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Central Bank Data Strategies to Support Regional Climate Risk Assessment

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Central Bank Data Strategies to Support Regional Climate Risk Assessment

Research conducted by the CERT Workstream 1 – Climate Change and Climate-Related Risks

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EXECUTIVE SUMMARY

The impact of climate change on macro-financial outcomes has gained considerable attention in recent years. For Central Banks in particular, climate change has become more relevant since its effects are intertwined with Central Banks' mandates of maintaining both monetary and financial stability. It is against this backdrop that many major agencies are at the forefront of assisting countries with incorporating climate-related risks into economic and financial risk assessment frameworks. Such agencies include the Network of Central Banks and Supervisors for Greening the Financial System (NGFS), the Financial Stability Board, the Bank for International Settlements (BIS), the United Nations Environment Programme's (UNEP) Inter-governmental Panel on Climate Change (IPCC), the International Monetary Fund (IMF) and the World Bank.

The Caribbean region is one of the most vulnerable regions to climatic events, with its exposure to both physical and transition risks. A January 2023 survey conducted by the Caribbean Economic Research Team (CERT) revealed that no central bank in the CARICOM region has begun to collect climate data to inform macro-financial risk assessments. Moreover, clarity on Central Banks' legal mandate to pursue climate objectives is necessary in order to set a firm foundation upon which subsequent work in the climate arena can be anchored. The international approaches and data requirements for climate risk assessments, including stress testing, are still at a nascent stage and no standard regulatory climate-risk stress test has been applied to financial systems to date. Several authorities, in analysing climate scenarios, have cited difficulties due to insufficiently granular climate and environmental data (including balance sheet exposures), as well as a lack of specific tools to capture unique features of climate-related risks.

According to Baudino and Svoronos (2021), assessing climate-related impacts requires fundamental changes from traditional stress tests designed to study the effects of external shocks on bank solvency. In a climate stress test, climate scenario models project pathways for specified physical and transition risk variables (UNEP FI 2021(a)). Integrated Assessment Models (IAMs) are computer-generated models that provide emission pathways used in climate models. These include; the National Institute Global Econometric Model (NiGEM), the Bank of Spain Carbon Tax Sectoral (CATS) Model as well as the Morgan Stanley Capital International (MSCI)ESG Research's Climate Value at Risk Model. IAMs have been developed to investigate long-term relationships between emissions, carbon prices and global economic variables.

However, since physical risks are more relevant for the Caribbean, short-term scenarios appear more relevant. In this regard, the NGFS has proposed five climate scenario narratives to reflect the short-term dynamics associated with different transition and physical impacts and their interaction with the

macro-economy and financial sector. These short-term scenarios will better allow for the use of static balance sheet data and account for acute physical risks. Meanwhile, the IMF began incorporating climate change considerations in risk analysis, regulation and supervision, and monetary policy operations. The IMF's Climate Risk Financial Sector Assessment Program (FSAP) methodology uses the NGFS reference scenarios for emissions and temperature, along with pathways for physical and transition risk, to analyse climate change. It uses IPCC pathways up to 2100, climate impacts projections, GDP, population and urbanisation rates to contextualise each emission pathway and make a range of assumptions about technology evolution.

An assessment of climate-related risks requires new and unique types of data, which differs from data Central Banks have traditionally used in their financial risk analyses. In the Caribbean, the development of the data needed to quantify climate-related risk is still at an early stage of development. A gap analysis illustrated that while some indicators are available at the regional level, not all the data needed to develop climate scenarios and conduct stress tests are currently being collected. In addition, the data currently available is collected only intermittently. While finance-related data, emissions data and alignment/transition data are fairly available in international data repositories, data on borrower exposures, geolocations and data for calculating expected losses are lacking. Climate hazard data appear partially available for most Caribbean countries covered in the study.

To combat these data deficiencies, a roadmap was developed to address climate data gaps in the region. The roadmap revolves around three themes; (i) broadening the access and scope of the data, (ii) building technical capacity and (iii) institutional strengthening. Broadening the access and scope of the data is heavily reliant on the procurement of loan exposure and geographic location data from financial institutions and/or third-party sources. Building technical capacity calls for leveraging technical assistance and knowledge transfer opportunities which focus more on 'learning by doing'. Lastly, institutional strengthening efforts lay in internal reorganisation at Central Banks to prioritise climate-related matters as well as the creation of new entities such as credit registries for comprehensive exposure reporting.

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Chapter 1: INTRODUCTION

The impact of climate change on macro-financial outcomes has come into sharper focus in recent years. For Central Banks in particular, climate change has become more relevant as its effects can intersect with Central Banks' mandates for preserving monetary and financial stability. A number of multilateral cooperation initiatives have spawned in order to address the potentially adverse consequences of climate change. The *Network of Central Banks and Supervisors for Greening the Financial System* (NGFS) – an amalgamation of Central Banks and financial regulators established in 2017[1] ; the *Financial Stability Board* - established a four-pillared Roadmap to address climate-related financial risks; the *Bank for International Settlements* (BIS) - launched its annual Green Swan Conference in 2021; the *United Nations* Environment Programme's (UNEP) Intergovernmental Panel on Climate Change (IPCC); the International Monetary Fund (IMF) and the World Bank are some of the agencies at the forefront of assisting countries with incorporating climate-related risks into economic and financial risk assessment frameworks.

The Caribbean is one of the most vulnerable regions to climatic events. While exposure to the physical risks[2] posed by climate change is partly evident, transition risks and their impact in the context of the small island developing states (SIDS) of the Caribbean are less clear given their long-term horizon. Faced with competing and more immediate priorities, CARICOM Central Banks have for the most part not fully engaged the climate agenda. The situation audit conducted in Chapter 2 highlights the results of a January 2023 CERT survey on climate change which indicated that no central bank had begun to collect climate data to inform risk assessments. The 2023 Climate Change and Climate Risk Survey revealed key gaps in the policy framework for Central Banks to effectively interface with climate change issues. While there has been notable progress by a few Central Banks with integrating climate change considerations into Central Banks' internal operations, the fundamentals to underpin the identification, analysis and reporting of climate-related risks relevant to Central Bank mandates are largely absent.

However, before Caribbean Central Banks can address perceived shortcomings related to their engagement with climate-related risks, clarity on Central Banks' legal mandate to pursue climate objectives is necessary in order to set a firm foundation upon which subsequent work in the climate dimension can be anchored. Central Banks are arguably unique organisations in terms of design and operation. Incorporating climate change objectives can therefore have implications for central bank governance. Organisational objectives are generally derived from codified laws in a highly rules-based

[1] Membership mushroomed to 127 (with 20 observers) as at June 2023

[2] Physical risk assessment consists of three dimensions; (i) Physical hazards; (ii) asset exposure and; (iii) vulnerability of assets to hazards (IMF 2023).

environment. While globally there has been a consensus that climate change issues should be addressed by Central Banks, as evidenced by the rapid expansion of membership in entities such as the NGFS, an emergent view led by the US Federal Reserve suggests that Central Banks should not delve too deeply in climate change issues unless explicitly provided with the legal mandate to do so. This view also carries merit given that the incorporation of climate change considerations can give rise to unintended consequences and adverse trade-offs with respect to the core central bank mandates of price and financial stability.

Caribbean Central Banks must examine their legal mandates carefully as they relate to climate change. Regional Central Banks cannot freely adopt the posture of peers such as European Central Bank (ECB) and the Bank of England (BOE), which have a more explicit mandate to support the policies of the government subject to their primary mandate of price stability. Most of the Central Banks in the Caribbean do not have this as part of their mandate. Also, most do not have a hierarchy of objectives in their mandates. Some may have developmental-type objectives, but they do not go so far as to supporting the policies of the government. However, since it has been recognised (for example, by the Financial Stability Board) that climate change can be a source of financial risk which can affect financial stability and the real economy, there is a strong case for Central Banks with a financial stability mandate to direct their supervisory efforts to ensuring that financial institutions build climate change risk into their risk management framework and also provide more specific climate-related considerations in their capital requirements. Nevertheless, it is still somewhat uncertain whether the financial stability mandate means that Central Banks can proactively take steps to green the financial system as this goes beyond risk-based supervision. The general sentiment is that greening the financial system should be facilitated maybe but not driven by Central Banks. Central Banks must also exercise caution in how they engage with climate change-related policies and initiatives in the context of monetary policy, especially when the policy toolkit to address these objectives has not sufficiently evolved.

While most regional Central Banks view climate change from the perspective of the potential impact on financial stability, a review of the central bank acts (Appendix I) from the 10 participating members of the CERT work-stream on climate change and climate-related risks suggests that powers to address climate change are indirect and subservient to the overarching mandates. For the Central Banks of Belize, Guyana and Curaçao and Sint Maarten, their acts provide limited to no justification (either explicit or implied) to tackle climate change[3]. Nevertheless, climate considerations are currently part of the strategic objectives of a few of these Central Banks, such as the Central Bank of Curaçao and Sint

[3] The Kingdom of the Netherlands is a signatory to the Paris Accords. However, neither Curaçao nor Sint Maarten have yet formally agreed with the Netherlands to a kingdom-wide adoption of the treaty's protocols into their respective domestic legislation.

Maarten. Clarity on this issue is important as missteps can expose Central Banks to litigation risks, affect internal governance frameworks and forestall intended efforts should legislative updates be required. It may also be important to develop a region-specific climate taxonomy to contextualise the climate issues. However, this is beyond the scope of this initial study. Appendix II outlines some existing climate taxonomies and proposes an approach for the development of a regional taxonomy.

Legal ramifications aside, regional Central Banks cannot circumvent climate change and its consequences. As such, the key focus of this paper is to identify, analyse and address the gaps which currently inhibit regional Central Banks from progressing on the climate change assessment front. The main gap is the data, specifically data availability, collection and capacity to utilise in a meaningful way. As previously stated, regional Central Banks have not commenced collecting data to adequately analyse climate-related risks. Part of the challenge involves capturing and incorporating non-traditional data, for example, meteorological and hazard data, in a format congruent with existing macro-financial analytical models. Further, the engagement of experts such as catastrophe modellers may be a costly endeavour for Central Banks with other pressing priorities. However, given that all Central Banks are either actively responding to or closely monitoring climate developments, building out the underlying data infrastructure cannot be overlooked. The objective of this paper is to explore the key components of a data strategy required for Central Banks to undertake climate risk diagnostics. Closing the data gaps related to safeguarding financial stability will require an understanding of the climate risk assessment tools, their underlying methodologies and data requirements - this is discussed in Chapter 3. Having performed a stocktake of the availability of climate data at the jurisdictional level, the available data is matched against the requirements for the climate risk assessment tool deemed appropriate for the region to determine the depth and scope of data collection efforts. This is informed by a gap analysis outlined in Chapter 4. In Chapter 5, a roadmap is presented to close the identified data gaps in the context of the selected climate risk assessment tool. The identification of potential data providers and data collection approaches are also discussed. The paper concludes in Chapter 6.

Chapter 2: SITUATION AUDIT

This chapter provides a snapshot of climate-related challenges in the CARICOM region as viewed by regional Central Banks. A *"CERT Climate Change and Climate-Related Risks Survey"* was disseminated to regional Central Banks over the period January 12 to February 3, 2023. The survey's intention was to assess the perception or importance of climate issues to regional Central Banks. With a response rate of 81.8 per cent, nine (9) Central Banks completed the survey[4]. The results disclosed perceptions about the potential impact of climate change on Central Banking in general, monetary policy, financial stability and internal operations (Appendix III).

Generally, Central Banks in the region see climate change as a concern which they are closely monitoring and actively working on, with an understanding of both physical and transition risks critical for policymaking. While most banks have acknowledged that their current monetary policy frameworks do not sufficiently address climate-related concerns, if at all, a few Central Banks have engaged in green asset investments as part of their cadre of reserves. Meanwhile, climate change issues have been incorporated and is now considered within the internal operations of most banks. This is evidenced by banks engaging in emissions reduction activities which include energy efficiency, energy conservation and recycling. Going forward the consensus is that to assess climate-related risks, the articulation of climate change scenarios should anchor the development of stress testing frameworks for all CARICOM Central Banks. Also, climate-related issues generally form part of institutions' strategic plans.

2.1 Climate Change and Central Banking

Climate change is a very clear and present concern for the Central Banks of the CARICOM region. Two-thirds of the respondents are closely monitoring climate change, while the other banks are actively addressing this concern in day-to-day operations (Figure 1a). Among the respondent Central Banks, seven (7) are actively working on climate change issues, with the remaining two (2) banks envisioning similar participation; one within the short-term (1 year) and the other over the medium term (2 – 5 years). The view of the most impactful risk for policymaking is balanced in the region. Five (5) Central Banks deemed physical risks more relevant than transition risk[5] (Figure 1b).

[4] These included Bank of Guyana; Bank of Jamaica; Central Bank of Aruba; Central Bank of Barbados; Central Bank of Belize; Central Bank of Suriname; Central Bank of the Bahamas; Central Bank of Trinidad and Tobago; and the Eastern Caribbean Central Bank.

[5] Climate risks to the economy can be divided into two categories, namely, physical risks and transition risks. Physical risks are environmental events such as floods or storms, whereas transition risks arise from changes in policy and new technologies, such as the growth of renewable energy.

Figure 1a: Views on Climate Change

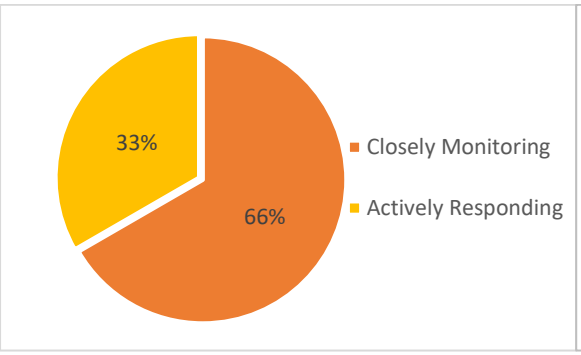
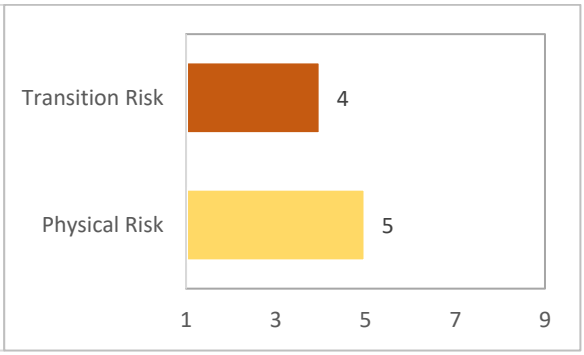


Figure 1b: Climate-Related Risk



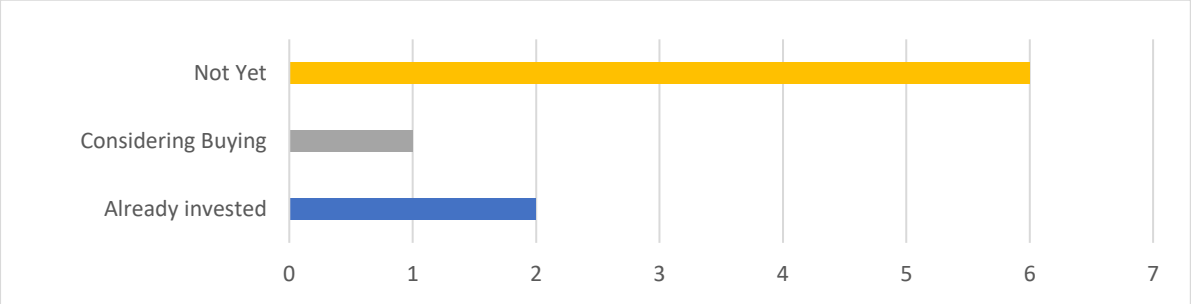
Source: CERT 2023

2.2 Monetary Policy and Climate Change

Adjustments regarding monetary policy have progressed slowly. Most respondents (66.6 per cent) have neither made, nor are considering adjusting their monetary policy frameworks to include climate-related variables. Of the three (3) banks that intend to, or have already adjusted, two (2) see the transmission taking place via balance sheets and interest rates, while the other bank identified credit channels. Correspondingly, six (6) banks deemed their existing toolkit of monetary policy instruments as inadequate for addressing climate-related concerns. One (1) of the three (3) banks that viewed their toolkit as satisfactory, believes that the direct or indirect usage of such policies was simply a matter of appropriate calibration. Another respondent recognised instruments such as their reserve requirement ratio, discount rate, selective credit controls, and the supplemental use of moral suasion, as adequate to address their climate-related risks.

While most banks have not begun investing in green assets, it is noteworthy that two (2) Central Banks have already made such investments. The Central Bank of Trinidad and Tobago has an approved mandate to invest between 1 and 5 per cent of its international reserves in ESG instruments, while the Central Bank of Belize has invested between 5 and 10 per cent. Of the remaining institutions, one (1) is considering green asset purchases, while this type of investment is not yet under consideration for the remaining six (6) Central Banks (Figure 2).

Figure 2: Investment into Green Assets

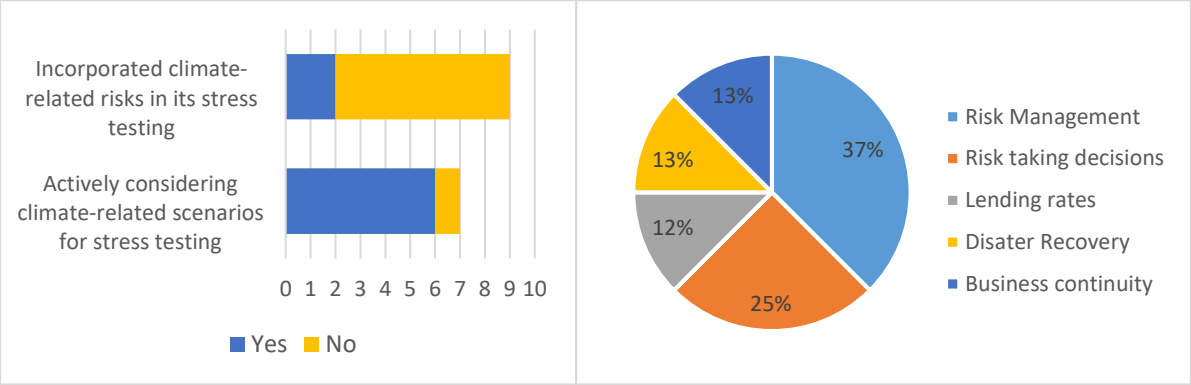


Source: CERT 2023

2.3 Financial Stability and Climate Change

Climate change is a major risk to financial stability for most Central Banks. Only one Central Bank did not consider it a major risk, but that institution is actively considering climate-related scenarios for stress testing. The Central Bank of Aruba and the Eastern Caribbean Central Bank already incorporated climate-related risks in their stress testing exercises, while almost all others (except for one) are actively considering climate-related scenarios for stress testing (Figure 3a).

Figure 3a: Climate Risk and Stress Testing Figure 3b: Impact of Climate Risks on Operations



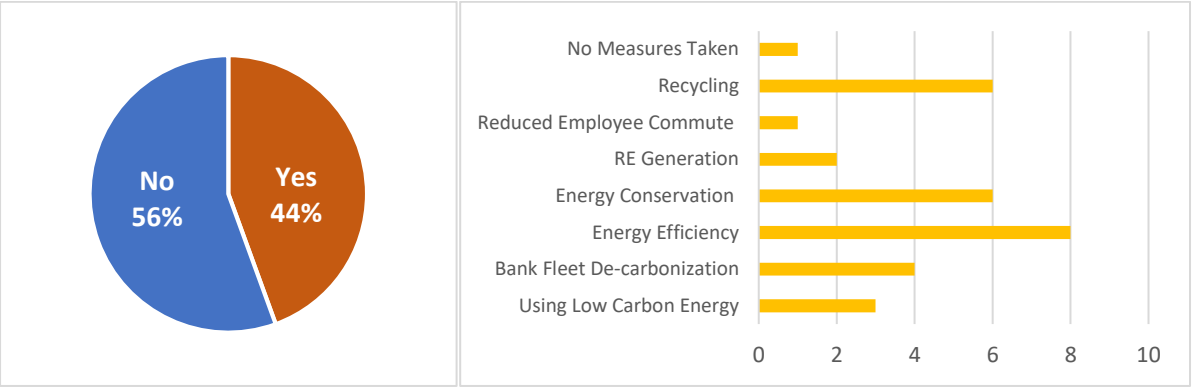
Source: CERT 2023

Commercial banks and other licensees have incorporated climate-related considerations into their operations in the Bahamas, Belize, Eastern Caribbean Currency Union and Trinidad and Tobago. Within these banking jurisdictions, the areas of risk management and risk-taking decisions have been the most impacted (Figure 3b). Other areas of impact noted include business continuity, disaster recovery and lending rates.

2.4 Internal Operations and Climate Change

CARICOM Central Banks have incorporated climate issues into their operations to varying degrees. Climate change policies are being implemented in four (4) Central Banks, with the earliest policy having been implemented since 2017 (Figure 4a). While only the Eastern Caribbean Central Bank has identified an emissions target, almost all banks have engaged in emissions reduction activities. The top emissions reduction practices include: energy efficiency, energy conservation and recycling (Figure 4b). However, there may be more impactful reductions strategies being missed as only three (3) banks have performed energy audits on their operations since 2019.

Figure 4a: Policy Implementation Figure 4b: Emissions Reduction Measures Implemented



Source: CERT 2023

Institutions remain keen on their involvement in international groups as two (2) Central Banks are involved with the NGFS and another bank is working with the UNEPN IPCC. Five banks have either accessed, or are in the process of accessing, international or regional grant funding for their adaptation and mitigations strategies against climate change. The survey results also show that more attention needs to be paid to measurement activities and education within the region. None of the respondent banks have begun collecting data in order to adequately analyse climate-related risks. Five (5) banks have not exposed their staff to climate-related training, with three (3) of those institutions having no intention to do so in the next year.

Chapter 3: CLIMATE RISK ASSESSMENT TOOLS AND DATA REQUIREMENTS

This chapter investigates the international approaches and data requirements for climate risk assessment, including stress testing. Although approaches for both physical and transition risk assessment are covered, the Caribbean's focus is tilted to scenario analysis and stress testing given a proposed emphasis on financial sector risks posed by the materialisation of acute/chronic physical climatic events. It should be noted that international approaches, particularly for incorporating climate-related risks in stress testing, are still at a nascent stage and no standard regulatory climate-risk stress test has been applied to financial systems to date. While climate risk awareness is building, further work and collaboration with external stakeholders in the financial and scientific fields is necessary to expand technical capacity for the assessment of climate-related risk (Duke & Persad, 2021).

3.1 International Experiences Assessing Climate-Related Risk

In April 2020, the Basel Committee on Banking Supervision (BCBS) conducted a stocktaking exercise of 27 members and observers to gather information on climate-related financial risk initiatives. Most respondents (24) indicated that research was undertaken to measure climate-related risk to the financial sector using varying approaches, including scenario analysis and stress testing. However, 18 respondents indicated that only a few banks in their jurisdictions had performed stress tests to ascertain the impact of climate-related risk on financial risks. Respondents noted that a lack of data and the uncertainty in measurement and tracing, were key challenges in the modelling exercise (Basel Committee on Banking Supervision, 2020). These results supported conclusions of a Central Banking focus report on climate change risk management[6] which indicated that most Central Banks were not yet collecting data on climate change, but rather, were developing proficiencies in this area (Central Banking, 2019).

Several authorities in analysing climate scenarios have cited difficulties, due to insufficiently granular climate and environmental data (including balance sheet exposures), as well as a lack of specific tools to capture distinguishing features of climate-related risks (including varying time horizons; uncertainty in the timing of "green" policy and technology development; and the complexity of transmission channels and macro-financial feedback loops).

Table 1 provides a summary of the various international approaches to stress testing climate-related risks. Scenarios range from orderly to disorderly to *'Hot House'*[7] for transition risks and increases in

[6] Thirty-four out of one hundred Central Banks provided responses, mainly from European countries (44 per cent). The study was conducted in March 2019.

[7] According to the NGFS, "orderly" scenarios consider the early introduction of climate policies, which gradually become more stringent. On the other hand, "disorderly" scenarios assume that policies have been delayed or are applied suddenly or

frequency and severity of natural disasters from floods, hurricanes and drought to typhoons and windstorms for physical risk. Rising sea level and temperatures are also included. Overall, various models and tools are employed when assessments are made, with only the NGFS scenarios gaining some traction in terms of application of a standardised approach.

Table 1: Summary of International Approaches to Stress Testing Climate-Related Risk

Jurisdiction	Organisation/ Author	Climate-related risk	Scenarios	Models/Tools employed
-	Network of Central Banks and Supervisors for Greening the Financial System **(NGFS)**	Physical and Transition	Explored scenarios that may be orderly or disorderly as well as scenarios that fail to mitigate rising temperatures (hot house world).	Utilized a suite of models
UK	Prudential Regulatory Authority* **(PRA)**	Physical	• Increase in the frequency of major hurricanes by 10 per cent in 2050 and 20 per cent in 2100. • Increase in average sea level by 4cm in 2050 and 10cm in 2100. • Increase in property related claims by 10 per cent in 2050 and 25 per cent in 2100.	Based on individual insurance company existing models
		Transition	• Decrease in 28 per cent of the equity value of the oil sector by 2022 and a decrease by 10 per cent in 2050. • Credit ratings downgrade as countries stress their balance sheets to cope with adaptation strategies to negative 5 basis points in 2050 and negative 10 basis points in 2100.	Based on individual insurance company existing models (not disclosed)
France	French Prudential Control and Supervision Authority **(ACPR)**	Physical	• The impact of natural disasters (property damage)	Météo-France model/ institutions' estimations and model/tools
		Transition	• Baseline scenario, or an orderly transition. • Disorderly transition scenario (GHG emission reduction not met by 2030). • A sudden transition scenario (increase in carbon prices to $917 per ton of CO^2 by 2050).	Based on institutions' estimations and model/tools
Europe	European Central Bank **(ECB)**	Physical	• Drought and heat scenario • Flood risk scenario	Based on institutions' estimations and model/tools
		Transition	• Orderly Scenario – climate polices are implemented early becoming severe gradually. • Disorderly Scenario – delays in climate policies. • Hot house world scenario – no climate policies.	Based on institutions' estimations and model/tools
-	UN Environment Finance Initiative	Physical	Incremental events (rising temperatures and changes in precipitation) and extreme climate events (cyclone, flood, wildfire, drought & heat) examined under a 2°C scenario in the 2020's and both a 2°C and 4°C scenario in the 2040's.	Based on institutions' estimations and model/tools
UK	Association of British Insurers **(ABI)**	Physical	• US Hurricanes - Increase in average wind speed by 4, 6 and 9 per cent. • Japanese typhoons - Increase in average wind speed by 4, 6 and 9 per cent. • European windstorm - Increase frequency of windstorms that occur once every 20 years or less by 20 per cent.	AIR catastrophe model (a software solution that estimates the risks emanating from natural perils)

unevenly across sectors and economies. The "hot house" scenarios reflect partial or no implementation of climate policies globally, which fail to limit temperature increases.

Jurisdiction	Organisation/ Author	Climate-related risk	Scenarios	Models/Tools employed
The Netherlands	**De Nederlandsche Bank* (DNB)**	**Transition**	• Government policy shock • Technological shock • Combination of policy and technological shock • Drop in consumer and investor confidence	NiGEM (National Institute Global Econometric Model)
Spain	Central Bank of Spain	Transition	• Higher emission price scenario – an increase in the price of a tonne of CO2 equivalent from €25 to €100. • Extension of Emissions Trading System (ETS) coverage to all business sectors scenario - emissions levied to all sectors regardless of if they are emitters or not. • Combined shock scenario – Raising the price of emissions and extending the coverage to all business sectors, • Combined shock scenario and extending the ETS coverage to households for fuel consumption.	CATS (Sectoral Carbon Tax Model) - a general equilibrium model
EU	Battiston (2016)	Transition	Assesses (i) a bank with all its current equity holdings in utilities invested in renewables-based utilities and no fossil fuel investments, (ii) a bank that keeps all current equity holdings in fossil fuel and all its equity holdings in utilities invested in fossil fuel-based utilities.	Climate Value-at-Risk (VAR) approach
China	Monasterolo, Zheng, and Battiston (2018)	Transition	Assesses the exposure of energy and non-energy projects for two Chinese policy banks under moderate to severe greenhouse gas emissions scenarios.	Climate Value-at-Risk (VAR) approach
Colombia	Sever and Perez-Archila (2021)	Transition	Evaluate high carbon tax (US$70 increase) impact on nonfinancial firms' balance sheets, and subsequent effects to the banking system via banks' exposure to these firms.	Static stress test (direct transmission channel), undisclosed models
Hungary	Várgedő (2022)	Transition	Focused on quantifying the impact of a carbon price shock on the Hungary banking sector.	Sectoral model/ Monte Carlo simulations

Source: Duke and Persad, 2021 compilation.
*Refers to a Central Bank.

3.2 Climate-Related Risk Assessment Models and Tools

Table 2 illustrates the multiplicity of approaches to climate risk assessment across country and regional groupings. This section and its constituent sub-sections examine select climate change risk assessment tools/models, their methodologies and types of data required.

3.2.1 Stress Testing and Scenario Analysis

According to Baudino and Svoronos (2021), assessing climate-related impacts requires fundamental changes from traditional stress tests designed to study the effects of external shocks on bank solvency. In a climatic stress test, climate scenario models project pathways for specified physical and transition risk variables (UNEP FI, 2021 (a)). Integrated Assessment Models (IAMs)[8] are computer-based models that provide emission pathways, optionally used in climate models[9]. These climate scenario models investigate prospective changes to the climate system and depict deviations in energy production and usage over time, technology advances, natural resource use, and the effects of climate policy. Scenario

[8] Examples of IAMs include; GCAM, MESSAGE-GLOBIOM, REMIND-MAgPIE, WITCH, AIM and IMAGE.
[9] IAMs do not consider non-monetary preferences, energy security and potential socio-political interactions. As a result, cost-optimal pathways may be less desirable and less politically viable than non-optimal pathways (UNEP FI 2021)

and variable expansion are often required to produce credible outputs for diverse geographies, sectors and asset types.

Modelling techniques for climate stress tests, at a minimum must be composed of four parts: (1) modelling the climate variables, (2) measuring the impact of climate on macroeconomic variables, (3) breaking down the overall macroeconomic impact across sectors, and (4) quantifying the combined impact on financial firms (Appendix IV (a)). Climate scenario models are required to estimate pathways for the relevant physical and transition risk factors, following which, macro-economic models are then required to translate variables from the climate model to selected macroeconomic variables, translating climate risks into monetary impacts. Climate stress testing necessitates the use of these models to break down macroeconomic consequences to the sector level. Following this, financial models at an institution-level are used to calculate a bank's exposures to climate risks, with such internal models assessing changes in metrics, such as probabilities of default (PD) and loss given default (LGD) (UNEP FI, 2021 (a)).

From the perspective of a financial regulator, two approaches feature when performing a climate stress test - a *'top-down'* and *'bottom-up'* approach. Top-down approaches feature a supervisory authority conducting the stress test themselves, using their own framework inclusive of a standardised methodology, assumptions, scenarios, and models. Conversely, when a supervised entity (financial institution) employs its own framework as part of a system-wide or supervisory exercise, this is regarded as a bottom-up approach to climate stress testing (UNEP FI, 2021 (a)).

The European Central Bank Stress Testing Framework

The climate stress test conducted by the European Central Bank (ECB) in 2022, was a constrained bottom-up stress test. Such that, banks under its supervision provided the qualitative and quantitative inputs for the exercise, while complying with a common methodology and applying a common set of scenarios as stipulated by the ECB. The scope of the exercise was limited to a selection of climate-related risk transmission channels, asset classes and scenarios to keep the exercise manageable at an operational level. Not covered in this exercise were the interlinkages between climate risk and banks' balance sheets. The ECB describes this bottom-up methodology and related scenarios, as a selective approach (ECB, 2022).

The methodology consisted of three distinct modules (Appendices IV (b) and (c)):

1. Framework questionnaire (a comprehensive qualitative questionnaire on 11 sections);
2. Stock-take on emissions (the estimation of two climate risk metrics: to provide insight into the sensitivity of banks' income to transition risk and their exposure to carbon emission-intensive industries);

3. Bottom-up climate stress test (these stress tests and projections were provided by the individual banks for different scenarios and risk areas provided by the ECB, covering both physical and transition risk).

The US Federal Reserve Pilot Climate Scenario Analysis (CSA) Exercise

In January of 2023, the United States Board of Governors of the Federal Reserve System (US Fed), embarked on a bottom-up Pilot Climate Scenario Analysis (CSA) Exercise. According to US Fed the exercise has two primary objectives – firstly, to learn about large banking operations' climate risk management practices and challenges and secondly, to enhance the ability of both large banking organisations and supervisors to identify measures, monitor and manage climate-related financial risks. Further, the exercise was described as exploratory in nature, with no intended consequences for bank capital or supervisory implications. Featured were six large banking organisations[10], all with material commercial and residential real estate exposures located in the North East Region of the United states, as defined as by the 'Fourth National Climate Assesment (NCA4).

This CSA exercise comprised two modules, assesing both qualitative and quantitative, physical and transition risk exposures of the participating banks[11]. Data templates and qualitative questionaires were supplied to all participants along with supporting documents (describing internal governance, risk management practices, measurement methodoligies, portfolio specific results and leasons learnt). US Fed (2023) stated that the exercise placed emphasis on the changes to broad credit risk parameters, such as PD, internal risk rating grade (RRG), and LGD, rather than on estimates of losses. This would provide information about how the relative riskiness of exposures within participants' credit portfolios may evolve over time in response to different climate scenarios, given the partial nature of the exercise, which focuses on specific regions and certain portfolios for the six participants.

For both modules, the participating banks were provided forward-looking scenarios leveraged from the existing work of the UNEP IPCC and the NGFS, including core climate, economic and financial variables. Participants were to estimate the effects of the scenarios on the relevant subset of their loan portfolios over a time horizon of 2022 to 2032. Two scenarios were used to assess both physical and transition risk; (1) A *'Baseline (NiGEM)'*, assuming all currently implemented policies and the adoption of no new policies, inclusive of those already announced, and (2) A *'Net Zero 2050*' scenario, where global warming is limited to 1.5 °C and immediate stringent policies achieve Net Zero $C0_2$ emissions by 2025. Additionally, carbon prices increase over the time horizon, alongside a relative rapid change in the

[10] Bank of America Corporation; Citigroup Inc.; The Goldman Sachs Group, Inc.; JPMorgan Chase & Co.; Morgan Stanley; and Wells Fargo & Company.

[11] Both physical and transition risks are viewed by the US Fed as manifesting as traditional prudential risks for large banking organisations.

technological landscape, with the medium-to-high use of CO_2 removal technology. Of the three IAMs[12] available from the NGFS, REMIND-MAgPIE was selected, with the NiGEM macroeconomic model utilised. Data was sourced from the NGFS Scenario Database[13] using variables paths from the NGFS Phase III[14] (NiGEM NGFS v1.22 [REMIND-MAgPIE 3.0-4.4] model).

UNEP FI (2021 (b)), identified a complete breakdown of the service providers for both transition and physical risk assessment tools and analytics services (Appendix IV (d)).

Table 2: Commonly used Models for Climate Scenario Analysis

Potential Models	Description	Open-source/License required
REMIND-(PIK)	**Integrated assessment model (IAMs),** combines socio-economic, climate and land-use assumptions. Used in NGFS reference scenarios and initial climate stress test scenario design.	Fully open-source
MESSAGE-(IIASA)		
GCAM - (PNNL-UMD)		
IMAGE - (PBL)	**Integrated assessment model**, combines socio-economic, climate and land-use assumptions.	
World Energy Model (IEA)	**Granular energy system model**, used to set IEA's World Energy Outlook Forecasts. Forthcoming Net-zero scenario.	License required, some assumptions proprietary
Energy Technology proprietary Perspectives (IEA)	**Bottom-up model** covering energy supply and technological development in the energy sector	
NiGEM (NIESR)	**General equilibrium model** used to produce macroeconomic variables. Now working with NGFS to produce macro outputs for their scenario pathways	License required. Some assumptions proprietary, NGFS data open-source.
GTAP (Purdue)	**General equilibrium model**, multiple regions and sectors available	Fully open-source
G-Cubed (McKibben)	**Macroeconomic model** used by IMF for economic scenarios on mitigating emissions and warming.	License required, some assumptions proprietary
One Earth Climate Model (UTS)	**Bottom-up model** designed to provide specific sectoral de-carbonisation pathways for members of the UN Net-Zero Asset Owners' Alliance (NZAOA).	Some data and assumptions open-source
En-ROADS/C-ROADS (MIT)	**Dynamic model** allowing users to alter numerous assumptions around technology and economics to attain particular temperature outcomes	Tool open-source, data/assumptions proprietary
AIM (NIES)	**Assesses the economic impact of policies** to reduce GHG emissions, with a focus on the Asia-Pacific region.	Free-of-charge
Industry models (Shell, BP, etc.)	Used **by fossil fuel firms to forecast future demand**, now expanded to function as de-carbonisation pathway models	Data open-source, some assumptions proprietary

Source: (NGFS, 2022) and (UNEP FI, 2021 (a))

[12] GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE

[13] Transition Risk Scenario data https://www.federalreserve.gov/publications/climate-scenario-analysis-exercise-instructions.htm.

[14] See https://www.ngfs.net/ngfs-scenarios-portal/

3.2.2 Integrated Assessment Models (IAMs)

NGFS (2022) identifies three well-established integrated assessment models (IAMs), namely GCAM, MESSAGEix-GLOBIOM and REMIND-MAgPIE.[15] They enable, in particular, the estimation of global and regional mitigation costs, the analysis of emission pathways, associated land use, energy system transition characteristics, the quantification of investments required to transform the energy system, and the identification of synergies and trade-offs of sustainable development pathways. Sharing a similar structure, the three models combine macro-economic, agriculture and land-use, energy, water and climate systems into a common numerical framework that enables the analysis of the complex and non-linear dynamics in and between these components. It should be emphasised, however, that these models do not account for climatic damages (the exception being the additional integrated damage scenarios with the REMIND-MAgPIE model version with integrated damages).

GCAM is a global model that represents the behaviour of, and interactions between five systems: the energy system, water, agriculture and land use, economy, and climate. MESSAGEix-GLOBIOM refers to the IIASA IAM framework, which consists of a combination of five different models: (i) energy model MESSAGE, (ii) land use model GLOBIOM, (iii) air pollution and greenhouse gas model GAINS, (iv) aggregated macro-economic model MACRO and (v) simple climate model MAGICC (Model for the Assessment of Greenhouse-gas Induced Climate Change. Lastly, REMIND-MAgPIE is a comprehensive IAM framework that simulates, in a forward-looking fashion, the dynamics within and between the energy, land-use, water, air pollution and health, economy and climate systems (NGFS, 2022).

3.2.3 Bank of Spain Carbon Tax Sectoral (CATS) Model

The CATS model is a general equilibrium sectoral model designed to produce macroeconomic scenarios relating to transition risks associated with climate change policies. The model is calibrated to the Spanish economy and can simulate the impact of shocks to the price and coverage of greenhouse gas emission allowances, with particular attention to sectoral asymmetries arising from (i) the energy intensity of each industry, (ii) the source of that energy, and (iii) the interdependencies with other industries. According to Baqaee and Farhi (2019), the model allows estimation of the impact of taxes on different sectors of the economy under several scenarios[16] such as a 'Combined Shock Scenario' and extending the ETS coverage to households for fuel consumption.

To construct the CATS model, data on energy intensity and emission type by technology was obtained from Spain's input-output tables that provide information. The application of the CATS model generates

[15] Access to these can be found at; https://www.ngfs.net/ngfs-scenarios-portal/

[16] The scenarios utilized were: (1) Higher Emission Price Scenario, (2) Extension of Emissions Trading System (ETS) Coverage to all Business Sectors Scenario, (3) Combined Shock Scenario.

estimated Gross Value Added (GVA) growth pathways for the energy sector. Following this, the 'Forward Looking Exercise' on Spanish Banks stress testing framework (FLESB) credit risk methodology was augmented to model the probability of default (PD) of banks' lending exposure. Data was sourced from the Central Bank of Spain's Credit Register for the different sectors and micro and large firms.

CATS works on a relatively short time horizon, as it is primarily used to generate transition-risk scenarios that assess the different productive sectors' degree of exposure in the event of an increase in the price of emission allowances or an extension of EU-ETS coverage. The model includes 51 non-energy industries and two energy industries (fuel and electricity). The economy is closed, with the exception of basic energy inputs, which are imported. The model is calibrated with observed 2015[17] data for Spain and matches trade relationships for the Spanish economy summarized in the input-output table.

3.2.4 Morgan Stanley Capital International (MSCI) ESG Research's Climate Value at Risk

MSCI ESG Research Products and Services is an analytics firm that provides risk and return assessments for global clients. The company provides research, ratings and analysis of environmental, social and governance-related business practices to companies. They developed a Climate Value-at-Risk (Climate VaR) service that focuses on the climate resilience of an entity and its portfolio. The service helps companies integrate climate and net-zero solutions into their investment processes. Climate VaR is one of the models in MSCI's toolkit for transitioning a company's portfolios to net-zero by measuring the climate-related risks and opportunities in investment portfolios. The model is a forward-looking risk metric that reflects the change in value of a company, a security, or portfolio in different real-world scenarios. It is expressed in US dollars or percentage of current portfolio capital value; and incorporates both transition and physical risk scenarios. The aggregated Climate VaR of both types of risk can then be used to compare investments across asset classes, including physical assets in a portfolio.

The Climate VaR is a fully quantitative model that offers insights into how climate change as well as current and forthcoming climate policies could affect company valuations. It is designed to provide a return-based valuation assessment and give insight into the potential climate-stressed market valuation of investment portfolios and downside risks. The model calculates the financial risks from climate change per security and per scenario. The aim is to provide a framework to help investors identify and understand these risks for portfolio performance optimization, risk management and regulatory reporting purposes. Climate VaR utilizes a four-phased modelling approach/methodology, consisting of: (1) Impact Modelling (2) Cost/profit Calculation, (3) Security Valuation and (4) Portfolio Aggregation.

[17] Input-output tables are available up to 2015 for the Spanish economy and for the euro area, which allows for a homogeneous alternative calibration that can highlight the effect of differences in the structure of the economy.

Data on company investment portfolios, equities, bonds and other institution-specific details; emissions; climate policies and climate-related costs; and weather are required.

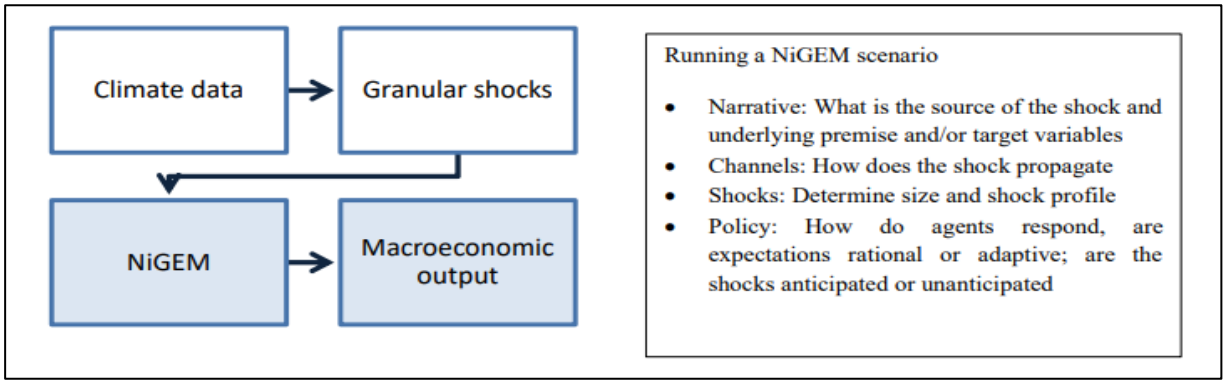
3.2.5 The National Institute Global Econometric Model (NiGEM)

The National Institute's Global Econometric Model (NiGEM) is a (multi-country) econometric model used for economic forecasting, scenario development, and stress testing by policymakers and private sector organisations worldwide. It is a transparent, peer-reviewed, global econometric model by the National Institute of Economic and Social Research (NIESR) (NIESR, 2019). The model consists of individual country models (major economies in the EU, OECD, and major emerging markets modelled individually), with the rest of the world modelled as a set of regional blocks connected via trade as well as integrated capital markets. NiGEM allows the macro-economy to be modelled (affected directly) by financial regulation and financial instability (NGFS, 2021 and Carreras, et al., 2018).

NiGEM uses historical data to econometrically model important behavioral equations. This guarantees that the model's dynamics and key elasticities match the properties of individual country data. NiGEM is a quarterly model, which allows for more detailed dynamic specifications and avoids problems with identification and convergence. Its structure is intended to correspond to macroeconomic policy requirements. Country models are structured around the identity of national income and include the factors of domestic demand, trade volumes, pricing, current accounts, and asset holdings (NGFS, 2021).

In producing NiGEM scenarios, IAMs are used as inputs, modelling GDP, population, primary energy consumption by fuel type, useful energy, and carbon taxes data (or national aggregates where country level disaggregation is not present). Transition paths for the NGFS scenarios are created using the three well-established IAMs discussed earlier: GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE. These models allow for the investigation of complex and non-linear dynamics within and across their components. Figure 5 shows the sequence for translating climate scenarios into the NiGEM.

Figure 5: Sequence for translating climate scenarios into NIGEM



Source: (NGFS, 2021)

NiGEM operates via a top-down approach and uses climate-related shocks (broadly categorised into physical and transition events) as its input shocks. The model then generates macro-economic responses, where these outputs serve as inputs into a granular stress testing exercise (NIESR, 2019). NiGEM output variables are characterized as either:

- *General Economic Output*: Gross Domestic Product (GDP); consumption, investment, government expenditure; Technological innovation and capital productivity; Unemployment rate; Corporate profits, household income; International trade flows; Gross domestic income; Trend capacity; Energy prices and consumption, or as
- *Specific Economic Output* in the context of financial risk analysis: Consumer price inflation; Energy and commodity prices; Interest rates; Government bond yields; Exchange rates between countries; Equity market indices; Real estate price indices (residential).

3.2.6 Proposed NGFS Short-term Scenarios

Short-term scenarios offer ways to better understand the near-term macro-financial impacts of the green transition and physical risks. This is achieved, through an improved understanding of adversity and non-linearities in business cycles, including interdependencies between climate risks and macro-financial developments. By covering a time horizon of three to five years, short-term scenarios can overcome limitations in macroeconomic and financial risk analysis stemming from the focus on long-term climate-economy relationships as captured in the current NGFS climate scenarios. As such, five climate scenario narratives were proposed to reflect the short-term dynamics associated with different transition and physical impacts and their interaction with the macro economy and financial sector. The scenarios capture the main sources of downside risks to an effective and timely transition (Figure 6).

Three of the scenarios, '*Highway to Paris'*, '*Green Bubble'* and '*Sudden wake-up call'*, shed light on possible avenues for reaching net zero by 2050 with different assumptions regarding climate policy stringency, the extent to which transition policies are expected, technology and the resilience of the financial sector. Underlying these scenarios is the current environment of elevated uncertainty related to future fossil energy supply, possibly driven by geopolitical tensions, which could lead to an acceleration or a delayed implementation of climate policies, depending on the evolution of public opinion. They contain different but generally elevated levels of transition risks, reflecting the gap between actions currently in place and efforts needed to reach net zero by 2050.

The '*Highway to Paris'* scenario reflects an immediate and technology-driven transition, in which the private sector develops and adopts green technologies faster than expected, inducing a rapid shift on the supply side. In the '*Green Bubble'* scenario, generous fiscal policy incentives in the form of subsidies lead to a glut of green private investment and expenditure. Investors pour money into green sectors

and the transition becomes finance-driven. The '*Sudden wake-up call*' scenario describes an abrupt and unanticipated transition, in which policy makers initially procrastinate on strengthening climate policies, essentially ignoring the need to accelerate the transition, until an event (e.g., a severe natural disaster) triggers a sudden change in policy stance. Governments hastily implement carbon policies to still reach net zero by 2050. This unanticipated change in mitigation policy sets off shock waves through the global economy and financial system.

The Low Policy Ambition and Disasters scenario is a *'Hot House World'* scenario, where extreme physical risk impacts are analysed. This scenario reflects the short-run repercussions of insufficient long-term policy ambition globally – and therefore bears high physical risks. The *'Diverging Realities'* scenario maps out possible futures with severe divergences across countries in the extent to which economies transition to net zero. The transition entails both strong transition risks in the countries which do transition and strong physical risks globally, in line with a broader long-term narrative of an ineffective transition globally. The Diverging realities scenario reflects the risk of a lack of external financing from advanced economies (AEs) and local circumstances in emerging markets and developing economies (EMDEs) and low-income countries (LICs) limiting the ability to transition globally in a timeline fashion.

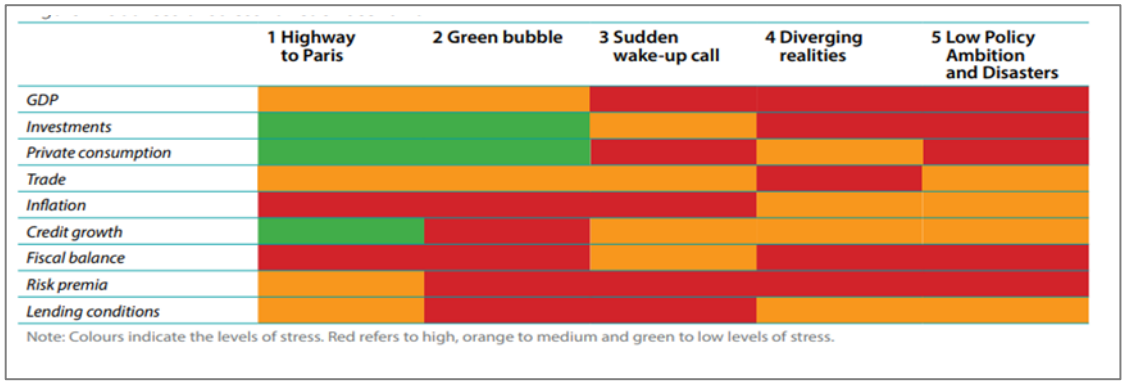
Figure 6: Overview of NGFS Narratives

Scenario	Narrative
Highway to Paris	Elevated levels of uncertainty related to fossil energy supply lead governments to implement an ambitious mitigation pathway in a timely and anticipated fashion. There is a boom in green public investment leading to a rapid reallocation of capital and across sectors as well as internationally via cross-country capital flows and lending patterns. Technology shocks lead to a faster-than-anticipated transition, inducing disorderliness. Green prudential policies prevent financial turmoil albeit with losses in some sectors due to stranded assets. In line with reaching net zero by 2050.
Green bubble	Elevated levels of uncertainty related to fossil energy supply limits governments in their ability to implement ambitious mitigation policy. Green regulation overtakes government policies in driving the transition, leading to a glut of green private investment and the build-up of a green credit bubble. A sunspot (i.e., an unrelated random event) leads to the burst of the bubble, a sharp rise in risk premia and a confidence crisis. In line with reaching net zero by 2050.
Sudden wake-up call	Elevated levels of uncertainty related to fossil energy supply limits governments in their ability to implement ambitious mitigation policy. Driven by an event that triggers a sudden change in public opinion (e.g. a severe natural disaster), an unanticipated and accelerated transition occurs.[1] The abrupt policy change sets off shock waves through the economy and financial system: stranded assets in polluting sectors cause severe financial stress which propagates internationally via capital, trade and financial flows. In line with reaching net zero by 2050.
Low Policy Ambition and Disasters	Severe acute physical disasters hit exposed jurisdictions. Investors price in a sizeable risk premium, which freezes private investment, and reduce their exposure to the jurisdictions and sectors whose assets are at greatest risk of disaster losses. Households consume less and save more due to the increase in uncertainty and insurance costs increase. **NOT** in line with reaching net zero by 2050.
Diverging realities	The world as a whole aims to avoid the worst impacts of global warming. However, severe natural disasters in the EMDEs and LICs and a lack of external financing lead to recovery traps, i.e., a lack of fiscal space for affected regions to transition. Meanwhile, the disruption of transition-critical mineral supply chains originating in disaster-prone regions hampers the speed of the global transition.[2] The sudden realization that the global transition is too slow to avoid a Hot House World leads to a sudden re-assessment of future physical impacts globally. As a result, risk premia rise sharply. **NOT** in line with reaching net zero by 2050.

Source: NGFS Technical Document "Conceptual Note on Short-term Climate Scenarios", October 2023.

Figure 7 contains a high-level overview of the sources of stress for each scenario. It should not be taken as precise forecasts of what will happen, but as an example for how one might think through these narratives. Red refers to a "high" level of stress, yellow to "medium" and green to "low". Economic activity would be affected under all scenarios, except in the Highway to Paris and Green bubble scenario as investments and private consumption support overall GDP. The source of adversity originates relatively more from the household side in the '*Sudden wake-up call*' scenario while the negative investment and trade effects are at the core of the '*Diverging realities*' scenario. The transition scenarios are expected to be more inflationary than the scenarios involving physical risks. Financing conditions are likely to be under stress in all scenarios but the '*Highway to Paris*'.

Figure 7: Sources of Stress for Proposed NGFS Scenarios



Source: NGFS Technical Document "Conceptual Note on Short-term Climate Scenarios", October 2023.

3.2.7 IMF Climate Risk Analysis in Financial Sector Assessment Program (FSAP)

Guided by its 2021 Climate Strategy, the IMF began incorporating climate change considerations in risk analysis, regulation and supervision, and monetary policy operations. Including climate risk analyses into the Financial Sector Assessment Program (FSAP) is the main way the IMF assesses risks to financial systems and policies to mitigate and manage said risks. According to the IMF, climate risk analysis cannot be treated as a standard stress test because of the level of uncertainty in climate modelling and long-term simulated horizons.

A climate risk analysis involves making future assumptions about the likelihood of global temperatures and greenhouse gas emissions trends, influenced by factors like emission reduction policies, research and technology development, and promoting adaptation and resilience to climate change's effects. The IMF (2022) suggests that global climate change scenarios involve trade-offs between the economic and financial costs of ongoing temperature rise and actions to mitigate it, as more policy steps to eliminate carbon intensity of economic activity lead to lower temperature rises.

IMF's Standard FSAP risk analysis involves scenario-based stress tests to assess bank solvency and liquidity. These top-down exercises, involving sectoral breakdown, evaluate credit, market, interest,

and foreign exchange risks over a three (3) to five (5) year stress-testing horizon. Adverse scenarios are used to predict country-specific linkages between macro drivers and risk indicators, influencing bank income and capital based on their historical association. Granular data for individual company and household balance sheets can be used in solvency examinations to analyse the impact of unfavourable scenarios and model risks at a more aggregated top-down level to help discover threshold effects and provide a more accurate understanding of financial situations (IMF, 2022).

The IMF's climate risk FSAP methodology uses the NGFS reference scenarios for emissions and temperature, along with pathways for physical and transition risk, to analyse climate change. It uses IPCC pathways up to 2100, climate impacts projections, GDP, population, and urbanization rate to contextualize each emission pathway and make a range of assumptions about technology evolution. Climate change hazards projections are sourced from private vendors or country authorities, covering various risks like precipitation, cyclones, floods, droughts, wildfires, heatwaves, and chronic physical risks. These projections align with NGFS scenarios, providing country-level aggregate risk indicators and location-specific data.

IMF's Climate Risk Analysis Approach involves:

i. Standard top-down FSAP Risk Analyses provides the starting point.
ii. Climate Risk Analysis modules are then included by identifying the most relevant climate risks and hazards for a country. This evaluation is based on a climate risk assessment matrix (C-RAM), which includes both transition and physical risk metrics and provides a narrative of transmission pathways.
iii. Estimating the impact of projected hazards on damages and productivity, as well as their effects on bank stability. These scenarios are then used to estimate the impact on bank solvency using the standard approach for banks' stress tests.
iv. Conduct of bank stability assessments using one of two approaches: A Macro approach that incorporates analysis of capital and productivity shocks due to hazard damages and; a Micro-macro approach which relies on an analysis of firms and households using micro models to estimate the impact of physical risk on individual balance sheets

3.3 Data Requirements for Climate Stress Testing

UNEP FI (2021) categorizes the data needed for a climate stress test as traditional macro-financial data and climate-related data (Table 3).

Table 3: Data Required for Climate Stress Testing

Traditional Macro-Financial Data Required for Climate Stress Testing		
Data Type	**Data required**	**Data source**
Finance-related data	• Portfolio composition by sector and geography. • External and internal credit and valuation criteria. • Local and global economic data. • Balance sheets.	• Internal systems
Macroeconomic data	• GDP, unemployment, population growth, inflation, interest rates and exchange rates.	• Scenarios
Data metrics for expected losses	• Probability of Default (PD). • Loss Given Default (LGD). • Average exposure at default (EAD)	• Internal systems
Borrower/asset financial data	• Costs and revenues by scenario. • Forward-looking metrics, such as OPEX and CapEx	• Internal systems • Scenarios
Climate hazard data	• Historical data on acute and chronic physical risks. • Projections of future acute and chronic physical risks, including their severity and frequency. • Adaptive capacity data to determine resilience and sensitivity to climate hazards, including current adaptation strategies. • Climate hazard data based on geography, sector and industry, including economic losses from past climate hazards	• Scenarios • Clients • External providers
Data describing transition risk drivers	• Transition risk drivers including policy implementation, market shifts, technological changes and reputation.	• Scenarios
Emissions data	• Energy and carbon mix of counterparties. • Published or estimated GHG emissions produced by portfolios and assets of clients. • GHG emissions data by region, sector or industry. • Energy efficiency data, for example real estate ratings such as the Energy Performance Certificate Rating. • Data on carbon pricing by jurisdiction	• Clients • External providers • Internal systems
Climate-related client data	• Identification of the physical assets owned by clients. • Detailed and granular geographical/geo-locational asset data	• Clients • External providers
Alignment and transition data	• Transition pathways set by clients in accordance with the Paris Climate Change Agreement. • Science-based emission reduction targets set by clients. • Climate policies and pledges of countries.	• Clients • External providers
Climate Data Required by Firms to Assess Counterparty-specific Climate Risks		
Type of Climate Risk	**Type of Climate Data**	
Physical	Adaptive capacity data, including: • Client's adaptation and resilience plans; • Client's sensitivity to past climate events, including data on how the client has tackled extreme weather events in the past. • Geographical data on the location of client's physical assets.	
Transition	• Alignment and transition plans (e.g. targets and pathways for reducing emissions). • Data on a client's preparedness to transition to a low-carbon economy. • Published or estimated emissions data by jurisdiction, asset or category of assets. • Data available on exposure to carbon prices by jurisdiction. • Energy efficiency and mix data by asset or category of assets.	

Source: (NGFS, 2022) and (UNEP FI, 2021 (a))

Chapter 4: AN ANALYSIS OF REGIONAL CENTRAL BANK CLIMATE DATA GAPS

This assessment provides an overview of the available climate change data at regional Central Banks and the gaps that need to be addressed to support the development of climate scenarios and climate stress testing. The review of the data required and available for climate stress testing for each jurisdiction at both granular and non-granular levels shows that there are wide data gaps to be filled. By understanding these gaps, stakeholders can prioritize data collection efforts to enhance risk assessment, adaptation planning, and resilience-building strategies in the region.

The assessment of climate-related risks requires new and unique types of data, different to the data Central Banks have traditionally used in their financial risk analyses. In the Caribbean region, the development of the data needed to quantify climate-related risks is still in its nascent stage of development. Table 3, details the data needed for climate-related stress testing and Table 4[18] gives a summary of data availability.

Table 4 is informed by the data submitted by the regional Central Banks and international institutions that have developed data sets and tools to help quantify and monitor the financial implications of climate change. The international institutions are:

- *The International Monetary Fund (IMF*) – The IMF published the Climate Change Indicators Dashboard (CID)[19] which allows one to visualise and compare the risk of crises and disasters across countries.
- *The NGFS*[20] – The NGFS developed a web-based interface that provides intuitive visualisations of physical risk scenarios.
- *The World Bank* – The World Bank created the Climate Change Knowledge Portal (CCKP)[21], which was designed as a 'one-stop shop' for climate-related information, data, and tools. The CCKP is an online tool for access to comprehensive global, regional and country data related to climate change and development.
- *United Nations Framework Convention on Climate Change (UNFCCC)*[22]: The UNFCCC is an international treaty that addresses climate change. They provide access to national reports submitted by countries, including those from Caribbean nations, which outline their efforts to mitigate and adapt to climate change.

[18] This table was populated based on the response of the Central Banks on their data availability and sources for Climate Change Data and it was supplemented by an online search from each country for the specific area of data identified for each country in this study.
[19] https://climatedata.imf.org/
[20] https://www.ngfs.net/ngfs-scenarios-portal/
[21] https://climateknowledgeportal.worldbank.org/
[22] https://unfccc.int/

- *Intergovernmental Panel on Climate Change (IPCC)*[23]: The IPCC produces comprehensive assessment reports on climate change, including regional impacts. While they do not focus specifically on the Caribbean, their reports can provide valuable information on global climate trends and projections.

The main Caribbean regional data sources for climate change data are:

- *Caribbean Community Climate Change Centre (CCCCC)*[24]: A organisation focused on addressing climate change issues in the Caribbean. They provide data and reports on climate change impacts, vulnerability assessments, and adaptation strategies specific to the Caribbean region.
- *Caribbean Institute for Meteorology and Hydrology (CIMH)*[25]: The CIMH collects and analyses meteorological and hydrological data for the Caribbean. They provide climate data, including historical records, climate models, and projections for the region.
- *National Meteorological and Hydrological Services (NMHS)*: Each country in the Caribbean has its own NMHS responsible for monitoring weather and climate conditions. They often collect local climate data and provide climate services to their respective countries.

Upon review of the data sources, while some indicators are available, not all the data needed to conduct the appropriate climate-related risk models for Caribbean economies are currently being collected. Central Banks need time series data that is accurate and valid to conduct their climate-related risk assessments. The data currently available is data that is collected intermittently and not consistently over time; these data are classified as "partial and not consistent data available" in Table 4. Although the data is available partially for some indicators[26] in the identified areas, Central Banks need more consistent and timely data to conduct climate-related risk scenarios. Long-term datasets that capture climate change trends over several decades are scarce. Such data is crucial for understanding gradual shifts in climate patterns and projecting future risks with some reasonable degree of validity.

Central Banks publish macroeconomic and financial indicators that are needed for the climate change risk modelling however, the data that specifically inform the climate–risk factors for both physical risk and transition risk are generated by institutions beyond the scope of Central Banks[27]. It should be noted that even the level of granular data needed from financial institutions under the regulation of the Central Banks are not always consistently collected and it may require survey and market studies to be done. For example, data on climate hazards is based on geography, sector and industry, including

[23] https://www.ipcc.ch/
[24] https://caricom.org/institutions/caribbean-community-climate-change-centre-ccccc/
[25] https://www.cimh.edu.bb/
[26] Data available intermittently for indicators such as historical data on acute and chronic physical risks,
[27] Addressing Climate Risk Data gaps to support Financial Stability, Financial Stability Report 2022, Central Bank of Trinidad and Tobago, August 2023.

economic losses from past climate hazards and climate-related client data such as the identification of the physical assets owned by clients and detailed and granular geographical/geo-locational asset data.

Assessing physical risks requires very geographically specific data such as location information, terrain characteristics, climate details, and atmospheric maps, as well as financial, economic, and socioeconomic variables, and combining these different types of data over a spatial dimension. Similarly, for transition risks, firm-specific information is needed for areas such as the financial institution's alignment and transition plans (for example, targets and pathways for reducing emissions), data on a clients' preparedness to transition to a low-carbon economy, energy efficiency and mixed data by asset or category of assets.

Addressing the identified data gaps is crucial for building resilience against climate change in the Caribbean economies. The main data gaps identified for the region from this initial study are:

1. Limited long-term/longitudinal data: Long-term, consistent data collection is essential for accurate trend analysis and projection modelling. Strengthening regional climate monitoring networks with Central Banks, financial institutions, government institutions (Ministries of Planning, Marine Affairs, Energy, etc.), environmental agencies, and meteorological agencies can address this gap.
2. Regional/Localised impact data: There is an absence of localised data that reflects the unique vulnerabilities of each Caribbean jurisdiction. This would assist in tailoring adaptation strategies. There is value in having a regional climate change interactive data website, that will provide the data that Caribbean economies need to assess country-specific risk. The work by Caribbean Community (CARICOM) can be noted as a starting point for the development of a regional Caribbean-specific Climate Change data repository for Caribbean economies. The CARICOM Climate Change Statistics: 2020[28], is the first publication on Climate Change Statistics for CARICOM countries containing data up to 2019 in some instances, while for other series it comprises data up to 2012/13[29].

By investing in data collection, analysis, and dissemination, policymakers, stakeholders and governments can make informed decisions, develop effective adaptation strategies, and ensure the long-term sustainability of the region.

[28] The Caribbean Community (CARICOM) Climate Change Statistics: 2020, aims at providing statistics on climate change for the region and follows the Framework for the Development of Environment Statistics (FDES 2013) of the United Nations Statistics Division (UNSD) and its refinements based on the Inter-Governmental Panel on Climate Change (IPCC) schematic framework. The IPCC framework summarises Climate Change into five components, Drivers, Impacts, Adaptation, Mitigation and Vulnerability. https://caricom.org/wp-content/uploads/CARICOM-Climate-Change-Statistics-2020.pdf

[29] This project has resulted in a series of capacity-building activities, which were undertaken in the Region with support from the Ninth and Tenth European Development Fund (EDF), which aimed to strengthen capacity and address the data gaps in selected areas of Environment Statistics.

Table 4: Availability of Climate Change Data in Selected Caribbean Countries

Traditional Macro-Financial Data Required for Climate Stress Testing										
			Aruba	Bahamas	Barbados	Belize	Curacao & Sint Maarten	Guyana	Jamaica	Trinidad & Tobago
Data Type	**Data required**	**Data source**								
Finance-related data	• Portfolio composition by sector and geography. • External and internal credit and valuation criteria. • Local and global economic data. • Balance sheets.	• Internal systems								
Macroeconomic data	• GDP, unemployment, population growth, inflation, interest rates and exchange rates.	• Scenarios								
Data metrics for expected losses	• Probability of Default (PD). • Loss Given Default (LGD). • Average exposure at default (EAD)	• Internal systems								
Borrower/asset financial data	• Costs and revenues by scenario. • Forward-looking metrics, such as OPEX and CapEx	• Internal systems • Scenarios								
Climate hazard data	• Historical data on acute and chronic physical risks. • Projections of future acute and chronic physical risks, including their severity and frequency. • Adaptive capacity data to determine resilience and sensitivity to climate hazards, including current adaptation strategies. • Climate hazard data based on geography, sector and industry, including economic losses from past climate hazards	• Scenarios • Clients • External providers								
Data describing transition risk drivers	• Transition risk drivers including policy implementation, market shifts, technological changes and reputation.	• Scenarios								
Emissions data	• Energy and carbon mix of counterparties. • Published or estimated GHG emissions produced by portfolios and assets of clients. • GHG emissions data by region, sector or industry. • Energy efficiency data, for example, real estate ratings like the Energy Performance Certificate Rating. • Data on carbon pricing by jurisdiction	• Clients • External providers • Internal systems								
Climate-related client data	• Identification of the physical assets owned by clients. • Detailed and granular geographical/geo-locational asset data	• Clients • External providers								
Alignment and transition data	• Transition pathways set by clients in accordance with the Paris Climate Change Agreement. • Science-based emission reduction targets set by clients. • Climate policies and pledges of countries.	• Clients • External providers								

Data Available | Partial and not consistent Data Available | Data Not Available

Climate Data Required by Firms to Assess Counterparty-specific Climate Risks										
Type of Climate Risk	Type of Climate Data	Aruba	Bahamas	Barbados	Belize	Curacao & Sint Maarten	Guyana	Jamaica	Trinidad & Tobago
Physical	Adaptive capacity data, including: • Client's adaptation and resilience plans; • Client's sensitivity to past climate events, including data on how the client has tackled extreme weather events in the past. • Geographical data on the location of the client's physical assets.								
Transition	• Alignment and transition plans (e.g. targets and pathways for reducing emissions). • Data on a client's preparedness to transition to a low-carbon economy. • Published or estimated emissions data by jurisdiction, asset or category of assets. • Data available on exposure to carbon prices by jurisdiction. • Energy efficiency and mix data by asset or category of assets.								
Data Available		Partial and not consistent Data Available			Data Not Available				

Chapter 5: ROADMAP TO ADDRESS CLIMATE DATA GAPS

The proposed roadmap to address climate data gaps comprises three signposts: (i) broadening access and scope of the data; (ii) building technical capacity and; (iii) institutional strengthening. Table 5 summaries the recommendations under each theme. The proposed measures are mutually reinforcing and can be pursued simultaneously in many instances.

Table 5: Recommendations to Address Climate Data Gaps

Theme	Measure	Comment	Time Horizon
Broadening Access and Scope of the Data	Collect loan/investment/equity exposures of regulated financial institutions	Amend/redesign regulatory returns to capture exposures to climate-sensitive sectors, including cross-border exposures.	Medium-term
	Segregate bank loan and insurance portfolios by geographic location	Assignment of geolocation identifiers to general insurance policies/bank loans exposed to adverse climatic events. This allows the calculation of PDs and LDGs.	Medium-term
	Introduce climate disclosure requirements	Task regional supervisory cooperation mechanisms (e.g. CGBS) with establishing climate reporting requirements in line with international standards	Medium-term
	Execute Memoranda of Understanding with third-party data providers	Secures ongoing access to GIS and climate variables and their forecasts which can be used as inputs in developing climate scenarios, climate models and calibrating climate stress tests.	Short-term
Building Technical Capacity	Join international climate change networks	Provides access to the latest developments in climate risk assessment and exposes staff to best practises.	Short-term
	Request technical assistance (TA) from the IMF, World Bank, UNEP, etc.	TA delivered to expose staff to climate issues. CARTAC to contract a resident climate advisor.	Short-term
	Explore opportunities for staff attachments/secondments	Permits staff to acquire 'hands on' experience with developing and executing climate risk assessments.	Short-term
Institutional Strengthening	Establish national credit registries	Central Banks to establish national credit registries to procure loan exposure data.	Long-term
	Restructure Research/Supervisory departments to include climate divisions	Changes in organisational structures ensure dedicated staff are assigned to address climate-related issues across Central Banks' functional areas.	Medium-term

Broadening Access and Scope of the Data

With the focus on assessing risks to financial stability, the data required to develop climate stress tests based on plausible regional climate scenarios could be categorised into financial and non-financial data. Central Banks have to balance granularity with practicality. While it would be optimal to get as much detailed data as possible, data requirements have to be conditioned on the intended sophistication of

the proposed climate stress tests as well as the regulatory burden of supplying the additional information. The financial data mostly comprises loan, investment and equity exposures at the sectoral level, counterparty-level data and insurance coverage, particularly for mortgage-related assets. In terms of commercial banks loan portfolios, calculating probability of defaults (PD) and loss given default (LGD) would be important. The non-financial data include information on hazards, geographic locations, damage costs, etc.

Financial Data

The regulatory and supervision remit of regional Central Banks generally covers the commercial banking sector. However, the spectrum of regulatory models spans the super regulator model in the case of the Bank of Jamaica, the twin peaks model where the central bank has prudential supervision and regulatory oversight for deposit–taking institutions while non-bank financial institutions are supervised by another entity and a decentralised model where special-purpose bodies are established to regulate particular entities. The data to develop climate scenarios and stress tests may require a modification to existing regulatory returns to capture financial institutions' exposure to brown sectors, that is, assessing how much CO_2 emissions they finance; the share of investment portfolios invested in CO_2 emitting industries, etc. Alternatively, new questionnaires could be designed to capture data from financial institutions where implementing legislative changes to support amended regulatory returns may be troublesome. This needs to be undergirded by a new financial reporting paradigm. In this regard, the Caribbean Group of Banking Supervisors (CGBS) as well as the Caribbean Association of Insurance Regulators (CAIR) could be tasked with championing the implementation of climate disclosures in line with evolving international reporting standards. While the data would be utilised to design top-down stress tests in the first instance, building licensees capacity to prepare bottom-up stress tests would aid precision.

Non-Financial Data

Caribbean countries are fairly well represented in international climate data repositories. For example, the NGFS Climate Impact Explorer has indicators which cover the economic and peril-specific hazards posed by acute and chronic physical for all countries represented in this working group. However, there are certain gaps that need to be filled in order to calibrate climate scenarios/stress tests to regional realities. Procurement of these data can be pursued through Memoranda of Understanding (MOU) for Information Sharing with institutions such as the Caribbean Regional Catastrophic Insurance Facility (CFRIF) or international reinsurers active in the region (for example, Swiss-Re and AoN). At the national level, MOUs with utility companies or other agencies such as postal corporations to access geographical location data (GIS) could be equally useful. Geolocation data is used to map loan exposures with

geographically vulnerable areas to assess the impact of physical risks on bank income. At this preliminary stage and given modest ambitions, the engagement of commercial data suppliers is not recommended given cost and other capacity considerations. Instead, accessing data from available open source datasets (Appendix V) could be actively pursued.

Building Technical Capacity

There is a need to develop in-house modelling capabilities which allow projections of the future path of climate variables and translating them to macroeconomic outcomes. Capacity building initiatives provided by the NGFS are a useful resource in this regard although the network is not a de facto training hub. The IMF is also ramping up its capacity to render advice on climate matters in the context of Article IV consultations and FSAPs. Opportunities for technical assistance should be explored in this regard. More specifically, Governors can, taking into account the funding envelope, lobby CARTAC for the assignment of a resident climate advisor and the development of a work program tailored to the region's priorities. Staff attachments and secondments, particularly to advanced economy Central Banks that have significant resources dedicated to climate change could be helpful with knowledge transfer beyond conventional training modalities.

Institutional Strengthening

On the institutional front, Central Banks could consider establishing credit registries in their respective jurisdictions to collect lending exposures as opposed to requiring financial institutions to report this data on an ongoing basis. This can lighten the regulatory reporting burden and avoid possible delays with amending existing legislation which govern financial institution reporting. In terms of central bank internal organisation initiatives, department restructuring to establish a division devoted to addressing climate issues across the central bank can be explored.

Chapter 6: CONCLUSION

This paper represented an opening salvo for a coordinated regional effort to address the data shortcomings which can plague the advancement of regional climate risk assessment ambitions. Although it is established that most Central Banks do not have an explicit legal mandate to pursue climate change objectives, there is alignment with the institutional view of the FSB that climate change has implications for financial stability. As such, addressing climate change and its potential impacts resonate with the core mandate of many Central Banks which is to protect and preserve the soundness of the financial system. A 2023 CERT Climate Change Survey confirmed that most Central Banks deem climate change a pressing issue and are actively addressing the topic in some instances. However, from a monetary policy standpoint, the toolkit of instruments is inadequate to address climate issues frontally. In this regard, very few Central Banks have progressed to incorporate climate considerations in monetary policy decisions. However, a few Central Banks have participated in green instruments by investing a small portion of their international reserves in the ESG asset class. Views were more buoyant on the financial stability front, with several Central Banks planning to incorporate climate-related risks in stress testing frameworks. However, no central bank has begun to collect data to support this intent – the raison d'être for this study. Meanwhile, most Central Banks have reviewed their internal operations and implemented various emission reducing measures.

A review of climate risk assessment approaches employed by leading Central Banks suggests that developments remain mostly at an exploratory stage. Where stress tests have been developed, they have been mostly bottom-up in orientation and utilised for building knowledge as opposed to inform supervisory actions as with conventional stress tests. Moreover, modelling the macroeconomic effects from varying climate outcomes is complex. The use of Integrated Assessment Models, NiGEM and other macroeconomic models have emerged, but standardised approaches are afar off. Most of the approaches are heavily skewed towards assessing transition risks. In the Caribbean where physical risks are more relevant, the ongoing development of NGFS short-term scenarios with a horizon of 3-5 years would be important for the region to leverage as they will be specifically geared to climate stress testing used for financial stability assessments. These shorter scenarios will better allow use of static balance sheet data and account for acute physical risks, focusing on shocks that have a short-term impact and moderate over the medium-long term as in the case of a hurricane.

With ambitions set on developing tailored regional climate scenarios and stress tests, the region's data gaps for macro-financial data to support climate stress testing are enormous. While finance-related data, emissions data and alignment/transition data are fairly available, data on borrower exposures and data for calculating expected losses are lacking. Climate hazard data appear partially available for most

Caribbean countries covered in the study. To address these data gaps, a roadmap was developed. The roadmap is hinged on three key themes; (i) broadening the access and scope of the data; (ii) building technical capacity and; (iii) institutional strengthening. Broadening the access and scope of the data is heavily reliant on the procurement of loan/investment/equity exposures and geographic location data from financial institutions and/or third-party sources. Building technical capacity calls for leveraging technical assistance and knowledge transfer opportunities which focus more on 'learning by doing'. Lastly, institutional strengthening efforts lay in internal reorganisation at Central Banks to prioritise climate-related matters as well as the creation of new entities such as national credit registries for comprehensive exposure reporting.

There is good reason for optimism that the proposed road is achievable as a few Central Banks are undertaking activities in alignment with some of the recommendations. For example, the Central Bank of Aruba is working on a new chart of accounts for financial reporting. Completion is expected in 2025. Meanwhile, the Bank of Jamaica is currently considering recommendations from an external consultant to strengthen its climate surveillance in the context of its expanded regulatory responsibilities. Implementation is usually a thorny issue, especially when coordination efforts are cross-border. In this regard, CARICOM Governors may wish to appoint a member Central Bank or create a sub-committee of Governors to oversee the execution of an approved roadmap.

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APPENDIX I: THE LEGAL MANDATE FOR CENTRAL BANKS' PURSUIT OF CLIMATE OBJECTIVES

Although specific mandates may vary across countries, the following roles and responsibilities for Central Banks concerning climate change may be derived from existing mandates:

1. Monetary Policy - Central Banks can incorporate climate considerations into their monetary policy frameworks. This involves assessing the potential impact of climate change on macroeconomic variables, such as inflation, employment, and economic growth, and adjusting monetary policy accordingly.

2. Financial Stability - Central Banks are responsible for ensuring the stability of the financial system. They can identify and mitigate climate-related risks that could pose threats to financial stability. This includes assessing the exposure of financial institutions to climate-related risks and encouraging the adoption of risk management practices that account for environmental factors.

3. Supervision and Regulation – Central Banks often have regulatory and supervisory authority over financial institutions. They can incorporate climate-related considerations into their prudential frameworks, requiring banks and other financial entities to assess and disclose their exposure to climate-related risks. This promotes transparency and helps ensure that financial institutions are adequately managing these risks.

4. Research and Analysis – Central Banks play a vital role in conducting research and analysis related to climate change and its economic implications. They can contribute to building models, methodologies, and data frameworks that assess the impact of climate change on the economy and financial markets.

5. Green Finance and Investment – Central Banks can promote the development of green finance and sustainable investment practices. This includes providing guidance and support for financial institutions to allocate capital towards environmentally friendly projects and activities.

Table A1 outlines the relevant sections of the central bank acts of selected CARICOM countries and their interpretation as to their applicability in addressing climate change and climate-related risks.

Table A1: Interpretive Summary of Selected Central Bank Acts on Validity of Climate Change Mandate

Central Bank	Act	Details
The Bahamas	Central Bank of The Bahamas Act, 2020, 5(1) (b)	Contribute to the stability of the financial system of The Bahamas.
Barbados	Central Bank of Barbados Act, 2020, 6(2), 6(3h) and 6(3k)	The secondary objective of the Bank is to promote financial stability which is conducive to the orderly and sustained economic development of Barbados. 6(3h) adopt and implement macro-prudential policy measures to promote financial stability. 6(3k) carry out any ancillary activities which are related to the exercise of its functions under this Act.
Belize	Central Bank of Belize Act, Revised Edition 2020	No justification found.
Curacao and Sint Maarten	Central Bank Statute for Curaçao and Sint Maarten 2010	Curaçao and Sint Maarten are member countries of the Kingdom of the Netherlands, and while the Kingdom of the Netherlands is a signatory to the Paris Accords, the government of the Netherlands has yet to reach a formal agreement with both the governments of Curaçao and Sint Maarten on a kingdom-wide application of the treaty's protocols that fits with their domestic context.
Guyana	Central Bank of Guyana Act 1998	No justification found.
Jamaica	Section 4(5)(2)(b) An Act to Amend the Bank of Jamaica Act	The function of the Bank includes the implementation of prudential and macro-prudential policies.
Suriname	Section 9(c) of the Central Bank of Suriname	To promote the development of a sound banking and credit system in Suriname.
Trinidad & Tobago	Section 3 (3) of the Central Bank Act (79.02) (f)	This section covers (i) legislation affecting the financial system; and (ii) developments in the field of banking and financial service which appear to be relevant to the exercise of its powers and the discharge of its duties in the realm of climate change.
Eastern Caribbean Currency Union	Section 72 (1)(f) of Banking Act 2015	The prudential requirements to be applied on a consolidated basis include (f) other prudential requirements as may be determined by the Central Bank to be necessary or appropriate.

Source: Authors' Compilation for Selected Caribbean Central Bank Acts

APPENDIX II: CLIMATE CHANGE TAXONOMIES - TOWARDS A REGION-SPECIFIC APPROACH

1. Background

A taxonomy for sustainable finance is a set of criteria which forms the basis for evaluation and classification of activities or investments (assets) as being either consistent or inconsistent with sustainability goals. This is critical since it provides a clear signal to investors, issuers and other stakeholders of the compatibility of activities or assets with the countries' targeted sustainability or environmental objectives. In this regard a key outcome is the reduction in information asymmetry thereby improving flow and efficiency of sustainable finance, channelling financing in support of projects to scale up sustainable investments.

Governments around the world are encouraging and channelling financial flows toward investments that support environmental objectives[30]. Inspired by the European Union (EU's) initiative to produce a green taxonomy, many emerging markets are seeking to develop clear classification for activities or investments that embody their own national or regional environmental objectives. Notably, sustainability goals and or the priorities ascribed to them differ across countries and therefore implies a need for taxonomies that accommodate the idiosyncrasies of regional economies. In the LAC region - Chile, Colombia, Mexico and Dominican Republic are currently developing their own taxonomies.

The rise of local taxonomies demonstrates the interest of countries and their governments in mobilizing capital flows towards sustainable and climate resilient development consistent with the environmental objectives of the country's overall sustainable development priorities and agenda. However, this has contributed to "taxonomic fragmentation and taxonomy competition", which complicates identification and classification of qualified activities or investments across countries or regions. Multiple classification frameworks with varied objectives and evaluation criteria impose significant costs and risk on seeking participation in qualified sustainable investments across different countries' regions. This can impair the flow of sustainable financing, particularly to small developing economies (like those in the Caribbean) if the critical criteria or requirements are not aligned with that in the investor's jurisdiction.

In this context, some have emphasized that harmonization across taxonomies is fundamental, as there must be a common global language for what is green and sustainable in order to attract financing. Standardization reduces the transaction costs by facilitating faster identification and verification of eligible assets.

[30] Of the major emitting economies, two jurisdictions already have sustainable finance taxonomies – the EU and China. While other countries have started work on the development of sustainable taxonomies, India and the USA have not made any significant progress in this area.

Comparability and interoperability are important taxonomic features that can support broad use of the classification framework and mitigate the potential negative effects of fragmentation and competition. This can ensure adherence to the standards consistent with scientifically based mitigation and adaptation targets, while allowing adequate flexibility for respective economies to transition toward more sustainable pathways.

In this regard, the Global Financial Markets Association identifies five broad guiding principles that should undergird all climate finance taxonomies[31]:

1. Assessment must go beyond use of proceeds to an output-based metric that captures activity and entity level performance.
2. The taxonomy should be objective – supported by clearly defined metrics and thresholds aligned to the Paris target (or national targets), based on scientific assessments.
3. Should adopt a consistent set of principles and definitions, but allow flexibility for regional and temporal variation to be consistent with differences in transition pathways.
4. The design and application of derived metrics and thresholds to activities and sectors should be transparent and robust, in support of climate impact assessment and easy third-party verification.
5. Should be based on a governance process that is robust, inclusive, and transparent – with adequate flexibility.

Given the aforementioned, taxonomies must balance the need to address country priorities and that of ensuring consistency and interoperability across countries. A regional taxonomy will help harmonise the definitions of green and sustainable activities and assets across the region and can provide the impetus needed to widen participation and access among market players. However, the Taxonomy must consider the specific situation of the individual member states, which may reflect a heterogeneous mix with regards to the country's environmental priorities. The International Finance Corporation (IFC) and the IDB have been active in supporting local taxonomy development in the region. Taxonomies from jurisdictions such as the EU, China, the Climate Bonds Initiative's (CBI) and more recently the Association of Southeast Asian Nations (ASEAN) have featured prominently as important benchmarks for taxonomies across the world, including in the LAC region.

[31] Global Guiding Principles for Developing Climate Finance Taxonomies: A Key Enabler for Transition Finance, June 2021

2. Comparison of Main Taxonomies

Taxonomies can be classified or differentiated along four key dimensions: objective, scope, target and output.

Objective. Taxonomies should be targeted at achieving national sustainability goals – consistent with the country's sustainable development priorities. These objectives should be in accordance with existing environmental plans, policies, and regulations, including commitments to international agreements. Taxonomies can also take on multiple objectives. The EU taxonomy currently adopts six objectives - mitigation, adaptation, sustainability and protection of water and marine resources, transition to a circular economy, pollution prevention and control and protection and restoration of biodiversity and ecosystems. In co-dependent taxonomical frameworks these different objectives are expected to complement each other and should not counteract or obstruct realization of any other objectives. The EU' s framework enforces this requirement via the adoption of a do no significant harm (DNSH) requirement for each objective.

Scope: Taxonomies should clearly outline the activities, industries and entities that are expected to deliver on the aforementioned objectives. The scope of the taxonomy also considers whether the targeted objectives relate to static or transition activities. Most existing taxonomies refer to activities which are already low-carbon. However much less focus has been placed on transition activities. These are activities in carbon intensive industries aimed at supporting the transition to net zero emissions consistent with a pathway to limit the temperature increase to 1.5° by 2050 – but are not currently "green". Emerging market and developing economies that are more likely to depend on these industries will be disadvantaged if these sectors are excluded.

With regards to the scoping, the issue of international comparability and interoperability arises. It is becoming increasingly important that the classification systems adopted across countries are able to capture economic activities outlined in the national taxonomies.

Target: Taxonomies will need to clearly define some objective against which compliance with established sustainability standards are assessed. These objectives or targets may be defined as an asset, at the activity level or at the entity level. More granular – activity level targets offer the advantage of a cleaner mapping to environmental objectives. In general, the selection of the appropriate target will depend on the country specific characteristics and objectives, reinforcing the need for careful national considerations in designing a taxonomy. However, it is important from an investors' perspective, to gauge the impact of a corporation's full range of economic activities. In this context

entity level criteria are important to an investor and it more effectively mitigates the risk of "greenwashing" by the corporation[32].

Output: Taxonomies are only effective if there are adequate data and disclosures that provide clear information to investors and other stakeholders on the non-financial benefits of the activity or asset. Appropriate and standardized disclosure of financially material sustainability data will be critical to ensure the integrity, transparency, consistency and compatibility of "green" investments across financial markets. At the same time onerous disclosure requirements for MSMEs in emerging and developing markets (like the Caribbean) may preclude "qualification" for financing and jeopardize the achievement of key environmental outcomes. In this regard, there may need to be some flexibility applied – where these entities are allowed to follow more simplified set of protocols.

Appropriate ex-post verification processes will be critical to mitigate the risk of greenwashing. The use of third-party verification is common in the EU bond market but there is a lack of standardization across the different providers/reviewers. The verification process is not addressed in the current EU Taxonomy and the Chinese taxonomy encourages the voluntary use of independent reviews. There is scope to significantly strengthen the verification processes in these frameworks. An approved verifier model (used by the CBI) could be considered.

While these are general issues, applicable to all taxonomies, we find differences in respect of the granularity in the score card used to assess compliance with the established standards or criteria. Some taxonomies adopt a binary assessment tool – an activity is either compliant or non-compliant with the standards. Others adopt a multi-modal approach where entities are graded on a scale from "most compliant" to "least compliant". With the binary approach, only the "greenest" activities will be assessed as taxonomy compliant and could limit access to financing for countries or firms that currently lack the capacity to meet these thresholds, but who are on transition pathways that are substantially consistent with the longer-term environmental objectives. This highlights the need for flexibility in standard setting – but great care must be taken to ensure that thresholds are set at appropriate levels (science based) so as not to compromise the green/environmental objectives and discourage impact investors.

The issue of granularity in the assessment tool may have differential implications for the countries at different levels of development and with different sustainability priorities. More granular output can better accommodate differences in the level of development across countries, as well as differences

[32] Example of green washing - A corporation issues bonds and though these bonds can be used to financed green investments, if the budget constrain is not binding (money is fungible) these funds could be used to support other less environmentally friendly projects

across sectors in their capacity to transition to sustainable pathways. While the EU taxonomy adopts a binary assessment tool, it has carved out separate assessments for transition activities and there is active engagement on the development of a "brown-to-green" taxonomy that more fulsomely addressed these issues. The CBI and ASEAN taxonomies adopt a multi-modal approach (including the stop light framework). Table A2 compares the main taxonomies in respect of the aforementioned key dimensions.

3. Conclusion

An appropriate regional taxonomy could marry key elements of the EU and ASEAN frameworks to glean the benefits of both taxonomies to create our very own Caribbean climate sustainable taxonomy which considers our unique realities. To effectively address climate change in the region it is imperative to create a Caribbean-centric taxonomy as this forms the basis/foundation of climate change mitigation and adaptation actions.

Table A2: Comparative Overview of Main Sustainable Finance Taxonomies

	EU Taxonomy [2020]	China Taxonomy	CBI Taxonomy	Another [ASEAN Taxonomy]
1. Objective: a. Alignment with policy goals	Six environmental objectives (mitigation, adaptation, sustainable use and protection of water and marine resources, protection and restoration of biodiversity and ecosystems, transition to a circular economy and pollution prevention and control) assessed on activity level criteria aligned with the Paris Agreement - target of net zero by 2050 and interim targets for 2030.	Three broad environmental objectives (climate change response, environmental improvement, more efficient resource utilization)	Project level criteria aligned with the levels of emissions reductions required to meet the 2°C target set by the Paris Agreement. Original CBT taxonomy does not appear to include projects or assets geared toward adaptation – focused on mitigation	Four environmental objectives (mitigation, adaptation, protection of healthy ecosystem and diversity and promotion of resource resilience and transition to a circular economy) aligned with the Paris target for emissions reduction. The current version only assessed activities based on their contribution to mitigation
b. Independence or co-dependency	Co-dependence principle as an activity must meet the criteria of "substantial contribution" to environmental objectives and DNSH harm to all other objectives	Co-dependence principle as an activity must meet the criteria of "substantial contribution" to environmental objectives and DNSH harm to all other objectives	GHG emissions screening criteria aimed at achieving climate mitigation	Co-dependence principle as an activity must meet the criteria of "substantial contribution" to environmental objectives and DNSH harm to all other objectives.
2. Scope: a. Transition and enabling activities	Includes transitional and enabling activities Qualifying criteria and thresholds for these activities are adjusted over time in line with the latest developments in climate science. Specific criteria for mitigation and adaptation measures with more specific metrics for the former	No transition or enabling activities included	No transition of enabling activities included. However, work is being done that would see these activities being included.	Includes transitional and enabling activities
b. Industrial classification	Two-digit NACE codes [Excludes fossil fuels]	Four-level Chinese Standard Industrial Classification (CSIC) [Does not exclude fossil fuels]	No reference to any industrial classification code	Uses the International Standard of Industrial Classification (ISIC) framework due to its strong compatibility with other international classification nomenclature

3. Target a. Unit of Measurement	Activity based metrics with thresholds (quantitative) in line with existing EU regulations and Paris Agreement. Note that assessments of adaptation activities are scored differently	Activity based metrics with thresholds (quantitative) in line with national standards	Asset based metrics in line with the Paris target.	Activity based metrics with thresholds (quantitative) in line with Paris targets
4. Output a. Data availability and disclosure	Further legislative guidance required to address data disclosures	Issuers are required to report use of proceeds and environmental impact reported is seemingly encouraged	Issuers are required to report use of proceeds and environmental objectives [not necessarily the impact]	……
b. Verification	Further legislative guidance required to address data disclosures	Independent review of green credentials is encouraged – but no standardized procedure in place for the conduct of such.	Climate Bonds Standard & Certification Scheme provides for independent third-party verification for green bonds	……
c. Granularity	Binary	Binary	Traffic light [more flexible]	Traffic light [more flexible]

APPENDIX III: CERT CLIMATE CHANGE AND CLIMATE-RELATED SURVEY (JAN 2023)

GENERAL

1.0 Please, indicate below which statement best represents your Central Bank's view of climate change.

Choices	Responses	Percentage
A concern we are closely monitoring	6	66.67 %
A key concern our institution is actively responding to	3	33.33 %

2.1 Is your Central Bank actively working on climate change issues?

Choices	Responses	Percentage
Yes	7	77.78 %
No	2	22.22 %

2.2 If No, when do you envision climate matters will be included in the work agenda?

Choices	Responses	Percentage
In the short run (within one year)	1	50%
In the medium term (within 2-5 years)	1	50%

MONETARY POLICY

3.0 Which climate-related risk do you consider more relevant for central bank policymaking?

Choices	Responses	Percentage
Physical Risks	5	55.56%
Transition Risks	4	44.44%

4.1 Has your Central Bank made adjustments or is considering making adjustments, to its monetary policy framework to include climate-related considerations?

Choices	Responses	Percentage
Yes	3	33.33%
No	6	66.67%

4.2 If Yes, how will the incorporation of climate-related variables affect monetary policy transmission? (Select All that may apply)

Choices	Responses	Percentage
Bank balance sheet channel	2	40%
Interest rate channel (Financial Markets)	2	40%
Credit channel	1	20%

5.0 Does your Central Bank consider its existing toolkit of monetary policy instruments adequate to address climate-related concerns?

Choices	Responses	Percentage
Yes	3	33.33%
No	6	66.67%

6.0 Has your Central Bank considered buying, or has already bought green assets for the Bank's investment portfolio and/or the country's stock of international reserves?

Choices	Responses	Percentage
Already invested	2	22.22%

Considered buying	1	11.11%
Not yet under consideration	6	66.67%

7.0 What proportion of your country's international reserves has been invested in green assets?

Choices	Responses	Percentage
None	7	77.78%
1% - 5%	1	11.11%
5% - 10%	1	11.11%

FINANCIAL STABILITY

8.0 Does your Central Bank view climate change as a major risk to financial stability?

Choices	Responses	Percentage
Yes	8	88.89%
No	1	11.11%

9.1 Has your Central Bank incorporated climate-related risks in its stress tests?

Choices	Responses	Percentage
Yes	2	22.2%
No	7	77.78%

9.2 If No, which statement below best represents your Central Bank's view?

Choices	Responses	Percentage
Actively considering climate-related scenarios for stress-testing	6	66.67%
Not currently considering the inclusion of climate-related scenarios in stress-testing	1	11.11%

10.1 Have commercial banks and other licensees incorporated climate-related considerations in their operations?

Choices	Responses	Percentage
Yes	4	44.44%
No	5	55.56%

10.2 If Yes, which aspect of operations has been impacted? (Select ALL that may apply)

Choices	Responses	Percentage
Risk management	3	75%
Risk taking decision (credit, investment)	2	50%
Lending rates	1	25%
Other (please specify)	1	25%

INTERNAL OPERATIONS

11.0 Has your Central Bank developed a climate change policy or included climate-related issues into your overall strategic plans and objectives?

Choices	Responses	Percentage
Yes	4	44.44%
No	5	55.56%

12.0 Does your Central Bank have emissions reduction targets?

Choices	Responses	Percentage
No Target	8	80%
Intensity Target	1	20%

13.0 Please identify the measures taken by your Central Bank to reduce emissions (Select All that may apply)

Choices	Responses	Percentage
Utilizing low-carbon energy sources	3	33.33%
Introducing electric or low-carbon vehicles into the bank fleet	4	44.44%
Lower electricity usage through technological changes (Energy Efficiency)	8	88.89%
Lower electricity usage through behavioural changes (Energy Conversation)	6	66.67%
Implementing stand-alone renewable energy generation	2	22.2%
Reducing employee commute	1	11.1%
Recycling (paper, plastic, glass, other)	6	66.67%
No measures taken to reduce emissions	1	11.1%

14.0 Is your central Bank a member of, or affiliated with, any international group on climate change issues?

Choices	Responses	Percentage
Yes	3	33.33%
No	6	66.67%

15.0 Has your country accessed any loans or funding from any International or Regional Institutions to finance your adaption and mitigation strategies against Climate Change?

Choices	Responses	Percentage
Yes	6	66.67%
No	3	33.33%

16.0 Does your Central Bank collect data to analyse climate-related risk?

Choices	Responses	Percentage
Yes	0	-
No	9	100%

17.0 Has your Central Bank performed an energy audit in the last 3 years?

Choices	Responses	Percentage
Yes	3	33.33%
No	6	66.67%

18.1 Has your staff been exposed to climate change training?

Choices	Responses	Percentage
Yes	4	44.44%
No	5	55.56%

18.2 If No, do you expect to introduce training in climate matters over the next year?

Choices	Responses	Percentage
Yes	2	40%
No	3	60%

18.3 If Yes, do you expect to ramp up training in climate matters over the next year?

Choices	Responses	Percentage
Yes	4	100%
No	0	-

APPENDIX IV(a): MODELLING APPROACHES FOR CLIMATE STRESS TESTING

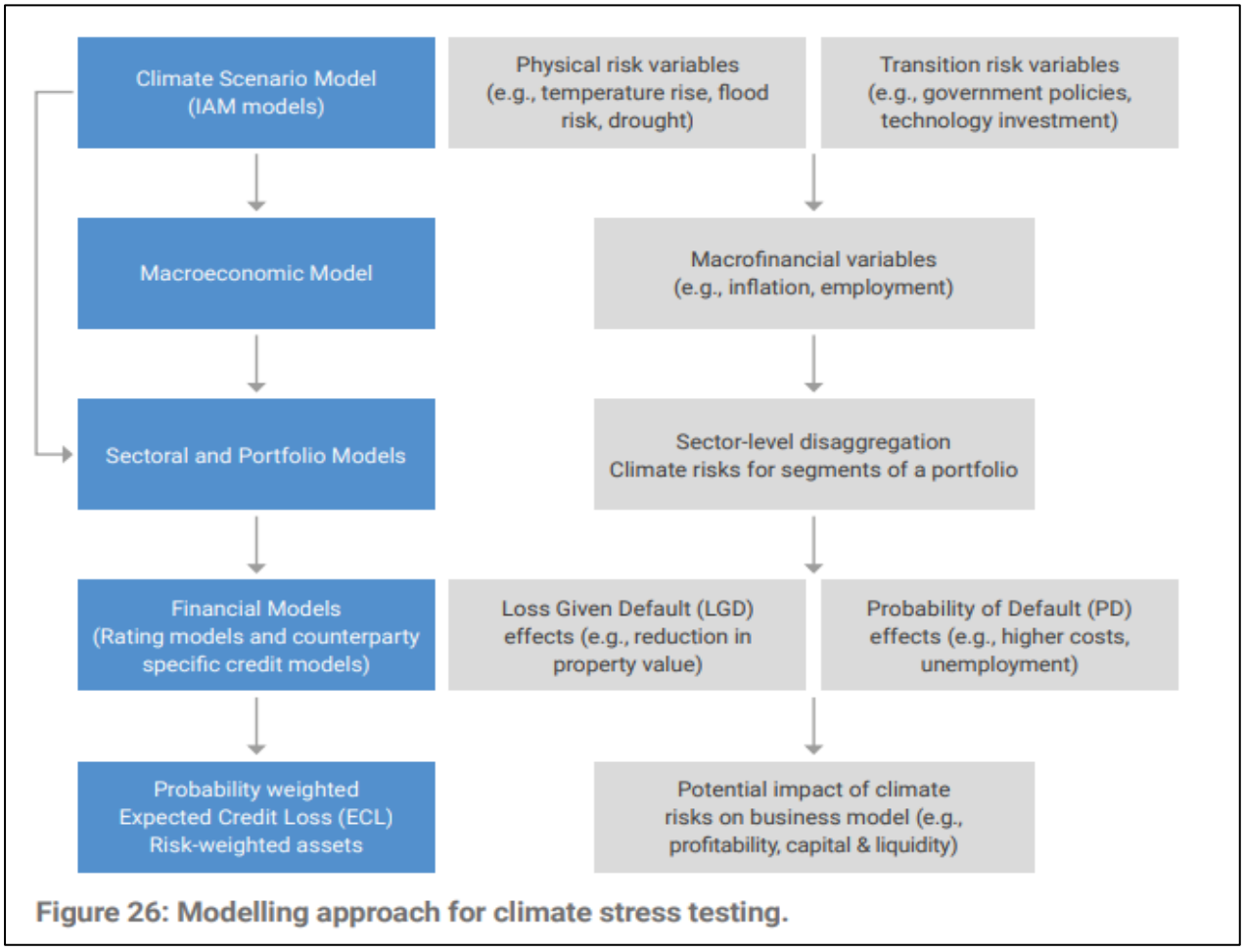

Figure 26: Modelling approach for climate stress testing.

Source: (UNEP FI, 2021 (a)); pg.110

APPENDIX IV(b): SUMMARY TABLE OF ECB'S BOTTOM-UP STRESS TESTING EXERCISE 2022

	Module 1: Framework questionnaire	Module 2: Stock-take on emissions	Module 3: Bottom-up climate ST
Description	**Qualitative questionnaire on 11 sections:** 1. Existence and use of ST exercises 2. Governance and inclusion in Risk Appetite 3. Integration into strategy 4. Methodology used 5. Scenarios 6. Data and sources of information 7. Inclusion on the ICAAP 8. Future development plan 9. Role of Internal Audit 10. EU subsidiaries of non-EU institutions 11. Methodological assumptions and choices	**Estimation of two metrics:** 1. Exposure to transition risks: Income (interest income, fees, commissions) from GHG intensive industries per sectors 2. Financed carbon intensity, separating Scope[1] 1, 2 and 3 Scope: • Non-financial corporate (non SME) • Metric 1: 80% gross interest income, max 5 countries. Reference date: from Jan-21 to Dec-21 • Metric 2: 15 counterparties per 22 sectors. Reference date: average revenues for 2018,2019 and 2020, emissions data as of December 2020	**Risk projections:** 1. Credit[2] (impact on impairment; static balance sheet in s/t, dynamic in l/t): • Transition: baseline and disorderly (3y), orderly, disorderly and hot house[3] (10-30y) • Physical (EU Corporates & SMEs and real state and mortgages): drought and heatwave, flood (1y from 1Jan22) 2. Market: • Bonds, equity and directly connected derivatives in the HFT • Shock on valuation 3. Operational: Qualitative questionnaire regarding operational and reputational risk

Requirements	• Completion of the questionnaire
	• No additional documentation requirement
		• Aligned with FINREP
		• Groups of sectors: NACE – level 2
		• Documentation:
		  • Actions carried out by the bank
		  • Emission calculation approach
			• Some banks don't submit projections
			• Groups of sectors: NACE – level 2
			• For mortgages, by EPC groups
			• Documentation:
			  • Assumptions and methodology
			  • Consistency w/ public commitments

Source: (Management Solutions, 2022)

APPENDIX IV(c): SUMMARY OF ECB'S MODULE 3 SCENARIOS AND RISKS DIMENSIONS

Module 3 scenarios and risk dimensions

	Exposures	Scenario	Projections[1]	Horizon	Credit risk	Market risk	Operational risk
Transition risk	Global	Short-term stress	Baseline	3 years (2022-2024)	Corporate loans (incl. SME, CRE) + mortgages	Bonds + stocks issued by NFCs[2] (incl. accounting and economic hedges)	Operational and reputational risks to be assessed via a qualitative questionnaire
			Stress				
		Long-term paths	Orderly	30 years (2030, 2040, 2050)	Corporate loans (incl. SME, CRE) + mortgages		
			Disorderly				
			Hot house				
Physical risk	EU countries	Drought & heat risk	Baseline	1 year (2022)	Corporate loans (incl. SME)	1.All projections with the exception of the long-term paths will be based on a static balance sheet. 2.The parent company needs to be an NFC, e.g. bonds issued by car financing company X are in scope.	
			Stress				
		Flood risk	Baseline	1 year (2022)	Mortgages + CRE loans		
			Stress				

Source: ECB, climate risk stress test 2022, methodology, October 2021.
Notes: CRE stands for commercial real estate; NFC stands for non-financial corporation; SMEs stands for small and medium-sized enterprises.

Source: (ECB, 2022)

APPENDIX IV(d): OVERVIEW OF TRANSITION RISK ASSESSMENT TOOLS AND ANALYTICS

			Provider																	
			2DII (1)	2DII (2)	BAR	C4	CFIN	CT	CW	MA-VE	MIS	MSCI	OF	OW	OW-S&P	PwC	SP(1)	SP(2)	TCS	VE-PL	VR
	Scenario Basis		IEA ETP | (IEA WEO) | (Gpeace)	IEA ETP	Bespoke, or |Industry standard, e.g. IEA	Bespoke | (based on IEA ETP, IPCC, ...)	IEA ETP | IEA WEO	IEA WEO | IEA ETP (B2DS)	IEA ETP | IEA WEO		IEA WEO	Bespoke (PIK-REMIND, IIASA, GCAM)	E3ME	NGFS | (PIK, IIASA, GCAM) | IAMC	NGFS Bespoke 3-yr Carbon Tax Scenario	IEA ETP	IEA ETP | IEA WEO | IIASA SSPs | AE[R] | DDD | NGFS	IEA ETP | IEA WEO | IIASA SSPs | AE[R] | DDD | NGFS	SSP3-60 | SSP3-45	Bespoke	Bespoke
Scenarios	<2.0°C (RCP 2.6)		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2.0°C (RCP 4.5)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	3.0°C (RCP 6.0)		✓	✓	✓	✓				✓		✓	(✓)	✓	✓		✓	✓	✓	✓	✓
	>4.0°C (RCP 8.5)				✓	✓			✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	Disorderly?			✓	✓		✓			✓		✓	✓	✓	✓	(✓)[i]	✓	✓		✓	✓
Time horizons	Near term (2025-2040)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Medium term (2050)				✓		✓						✓	✓	✓	✓	✓	✓	✓	✓	✓[ii]
	Long-term (2100)						✓[iii]						✓				✓	✓	✓	✓	
Transition Hazards	Policy		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Technology		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
Risk analysis	Level of analysis	Asset	✓		✓			✓	✓	✓		✓			✓	✓		✓	✓	✓	✓
		Firm	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
		Sector	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓
		Country			✓	✓	✓		✓	✓		✓	✓	✓		✓[iv]			✓	✓	✓
	Impact Channel	Macroenvironment		✓	✓	✓	✓		✓	✓		✓	✓		✓		✓	✓		✓	✓
		Supply chain			✓	✓	✓		✓	✓		(✓)[v]	✓	✓	✓		✓	✓	✓	✓	
		Operations and assets	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Markets and clients	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓
	Depth	Exposure	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Sensitivity	✓	✓	✓	✓	✓	(✓)[vi]	(✓)[vii]	✓		✓	✓	✓	✓	✓		(✓)[vii]	✓	✓	✓
		Adaptive Capacity		✓	✓	✓	✓			✓			(✓)[viii]	(✓)[viii]	✓	✓		(✓)[v]		✓	(✓)[vi]
	Approach	Top-Down		✓			✓				✓		✓		✓		✓				
		Bottom-Up	✓		✓	✓		✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓
Asset classes	Equity		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
	Bonds, Corporate		✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓		✓	
	Bonds, Government				✓	✓	✓			✓			✓		✓			✓		✓	✓
	Loans, Corporate		✓	✓	✓	✓	✓			✓			✓		✓	✓		✓		✓	
	Loans, Project				✓	✓	✓			✓			✓	✓	✓	✓		✓		✓	✓
	Mortgages				✓	✓				✓			✓			✓		✓	✓	✓	
	Real Estate / Real Assets				✓	✓			(✓)[viii]	✓		✓	✓			✓		✓	✓	✓	✓
User inputs	Counterparty name		✓	✓	✓	✓	✓	✓		✓	✓	✓	*	(✓)[ix]	✓	✓	✓	✓	✓	(✓)[xi]	✓
	Location				✓				✓			✓		(✓)			(✓)[ix]	✓	✓	(✓)	✓
	Value of asset		✓	✓	✓				(✓)[ix]	(✓)[ix]		✓		(✓)			✓	✓	✓	(✓)	✓
Validity	Open-source		✓	✓	(✓)[xii]	(✓)[xii]			✓				(✓)[xiii]		(✓)[xiv]		(✓)[xii]	(✓)[xii]		(✓)[xii]	
	Peer-reviewed		✓		✓	✓			✓				✓		(✓)[xvii]		✓	✓	✓	(✓)[xv]	
	Source references		✓	✓	✓	✓			✓				✓				✓	✓	✓	✓	✓
Outputs	Quantitative		✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Semi-quantitative					✓		✓	✓	✓	✓						✓			✓	✓
	Non-financial metrics		✓	✓	✓	✓		✓	✓	✓	✓		✓						✓		
	Financial metrics			✓	✓		✓			(✓)[i]		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Temperature Alignment		✓	✓	✓	✓						✓	✓			(✓)[xv]				✓	

Table 3: Overview of transition risk assessment tools and analytics

Abbreviation	Service Provider	Tool
2DII (1)	Two Degrees Investing Initiative	PACTA for banks
2DII (2)	Two Degrees Investing Initiative	PACTA stress testing module
BAR	Baringa Partners	Climate Change Scenario Model
C4	Carbone 4	Carbon Impact Analytics
CFIN	Climate Finance Alpha	Transition risk toolbox
CT	Carbon Tracker	2 degrees of separation
CW	ClimateWise (CISL)	Transition risk framework
MA-VE	Moody's Analytics-V.E	On-demand transition climate risk scoring application
MIS	Moody's Investor Services	Carbon transition assessment
MSCI	MSCI-Carbon Delta	Climate Value-at-Risk (CVaR)
OF	Ortec Finance	ClimateMAPS
OW	Oliver Wyman	Transition Check
OW-S&P	Oliver Wyman & S&P Global Market Intelligence	Climate Credit Analytics
PwC-COF	PwC (formerly CO-Firm)	Climate Excellence
SP(1)	South Pole	Risk screening tool
SP(2)	South Pole	Climate risk deep-dive assessment
TCS	The Climate Service	TCS Climanomics
VE-PL	Planetrics	PlanetView
VR	Verisk Analytics	Transition risk

Notes

i. Under development for 2021
ii. Up to 2064
iii. Up to 2080
iv. At regional level
v. Operations only
vi. Not macroenvironment
vii. Macroenvironment only
viii. Infrastructure / real assets only
ix. Optional (but preferable)
x. Top-down approach does not need company/asset information
xi. Outside of ~20,000 company database
xii. Methodology, not source code
xiii. Open-source version will be available on OS-Climate platform
xiv. Within Vivid Economics' academic network
xv. Climate target alignment
xvi. Framework is open-source
xvii. Reviewed and vetted by financial institution, not academic

Source: (UNEP FI, 2021 (b))

Appendix IV (e): OVERVIEW OF PHYSICAL RISK ASSESSMENT TOOLS AND ANALYTICS

			Provider																	
			427 (1)	427 (2)	ACC	ACC-WTW	C4 (1)	C4 (2)	CFIN	CW	MSCI	OF (1)	OF (2)	RhG	RMS	SP (1)	SP (2)	TCS	VE-PL	VR	XDI
Scenarios	<2.0°C (RCP 2.6)				✓	✓			✓		(✓)[i]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2.0°C (RCP 4.5)		(✓)[i]		✓	✓	✓	✓	✓	✓	(✓)[i]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	3.0°C (RCP 6.0)				✓	✓	✓		✓		(✓)[i]	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	>4.0°C (RCP 8.5)		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Time horizons	Baseline / historical				✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Near term (2025-2040)		✓	✓	✓	✓			✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Medium term (2050)		(✓)[i]		✓	✓	✓	✓	✓	✓[ii]		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Long-term (2100)		(✓)[i]				✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Physical Hazards	Chronic		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Acute		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Risk analysis	Level of analysis	Asset	✓	✓	✓	✓	✓	✓		✓			✓	✓	✓		✓	✓	✓	✓	✓
		Firm	✓	✓	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	✓	✓
		Sector	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓			✓	✓	✓	✓
		Country	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓			✓	✓	✓	✓
		Portfolio	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓
	Impact Channel	Macroenvironment		✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	
		Supply chain		✓	✓	✓	✓		✓			✓	✓		✓	✓	✓	✓	✓	✓	✓
		Operations and assets	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Markets and customers		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
	Method	Physical Exposure	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Vulnerability indicators		✓	✓		✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓
		Physical impact modeling	✓	✓		✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		Financial modeling	✓	✓		✓			✓			✓	✓	✓	✓		✓	✓	✓	✓	✓
Physical Hazard Type	Flood, coast		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	Flood, inland		✓	✓	✓	✓	✓	✓	✓	✓	(✓)[i]	✓	✓		✓		✓	✓	✓	✓	✓
	Extreme weather		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
	Extreme heat		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓
	Extreme precipitation		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓		✓	✓	✓	✓	✓
	Landslide				✓	✓	✓	✓				✓	✓						✓	✓	✓
	Drought		✓	✓	✓	✓	✓	✓			(✓)[i]	✓	✓		✓		✓	✓	✓	✓	✓
	Water scarcity		✓	✓	✓	✓	✓	✓									✓	✓	✓	✓	
	Wildfire		✓	✓	✓	✓	✓	✓	✓		(✓)[i]	✓	✓		✓		✓	✓	✓	✓	✓
Asset classes	Equity		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓
	Bonds, Corporate			✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓		✓	✓	✓
	Bonds, Government		✓		✓	✓	✓	✓	✓			✓		✓	✓		✓		✓	✓	✓
	Loans, Corporate			✓	✓	✓	✓	✓	✓			✓			✓		✓		✓	✓	✓
	Loans, Project		✓		✓	✓	✓	✓	✓			✓		✓	✓		✓		✓	✓	✓
	Mortgages		✓		✓	✓	✓	✓				✓	✓	✓	✓		✓	✓	✓	✓	✓
	Real Estate / Real Assets		✓		✓	✓	✓	✓	✓	(✓)[iii]	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
User inputs	Counterparty name			✓	✓	✓	✓	✓	✓		✓	[v]	[v]	✓	✓	✓	✓	✓	✓	✓	✓
	Location		✓		✓	✓		✓		✓	✓	[v]	[v]	✓	✓		✓	✓	✓	✓	✓
	Value of asset				✓	✓		✓		(✓)[iv]	✓	[v]	[v]	✓	✓	✓	✓	✓	✓	✓	✓
	Characteristics of asset		✓		✓	✓		✓			✓	[v]	[v]	✓	✓		✓		✓	✓	✓
Validity	Open-source		(✓)[vi]						✓	✓		(✓)[viii]				(✓)[ix]	(✓)[ix]		(✓)[vi]		
	Peer-reviewed		(✓)[vii]		✓	✓			✓	✓		✓	✓		✓	✓	✓	✓	(✓)[x]	✓	✓
	Source references		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Outputs	Quantitative		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
	Semi-quantitative			✓		✓		✓		✓				✓	✓		✓				
	Non-financial metrics		✓		✓		✓	✓		✓		✓	✓		✓		✓	✓	✓		
	Financial metrics		(✓)[i]	✓[xi]		✓			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 5: Overview of physical risk assessment tools and analytics

Abbreviation	Service Provider	Tool
427 (1)	Four Twenty Seven	On-demand physical climate risk scoring application
427 (2)	Four Twenty Seven	Physical climate-risk scores for publicly listed companies
ACC	Acclimatise	Physical climate risk heatmapping tool
ACC-WTW	Acclimatise-Willis Towers Watson	Sector deep-dive assessments tool
C4 (1)	Carbone 4	Climate risk impact screening (CRIS)
C4 (2)	Carbone 4	Infrastructure and real estate portfolio assessment tools
CFIN	Climate Finance Alpha	Physical risk toolbox
CW	ClimateWise (CISL)	Physical risk framework
MSCI	MSCI-Carbon Delta	Climate Value-at-Risk (CVaR)
OF (1)	Ortec Finance	ClimateMAPS
OF (2)	Ortec Finance	ClimatePREDICT
RhG	Rhodium Group	Valued asset-level physical risk data
RMS	RMS	Climate risk models and consultancy service
SP (1)	South Pole	Risk screening tool
SP (2)	South Pole	Climate risk deep-dive assessment
TCS	The Climate Service	TCS Climanomics
VE-PL	Planetrics	PlanetView
VR	Verisk Analytics	AIR
XDI	XDI Systems (physical risk only or in partnership with Baringa for physical & transition)	

Notes

i. Under development for 2021
ii. Up to 2080
iii. Infrastructure / real assets only
iv. Optional (but preferable)
v. Top-down approach does not need company/asset information
vi. Methodology available for users
vii. Elements of the methodology are peer-reviewed
viii. Open-source version will be available on OS-Climate platform
ix. Methodology, not source code
x. Within Vivid Economics' academic network
xi. Leveraging Moody's Analytics' Public Expected Default Frequency structural credit risk model, 427's physical climate risk scores for listed companies can be translated into credit metrics such as probability of default term structures, expected loss estimates, credit spread effects, price effects, and value-at-risk. This is currently offered as consultancy services and will be offered in future as an on-demand analytics product.

Source (UNEP FI, 2021 (b))

APPENDIX V: OPEN SOURCE DATASETS

Open-source data for Physical Risks (UNEP, 2021)

Data Source	Physical hazards covered	Geographical Coverage
Climate Central	Extreme sea levels, storm surge data, high tide events, coastal flooding, sea level changes and severe winds	Global
PREPdata	Temperature rise, precipitation, coastal risk, water risk and other extreme events	Global coverage with low granularity for specific countries
UNEP Global Risk Data Platform	Tropical cyclones, storm surges, drought, earthquakes, fires, floods and landslides	Global
KNMI—Climate Explorer	Temperature, droughts, cyclones and precipitation	Global
World Bank Climate Change Knowledge Portal	Temperature rise, seasonal precipitation, sea level rise, extreme weather events such as floods, droughts and heat waves	Global
WRI Aqueduct Water Risk Atlas	Water risks, including flood and drought risk	Global
CDP Open Data Portal	Storms, extreme heat, sea water intrusion, drought, floods and forest fires	Global coverage of CDP cities
GFDRR ThinkHazard!	Extreme heat, floods, earthquakes, landslides, sea level rise, water scarcity, and wildfires	Global
Oasis Hub	Flooding, cyclones, earthquakes, extreme weather and landslides	Global
Open Data for Resilience Index	Flooding and cyclones	Estimated 55 countries covered
Google dataset search	Hurricanes, sea level rise and temperature rise	Global

Open data sources for Emissions Data (UNEP, 2021)

Data Source	Transition Risks Covered	Geographical Coverage
CAIT Climate Data Explorer (by WRI)	GHG emissions, emission pathways, pledges and targets	Global
CDP Open Data Portal	GHG emissions	Global
The Carbon Monitoring for Action (CARMA) database	GHG emissions estimates for power plants	United States of America, European Union, Canada, India, South Africa, as well as data from the International Atomic Energy Agency
Greenhouse Gas Protocol	Product life cycle and corporate value chain (Scope 3) GHG inventories	Global
The Lowdown v2.0	Coal capacity for countries	Global
UNdata	Methane, Carbon Dioxide, Hydrofluorocarbons, Nitrous oxide, Nitrogen trifluoride, Perfluorocarbons and Sulphur hexafluoride	43 countries, however, data is only available for 29 years

Examples of data and sources for Climate-related Risk Management (BIS, 2022)

Data	Source	Link
Carbon emissions	International Energy Agency	www.iea.org/data-and-statistics/databrowser/?country=WORLD&fuel=CO2%20emissions&indicator=CO2BySource
	Worldometer	www.worldometers.info/co2-emissions/co2-emissions-bycountry/
	European Commission (EDGAR)	https://edgar.jrc.ec.europa.eu/report_2021
Energy supply	International Energy Agency	www.iea.org/data-and-statistics/databrowser/?country=WORLD&fuel=Energy%20supply&indicator=TESbySource
ESG scores	Sustainalytics	www.sustainalytics.com/esg-ratings
	MSCI	www.msci.com/our-solutions/esg-investing/esg-ratings
Credit ratings	S&P Global	www.spglobal.com/ratings/en/
	Fitch	www.fitchsolutions.com/
	Moody's	esg.moodys.io/
Climate adaptation	University of Notre Dame	gain.nd.edu/
Implied temperature	Climate Action Tracker	climateactiontracker.org/global/temperatures/
	MSCI	www.msci.com/our-solutions/climate-investing/net-zerosolutions/implied-temperature-rise
Green bonds	Climate Bond Initiative	www.climatebonds.net/