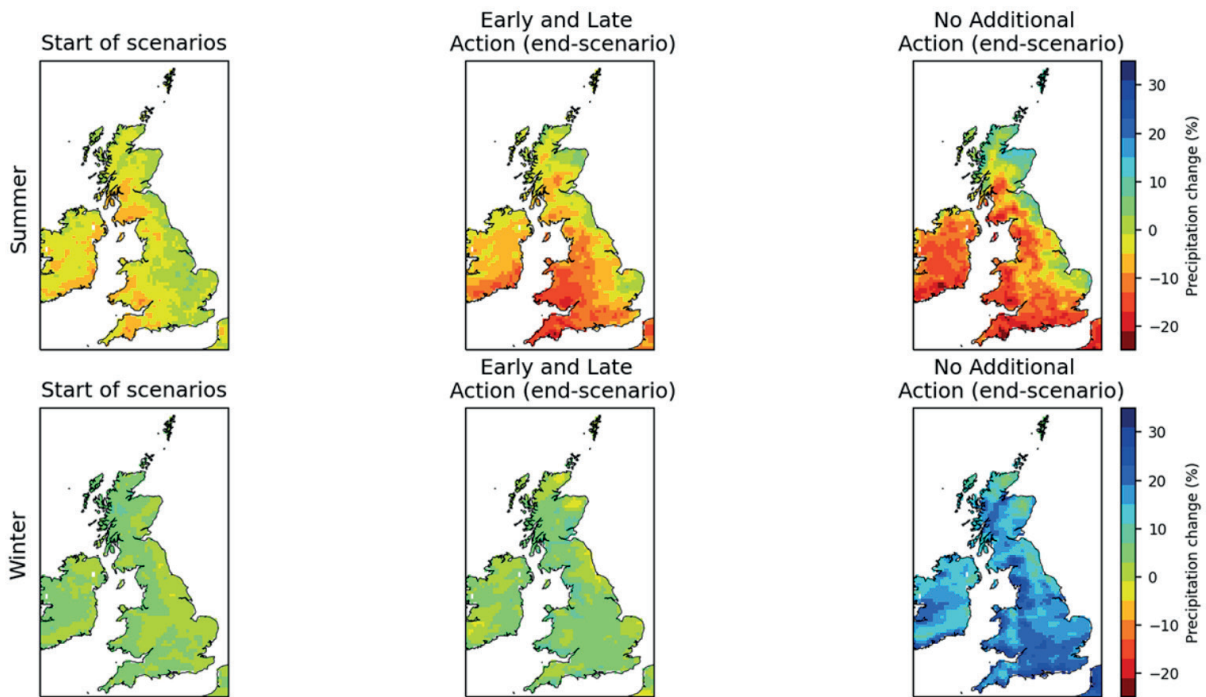
REs assumed static balance sheets for the CBES, and consider the impacts of transition and physical risks on counterparties. Three scenarios over a 30-year time horizon were developed: ‘Early Action’, ‘Late Action’ and ‘No Additional Action’. Scenarios were generated using the National Institute of Social and Economic Research’s NiGEM model and based on NGFS scenarios (Net Zero 2050, Delayed Transition and Current Policies), but included additional transmission channels and variables consistent with, but not identical to, many variables produced by the NGFS.

The scenarios take into account the time-limited subsidy to insurers for flood risk provided by the UK government (via the state-backed FloodRe), capping their exposure to flood risk to ensure that some localities do not become uninsurable. The scenarios vary the duration of the government backstop reinsurance support.

Data availability and technical capacity

CBES participants were provided with data on physical climate risks, particularly on summer and winter precipitation, sea-level rise and flooding risk. Figure 4 shows UK summer and winter precipitation for the base year and two of the scenarios, calculated by the Met Office on behalf of the BoE. NGFS data was used for rest-of-the-world’s physical impacts.

Figure 4 Change in average summer and winter precipitation since the late twentieth century in the CBES scenarios



Source: Met Office and BoE calculations (from Chart 4.3 BoE, 2021a)

Generally, most participating banks have the technical capacity to conduct the CBES climate scenario analysis. All but one participant reported heavy reliance on third-party services for modelling support and data collection with counterparties (CFRF, 2023). The most advanced banks had significant geographic and sectoral detail in their modelled risks. Insurers were more advanced in their capability to model physical risks with a high degree of geographic granularity. Participating banks and insurers also reported the following data and assumption challenges during the exercise (CFRF, 2023):

- Difficulty in projecting losses from the scenarios due to lack of knowledge on counterparties' emissions or transition plans.
- Most participants suggested that the static balance sheet assumption 'limited or even negated the usefulness of the results'. However, the BoE felt the assumption showed REs the impact of their current business models and prevented banks from simply assuming that they would divest their problematic assets to another entity, transferring risk elsewhere in the banking system.
- Participants found that the requirement to report counterparty analysis was counter-productive given uncertainties and lack of data, but the BoE included the requirement to encourage the generation of that data.

Key lessons and future plans

BoE found the CBES had pushed REs to identify gaps in their models, data and capabilities, and develop plans to address these to better measure and manage risks. The exercise encouraged REs, especially banks and insurers, to extend their time horizons beyond five years to 30 years for long-term strategy and lending decisions.

The results of the CBES highlighted issues with modelling, capacities and data availability. Feedback from one individual suggested the potential risk of many REs relying on the same third-party models and data providers (FCA, 2023), which may encourage group think.

REs felt that the responsibility for addressing the causes of climate change ultimately lies with governments, businesses and households, and the analysis suggested that the highest financial losses arose when no further action is taken. They stressed the need for a joined-up approach between financial regulators and government, especially on issues including disclosure and climate scenarios.

A BoE official said the CFRF and its working groups on data needs, modelling and strategy helped financial institutions establish 'leading practice' in a still-evolving field. In terms of policy implications, BoE's capital report (BoE, 2023) hinted that capital requirement penalties might be appropriate to incentivise financial resilience to the consequences of climate change (physical risks), but are not appropriate to address causes of climate change (transition risks). This echoes the BoE's Climate Adaptation Report (BoE, 2021b), that there might be a case for increasing the capital requirements for banks and insurers to increase their resilience to physical climate impacts, but risk weights should not be changed for climate transition risks. The report suggests more effective ways of reducing emissions (e.g. carbon pricing) than capital requirement penalties.

BoE has not decided whether to repeat the CBES. Supervisory expectations stipulate that BoE-regulated firms have to conduct climate scenario analysis on a regular basis, which BoE's supervisory activity will reinforce.

3.3 Bank Negara Malaysia (BNM)

Background

BNM has been integrating climate risks into its banking supervision work since 2019. In its 2019 annual report, it published results from an internal exercise looking at the banking and insurance industries' potential exposure to climate risks (BNM, 2020). It concluded that 10.3% of bank assets and 24.4% of insurance assets are potentially exposed. The risks were concentrated in loans and underwriting risks in the construction, utilities and transport industries.

In 2021, BNM published 'Climate Change and Principles-Based Taxonomy' (which aimed to reduce the scope for greenwashing of ESG-labelled financial products) (BNM, 2021). In 2020 it coordinated

the production of the ‘Report on the Roles of ASEAN Central Banks in Managing Climate and Environment-related Risks’, which recommended undertaking climate stress tests (Anwar et al., 2020).

In June 2022, BNM issued a discussion paper – ‘2024 Climate Risk Stress Testing (CRST) Exercise’ – proposing an industry-wide exercise for banks and insurers. It was followed in December with a policy document confirming the CRST. This case study focuses on BNM’s ongoing stress test exercise which will be implemented in 2024. The following discussion highlights the CRST process and guidance materials prepared to assist banks and insurers.

Identifying needs and objectives

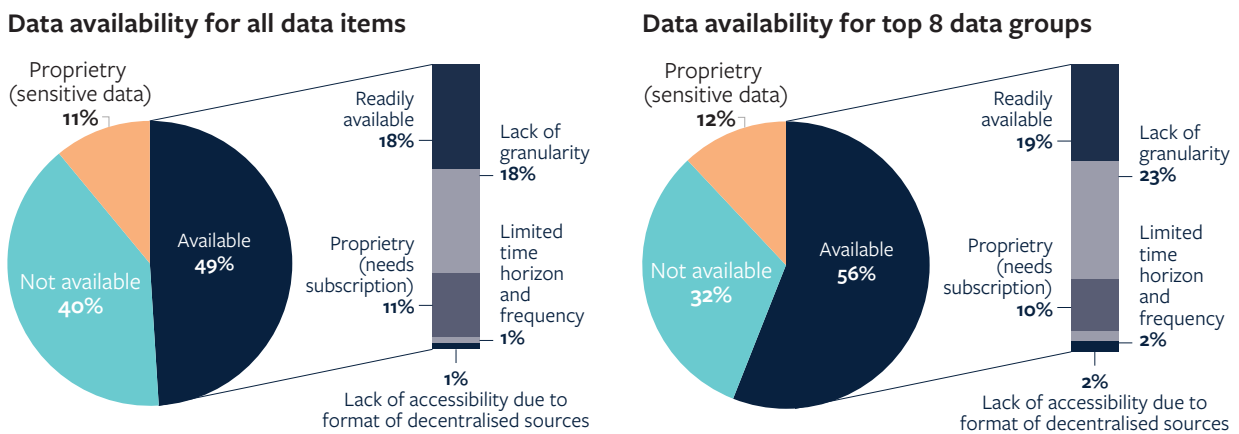
The 2024 CRST is intended to:

- quantify REs’ exposure;
- facilitate REs’ capacity-building;
- strengthen stress testing to incorporate climate-related risks;
- initiate discussions among board and senior management;
- identify responses that REs might adopt;
- identify current gaps and challenges faced by REs; and
- accelerate REs’ data collection and improve data quality to manage climate-related risks.

Available data and technical capacity

The ‘Joint Committee on Climate Change’ (JC3), consisting of staff from BNM, banks and insurers, published a Data Catalogue Report with accompanying excel spreadsheet in December 2022 (BNM, 2022c). The report identified 82 data items encompassing physical and financial data and ESG scores. Discussions with data providers suggest just 49% are currently available and 18% are readily available. Figure 5 shows the challenges in accessing data.

Figure 5 Climate data needs and availability



Source: BNM (2022a)

Of the 82 indicators in the spreadsheet, 27 relate to physical climate risk. These include meteorological data (temperature, rainfall), physical data (sea-level rise, river flows), composite indicators (coastal vulnerability index) and financial data (litigation claims, insured losses). Backward-looking data, disaggregated by district, could be used by insurers to calibrate their models of weather-related losses, for projecting future losses in the BNM scenarios. Many of these data items need further disaggregation by location or sector. A variety of national, academic, commercial and global data providers were identified. However, some important datasets (natural hazard data, heatwaves) are not yet available. Many of the datasets are collected by international agencies including the World Bank, and could readily be used by other emerging markets including India.

Seven of the datasets are forward-looking climatic modelling datasets (on heatwaves, storms, droughts) and have been collated at the national level by data providers including the World Meteorological Organisation, World Bank and MCSI.

BNM engagements with REs

Between June and September 2022, the BNM organised a formal consultation on the planned CRST (BNM, 2022a). A summary of stakeholder responses and BNM's revised proposal on the CRST was issued in December 2022 (BNM, 2022b). Altogether, 99 stakeholders responded, with responses being broadly supportive. BNM also clarified several outstanding questions raised by REs during the consultation. Some of the CRST requirements were made less prescriptive (see below) between the June consultation and December 2022 policy document.

Approach and methodology

The CRST is mandatory for banks, investment banks and insurers, including reinsurers. Institutions can respond at entity or consolidated levels depending on their internal organisation.

Banks are being asked to analyse credit risk and insurers market risk. The new policy recommends REs look at probability of default, loss given default and exposure at default due to climate change risks. Implementing short-term and 30-year long-term time horizons is suggested for the CRST.

Several datasets in the Data Catalogue, especially those around transition risks and insurance claims, have sectoral breakdowns. The residential sector appears to be the only sector identified as relevant for physical risk assessment. BNM does not specify its preferred sectoral breakdown for RE reporting to BNM.

Scenario-building and stress-testing

In the consultation with REs (BNM, 2022a: 8–9), the BNM proposed using the three scenarios from the NGFS’ Hot House World and Disorderly categories:

- (a) Current Policies scenario
- (b) Nationally Determined Contributions (NDCs) scenario
- (c) Delayed Transition scenario

In the final policy document (BNM, 2022c: 19), BNM is less prescriptive, saying:

‘financial institutions may adopt a phased approach when developing better internal scenario analysis capabilities. As a starting point, financial institutions may consider the use of simpler, qualitative models and narratives to explore various climate pathways, outcomes and mitigation plans’.

Key lessons and future plans

The BNM will finalise the key elements of the CRST and publish a methodology paper by end-2023. The methodology paper will consist of the final scenarios, including the relevant variables, and guidance on other elements such as the expected risk coverage and level of granularity.

BNM has adopted a measured approach extended over two years to change expectations and help REs to introduce climate risk into their decision-making. Key features include:

- Setting out expectations and raising awareness early, producing a detailed discussion paper and showing flexibility by simplifying the 2024 exercise, following feedback from REs.
- Recognising that data availability was likely to be a constraint, BNM convened a joint committee (JC3) with REs to produce a common and Malaysia-tailored dataset of variables needed to undertake stress tests, not all of which are presently available, and made these publicly available. Creation of international data norms, particularly ISSB, will improve some datasets.
- REs differ significantly in their internal capabilities to incorporate climate risks. Banks that operate in Europe or Singapore are more familiar with climate risk assessment while local banks are lacking internal capability and are more reliant on support from consultancy firms.

3.4 Bangko Sentral ng Pilipinas (BSP)

Background

The Philippines is one of the world’s most vulnerable countries to the adverse impacts of climate change. Since 2017 (Circular No. 951) the BSP has required all REs to put in place recovery protocols for branches and offices to resume financial services even in disaster-hit areas, and for

domestic systemically important banks (DSIBs) to have a maximum of four hours' response time to resume operations when disaster strikes (Bayangos et al., 2020).

In June 2020, the BSP published a study using data from 92,000 banking units across the Philippines. This found that extreme weather conditions negatively affect the growth of deposits and loans, loan quality and the profitability of banks, with implications for microprudential policy (Bayangos et al., 2020).

This case study analyses BSP's latest milestones, regulations⁵ and initiatives on enabling banks' physical climate risk assessments and disclosures as well as related studies. Major banks' responses to BSP regulation are in Appendix 2.

Identifying needs and objectives

In April 2020, the BSP released the Sustainable Finance Framework (SFF, Circular No. 1085) setting out broad expectations for REs to integrate sustainability principles in their corporate governance, risk management, strategic objectives and operations within three years. In September 2022, the BSP released Memorandum No. M-2022-042, which provides supplemental guidance on minimum regulatory expectations in developing banks' environment and social risk management (ESRM) system. Based on the guidance, REs:

- Prior to developing tools and strategies for ESRM, must comprehensively understand transmission channels through which E&S risks translate to financial risks.
- Shall identify strategic E&S objectives over short-, medium- and long-term horizons and set risk appetite, as well as review the composition of loans and investment exposures and their alignment with the overall objectives.
- Shall aim for the results of climate stress-testing to inform banks' capital and liquidity planning and disaster recovery plans.

Scope of risk assessment

The BSP expects that banks' E&S risk assessment, particularly for physical risks, will involve:⁶

- identifying the geographical location of the bank and its assets, as well as bank clients' business or sources of income, collaterals pledged or projects being financed;

5 Environmental and Social Risk Management (ESRM) Framework (Circular No. 1128, October 2021); Guidelines on the Integration of Sustainability Principles in Investment Activities of Banks (Circular No. 1149, August 2022); Guidance on the Implementation of ESRM System (Memorandum No. M-2022-042, September 2022); BSP's Sustainable Central Banking Strategy (December 2022).

6 Based on BSP Memorandum No. M-2022-042.

- understanding the climate and environmental risks in geographical areas or vulnerable sectors where the bank operates, and in its assets or loan portfolios, which can translate to financial risks. Identification and assessment of exposure to E&R risks shall be done at the counterparty and portfolio levels; and
- performing analysis of how physical risk scenarios would affect their financial statements from short- to long-term, and may cover one or two key financial risks (e.g. credit and/or liquidity).

Available data and technical capacity

The BSP policy guidance provides information on publicly available tools that banks may consider in the conduct of their E&S risk assessment. To understand and map out geographical risk exposures of bank assets and portfolios to physical climate events, the Memorandum provides that banks may use hazard mapping tools such as HazardHunterPH, LiDAR Portal for Archiving and Distribution and the Climate Central Coastal Risk Screening Tool.⁷ The BSP also points banks towards NGFS materials as additional references for the conduct of initial scenario analysis exercises and environmental risk assessments.

The BSP also recognises banks' varied capabilities and needs. As such, it emphasises application of the principle of proportionality in reviewing banks' approaches to climate risk assessment. For example, larger banks may already have existing frameworks or tools for climate stress testing and may be able to conduct the exercise sooner compared to smaller banks that may need to initially focus on capacity-building actions to comprehensively understand and effectively manage E&S risks.⁸ Smaller banks may begin their E&S risk assessments by using available tools for identifying and measuring the physical risk exposure of loan portfolios to various natural hazards, and assessing the potential financial risk arising from such exposure.

An examination of the latest annual reports of the three biggest banks by total assets as of March 2023⁹ in the Philippines indicated that only one has explicitly reported details of its physical climate risk exposure assessment (see Appendix 2). Building technical capacity is also necessary among smaller banks. A survey by Allotrope Partners (2021) among rural and thrift banks (484 respondents) conducted in February 2021 suggests that 52% of the respondents are slightly or not at all familiar with how to proceed with physical risk assessment. To help address this, the BSP regulation mandates banks to implement capacity-building programmes to increase knowledge and skills of the units and personnel managing E&S risks.

7 HazardHunterPH provides reports on critical facilities and areas in the Philippines prone to different hazards. *LiDAR Portal for Archiving and Distribution* produces detailed flood hazard maps and resource maps. *Climate Central Coastal Risk Screening Tool* provides elevation data for assessing coastal flood risks and shows areas vulnerable to permanent submergence from sea level rise or flooding caused by storm surges, tides, and tsunamis. Above online source can be accessed at: <https://hazardhunter.georisk.gov.ph/>; <https://lipad.dream.upd.edu.ph/>; and <https://coastal.climatecentral.org/>

8 Based on authors' interviews with BSP officials, 4 July 2023.

9 Based on BSP website: www.bsp.gov.ph/Statistics/Financial%20Statements/Commercial/assets.aspx

Approach and methodology for scenario-building and stress- testing

The BSP is working with a development partner for climate stress-testing and undertaking climate vulnerability assessments with volunteer small banks.¹⁰ However, within the context of the Financial Sector Assessment Program (FSAP), the IMF and World Bank conducted a bank solvency stress test for the Philippine banking system covering physical risks (IMF, 2022).

The FSAP stress-test utilised three scenarios: i) climate scenario, showing typhoon intensity and frequency in the Philippines by mid-twenty-first century; ii) disaster scenario, estimating physical capital damage of typhoons for a given probability; and iii) macro-financial scenario, based on a dynamic stochastic general equilibrium (DSGE) calibrated for the Philippines modelling economy-wide impacts of a capital depreciation shock. Two baseline scenarios – with and without pandemic – were considered, the former representing a compound shock.

The IMF exercise revealed that climate change could cause significant risks to financial stability in a compound shock scenario – that is, typhoons and a joint shock (such as a pandemic) would reduce bank capital ratios by nearly 8½ percentage points compared to the normal baseline case. Nevertheless, the IMF highlighted that there is deep uncertainty in climate scenario assumptions and there may not be appropriate evidence to draw on for prudential policy.

Recognising the challenges that the banking sector faces in terms of data availability and designing climate scenarios, the BSP has yet to provide specific methodologies or scenarios for banks' climate stress-testing. Pending regulatory issuance, banks are expected to explore available NGFS guidance and methodologies best suited to their needs, capacities and exposures. Nevertheless, the conduct of climate stress-testing should be aligned with the overall principles provided in Section 151 of the Manual of Regulations for Banks.

Disclosure requirements

The BSP Circular 1085 requires banks to disclose in their annual report the following information related to their ESRM system:

- Sustainability objective and risk appetite.
- Overview of risk management system.
- Products and services with internationally recognised sustainability standards.
- Breakdown of banks' E&S risk exposures per industry or sector.
- Existing and emerging E&S risks and their impact on the bank.
- Adherence to international sustainability standards and practices.
- Progress of implementation in integrating sustainability principles in their governance framework, risk management system and business strategy and operations.

10 Based on authors' interviews with BSP officials, 4 July 2023.

Key learning and future plans

The BSP underscored the importance of building the capacity of banks to reinforce the implementation of regulations for climate risk assessment and disclosure. BSP supervisors and financial institutions benefitted from technical/capacity-building support extended by international and regional organisations and bilateral partners (e.g. IMF, World Bank, ADB, UK FCDO).

Moreover, the BSP expressed the critical application of the principle of proportionality in terms of banks' adoption and implementation of the sustainability-related regulations as well as supervisors' assessment of banks' practices. For instance, large banks may cover both physical and transition risks in their climate risk assessment, while smaller banks may initially strengthen their operational resilience since their operations are vulnerable to extreme weather events.

To improve the surveillance of emerging risks to the banking system, the BSP will enhance its prudential reporting requirements to facilitate the collection of granular data such as geographical location of assets, in addition to existing data on economic activities using the Philippine Standard Industrial Classification (PSIC). BSP also plans to amend current E&S disclosure requirements following the harmonisation of sustainability disclosure requirements by Philippine financial sector regulators and the release of Sustainability Disclosure Standards by the IFRS.

The BSP has also highlighted the need to balance sustainability and financial inclusion objectives, having in mind the role of MSMEs in supply chains. In line with this, the BSP will promote inclusive green finance as part of its 11-point Sustainable Central Banking Strategy.

3.5 Hong Kong Monetary Authority (HKMA)

Background

Recognising the significant risk from climate change to the financial sector, in May 2019 the HKMA launched its strategic framework on green finance (HKMA, 2019a). The following July, the HKMA formed a Working Group on Green and Sustainable Banking to develop a framework to assess authorised institutions¹¹ (AIs, referred to here as REs) progress in managing climate and environmental risks (HKMA, 2020a). The results of the assessment suggest that only just over a third (38%) of REs were at the planning stage of incorporating climate and environmental issues in their business processes (HKMA, 2020a). In June 2020, the HKMA released a white paper setting out its supervisory expectations regarding climate-related issues (HKMA, 2020b).

11 Institutions intending to carry on banking business or taking deposits in Hong Kong are required to be authorised by the HKMA. An authorised institution may be a bank, a restricted licence bank or a deposit-taking company (HKMA, 2022a).

In January 2021, the HKMA launched its pilot climate risk stress test (CRST) (HKMA, 2021a). This case study focuses on the physical climate risk assessment within the pilot CRST exercise, as well as the contribution of the pilot CRST in subsequent related initiatives at level of the HKMA and REs.

Identifying needs and objectives

In recognition of the increasing threats that the climate change may pose to the financial sector, the HKMA's pilot CRST identified two main objectives: to assess the climate resilience of the Hong Kong banking sector as a whole under various climate change scenarios; and to facilitate capability-building of participating banks with respect to climate risk management. The pilot is conducted through a bottom-up approach.

Available data and technical capacity

Data on climate change projections is from Hong Kong Observatory (HKO), particularly projected lower- and upper-bound changes in annual temperature and sea level under a high greenhouse gas scenario.

Bank-level data covers 20 major retail banks and seven branches of international banking groups. Together, these banks account for 80% of banking sector lending. A number of challenges were encountered during the exercise, including lack of detailed information of collateral properties' precise location, lack of widely accepted standards for climate risk identification and insufficient expertise in modelling climate risks.

Scope of analysis

For the physical risk assessment, participating banks were required to assess impacts resulting directly from weather-related events and shifts (e.g. damage to property), and those ensuing indirectly from subsequent events (e.g. disruption to global supply chains) under one prescribed scenario of the climate situation in Hong Kong in the mid-twenty-first century (e.g. 2051–2060). Emphasis was placed on participating banks assessing their exposure through potential credit losses of residential mortgages and other property-related lending in Hong Kong, and operational losses associated with climate events in Hong Kong.

Approach and methodology

The HKMA provided guidance on the scope of the exercise, such as covering both physical and transition risks, scenarios and transmission channels of climate impact to financial risks. It also required banks to use a static balance sheet approach, wherein it was assumed that banks would not change their business strategies over the assessment time horizon.

While the HKMA provides general guidance, participating banks directly perform the climate risk assessment based on their respective data and climate risk modelling approach/methodology. In a separate report by FSB (2022), the HKMA indicates that such ‘flexibility is warranted given the challenge of data availability and the varying level of sophistication among financial institutions’, and that the approach may encourage capacity-building.

Physical climate risk assessment

The CRST scenario for physical climate risk assessment assumes a hypothetical scenario that Hong Kong will be affected by the acute impacts of extreme weather events. The scenario is based on HKO’s climate change pathways projections for Hong Kong up to mid-century, which includes projected increases in temperature and rising sea levels. This scenario is consistent with the IPCC’s RCP8.5 high GHG concentration scenario. Most of the participating banks assessed the physical risk impact over a one-year horizon by assuming an instant switch from the current climate situation of Hong Kong to that in the middle of the twenty-first century.

Participating banks in the CRST exercise identified tropical cyclones as posing significant financial risks. In terms of credit risk, physical damage to property and changes in market perception of the vulnerability of property to climate events may lead to devaluation and increased credit risk of a bank’s property-related lending. In terms of operational risk, business disruption and damage to bank premises during climate events may be major sources of operational losses. Estimates of such climate hazard damage were based on historical data and academic literature, with some adjustments for more intense climate hazard scenarios.

Assessment results

Given the identified channel of impact, the exercise assessed that vulnerabilities may emerge from exposure to residential mortgages and other property-related lending in Hong Kong, which account for 28% of the participating banks’ total lending, and from potential operational losses associated with climate events. Devaluation from physical damage may result in a sharp rise in expected credit losses of participating banks’ residential mortgages by 25 times, from HK\$0.7 billion to HK\$17.3 billion.

Meanwhile, annual operational costs from damage to office premises and disruption to business operations could reach HK\$2.2 billion, equivalent to 0.8% of profit before tax of participating banks in 2019. The seemingly small operational costs are anticipated to be mitigated by technology solutions, flexible working arrangements and business continuity plans.

Despite the potential adverse effects of climate risks to banks’ profitability, capital positions and operations, the banking sector was assessed as remaining resilient to climate shocks given existing strong levels of capital buffers.

Disclosure

The results of the CRST exercise at the banking sector level were published on 30 December 2021, together with a list of the banks that participated in the exercise. No banking-level data assessment of physical climate risks was published.

Key lessons and future plans

Through the pilot CRST exercise:

- Some modelling limitations on the coverage of the assessment were revealed. For instance, while banks were required to assess direct (e.g. damage to properties) and indirect impact (e.g. global supply chain disruptions), the latter was not sufficiently assessed due to challenges in modelling.¹² The pilot CRST report also did not account for insurance recovery for physical damage, or for the indirect effects of the broader economic impact of hazards which may affect borrowers' repayment ability (HKMA, 2021). In addition, estimates of direct physical damage are based on historical data, which may not capture the potential higher severity of climate events in the future (ibid.).
- The HKMA and participating banks became more aware of major gaps in the availability of granular data and climate risk methodologies, enabling HKMA to provide targeted support to/ engagement with financial institutions.
- Firm-wide awareness of climate risks was expedited as the HKMA required participating banks to present the results of the exercise to their respective senior management.
- A benchmark for subsequent initiatives was established, including release of the HKMA SPM on Climate Risk Management, a non-statutory guidance for REs on HKMA's approach to and expectations regarding reviewing REs' climate-related risk management (HKMA, 2021b).
- Enhanced CRST guidelines for the banking sector were developed, particularly on implementing climate scenarios, assumptions, assessment approaches, a broader scope of analysis, and reporting requirements. The guidance was released in April 2023, and the CRST is slated to be conducted by REs over June 2023–June 2024 (HKMA, 2023).

Based on this analysis, HKMA appears to have benefitted from adopting a phased approach by gaining and building important insights at every stage of policy effort. For instance, the initial pilot climate stress-testing exercise allowed for flexibility and a pragmatic approach. Despite major limitations in comparability and coverage, allowing banks to use their own methodologies facilitated higher participation and expedited knowledge-sharing among banks. This learning fed into HKMA's subsequent policy initiatives, including the expanded coverage assessment for the second round of CRST, relevant SPM policy guidance, and plans for targeted capacity-building support to industry.

12 Based on written feedback from HKMA.

3.6 South African Reserve Bank (SARB)

Background

The South African case presents an example of a bottom-up approach to physical climate risks and how central banks may support REs to integrate climate risk models into their own risk frameworks. The study draws largely on the climate change risk add-on to SARB's 2021 common scenario stress test (CSST), and complementary information in the 2021 Prudential Authority Climate Risk Survey Report and 2022 SARB working paper on climate risk modelling frameworks relevant to South Africa.

In line with its price and financial stability mandate, the SARB climate change programme consists of seven workstreams, coordinated by a steering committee and managed by different departments in the SARB:

- Regulatory Framework
- Supervisory Framework
- Stress Testing
- Macroprudential Framework
- Structural Changes
- Monetary Policy
- Net Zero for Central Bank

The SARB Prudential Authority (PA) is responsible for the first two workstreams, which involves adjusting the regulatory and supervisory framework to incorporate climate-related risks.

In 2019, the PA established a Prudential Authority Climate Task Team to promote, develop and coordinate its regulatory and supervisory response to climate-related risks over 2021–2024, including providing potential guidance to REs on how to account for climate risk within their own risk solvency assessments and internal capital adequacy assessments, how climate risk might feature in risk management requirements and enhanced reporting frameworks for top-down assessments conducted by the PA in line with the TCFD (SARB Prudential Authority, 2021). In July 2022, the PA published a prudential policy communication explaining that it would begin monitoring how REs have integrated climate risk management (SARB Prudential Authority, 2022).

Identifying needs and objectives

In 2019, the PA conducted an information-gathering exercise on the insurance and banking sectors' awareness of climate change and reporting of climate-related information. The PA's 2021 climate risk survey builds on the 2019 TCFD survey to inform the PA's strategy and supervisory approach towards climate risk with the objective of 'driving the PA's prioritisation of its climate risk-related initiatives' (SARB Prudential Authority, 2021). The 2021 survey revealed that over half (59%) of the largest South

African REs had never discussed climate-related risks at board level, and 61% had no policy on climate-related risks (SARB Prudential Authority, 2021). Data availability and quality were cited as a primary challenge for REs, highlighting the importance of reporting initiatives to close data gaps and increase data quality, as well as increasing the capacities of reporting organisations (SARB Prudential Authority, 2021). In its 2022–2023 annual report, the PA announced that it had compiled a set of climate risk indicators to be piloted in 2023; at the time of writing, these have not been publicly released.

Beyond assessing REs' awareness of climate risks, the 2021 inclusion of the bottom-up climate change risk add-on is a signal towards a model frameworks approach that integrates assessments of relevant climate risks into SARB's existing biennial CSST. For the first time, in 2021 SARB added a climate change risk add-on to its CSST of six systematically important banks in the country (SIFIs). The bottom-up climate change add-on focused on physical risks from climate change as well as from a drought scenario.

Available data and technical capacity

The 2021 CSST climate risk add-on used rainfall data from the South African Weather Service to design a drought scenario. Bank-level data from the six SIFIs was used to estimate the impact of the drought scenario. Together, these SIFIs comprise a combined market share of 92% (SARB Prudential Authority, 2021), and are regularly included in special exercises such as the 2020 top-down solvency stress test conducted by SARB in response to the Covid-19 pandemic.

However, feedback from and review of the CSST climate change add-on exercise highlighted difficulties SIFIs faced in integrating model frameworks which aim to accomplish three objectives: (i) to build climate risk scenarios that adequately cover relevant transition and physical risks; (ii) to translate climate scenario impacts into macroeconomic scenarios, or economic vulnerability to risks related to climate change; and (iii) to produce outcomes for the financial sector, or measuring the sector's vulnerability and exposure to the macroeconomic impacts of climate change.

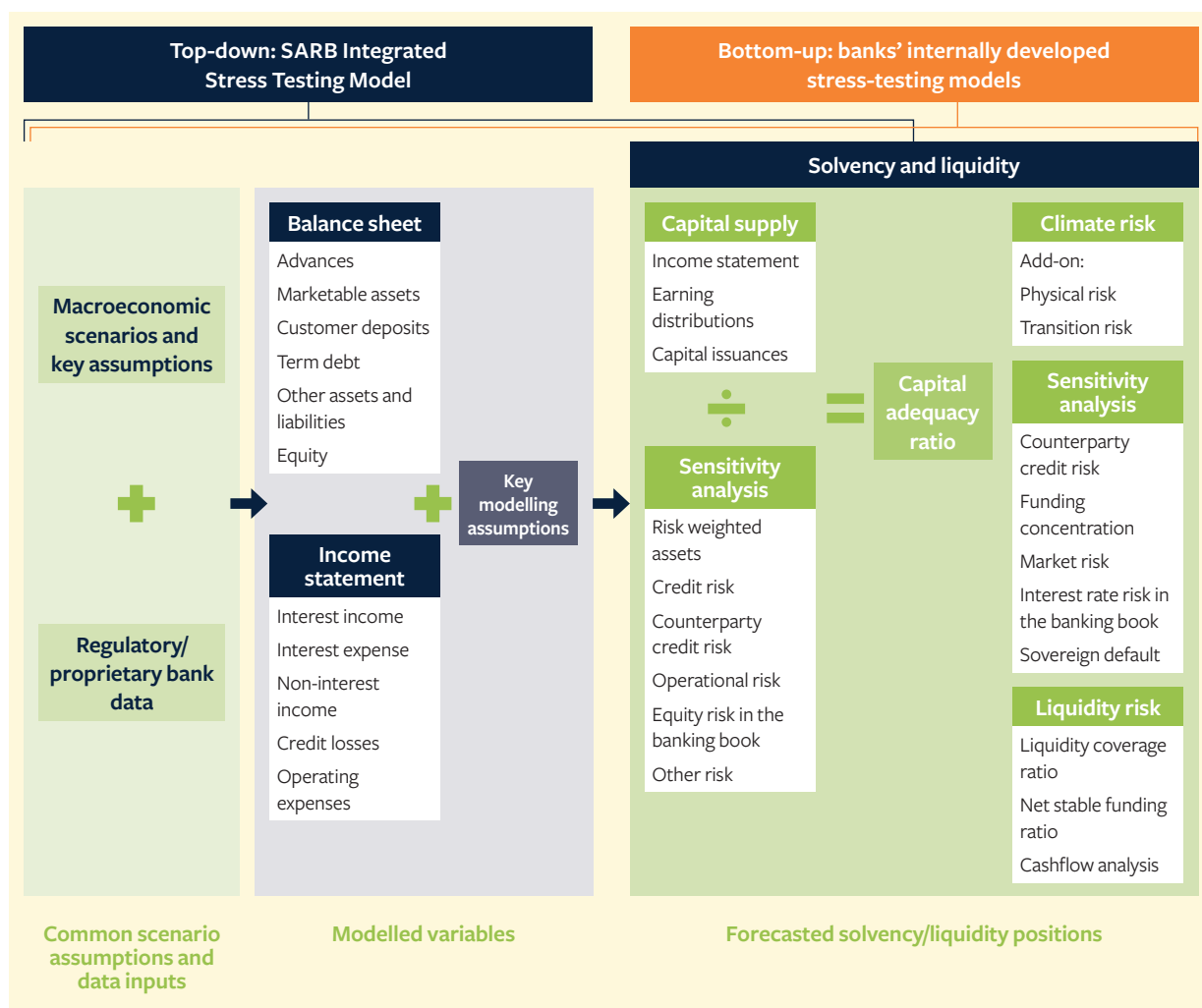
The 2022 SARB working paper attempts to address some of these gaps by providing an overview of modelling frameworks appropriate for REs to build scenarios and assess climate impacts. SARB describes this as part of central banks' 'objective ... [to] improve the integration of climate-related risks into financial companies' decisions' (Anvari et al., 2022: 2). The working paper also outlines remaining data and capacity gaps, including: i) the lack of disclosure and taxonomy requirements to distinguish between green and brown financial assets; ii) lack of a central credit register by economic activity classification at the municipal level in South Africa (unlike other G20 countries), which hinders development of granular models with credit and economic linkages; and iii) data gaps beyond economic and financial models, such as lack of comprehensive weather data across the country.

Approach and methodologies

The SARB CSST framework incorporates bottom-up and top-down approaches over a three-year horizon, summarised in Figure 6. The six participating SIFIs conduct bottom-up tests based on their internal models, while SARB simultaneously conducts a top-down stress test to validate and benchmark results.

Two scenarios were adopted for the 2021 SARB CSST exercise: a baseline scenario and an adverse scenario. The adverse scenario was calibrated to be ‘severe, yet plausible, and economically consistent’ (Anvari et al., 2022: 3). The climate change risk add-on focused on the solvency impact of a drought scenario over a three-year period. The quantitative assessment was complemented by a qualitative assessment of transition risks and the materiality of environmental risks to different sectors.

Figure 6 SARB 2021 CSST framework – top-down and bottom-up approaches



Source: SARB (2021)

CSST climate risk add-on results and scenario-building

The SARB conducts the CSST biennially, covering both solvency and liquidity risk. A climate risk add-on was included in the 2021 CSST, in which the six participating banks were requested to estimate the impact of the drought scenario on credit exposure per sector and report probability of default and NPL, as well as the impact on the creditworthiness of the sovereign (SARB, 2021). The climate risk add-on was only conducted on a bottom-up basis and the results of the exercise concluded a deterioration of the common equity tier 1 capital adequacy ratio of roughly 30 basis points (SARB, 2021).

Disclosure

Individual bank results of the CSST are not published, although sector-wide results are available in the SARB's 2021 Financial Stability Review. The methodology and high-level results of the climate risk add-on are covered in this report.

Key learning and future plans

SARB and PA officials interviewed for this paper advised adopting a 'building-block' approach and 'learn-as-you-go' attitude, starting with the most adverse scenario or biggest physical climate risk to maximise the utility of such exercises given limited technical capacities. As in other jurisdictions, large foreign REs follow the regulations and guidance of their parent countries ahead of SARB guidance.

The SARB aims to build from the lessons of the 2021 CSST climate add-on exercise by conducting an inaugural stand-alone CRST in 2024, and is currently in the process of doing so. Future macroprudential stress-test exercises are 'envisaged to include forward-looking scenarios and incorporate elements of climate change risks' and may cover domestic systemically important insurers (DSIIs) once these are designated in terms laid out by the Financial Sector Regulation Act 9 (FSR Act 2017) (SARB, 2021: 26).

A set of benchmark climate risk scenarios was finalised by the Sustainable Finance Initiative in May 2023, providing open-access, locally appropriate tools and modelling frameworks, but is not a mandated tool of the SARB, PA, Financial Sector Conduct Authority (FSCA) or National Treasury.

In August 2023, the PA published four Proposed Guidance Notices for consultation with banks and insurers, providing guidance on climate-related risk integration and practices and on climate-related disclosures. In notices on climate-related disclosures in line with TCFD and ISSB guidelines, the PA acknowledged that '[c]limate risk management is a developing area and approaches will evolve and mature over time' and emphasised the importance of 'build[ing] the necessary capacity and capabilities to assess, manage and disclose climate-related risks and opportunities' within banks' and insurers' existing risk management and governance frameworks (SARB Prudential Authority, 2023b; SARB Prudential Authority, 2023d).

3.7 Recent initiatives by the RBI on climate risk assessment

The RBI plays an active role internationally and domestically in understanding the impact of climate change for the Indian economy and helping move forward the integration of climate risks in bank supervision.

One of the earliest efforts was RBI's analysis of the impact of climate risks – measured by changes in precipitation and temperature – on inflation and economic activity (Dilip and Kundu, 2020). The result of the empirical exercise suggests that weather conditions have a strong influence on food inflation, with rainfall shocks having strong effects on vegetable prices. The results also point to significant impacts of weather conditions on economic activity, such as manufacturing, services, demand for electricity, trade, tourist arrivals and tractor and automobile sales.

In April 2021, the RBI has joined the NGFS, and is a member of the Task Force on Climate-related Financial Risks set up by the BCBS and the International Platform on Sustainable Finance. Within RBI, a dedicated Sustainable Finance Group (SFG) in the Department of Regulation (DoR) was established in May 2021 to lead regulatory initiatives in the area of climate risk and sustainable finance. Since then, the RBI has released the following documents/statements related to understanding and addressing the impacts of climate change for Indian REs:

- Survey on climate risk and sustainable finance in January 2022, published in July 2022 (RBI, 2022a).
- Discussion paper on climate risk and sustainable finance, published in July 2022 (RBI, 2022b).
- Monetary policy statement on 8 February 2023 on RBI plans for climate-related policy guidance and frameworks.
- Climate change-focused chapters in the Report on Currency and Finance (RCF) published in May 2023 (RBI, 2023a).
- Framework for acceptance of green deposits, released in April 2023 and effective from June 2023 (RBI, 2023b).

Initial efforts by the RBI to understand the level of preparedness of REs on climate risk management and sustainable finance was conducted through a survey among 34 major banks in India¹³ in January 2022 (RBI, 2022a). The survey findings suggest that, while the majority of surveyed banks consider climate-related risks as a material threat to businesses, only a few banks had a strategy for embedding ESG principles in their business operations. In addition, only one in three banks (with a lower ratio of 1:12 among public banks) attempted to quantify the amount of loans and investment portfolios susceptible to climate-related risks.

To further gather insights from REs and stakeholders, RBI released a discussion paper in July 2022 to solicit feedback on its suggested action points for REs (based on global best practice) in the following areas:

13 Consisting of 12 public sector banks, 16 private sector banks and six foreign banks.

- Appropriate governance, strategy and risk management of climate change risks for REs.
- Exploring forward-looking tools such as stress-testing and climate scenario analysis to identify and assess vulnerabilities in REs.
- Climate risk-related financial disclosure and reporting for REs.
- Capacity-building.
- Voluntary initiatives around green financing, green branches (i.e. promoting paperless transactions), and green data centres (i.e. sourcing power from renewable sources).

After reviewing feedback on the discussion paper, in February 2023 RBI announced plans to provide policy guidance in specific areas, particularly on green deposits, disclosure frameworks for climate-related financial risks, and climate scenario analysis and stress-testing (RBI, 2023c). The framework for green deposits was released in April 2023, which provided banks with guidance on specific ‘green’ sectors, activities and projects¹⁴ that green deposits could finance.

RBI conducted a survey among stakeholders (e.g. major banks, non-banking financial companies (NBFCs), brokerage institutions and other financial firms) in December 2022 to gauge their progress on assessing climate risks. The survey results, published in the 2022–2023 Report on Currency and Finance (RBI, 2023a), highlight major challenges, with most respondents (95%) suggesting they lack appropriate data to robustly assess climate risk, and only a quarter of respondents using scenario analysis to assess climate risk.

In the same report, the RBI highlights the result of a DSGE model showing that any large-scale default of NBFCs – with strong backward and forward linkages to the financial system and the real sector – arising from physical or transition risks might translate into macro-instability. The RBI has also published results of its stress-test, which estimates the impact of climate transition risk (based on stranded asset portfolio returns) on REs’ stock returns, and subsequently on capital reserves (RBI, 2023a). Findings suggest that banks can remain solvent and meet capital requirements in the event of a sudden adverse climate shock obliging them to repay depositors. However, capital shortfalls will be larger if banks are required to pay both borrowings and deposits – and in this case, public banks face greater capital shortfalls than private banks.

RBI is working on regulatory initiatives on disclosure frameworks on climate-related financial risks, and guidance for climate scenario analysis and stress-testing as of July 2023 (BIS, 2023c), which are to be delivered in 2023–2024 (RBI, 2023d). In addition, the RBI plans to launch a dedicated page on its website covering regulations, publications and speeches related to its communications on climate and sustainable finance (ibid.).

14 Green activities/projects which encourage energy efficiency, reductions in carbon emissions and greenhouse gases, promote climate resilience and/or adaptation and improve natural ecosystems and biodiversity.

4 Conclusions and policy implications

Globally, central banks are increasingly recognising the implications of climate change impacts on price stability, financial stability and financial inclusion. The RBI has launched several initiatives and has a pipeline of further regulatory activities in areas of climate risk mitigation and sustainable finance. This paper investigates the existing literature and best practice of selected central banks with the aim of contributing to RBI's efforts to develop microprudential guidance on identifying, measuring, stress-testing, managing and disclosing REs' exposure to financial risks from likely physical climate change.

The six case studies detailed here focus on central banks' policy development processes and guidance provided to and disclosure requirements for REs. An overarching development is that central banks currently focus on enhancing REs' capabilities to understand and manage their exposure to physical risks, rather than modifying regulatory capital requirements. Recognising the absence of data and models to accurately quantify climate risks, central bank officials highlighted the benefits of adopting a phased approach to proactively raise awareness, set regulatory expectations and engage with and provide support to REs before mandatory reporting standards are introduced.

Although central banks differed in the sequencing, most took the following steps:

1. Introducing climate risk into central banks' mandates/objectives.
2. Stocktake of data availability and REs' technical capacity.
3. Developing regulatory expectations.
4. Developing climate scenario/stress-testing exercises for REs.
5. Refining regulations and mainstreaming physical climate risk assessments and disclosures in supervision.

Central banks recognised significant challenges to implementing the above steps, including data availability, extending REs' time horizon for risk modelling from five years to as much as 30 years, and wide variation in resources and technical capacities among REs, and in the pool of local consultants to aid REs. Central banks in emerging markets also recognised that climate risk was not necessarily the highest priority, bearing in mind other country-specific risks to price and financial stability in their jurisdictions. However, the increasing frequency and intensity of climate change events are acknowledged to be potentially more important in coming years, motivating central banks' early action to encourage REs to build their capacity to understand these risks and embed this in their short- and long-term risk management strategies.

In this regard, many emerging-market central banks adopt (or plan to implement) the principle of proportionality in monitoring compliance for physical climate risk assessment and disclosure,

with stricter expectations for systemically important REs, while sometimes excusing small banks completely. In one case (BSP), supervisors ask banks which cannot comply within suggested timelines to submit transition plans.

Some central banks organised other distinctive initiatives:

- Creating working groups of REs to share good practice on challenges identified by the industry, such as data on counterparty exposure.
- Leveraging publicly available data and tools and global regulatory guidance (e.g. BCBS, NGFS, IFRS), often tailored to local needs.
- Institutionalising inter-agency collaboration to foster harmonised climate-related taxonomies and disclosure requirements among different financial regulators.

Specific insights from interviews suggest:

- Working groups of REs should include a mix of small and large banks and insurers, to exchange good practice but also to ensure that smaller institutions are not left behind. If feasible, working groups should be led by engaged representatives from within the industry, with a specific set of problems to solve.
- Undertaking stress tests using climate scenarios is not the main objective per se; rather, the objective is to improve strategic management of climate risks by REs and their clients.
- Deficiencies in data cannot be resolved overnight. REs collectively need to support counterparties in developing and disclosing transition plans which set out their treatment of mitigation and physical risk, and their plans to improve data by inspecting and validating counterparties' transition plans.
- Some central banks adjust requirements between banks, sometimes excusing small banks completely to allow for varying staff capacity, and to reflect their lower systemic risk from a macro-prudential perspective.

Based on the main lessons from the literature and the practical experiences of six central banks, Table 3 provides a stylised phasing/roadmap with practical steps that the RBI and other central banks might consider in designing and implementing climate risk assessment and disclosure policies within their jurisdictions.

Table 3 Stylised roadmap on establishing physical climate risk assessment and disclosure regimes

Phase	Suggested action points
Phase I Raising awareness of REs on climate-related issues	1. Central bank senior staff communication on the importance of climate change and introducing climate change issues into central bank mandates/objectives 2. Identifying data availability and technical capabilities of REs through consultations (e.g. via a working group), ad hoc surveys, stock-taking exercises
Phase II Developing policy guidance on physical climate risk assessment and disclosure requirements	3. Issuing regulatory expectations on REs' physical climate risk assessment, management and disclosure, in consultation with REs and leveraging global practices and guidance by international standard-setting bodies 4. Some central banks might undertake top-down assessment of exposure or stress tests with internal data and models 5. Solicit feedback and co-develop detailed policy guidance with REs and stakeholders
Phase III Understanding and implementing measures on physical climate risk assessment and disclosure requirements	6. Provide guidelines and conduct a pilot climate scenario analysis and stress-testing, allowing for flexible and narrower scope in earlier stages when there are major data limitations and variation in technical capacities among participating REs 7. Enhance climate scenario analysis and stress-testing guidance based on disclosed results and lessons from pilot exercises
Phase IV Continuous refinement of policies and capacity-building on climate risk management and disclosure	8. Amend or issue new regulations to mainstream climate risk assessment and disclosure in supervisory processes. Consider implementing compliance under the principle of proportionality or providing room for transition plans might help REs build data and technical capacities 9. Provide targeted support for capacity-building efforts based on stakeholder feedback, as well as local and international policy developments

Source: Authors

If situated in the above roadmap, the RBI has conducted Phase I activities (from 2020 to 2023), including communicating its recognition of the importance of climate risk in financial sector stability, undertaking stocktaking exercises on REs' technical capacities and preparedness for climate risk assessment (RBI 2022a, 2022b, 2023a), and conducting studies on macroeconomic implications of physical and transition risks (Dilip and Kundu, 2020; RBI, 2023a). It is important to maintain this momentum by setting clear and ambitious timelines on the next policy steps.

The RBI is yet to issue specific policy guidance on climate scenario analysis, stress-testing and disclosure frameworks. Once policies are in place, there is a need for continuous effort by RBI to conduct intensive and patient engagement with REs and assess the scope for mandatory requirements and application of the principle of proportionality. RBI may also consider how developments in climate-related international standards (e.g. IFRS sustainability disclosure standards) may affect its future domestic policy design.

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Appendix 1 Physical climate risk assessment data sources and methodologies

This appendix presents potential data sources and methodologies relevant to assessing physical climate risks in the Indian context. The following tables are based on existing, broader reviews of climate risk indicators and methodologies, which have been checked for relevance to India.

Data, modelling and capacity gaps were identified as common challenges in case studies and the literature review. Vulnerability to the physical impacts of climate change is generally assessed using three key methodologies: indicator- and score-based approaches, which provide relative risk information; model- and GIS-based approaches that require varying levels of data granularity and processing capacities, and participatory approaches such as mapping, interviews and surveys.

Each methodology has distinct strengths and weaknesses, and can be useful when combined (Davis-Reddy and Vincent, 2017). However, methodologies that ultimately produce quantitative outputs are necessary for integration into central bank stress-testing modelling frameworks (Anvari et al. 2022). Table A1 evaluates physical climate risk methodologies by risk analysis conducted and their data requirements. This evaluation structure is adapted from 'The Climate Risk Landscape Report' published by UNEP FI (2021), and is limited to methodologies with physical climate risk coverage. Each methodology was validated as of February 2023 and checked for the level of granular coverage relevant to the Indian context.

Table A1 Physical risk methodologies and relevance for Indian coverage¹⁵

Key

India coverage	Yes	Not public	Partial
Methodology coverage	Yes	No	N/A

	Provider	Tool	Source
ACC-WTW	Acclimatise-Willis Towers Watson	Sector deep-dive assessments tool	www.wtwco.com/en-GB/Solutions/climate#Climate-Quantified-Climate-and-Resilience
C4 (1)	Carbone 4	Climate risk impact screening (CRIS)	www.carbone4.com/en/cris
CA-CIE	Climate Analytics	Climate Impact Explorer	https://climate-impact-explorer.climateanalytics.org/
CFIN	Climate Finance Alpha	Physical risk toolbox	https://climafin.com/#science
M-Re (CCFI)	Munich Re (Location Risk)	Location Risk Intelligence	www.munichre.com/en/solutions/for-industry-clients/location-risk-intelligence.html
Mck-PL	McKinsey (Planetrics)	PlanetView	www.mckinsey.com/capabilities/sustainability/how-we-help-clients/planetrics/planetview
MSCI	MSCI-Carbon Delta	Climate Value-at-Risk	www.msci.com/documents/1296102/16985724/MSCI-ClimateVaR-Introduction-Feb2020.pdf/f0ff1d77-3278-e409-7a2a-bf1da9d53f30?t=1580472788213
OF (1)	Ortec Finance	ClimateMAPS	www.ortecfinance.com/en/about-ortec-finance/news-and-events/climatemaps
OF (2)	Ortec Finance	ClimatePREDICT	www.ortecfinance.com/en/insights/product/climate-predict
BR-A	BlackRock (Rhodium Group)	Aladdin	www.blackrock.com/aladdin/products/aladdin-climate
SP (1)	South Pole	Risk screening tool	www.southpole.com/publications/physical-climate-risk-screening
SP (2)	South Pole	Climate risk and opportunities assessment	www.southpole.com/sustainability-solutions/climate-risks-opportunities-analysis
S&P-CS	S&P (TCS)	Climanomics	www.spglobal.com/esg/solutions/the-climate-service
VR	Verisk Analytics	AIR	www.air-worldwide.com/models/Climate-Change/
XDI	XDI Systems	Gross Domestic Climate Risk	https://xdi.systems/xdi-benchmark-gdcr/
WWF	WWF	Risk Filter Suite	https://riskfilter.org/

¹⁵ This evaluation structure is adapted from UNEP FI (2021: 30–31) ‘The Climate Risk Landscape Report’, available at www.unepfi.org/industries/banking/the-climate-risk-landscape/. Each methodology was updated as of February 2023 and checked for level of granular coverage relevant to Indian geography.

Appendix 2 Progress of Philippine major banks on physical climate risk assessment

The BSP expects all banks to integrate E&S risks (including climate physical risk) in their risk management frameworks, including in stress-testing exercises. Based on latest annual reports,¹⁶ the following describes the progress made by three major Philippine banks (by asset) in compliance with the BSP regulation.

1. Banco de Oro (BDO).

In 2021, BDO engaged third-party services (Ernst & Young/SGV) to assist in crafting its transition plan to comply with the BSP regulation, including identifying seven focus areas covering counterparties, products and services, key processes, HR policies, facilities management, strategic focus and board governance. BDO has established a sustainability governance framework with technical working groups for each focus area to implement the plan. BDO reports that data and analytics will be critical in tracking progress and identifying metrics for sustainability goals at different time horizons. It also reports major challenges in bank operation and supply chain data gathering given BDO's scope and complexity.

2. Land Bank of the Philippines (LBP).

Led by a dedicated project working team, LBP submitted its transition plan to the BSP on adopting a sustainable finance framework in June 2021. The plan covers the bank's strategies, policies, action plans and timelines. Since August 2021, the LBP has been implementing its 'enhanced environmental and social safeguards relative to credit policy', which has improved and updated bank-wide systems and methods; the parameters of reporting in terms of identification, assessment, mitigation, monitoring of environmental, climate change and social risks; and E&S benefits applicable to all projects financed by the bank. LBP intends to be fully compliant with the BSP regulation in 2023.

3. Bank of the Philippine Islands (BPI).

Among the three major banks, BPI reports more explicit recognition and assessment of its exposure to E&R risks, and assesses that identified risks are mitigated. It has reported an overview of the potential impact of physical and transition risks to the bank (e.g. credit, market, operational and reputational risks), and corresponding risk mitigation strategies. BPI has also assessed the exposure of its client locations and collaterals, bank branches, automated teller machines, cash accept machines, and employee residences in relation to the following physical climate risks: flooding, typhoons/severe wind, storm surge and rain-induced landslides. Tools and metrics are being developed to improve understanding of the bank's climate risk profile and fully integrate climate risk management in product and service delivery and operations.

¹⁶ Sources: compiled based on BDO (2022a; 2022b); LBP (2021); BPI (2022).

Appendix 3 Interview guide questions

For the case studies, interviews with central bank officials were conducted between July and August 2023 to complement the literature and central banks reports. Below is the generalised list of interview guide questions, which were tailored to specific developments in each jurisdiction. Interviews were held with officials from BNM, BSP, BoE and SARB, while written feedback was gathered from BCB and HKMA. Prior to finalisation of the paper, the draft of each case study and interview was shared with each central bank for feedback.

Needs, objectives and scope

- Are there specific physical risks (e.g. specific hazards or more generally, acute vs. chronic) [central bank] is interested in?
- Did you get any feedback from banks or insurers about the long-term scenarios used (e.g. 30-year time horizon)?
- Was the [stress test/major exercise] conducted in a top-down or bottom-up basis? What was the feedback from this?
- Lending to which economic sectors most concerns you? Did you consider suggesting a list of sectors that physical risks should be assessed for, e.g. agriculture, construction, transport?

Data availability and technical capacity

- What actions has [central bank] been performing to ensure the [stress test/major exercise] was successful? Any seminars, support or training provided to banks? Was this gestation period necessary in order for industry to prepare?
- Have other financial institutions shared their climate risk management/what other financial institutions has [central bank] been in contact with on their climate risks?
- In your interactions with banks/insurers did you have a smaller group of volunteers that you've informally discussed proposals with e.g. an advisory panel? If yes, how was this selected?

Climate scenarios and climate stress-testing

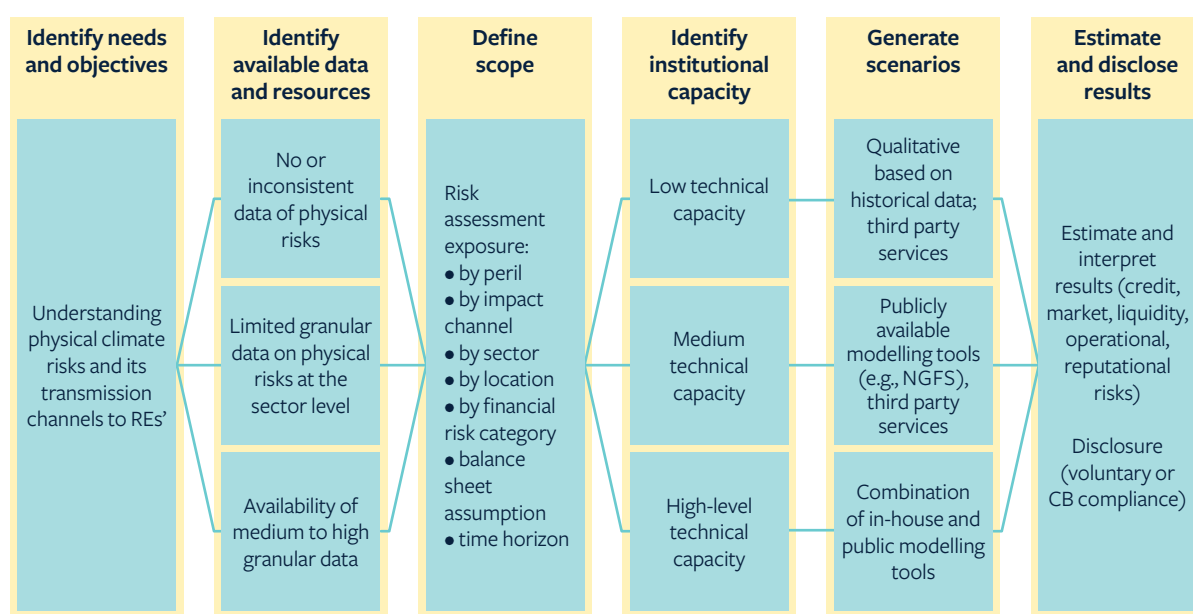
- Does [central bank] plan to provide specific scenarios, bank variables and thresholds for banks' stress testing?
- Are there international standards (e.g. ISSB, TCFD) that [central bank] is particularly looking toward?
- Was there any peer-to-peer opportunities for banks to learn, or opportunities from bank trade associations?
- Did you receive support from other central banks from the region or NGFS members while designing the [stress test/major exercise], or in this current phase of development?

Reporting and disclosure

- Have banks and insurers provided any feedback on their internal models or capability on assessing exposure to climate hazards assessed? What methodologies are used? How much variation is there between banks?
- Can you suggest banks that have conducted advanced or useful approaches for their physical climate risk assessment?

Lessons learned and future plans

- What feedback do you have on the framework below? Does this accurately capture your approach to conducting physical risk assessments? Kindly note that the framework below was based on an initial draft of the paper and has been revised to Figure 2 in Section 2 of the main text.



- What types of international support (e.g. from bilateral/regional CB partnerships, multilateral development partners, and organizations such as NGFS, Basel, ISSB) have been useful so far? What would be most useful for future plans?
- Any major lessons to share with RBI?