BIS Innovation Hub

Project Viridis

A climate risk platform for financial authorities

June 2024

BIS Innovation Hub

MAS
Monetary Authority of Singapore

Contents

Acronyms/Glossary 3

Tables and graphs 4

Executive summary 5

1 Introduction 6

2 **Identifying, monitoring and managing climate-related financial risks** 9

2.1 Climate-related financial risk and expectations for supervisors 10
2.2 Challenges with managing climate-related financial risks 14

3 **Project Viridis: what a climate risk platform could deliver** 17

3.1 Understanding the problem statement 18
3.2 Prioritising user needs 20
3.3 Viridis solution design and blueprinting 23

4 **The Viridis solution** 26

5 **Findings, opportunities and considerations** 31

5.1 Findings from Project Viridis 32
5.2 Opportunities and considerations 33

Annex 34

References 42

Contributors 43

Acronyms/Glossary

BCBS	Basel Committee on Banking Supervision
BIS	Bank for International Settlements
CDP	Carbon Disclosure Project (formerly)
CSV	Comma-separated values
EDKP	Ellipse Data and Knowledge Platform
EVIC	Enterprise value including cash
FI	Financial Institutions
FSB	Financial Stability Board
ICE	Intercontinental Exchange
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
MAS	Monetary Authority of Singapore
ND-GAIN	Notre Dame Global Adaptation Initiative
NGFS	Network for Greening the Financial System
PACTA	Paris Agreement Capital Transition Assessment
PCAF	Partnership for Carbon Accounting Financials
SBTi	Science-Based Targets Initiative
SSP	Shared Socioeconomic Pathways
TPI	Transition Pathway Initiative

Tables and graphs

Tables

Table 1	Scope 1, 2 and 3 absolute emissions and emission intensities
Table 2	Impact of carbon pricing trajectories
Table 3	Impact on counterparty or borrower

Graphs

Graph 1	Top borrowers of supervised entity, sorted by industry and by country
Graph 2	Financed emission trajectories
Graph 3	Exposure to physical hazards

Executive summary

Central banks and financial authorities around the world recognise that both the physical effects of climate change and the transition to a low-carbon economy are sources of financial risks. In recent years, there has been a growing international call for financial authorities to monitor, manage and mitigate risks arising from climate change and to ensure climate-sensitive regulatory oversight of their supervised financial institutions. This is because of the strong impact that supervision has on the financial sector, which in turn plays a significant role in the sustainability of the firms that banks lend to. However, monitoring and analysing climate-related financial risks are particularly challenging because of the complex nature of climate change, its global impact, and the varying mitigation strategies across jurisdictions. Data and climate-related disclosures used to analyse climate risk also vary widely, meaning they are hard to compare in a consistent way.

In response to these challenges, the Bank for International Settlements Innovation Hub, together with the Monetary Authority of Singapore, launched Project Viridis to explore the development of a climate risk platform that could help central banks and authorities identify and assess material climate-related financial risks. Project Viridis is built on the premise that insights on climate risks could be drawn *initially* from existing available data sources. These insights could provide supervisors with an early understanding of which entities could be more exposed to climate-related financial risks and any potential systemic exposure to sectors and geographies. As a modular platform, further advancements and international alignment on climate data and metrics could then be integrated into the platform, providing richer insights.

The Viridis climate risk platform prototyped the development of several features. These include:

i. banking and financial system-wide and financial institution-level views of financed emissions;

ii. consolidation of reported and modelled emissions of entities that are key counterparties to financial institutions; and

iii. mapping the geographical distribution of entities' assets to assess the entities' transition risk exposure arising from changes in carbon pricing policies and exposure to different physical hazards.

This report outlines a solution design for future platform functionalities, as and when more data become available, and methodologies established. It also shows how, over time, the conversations, standards, technologies and methodologies will most certainly evolve and how the platform too must evolve. During this process, the blueprint could form the basis for supervisors to understand their data gaps and explore with the supervised banks how to collect such data.

1

Introduction

1. Introduction

Central banks, regulators and supervisors around the world ("financial authorities") recognise that extreme climate events, as well as a disorderly transition to a low-carbon economy, will have destabilising effects on the financial system. Climate-related financial risks, stemming from physical and transition risks, pose new challenges to financial authorities because they are subject to substantial uncertainty and long horizons. Collective actions taken today may determine the severity of risks in the years ahead, but exact pathways are uncertain. The possible simultaneous occurrence of climate risks across multiple jurisdictions and sectors also has implications for financial stability.[1]

Understanding how these climate-related physical and transition risks affect financial stability is therefore critical for financial authorities. In recent years, there has been a growing international call for financial authorities to adopt more structured approaches to monitor, manage and mitigate risks arising from climate change and to ensure climate-sensitive regulatory oversight of their supervised financial institutions (FI).[2] However, monitoring and analysing climate-related financial risks are particularly challenging because of the complex nature of climate change. These challenges even increase because of disparate and inconsistent sources of data, and while there is an effort to converge on reporting requirements, these are still being developed.

With these challenges in mind, the Bank for International Settlements (BIS) Innovation Hub Singapore Centre and the Monetary Authority of Singapore (MAS) launched Project Viridis. Project Viridis extends the work undertaken for Project Ellipse[3] and explores how central banks and supervisors could monitor climate-related financial risks by using an integrated regulatory data and analytics platform. Project Viridis is built on the premise that insights on climate risks could be *initially* drawn from existing available data sources. These insights could provide supervisors with an early understanding of which entities could be more exposed to climate-related financial risks and any potential systemic exposure to sectors and geographies. As a modular platform, further advancements and international alignment on climate data and metrics could then be integrated into the platform, providing richer insights.

1 Financial Stability Board (FSB), "Climate-related risks", www.fsb.org/work-of-the-fsb/financial-innovation-and-structural-change/climate-related-risks/.

2 See for example Network for Greening the Financial System (NGFS) (2020), Basel Committee on Banking Supervision (BCBS) (2022) and FSB (2022).

3 The BIS Innovation Hub's Project Ellipse is a prototype that authorities can test in their own environments, which may help them to explore new solutions. It also presents an opportunity for the global regulatory community to further consider, explore and collaborate on common solutions to future-proof the data and analytical capabilities of supervisors.

This report provides a detailed description of how Project Viridis adopts the Ellipse Data and Knowledge Platform (EDKP) as the foundational architecture for integrating regulatory exposures and climate data, applying natural language processing techniques to find, extract and process climate-relevant information from corporate disclosures. The report furthermore outlines the features and functionalities that were built to demonstrate the utility of a climate-risk platform for supervisors. The structure of the report is as follows:

- **Section 2** sets out the challenges supervisors and other entities face in identifying, monitoring and managing climate-related financial risks and outlines the scope of the project.

- **Section 3** describes the user stories and features of a climate-risk platform that were categorised into supervisory priority areas and the use case for Viridis.

- **Section 4** outlines the features developed and the underlying Ellipse architecture that supports it.

- **Section 5** concludes with the project findings, opportunities and further considerations for supervisors.

2

Identifying, monitoring and managing climate-related financial risks

2. Identifying, monitoring and managing climate-related financial risks

2.1 Climate-related financial risk and expectations for supervisors

Financial authorities around the world recognise that both the physical effects of climate change and the transition to a low-carbon economy are sources of financial risks. The physical effects of climate change are referred to as physical risks characterised as either acute or chronic (Box 1). Acute physical risks arise due to the increasing severity and frequency of extreme weather events related to climate change (such as heat waves, droughts, landslides, floods, wildfires and storms). Chronic risks refer to longer-term progressive shifts in the climate (such as ocean acidification, rising sea levels and average temperatures).[4] While the frequency and severity of climate events vary by geography and are difficult to model or predict, the overall losses resulting from global natural disasters between 1980 and 2018 were estimated to be more than $5 trillion.[5]

In line with national commitments made under the Paris Agreement to move towards net zero carbon emissions, transitioning to a low-carbon economy could also result in financial risks (Box 2). These risks potentially arise from changes in climate-related policies, technology and consumer sentiment as economies work towards reducing their reliance on certain carbon-intensive industries. Containing global temperature rises to well below 2°C, for example, would require the world's economies to refrain from using and extracting a large proportion of existing fossil fuel reserves. This would mean that fossil fuel infrastructure and assets (such as power plants, pipelines and downstream refineries could no longer be used and may become a liability even though they are still economically productive. They would become what is often referred to as stranded assets.[6] The process of proactively reducing carbon emissions through new regulations such as carbon pricing or support for renewable energy could therefore disrupt different sectors of the economy, particularly if this happens too quickly or without adequate contingency plans.[7]

4 NGFS (2020).
5 BCBS (2021a).
6 Grantham Research Institute on Climate Change and the Environment (2022).
7 BCBS (2021a).

Work being undertaken by the standard-setting community and other international bodies is focusing on the transmission channels of climate risk, which are described as the causal chains linking physical and transition risks to the *financial risks* faced by banks and the banking sector. These channels can also feed into microeconomic and macroeconomic channels through which climate change might materialise as a source of financial risk. Microeconomic transmission channels include the way climate risk drivers affect the individual counterparties of banks, potentially increasing the exposure of banks to potential losses if those counterparties become stressed. Macroeconomic transmission channels refer to how climate risk drivers affect macroeconomic factors such as economic growth and how these, in turn, may have an impact on banks by affecting the economy in which banks operate. These would also capture the effects on macroeconomic market variables such as risk-free interest rates, inflation, commodities and foreign exchange rates.[8]

Importantly, evidence suggests that climate-risk drivers can be linked to financial risk categories that authorities use to monitor prudential risks and financial stability.[9] For example, climate risks can give rise to credit risk if a borrower's ability to repay and service debt is reduced or impaired or if a bank is unable to fully recover the value of a loan made to a borrower in the event of default. Market risk could arise if there is a reduction in the value of financial assets, which could include the potential to trigger large, sudden and negative price adjustments where climate risk is not yet incorporated into prices. Should there be climate risk events, banks' access to stable sources of funding could also be reduced as market conditions change, giving rise to liquidity risk. Operational risks may increase if banks have exposures to legal and regulatory compliance risk associated with climate-sensitive investments and businesses.

Box 1: Physical risks

Physical climate risk refers to the increasing severity and frequency of extreme climate change events that may result in severe humanitarian and economic damage. For instance, banks face greater credit risk and less protection against borrower default when housing used as collateral is destroyed by hurricanes and wildfires. This could prompt banks to restrict their lending in certain regions, reducing the amount of financing available for reconstruction in more heavily affected areas. Physical climate risks may also entail unprecedented systemic risk in other situations where environmental tipping points are crossed, leading to irreversible, catastrophic outcomes on the climate and economic systems globally.

8 BCBS (2021a).
9 NGFS (2020).

Box 2: Transition risks

Transition risks arise when policies that penalise carbon-intensive sectors put increasing pressure on businesses to adjust their decisions and operations. There is an ongoing global movement where economic actors are transitioning from carbon-intensive to net zero. If businesses fail to conduct appropriate analysis and management of these risks and realign their business models, they will be more vulnerable to assets, equipment and plants being stranded, alongside sharp fluctuations of asset prices. Feedback loops will reverberate between the financial system and the macroeconomy, which may further exacerbate the risks and impacts generated.

The main aim of prudential regulation and oversight is to ensure the safety and soundness of financial institutions and to safeguard the stability of the financial system. The potential economic and financial impact that climate change has on financial institutions and financial stability therefore means that central banks, regulators and supervisors are expected to ensure the financial system is resilient to these risks.[10] International bodies have outlined some of these expectations through principles and guidance, which are intended to articulate how supervisors and regulators can better incorporate climate-related risks into risk assessments and policies.[11] The major expectations are summarised in Box 3.

10 NGFS (2020).
11 See for example NGFS (2020), BCBS (2020) and FSB (2022).

Box 3: Expectations for supervisors

The Network for Greening the Financial System (NGFS) has made a number of recommendations to its member authorities, including the need for supervisors to determine how climate-related and environmental risks transmit to the economy and their financial sectors and to identify the materiality of these risks for their supervised entities. The NGFS also recommends that authorities identify the exposures of supervised entities that are vulnerable to climate-related and environmental risks and assess the potential losses should these risks materialise. To do this, the NGFS suggests that supervisors should understand the determinants of physical risk (eg the climate sensitivity of the sector, geographical location) and transition risk (eg policy sensitivity).

The Financial Stability Board (FSB) has also outlined the need to adjust the existing supervisory and regulatory risk assessments and policies to be able to oversee climate-related financial risks. The risk assessment and policies need to better incorporate the channels through which climate-related risks to financial institutions may be transferred across sectors or borders. Applying a system-wide approach to climate-related risks should also draw on elements of existing prudential frameworks, such as:

- supervisory review and evaluation processes;
- risk analytical tools like scenario analysis; and
- stress-testing exercises and macroprudential tools and policies to address systemic risks.

Importantly, to enable supervisors to draw on elements of existing prudential frameworks, authorities would need to accelerate the identification of their information needs for supervisory and regulatory purposes to address climate-related risks and work towards identifying, defining and collecting climate-related data and key metrics that can inform climate risk assessment and monitoring.

The Basel Committee on Banking Supervision (BCBS) has proposed that an effective climate-risk management framework for banks and supervisors should have three goals:

i. to identify material climate risk drivers and their transmission channels;

ii. to map and measure climate-related exposures and any area of risk concentration; and

iii. to translate climate-related risks into quantifiable financial risk metrics.

Importantly, there is an expectation that supervisors should be in a position to oversee how banks and supervised financial institutions can adequately identify, monitor and manage all material climate-related financial risks as part of their assessments of banks' risk appetite and risk management frameworks. This includes understanding and assessing the impact of climate risk drivers on their risk profile and integrating climate-related financial risks in the management of credit, market, liquidity, operational and other types of risk.

2.2 Challenges with managing climate-related financial risks

Financial authorities are actively taking steps to appropriately consider climate-related financial risks and incorporate these risks into their risk assessments. However, integrating climate-related risk analysis into risk management frameworks and financial stability monitoring is particularly challenging because, unlike traditional risk measurement, climate-related risks are characterised by data gaps, complex physical phenomena and societal responses that cannot be known with certainty in advance. The assessment of climate-related risks therefore faces two broad sets of challenges:

i. methodological questions on to how to evaluate inherently unknowable, complex future trajectories; and

ii. practical limitations on the current standardisation and availability of data.

Methodological challenges

The assessment of climate-related financial risks introduces new concepts to financial authorities and risk managers. One of the key challenges for financial authorities is the epistemological question of "risk" versus "uncertainty". Authorities recognise the need to draw a sharper distinction between risk and uncertainty to help practitioners better appreciate the inherent limitations involved in assessing climate-related financial risks. While risk refers to quantifiable knowledge of a possible occurrence, uncertainty refers to unmeasurable future states that cannot be quantified with any degree of certainty. Defined by fundamental limitations on potential knowledge and measurement of future states, climate-related risks are distinctly uncertain and the data that are available are far from perfect.

Climate risks will materialise through future states of the world that contain various elements of physical and transition risks. Such future states will inherently be determined by decisions made today and yet to be made. For example, the magnitude and timing of action to tackle climate change is dependent on complex societal responses that cannot be known with certainty in advance. While past data can be used to draw representative examples, relevant parallels are scarce, and hypothetical scenarios cannot be easily assigned probabilities. These climate-related risks may also materialise beyond a bank's traditional two- to three-year capital planning horizon but still within the maturities of longer-dated positions. The key role that tipping points can play in rapidly shifting the climate system from one state to another is also poorly understood and remains largely unquantified.

A main challenge identified by the BCBS in a survey of authorities is therefore the lack of a harmonised and robust analytical framework for assessing climate-related financial risks.[12] Measuring climate-related financial risks therefore involves a high degree of uncertainty that may lead to misestimation of risks. Given that future climate-related financial risks will probably differ from observed patterns, measuring and estimating the impact of climate-related risks on banks requires authorities to take a broader view of assumptions about the interactions between the climate, anthropogenic activity and economic activity. As these assumptions will involve forecasting the behaviour of economic actors and policymakers and the future of technological advancement, any solution looking to provide a realistic assessment of risk exposures must therefore contend with these epistemological limitations.

Consequently, financial authorities may need to allow a more heuristic, "roughly right" approach that transparently reflects assumptions made, as this may capture uncertainty better than highly quantified approaches. Tools that are transparent about the fundamental unknowns in projections would likely prove more valuable for supervisory dialogue. "Roughly right" approaches would allow regulators and supervisors to apply flexibility and pragmatism to assessing preparedness for material climate risks. This is even more crucial when considering challenges with data availability and greenwashing, which are discussed below.

Data gaps

The assessment of climate-related financial risks requires the incorporation of vastly different types of data with existing financial and regulatory data that banks and financial authorities traditionally use. The BCBS has identified three broad categories of data that are needed to assess climate-related financial risk:

i. data describing physical and transition risk drivers needed to translate climate risk drivers into economic risk factors (ie climate-adjusted economic risk factors);

ii. data describing the vulnerability of exposures, linking climate-adjusted economic risk factors to exposures; and

iii. financial exposure data, needed to translate climate-adjusted economic risk into financial risk.[13]

Data that can inform physical and transition risks are key for assessing how climate-related risks can impact banking exposures. These include information related to climate hazard events and geographic data on locations that may be more at risk of projected hazards. In addition, banks and supervisors need information to assess the vulnerability of bank exposures to physical and transition risks.

12 BCBS (2020).
13 BCBS (2021b).

Specifically, to assess the vulnerability of bank exposures to physical risk, authorities would need information such as the geospatial location of banks' counterparties (including their value and supply chains). For transition risk, a bank's exposure to a corporate would require information on the sector or economic activity to determine how sensitive that corporate is to carbon emissions in its production and distribution processes. Finally, to facilitate the risk assessment or translation of the climate-related risks to financial exposures, authorities require data on banks' exposures to counterparties, both at a portfolio composition level as well as at a more granular loan level, to estimate potential impacts of these exposures.

However, many authorities cited challenges with data, indicating that current data are not sufficiently granular or reliable to feed into the potential assessment models.[14] Consistent emissions and climate-related data across jurisdictions and across sectors would be needed to undertake further comparable risk analysis. Although the range of data and disclosure requirements is growing rapidly, industry participants are also struggling to evaluate what data are relevant, how to collect the relevant data and how to interpret them.[15] Where data are potentially available, data quality is compromised, as they are often not consistently described and lack completeness and granularity to support detailed estimates.[16] To illustrate, a key data set for the evaluation of transition risk is Scope 1, 2 and 3 emissions data. Despite its prominence over the years, disclosure of these emissions estimates remains inconsistent and estimation methodologies often lack transparency. Emissions figures from various data providers also vary, making them difficult to rely on for evaluating risk exposures. In addition, relevant data at the entity's asset level (eg factories) are neither widely collected nor disclosed – at least in a format that could be compared across multiple jurisdictions.

Data gaps are also often more pronounced for emerging economies, with data from developed markets unrepresentative of developing markets. Often, financial institutions do not have access to data on key variables for assessing climate-related risk exposures in emerging and frontier markets. For example, scenarios for sectoral transition pathways are broadly constructed with a focus on developed economies, with limited applicability for emerging markets that are significantly different in their economic make-up. Similarly for physical risks, more granular regional climate models exist for many developed jurisdictions but are unavailable for emerging markets where banks have sizeable exposures.

Overall, financial authorities will need to embrace ambiguity and unknowns in designing solutions for better climate risk assessment as well as in actively exercising mandates to create more reliable and comprehensive data on risk exposures. Navigating the fundamental uncertainties inherent in climate risk analysis is also dependent on high transparency of data and assumptions used as well as open acceptance of their limitations.

14 For example, see BCBS (2020) and FSB (2021).
15 In 2022, the Project Viridis team held a number of workshops with members of both the public and private sector where industry participants shared their views on the data challenges.
16 BCBS (2021b).

3

Project Viridis: what a climate risk platform could deliver

3. Project Viridis: what a climate risk platform could deliver

3.1 Understanding the problem statement

Given the constraints mentioned above, how might authorities and supervisors identify and assess relevant drivers of climate-related risk that affect individual banks and the broader financial system without access to full, complete and standardised climate data? Without being prescriptive on specific methodological choices, how might a potential solution help central banks and regulators assess financial exposures to and preparedness for climate-related risks? As a central guiding question, Project Viridis therefore focuses on the problem statement of how authorities and supervisors could identify and make sense of relevant climate-related risk drivers when data are currently limited and a common understanding on how to measure climate-related financial risk is still being resolved.

A climate risk tool for supervisors

The Project Viridis use case proposes that a climate risk tool could help authorities interpret available data to form a "triangulated" view of climate risk exposures to assist in supervisory conversations. Noting the inherently unquantifiable uncertainty, a qualitative, "roughly right" approach based on the integration of available climate data with regulatory exposures is therefore likely to produce a more realistic evaluation of climate-related risk. This means that the tool could at best provide insights into which exposures may be more vulnerable to climate-related physical and transition risks. However, it would still rely heavily on supervisory judgment and dialogue with supervised entities to account for measures taken to build resilience against these risks.

This type of problem solving builds on the work developed for Project Ellipse, which stemmed from a similar challenge of how supervisors could gain predictive insights into emerging risks using disparate regulatory and other unstructured data. The primary objective of Project Ellipse was to explore and demonstrate how an integrated data and analytics platform solution could enable supervisors to digitally extract, access and analyse in real time large and diverse sources of data that are relevant to current events. Project Viridis therefore adopts the Ellipse Data and Knowledge Platform as the foundational architecture for integrating regulatory exposures and climate data, applying natural language processing techniques to find, extract and process climate-relevant information from corporate disclosures. By building Viridis using the EDKP, the project also intends to extend the use cases currently available to authorities through the BIS Open Tech community (Box 4).

Box 4: BIS Open Tech and the Ellipse Data and Knowledge Platform collaboration community

The BIS Open Tech is a platform for sharing statistical and financial software as public goods, by promoting international cooperation and coordination. These software tools are developed to be reused and further developed in a wide variety of environments.

In 2022, following the release of the Project Ellipse prototype, the BIS Innovation Hub invited central banks and regulatory authorities to form a collaboration community where authorities can work together to create new applications to serve common use cases and priorities. The collaboration community has access to the Project Ellipse platform, which is known as the Ellipse Data and Knowledge Platform. The EDKP is built using a technology stack developed by the Monetary Authority of Singapore (MAS), which is known as the Data and Knowledge Platform. The community intends to enable participation, usage and contributions in much the same way as a fully open source environment.

The objectives of the community are to:

- create a forum for participants to collaborate and develop new technologies to serve common use cases and priorities;
- foster and promote the importance of this new form of international collaboration for the central banking community to support digital innovation and transformation; and
- encourage the development of globally relevant public or community goods to improve the functioning of the financial system.

To catalyse the idea of community-oriented sharing and create new use cases, the BIS Innovation Hub together with the MAS hosted the first BIS Open Tech Digital Transformation Workshop and a hackathon on 7–9 March 2023. Since the launch of the BIS Open Tech, the community of supervisors and regulators has grown to 14 institutions, with growing interest from others to join as well.

In the hybrid workshop, the focus was on knowledge sharing. Over 80 people participated online with another 30 in-person participants in Singapore. The MAS shared information on data management, De Nederlandsche Bank and the Swiss Financial Market Supervisory Authority contributed use cases they developed in-house, while the BIS Innovation Hub shared lessons learned on digital collaboration in regulation and presented BIS Open Tech and the EDKP.

A hackathon was conducted over two days with four teams of participating authorities developing solutions on EDKP to help regulators with different use cases:

- **Team 1** designed a liquidity monitoring dashboard to track the overall liquidity needs in the financial system and to assess (emergency) liquidity needs from banks.
- **Team 2** developed and tested the performance of a chatbot in analysing regulatory and legislative documents to help regulators access relevant information.
- **Team 3** introduced a social media-based sentiment analysis tool, which could provide authorities with a good overview of the topics of supervisory relevance gaining traction on social media and the prevailing sentiment around such topics.
- **Team 4** built a tool to assess customer satisfaction with different bank branches using posted Google reviews to enable monitoring of developments that shed light on operational risk (eg regularly defective automated teller machines).

3.2 Prioritising user needs

As part of the project's scoping phase, *outreach and design thinking workshops* were held with participants from central banks, supervisory authorities, industry and academia. Participants were asked how financial authorities and supervisors might determine that banks are comprehensively identifying and assessing the impact of climate-related risk drivers on their risk profile. To further narrow the scope of possible solutions, it was acknowledged that while financial authorities in general are mandated to safeguard the stability and resilience of the financial sector, supervisors specifically have either microprudential or macroprudential oversight responsibilities. Microprudential supervisors in particular fulfil that mandate by assessing the risk exposures of individual financial institutions and challenging those institutions on mitigation measures to address the identified risks. Supervisors with a macroprudential lens may utilise the same underlying data to assess system-wide stress or the buildup of risks. The users identified for the project are therefore primarily microprudential supervisors, with the assumption that macroprudential supervisors could also use the tool if aggregation functionalities were built into the platform.

A survey of financial authorities shows that varying approaches are currently being adopted to assess climate-related financial risks. The most commonly used approaches include:

i. qualitative assessments on the climate risk transmission channels to financial risks and financial stability;

ii. quantitative estimates of the exposures of the financial sector to sectors or geographies that might be vulnerable to climate change; and

iii. scenario analysis and stress testing on climate-related financial risks.

Some authorities are also adopting the use of scorecards or heatmaps to assess the materiality of specific physical or transition risks and constructing key risk indicators to monitor risks related to climate change.[17]

Building on these approaches, participants in our workshops identified a list of user stories that were prioritised in order of "must-haves", "should-haves" and "nice-to-haves" (Box 5). For simplicity, the first five user stories were earmarked as the first few features to be prioritised in the platform in the short term, while the rest could be added as additional features over time. Overarching suggestions included the desire by all participants to have enhanced comparability of data, methods and tools across financial institutions (FIs), sectors, regions and timescales, with a focus on accessibility, transparency, diversity, standardisation and quality. Participants also highlighted that an ideal solution would make clear distinctions between risks, uncertainties, expected vs observed impacts, and opportunity areas for adaptation, mitigation and resilience efforts in assessment reporting. There was also a desire to understand divergences and differences in data and methodologies between climate-related risks and exposures faced by various asset classes as well as an overview on data gaps and limitations (eg climate-related disclosures in emerging contexts).

Participants also agreed that a climate platform would need to be kept up to date with the latest data and agreed methodologies, as and when they became available. The key differentiators for the platform then would be the transparency of the underlying data (highlighting gaps or divergences if applicable) and a clear selection of data points or proxies that capture the key aspects of climate-related risks and opportunities for decision-useful insights. Importantly, working with the deep uncertainties involved in climate-related financial risks will require new modes of thinking about risk exposures. While the significant unknowns and new risk assessment approaches required will likely cause some discomfort with supervisors, the serious threat these risks pose to the financial system will require facing these challenges head on.

17 BCBS (2020).

Box 5: User stories in order of importance from highest to lowest

As part of the discovery and scoping phase of the project, we conducted several workshops with groups of regulators and supervisors and also invited experts from the industry and academia to participate. These workshops focused on addressing the question, "How might supervisors determine that banks are comprehensively identifying and addressing the impact of climate-related risk drivers on their risk profile?" Consolidating these inputs, we were able to distil the following insights (in order of importance).

As a supervisor, I want...

- to see the Scope 1, 2 and 3 emissions footprints of a financial institution's portfolio (FI portfolio) so that I can assess its level of exposure and climate risk materiality.
- to map all assets within an FI portfolio so that a location-specific physical risk assessment can be conducted with high precision.
- to see sector-level emissions footprints and sector-average decarbonisation targets so that I can benchmark FI portfolios against science-based global targets.
- a comparative matrix with standardized metrics so that I can compare risk exposures across multiple FI portfolios in an "apples to apples" manner.
- to see physical risks at a country/grid level and transition risks at a country/sector level, as well as sectoral/national averages on an aggregated basis, so that I can monitor risk exposures across multiple FI portfolios.
- to assess whether the transition plans of a financial institution (FI) are viable as a business model so that I can advise the FI if it is not addressing the climate risks it is exposed to.
- to assess and compare individual FI mitigation measures and climate pledges or commitments against science-based net zero targets so that I can detect early if proposed measures or commitments are incapable of reaching stated goals and regulate accordingly.
- to know the financial impact breakdown of a severe weather event on supervised institutions so that we can build resilience to such damage in future.
- to be able to export the data analysis, especially the key insights, so that I can share and discuss these with my stakeholders in the supervisory process.
- the platform to be capable of interactive and explorable data visualisation so that I can intuitively understand and communicate insights.

- high-quality data and disclosures on climate-related risks from emerging markets so that these regions are no longer blind spots in risk assessment.
- to track the evolution of an FI's portfolio risks over time (months, years, decades) so that I can see the trajectory of a portfolio.
- to see future projections and impacts of climate trends and shocks so that they inform my future-oriented decision-making.
- to see climate-related risk exposure of non-bank financial institutions for a holistic analysis.

3.3 Viridis solution design and blueprinting

While challenges exist in terms of data quality and availability alongside deep uncertainties on future trajectories, data and metrics currently provide supervisors with a significantly improved view of banks risk exposures for more effective supervisory dialogue compared with previous years. Based on insights drawn from workshop participants' views on metrics, indicators and essential features of a climate-risk platform, the project developed a high-level blueprint of metrics that could form the basis of a climate-risk solution for supervisors (Annex 1).[18]

The blueprint is split into five main categories covering transition risks, physical risks, asset and economic data, systemic macro views, and essential user features. The transition and physical risk categories cover proposed metrics for each risk category. The systemic macro category discusses a system-level view, while the essential user features section highlights participant views on critical features for usability. A brief overview of the key categories and metrics are summarised below.

Transition risks

- Portfolio sector composition
- Scope 1, 2 and 3 financed emissions (absolute and intensity numbers)
- Portfolio, sector and company alignment with transition pathways
- Carbon pricing impacts
- Assessment of transition plans

18 With thanks to Climate Risk Services for developing for the BIS Innovation Hub this blueprint based on the workshops.

Physical risks

- Hazard exposure
- Sector sensitivities to physical hazards
- Adaptive capacity and adaptation plans
- Insurance coverage
- Physical vs transition risk matrix

Asset-level and economic data

- Asset locations
- Asset characteristics
- Supply chains and value chains

Systemic and macroeconomic view

- Overlapping risk concentrations between financial institutions
- Consilience of targets against global constraints

General features for usability

- Interactive and explorable map view and benchmark data
- Standard guidance on weighting multiple data sets
- Ability to export data

The blueprint provides the basis of the metrics and features that were used for rapid prototyping of Project Viridis. However, with current limitations in data availability, not all metrics can be fully captured, and in some instances, proxies were used to model data. Time and resource constraints also mean that the full wish list was not captured in the first iteration of Project Viridis, and key features have been prioritised based on inputs from workshop participants. Nevertheless, we encourage authorities to use the blueprint as a reference to explore the development of their own solutions.

Though the metrics and features have been separated into individual sections for clarity of discussion, they should be viewed as connected. For example, transition and physical risks cannot be viewed in isolation; increased physical impacts could lead to further policy measures to limit emissions (ie transition risks), while emissions will now determine future physical risks. Participants expressed that the platform should allow users to assess both transition and physical risks together as a part of the same dashboard.

Overall, workshop participants stressed that as much as the prototyping should incorporate relevant metrics, the success of the platform would depend on providing insight into what the presented data mean in practice. Supervisors and regulators using the platform should be able to identify early warning signs of vulnerability and be able to easily interrogate chosen metrics for meaningful supervisory dialogue. Participants strongly suggested that many of the emerging climate risk concepts were new to supervisory authorities and that success would depend on the clarity of insights provided on a currently confusing jungle of metrics and indicators.

Participants also noted that due to known data restrictions and questions on data quality, the platform should be able to collate multiple sets of data from various sources together in a comparable manner to enhance reliability. All underlying assumptions should be transparently outlined for users to be able to check their validity. Many workshop participants also strongly voiced the preference for open source data and models that would address many concerns around the reliability of proprietary black box models.

From a methodological point of view, all metrics and features discussed in the following sections will need to be viewed under multiple scenarios (eg disorderly transition, "hot house world" etc) from a range of scenario providers. Users will need to be able to interrogate the behaviour of each chosen metric (and relevant combinations) in different scenarios and time periods for realistic assessment of climate-related risk exposures and the effectiveness of risk mitigation strategies. In essence, each indicator provides views on the risk exposure of a supervised institution in a specific scenario narrative.

Finally, the platform should be able to define relevant risk thresholds and flag areas of concern. Thresholds will need to be defined for all relevant metrics and presented in easy-to-understand risk schema, such as low to high risk, using for example colour coding.

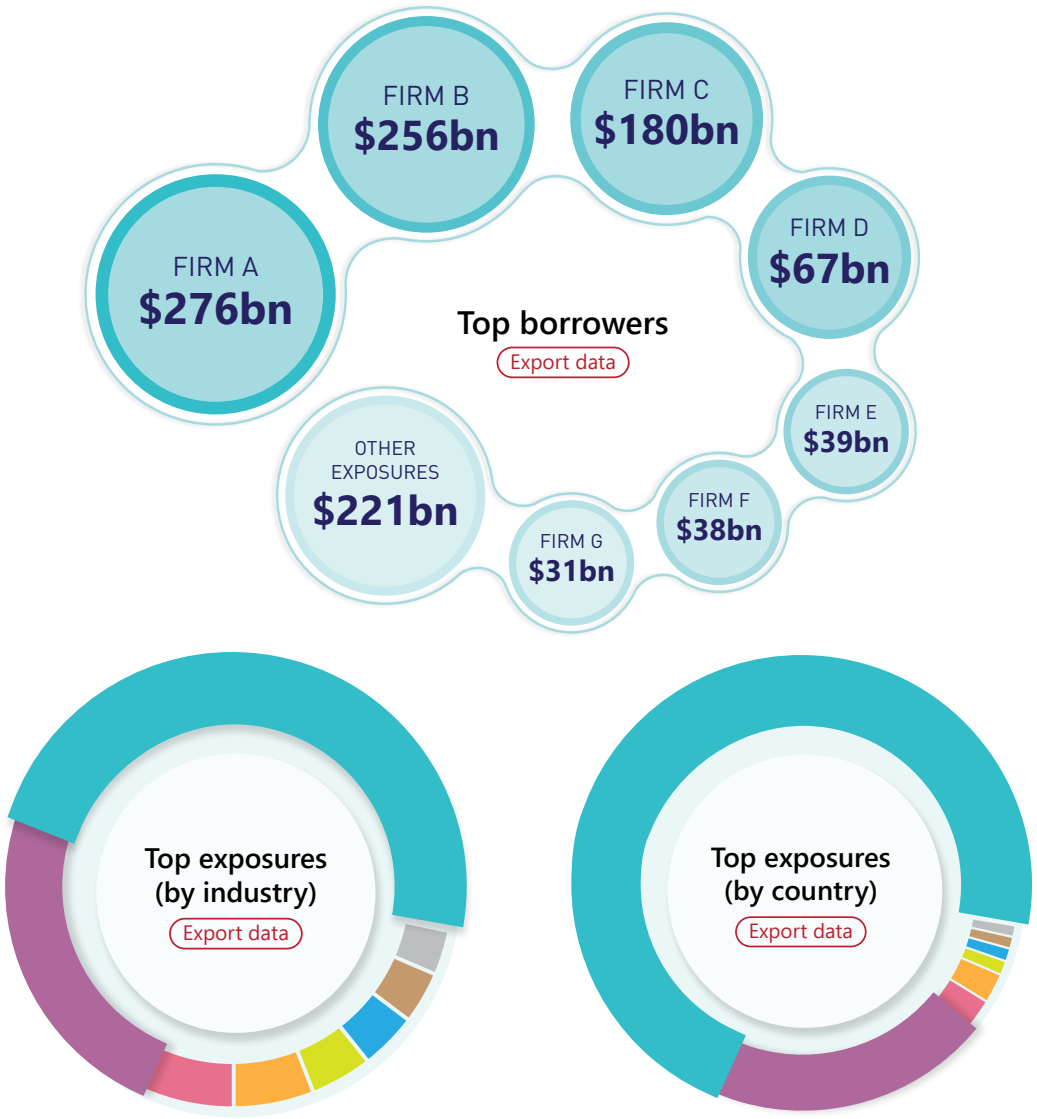
4

The Viridis solution

4. The Viridis solution

The Viridis platform provides authorities with a consolidated view of the climate-related risk of financial institutions and the financial system in aggregate, built up from the risks faced by the entities the financial institutions have exposures to. At the institution level, supervisors can see the top entities each bank is exposed to (see, as an example, Graph 1 for top borrowers of supervised entity A). Its portfolio of borrowers is also sorted by industry sectors and countries to easily highlight risk concentrations.

Graph 1 — Top borrowers of supervised entity, sorted by industry and by country



For each entity that the financial system has exposures to, where available, reported and modelled data on Scope 1, 2 and 3 absolute emissions and emission intensities are presented (Table 1). Each entity's emissions are benchmarked against emissions of the universe of entities for which data are available to identify firms or corporates with a relatively higher carbon footprint. One measure of transition risk is the impact of expected carbon prices (or taxation) in jurisdictions where entities operate. If entities have disclosed information about their transition plans, such plans can be combined with information on carbon pricing trajectories to assess monetary impact on the entity under different scenarios (Table 2).

Table 1 — Scope 1, 2 and 3 absolute emissions and emission intensities

Emissions

SCOPE	ABSOLUTE (IN TONNES)	WEIGHTED INTENSITY (TONNES PER SGD MILLION OF EVIC)	WEIGHTED BENCHMARK
Scope 1	68,000	7.4	3
Scope 2	46,000	3.6	8
Scope 3	95,000	9.5	9.5

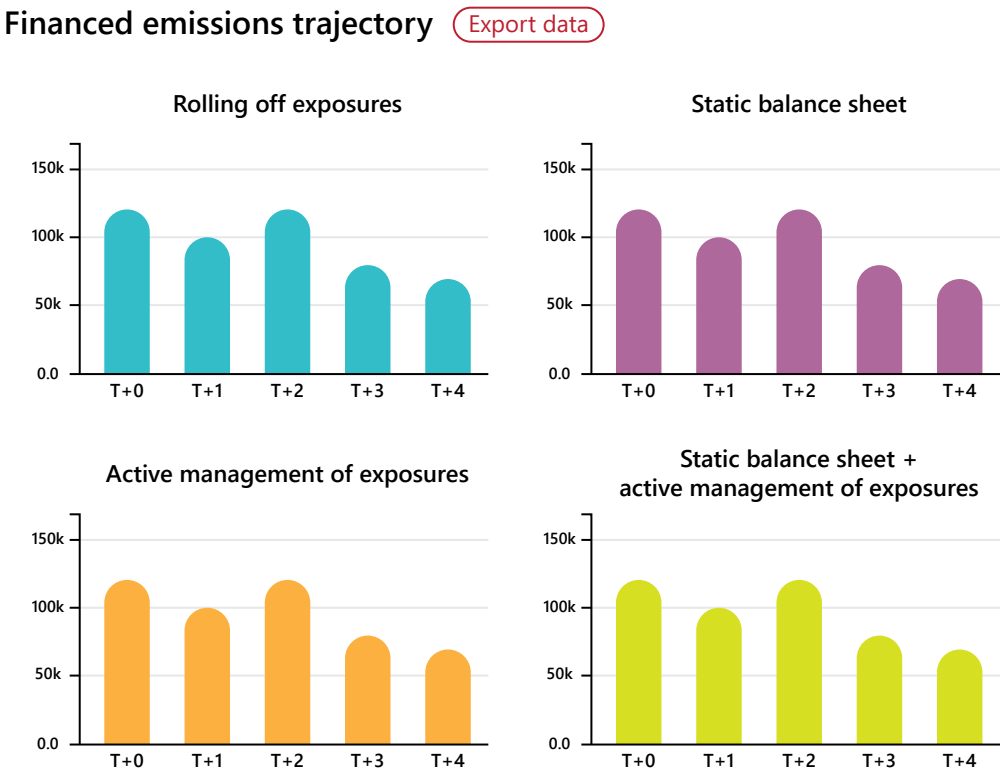
Table 2 — Impact of carbon pricing trajectories

Impact of carbon pricing trajectories

NGFS SCENARIO	ANNUAL COST (EMISSION X CARBON PRICE)
Net zero 2050	**$140 million**
Nationally determined contributors	**$180 million**
Current policies	**$250 million**

If financial institutions have good data on the share of their counterparties' emissions attributable to financing they provided to the counterparties, a view of financed emissions (by Scope) can be aggregated and presented. Banks can also aggregate the emissions trajectory (accounting for transition plans) of their counterparties to lay out their own financed emission trajectories under various scenarios (Graph 2). In some cases, banks have their own transition plans, which could range from simply rolling off existing non-green exposures to deliberately pivoting their business away from certain firms or products. Such transition plans can be overlayed to present authorities with a concrete view of the financed emissions trajectories and to assess the relative impact of assumptions made by the bank in making these projections. To access such detailed data would likely require an extended engagement between supervisor and supervisee.

Graph 2 — Financed emission trajectories



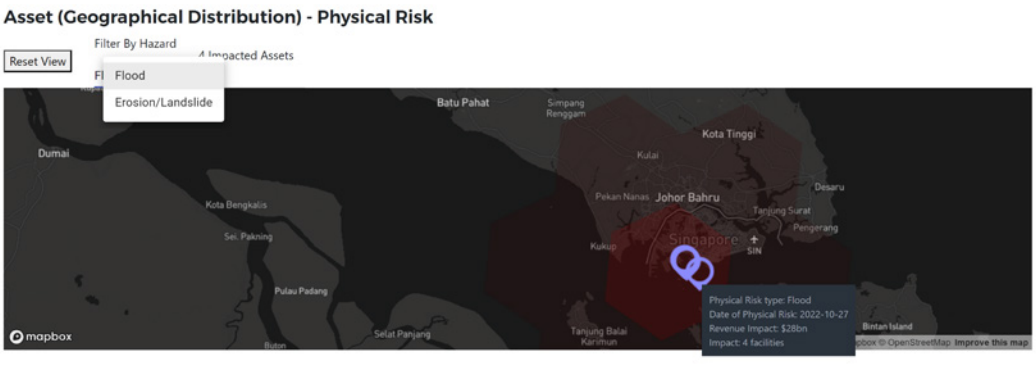
Where information on the assets (eg factories, production centres etc) of entities are available, the Viridis climate risk platform can provide a finer-grained view of the physical risks such entities are exposed to. The platform can scrape such information from the disclosures of entities, which could touch on key centres of operations, or disaggregate operation costs to countries or regions where the entities have production presences. Data on incidence of different physical hazards (eg floods, erosion etc) by geographical location can provide an initial view (Table 3). Such a view, where information is available, can be overlayed with existing mitigants that different jurisdictions have put in place (eg tougher building code expectations in jurisdictions with high winds) to arrive at a view of how sensitive an entity is to different physical hazards (Graph 3).

Table 3 — Impact on counterparty or borrower

Impact on counterparty/borrower

ASSET	REVENUE AT RISK	COUNTRY
ABC	**$2bn**	Singapore
DEF	**$7bn**	Singapore
GHI	**$7bn**	Singapore
JKL	**$3bn**	Singapore

Graph 3 — Exposure to physical hazards



Finally, the Viridis climate risk platform is built using the modular components of the EDKP. A key addition to the EDKP is the ability to parse and present geospatial data, which is key to assessing physical and transition risks.

5

Findings, opportunities and considerations

5. Findings, opportunities and considerations

5.1 Findings from Project Viridis

Project Viridis set out to explore how central banks and supervisors could monitor climate-related financial risks by using an integrated regulatory data and analytics platform. With a myriad of data and methodological challenges, Project Viridis demonstrates that insights on climate risks could initially be drawn from existing available data sources and broadly accepted assessment approaches, albeit nascent. These insights provide supervisors with an early understanding of which entities are more exposed to climate-related financial risks and any potential systemic exposure to sectors and geographies. Since the platform is modular, further advancements and international alignment on climate data and metrics could then be integrated into it, providing richer insights.

The key objective of our prototype was to focus on gathering "roughly right" data and to provide authorities with a tool that can help their own efforts under way. While an ideal solution with perfect information and perfect execution may not be quite within reach, the benefits of consolidating what is already available and making it even more broadly accessible cannot be understated. The Viridis prototype demonstrates this by:

- providing banking/financial system-wide and financial institution-level views of financed emissions, with breakdowns by countries and industry sectors, and their trajectories under various scenarios;

- consolidating reported and modelled emissions of entities that are key financial institutions' counterparties; and

- mapping the geographical distribution of entities' assets in order to assess the entities' transition risk exposure arising from changes in carbon pricing policies and exposure to different physical hazards.

5.2 Opportunities and considerations

As an exploratory project, the Viridis platform nevertheless presents an opportunity for the global regulatory community to further consider ways to identify, monitor and manage climate-related financial risks. The complexity of this undertaking is clear and unmissable, and yet there is a clear benefit in taking action as soon as possible. Key metrics have already been identified (including in this report) and supporting data and/or proxies can already be incorporated in climate-related risk analyses. The blueprint for the platform we have described in this report represents just the starting point and can serve as a foundation for ongoing intensive and extensive development. Over time, the conversations, standards, technologies and methodologies will most certainly evolve, and the platform must evolve too. During this process, the blueprint could also form the basis for supervisors to understand their data gaps and explore with the supervised banks how to collect such data.

Collaborating on common solutions that can future-proof the data and analytical capabilities of supervisors is one way of taking small but coordinated steps towards logical science-based goals. Project Viridis will be a module added onto the EDKP and made available to EDKP community members.

Annex: Solution blueprint for a climate risk platform

I. Transition risks

The following section summarises metrics and indicators that broadly sit in the transition risk category of risk metrics. Transition risks result from the transition to a lower-carbon economy and are further categorised into policy and legal, technology, market and reputational risks. The section discusses each proposed metric, with descriptions of how best to present them.

- **Portfolio sector composition**

As a first transition risk metric, participants stressed the need to gain an understanding of portfolio composition across sectors and countries. Data on portfolio sector composition are available from relevant financial institutions and are collected by regulators. Using the metric, supervisors would be able to assess whether a bank's portfolio significantly differs from the broad composition of the economy and whether this could cause additional risks. A sector breakdown view would allow supervisors to assess banks' exposure to high-carbon activities most at risk in a transition to a lower-carbon economy. A country view would allow supervisors to evaluate whether a bank's exposures are concentrated in countries with higher climate ambitions (ie current transition risks) or lower climate ambitions (potentially high transition risks in a late action or disorderly scenario). Banks focused on lending to higher-carbon sectors could be significantly risk-exposed, though with potential differences in timing of risk materialisation across different scenarios and levels of policy ambition between jurisdictions. Portfolio composition could be provided based on industry classification standards.

- **Scope 1, 2 and 3 financed emissions (absolute and intensity numbers)**

Financed emissions (emissions of a bank's clients) are a key metric identified, where emissions data should ideally cover a client's direct emissions (Scope 1), the electricity it purchases (Scope 2), and its supply chain emissions, including emissions from products and product inputs (Scope 3). Participants expressed a need for emissions data in terms of both "absolute" (ie total emissions in tonnes) and "intensity" (eg in tonnes of carbon dioxide equivalent per million dollars of enterprise value including cash (EVIC)). Scope 1 through 3 emissions data are increasingly available from a range of providers, though these data still have significant gaps.[19]

19 Considering that Scope 3 emissions data are still largely modelled, it is recommended that data sets with transparent modelling methodologies are prioritised. Scope 1–3 providers with publicly available methodologies include the following: CDP (formerly the Carbon Disclosure Project) provides disclosed and modelled data for over 5,500 corporates. Partnership for Carbon Accounting Financials (PCAF), while not providing corporate-specific emissions data, provides access to data on a number of sectoral and regional emissions factors. With information on corporate revenues, these can be used to approximate corporate emissions. The International Monetary Fund (IMF) provides data on emissions factors for country-sector pairs. The IMF data, however, are not broken down into Scope 1, 2 and 3 categories. Intercontinental Exchange (ICE) provides data on Scope 1–3 emissions for over 5,500 corporates. Importantly, data are directly collected from corporates rather than built on a proprietary emissions model.

An absolute emissions lens allows users to identify the scale of the potential risks with regard to financial exposure. Clients with the greatest overall emissions (usually a result of both significant emissions intensity and financial exposure) are likely to be greatly exposed to transition risks. Similarly, portfolios with high emissions – resulting from both the size of the portfolio and the intensity of underlying activities – could pose systemic concerns. Using an intensity lens, users can compare clients, sectors and portfolios with each other to benchmark relative performance. Particularly from a supervisory viewpoint, intensity can be used for a quick high-level comparison of transition risks between banks' portfolios. Clients and sectors with the greatest emissions intensities are likely to be most at risk, allowing users to assess potential risk concentrations.

Financed emissions, particularly across the full chain of Scope 1, 2 and 3 emissions, give a general understanding of how exposed a bank's client is to transition risks as well as the exposure a bank has to that client. Roughly, the more emissions, the greater the risk the bank's client will face transition risks (impacts from measures to reduce emissions). If available, using a Scope 3 emissions lens (emissions from clients' products and associated inputs into the product) can give a view of the risks associated with a company's main revenue lines. Emissions data can be interrogated on a client, sector or portfolio level allowing multiple views on exposure. For example, specific clients or sectors with sizeable emissions exposure can be identified as key risk areas.

- **Portfolio, sector and company alignment with transition pathways**

Participants expressed a need to be able to monitor the evolution of emissions for a portfolio, sector or bank's client over time as well as get a sense of whether this trajectory was in line with emissions pathways from specific scenarios. For example, for an orderly transition scenario, historical emissions could be benchmarked against an emissions pathway limiting warming to 1.5°C. If emissions were out of line with a specific trajectory, this would imply the need for corrective action later if pressure to decarbonise were to grow, resulting in greater exposure to transition risks. Pathway alignment over time could be used in combination with current emissions to identify broad concentrations of transition risk exposure.

A high-level aggregated view of the percentage of assets in a portfolio aligned with a chosen lower-carbon emissions pathway (eg 1.5°C) could give insight to risk mitigating factors. A high percentage of assets aligned with a chosen transition pathway would signal reduced exposure to transition risks. Sector- and geography-specific trajectories could be used to benchmark the risks for a specific client or sector in a portfolio, such as for example the steel or aviation sectors globally or in specific jurisdictions. Significant misalignment with a sector- or geography-specific decarbonisation pathway could highlight potential problem areas in a portfolio. Noting the multitude of scenarios and resulting decarbonisation trajectories available, participants stressed that the dashboard should use a broad variety of scenarios.[20]

20 A range of transition pathways for various sectors and geographies are available from various providers, including the following. The International Energy Agency (IEA) provides a range of transition scenarios, sectors and geographies, including a 1.5°C 2050 net zero emissions scenario. The Network for Greening the Financial System (NGFS) offers a range of transition pathways through its Scenario Explorer Platform. The Paris Agreement Capital Transition Assessment (PACTA), currently hosted by the Rocky Mountain Institute, provides variations of IEA transition scenarios and is widely used by financial institutions. PACTA provides scenarios at a sector and geography level for individual corporates and portfolios. The Intergovernmental Panel on Climate Change (IPCC) provides a range of global transition pathways, recently updated under the shared socioeconomic pathways (SSPs) framework. Scenarios are not sector- or region-specific, however.

- **Carbon pricing impacts**

Participants noted that carbon pricing will likely be a significant policy to employ to further the low-carbon transition and is already resulting in direct financial impacts to banks and clients in key jurisdictions. Adding carbon pricing to emissions data allows a user to produce initial quantifications of financial costs from policy measures to banks' clients and portfolios. Note here that there is a large variance in carbon prices across various scenarios. In some scenarios (eg net zero by 2050), high carbon prices could even lead to collapse of whole business models as well as significantly increased probabilities of default and impairment of banks' balance sheets.

Multiple forward-looking carbon pricing trajectories are available. Multiplying emissions by a specific carbon price would give an initial indication of the potential magnitude of direct financial costs at future dates. Additionally, carbon pricing mechanisms could cover carbon border taxes where emissions-heavy exports into specific markets face a carbon tax (see for example the European Union's Carbon Border Adjustment Mechanism). Broad export data could be used to draw initial conclusions on bank exposures to clients that will be impacted by carbon border taxes.

- **Assessment of transition plans**

Participants stressed the need to be able to assess the plans to transition to a low-carbon economy of both banks and clients. Whether a bank would be able to adjust to a potentially disruptive transition would need to be evaluated based on the robustness of its transition plan. This would need to include factors such as how a bank was looking to shift its portfolio and capital allocation, its overall strategy, and how it was going to assist clients in decarbonisation. The quality of banks' transition plans can be seen as a broad indication of their readiness and capacity to adapt to new operating environments and of the strength of their risk management processes. This will likely be a cornerstone for supervisory dialogues on managing climate-related financial risks in coming years.

Participants emphasised that having these data in a systematic form would allow supervisors to quickly make sense of an as-of-yet poorly evaluated area. Participants also noted that, currently, opportunities from a low-carbon transition were poorly identified and assessed. Increasingly, new tools, such as AI-based unstructured text assessment tools, could be used to better evaluate transition plans systematically and more efficiently. It was also noted that prevailing assessments use static portfolios to evaluate climate risks for banks. While this view allows for a better understanding of banks' exposures today, banks portfolios are likely to change over time. Assessment of static portfolios could be combined with a dynamic portfolio approach where banks are allowed some leeway to adjust capital allocation under different climate scenarios.[21]

21 Though transition plans are a critical part of assessing financial institution and corporate preparedness for transition risks, methodologies for assessment are still in a nascent state. Forward-looking assessments of corporate emissions reductions have been developed by select providers, though the scientific validity of methodologies has been called into question. Currently available methodologies include the following. The Transition Pathway Initiative (TPI) assesses preparedness for a select set of large-cap corporates. Though perhaps the most developed framework on transition risks, application to wider a universe of corporates would require manual assessment of transition plans. The Science-Based Targets Initiative (SBTi) provides emissions reduction targets for corporates in line with transition pathways from IEA scenarios. Assessment for banks' clients would need to be done individually. Recently the SBTi has also come under high-profile criticism for methodological limitations.

II. Physical Risks

Physical risks refer to the changing physical hazards, from water stress to floods, that result from a changing climate. This section discusses each proposed metric and why the metric has been chosen, with descriptions of how best to present it.

- **Hazard exposure**

Hazard risks (ie the changing intensity and/or frequency of physical hazards) can be modelled for a key set of hazards. Using open source data from a range of leading research institutions, we can map changing hazards down to granular resolutions (eg grids of 50 km by 50 km over 30-year time periods). The level of precision is expected to increase with higher demand and better technical methods over time, though this would require significant investment in a new generation of climate models. An initial set of key hazards that could be included in the dashboard with the ability to expand the range in the future generally include coastal and river flooding, wildfires, cold and heat stress, drought, water stress, erosion and landslides, among others. Using hazard data, supervisors could assess bank exposures to geographical areas most at risk, including country- and province-level risk concentrations. Workshop participants suggested that these should be presented on a map to easily identify areas at risk.

Hazard models are widely available from a range of leading research institutions and can be combined with open source climate data (eg from Intergovernmental Panel on Climate Change (IPCC), European Space Agency) to provide forward-looking projections. Relevant forward-looking climate hazard models can either be manually constructed per hazard (eg water stress, wildfire, flooding etc) or broad proxies can be downloaded from sources such as Notre Dame Global Adaptation Initiative (ND-GAIN).[22]

- **Sector sensitivities to physical hazards**

Combining physical hazard data with the sensitivity of sectors to specific physical hazards – for example the sensitivity of agriculture to water stress – could allow supervisors to interrogate impacts of physical hazards on banks' clients when they occur. This allows supervisors to identify bank assets that are not only located in areas most exposed to physical risks but could also be most sensitive to physical hazards. Using these scores, regulators could identify key physical risk concentrations across specific hazards, time periods, geographical regions and scenarios on a bank's balance sheet.

Banks' exposure to their clients' assets would ideally be measured on an asset location level (eg the specific geolocation of a factory or farm for example) depending on the availability of data. Using the portfolio composition data discussed in the transition risk section, country data could also be used as proxies. The uncertainty across country risk scores could be evaluated by creating a variance score for hazards across the country (ie the distribution of risk scores for a specific hazard across 50 km by 50 km grid cells in a given region). Countries with higher variance scores (greater differences in a hazard across a country) would need at least province-level data on asset locations.

22 ND-GAIN Vulnerability: While not hazard-specific, ND-GAIN offers open source data on the vulnerability of countries globally to changing climate hazards.

Specific thresholds can be set per physical hazard with easy-to-use colour codes from low to high risk. Participants suggested that sensitivities could be adjusted using data on reinsurance claims, though the current availability of public data on sector-specific insurance claims is sparse.

- **Adaptive capacity and adaptation plans**

Adaptation plans refer to plans by banks' clients to adapt to changing exposure to physical hazards (as opposed to transition plans that reflect corporate plans to decarbonise). Like with transition plans, participants brought up the value in being able to evaluate adaptation measures being taken by banks' clients. Being able to assess the robustness of mitigation actions taken by banks and their clients to build resilience against climate-related physical hazards would need to feature assessments of net risk exposure. Quantifying the impact of adaptation measures would allow supervisors to test bank assessments of resilience and enable banks to have conversations with their clients on adapting to rapidly changing physical environments. Again, combining insights from dynamic portfolio changes, where banks could be allowed to make shifts in future capital allocation in scenarios, could be used to assess banks' adaptation responses. From a systemic view, aggregating bank responses could highlight areas of capital flight if banks begin to withdraw from high physical risk locations.

Assessments of adaptive capacity exist on a country level, though corporate- and site-level adaptation plans exist for a very limited number of corporates. No comprehensive database of corporate adaptation plans exists, and literature on corporate adaptation measures is in a nascent state. Hence, country-level adaptive capacity could be presented on the prototype dashboard, with corporate-level assessment beyond current feasibility.[23]

- **Insurance coverage**

Data on insurance coverage would allow supervisors to assess mitigants to banks' physical risk exposures. If potential losses faced by corporates are covered by insurance, this would increase credit quality. Though insurance coverage is an essential mitigant for physical risks, current data at the client level are sparse, and forward-looking data are non-existent. With the significant gaps in data and the scope of work required for a solution, it is recommended that the metric be incorporated when data become more readily available or collected.

- **Physical vs transition risk matrix**

Workshop participants indicated that it would be useful to see a high-level summary of physical and transition risks and how both compare with each other on a bank's balance sheet. It was suggested that a high-level overview be presented in a matrix format, broadly illustrating a bank's risk profile in terms of combinations of physical and transition risks. For example, a bank could be deemed to have high transition risk but low physical risk, giving supervisors an immediate snapshot of focus areas for risk mitigation. The matrix could be presented using both average and maximum risk

23 ND-GAIN Readiness: ND-GAIN also offers scores on country readiness to adapt to changing physical hazards. The open source data set could be added onto the platform to show a country-level view of preparedness for physical risks.

exposures across transition and physical risk categories. For example, the highest individual hazard score could be paired against the highest-scoring transition indicator. Alternatively, an average could be created for indicators for both risk types. With an option to change scenarios and time periods, supervisors could use the metric to evaluate exposure to transition and physical risks on a forward-looking basis with a scenario lens.

III. Asset-level and economic data

Participants highlighted asset-level (ie plant- or site-level) data on locations and characteristics as a key feature for both physical and transition risk analysis. This section provides a brief overview of suggested asset-level data requirements.

- **Asset locations**

Participants stressed that granular data on the locations of the assets of banks' clients would be a leap forward in current risk analyses. Being able to place specific assets at a geolocation (eg next to a coast, in a water-stressed area etc) would allow for the assessment of real exposure to physical risks rather than using wide regional proxies. From a transition risk perspective, placing assets in specific jurisdictions would give insight to their exposure to local and national efforts to mitigate climate change (ie transition risks). Asset location data would also need to move from using corporate headquarters as proxies for company-wide risks. In most sectors, critical assets are often located far from main offices and have widely diverging risk profiles. For example, TotalEnergies' risk exposure would not be captured by looking at its headquarters near Paris but would have to factor in its various assets, from oil platforms to solar panels, in a wide range of global locations. Asset locations could be overlayed onto risk maps to visualise risk exposures so that a corporate can easily identify key assets most at risk.[24]

- **Asset characteristics**

Participants also noted the value of economic data on specific assets. Knowing an asset's function in a production process, the output and revenue it generates, its economic value, age and other associated characteristics would provide valuable nuance to analysis. For example, the loss of a few individual high-value assets critical to a production process could be far more damaging to a bank's client than a shutdown of the corporate headquarters. Asset-specific emissions data would also allow pinpointing of the most polluting corporate assets, highlighting assets that are both most exposed to transition risks and are key for transition plans. Participants also suggested that capital expenditure data at the asset level would be useful to identify whether corporates were taking action to transition and climate-proof assets. The validity of both transition and adaptation plans would rest on actual committed capital expenditures to bring plans to fruition.

24 While the comprehensiveness of the coverage of asset location data is difficult to evaluate, multiple data sets offer asset location data. These include the following. Geospatial Finance Initiative – GeoAsset is a free database on geolocated cement and steel assets: 3,117 cement assets, 1,598 steel assets, with data on locations, production type, plant type, capacity and start year. Orbis (paid) is a database on ownership structures for approximately 400 million companies.

- **Supply chains and value chains**

Banks could also face significant climate risks through supply chain disruption via their clients. Disruptions to client supply chains from physical hazards or sudden increases in product input costs due to transition risks could lead to rapid deterioration in corporate credit quality. With the capacity to overlay physical and transition risk exposures over supply chains, supervisors could assess bank exposure to these risks that are currently largely unknown.

While a number of providers offer high-level views on corporate supply chains, data are still limited and data quality is difficult to currently verify. Methodological complexities also relate to evaluation of how climate-related risks might propagate through supply chains. While supply chains are a key consideration in evaluating climate-related risk exposures for banks' clients, it is recommended that the feature be considered only when more robust methodologies and data sources become available.

IV. Systemic and macroeconomic view

The discussion in previous sections has largely focused on features and indicators for exploring risk exposures for individual banks. Workshop participants also highlighted the need for supervisors to be able to assess an aggregated view of exposures across financial institutions on a systemic level. Additionally, participants noted that the direction of transmission could go both ways, with systemic impacts affecting the robustness of individual financial institutions. The following discussion summarises considerations raised by the participants on being able to identify how climate risk exposures across multiple supervised institutions could affect financial stability. The discussion is by no means exhaustive and recognises that literature evaluating systemic climate-related impacts on financial stability is still nascent. Complex feedback loops, endogenous systemic processes and the interconnected web of financial institutions are recognised as playing a role in the propagation of climate-related risks but are initially outside the scope of the discussion.

- **Overlapping risk concentrations between financial institutions**

Workshop participants expressed a need to see overlapping climate risk concentrations between financial institutions. Particularly, concentrations to the same clients across multiple financial institutions were raised as a concern. Similarly, exposure to overlapping sector-geography (eg oil and gas in the United States) or to sectors or geographies alone could pose systemic risks. Participants expressed a wish to be able to see how the materialisation of climate risks in a single corporate, jurisdiction or sector could propagate through multiple financial institutions. This was noted as an issue of particular concern if severe risks were to materialise across multiple systemically important financial institutions. Using a map view, regulators could assess financial exposure across multiple supervised institutions to corporates or sector-geography pairs at risk.

- **Consilience of targets against global constraints**

Some participants voiced concerns that decarbonisation scenarios and transition plans used by organisations may be logical in theory but collectively impossible to deliver. For example, if hundreds of supervised institutions rely on carbon offsets and biofuels in their decarbonisation strategy, there may not be enough land overall to accommodate these pledges and meet other land use requirements in a world with a growing population.[25] Similarly, there may be absolute resource scarcity constraints for the raw materials needed for the growing global demand for batteries. As well, human capital constraints may limit how many solar panels or heat pumps can be manufactured and installed in a given year without a supporting pipeline of enough trained personnel with the required expertise.

On an aggregate level, regions highly exposed to physical hazards could also face capital flight as banks reduce exposure to physical risks. Capital flight could affect high-carbon industries as banks cut exposure to sectors deemed at risk from a climate transition. These processes, while rational on an individual bank level, would decrease financial flows to critical adaptation and decarbonisation efforts as well as potentially lead to systemic financial impacts such as asset fire sales. These concerns may not be obvious at the level of a single FI's portfolio or transition plan but may become untenable at an aggregate level across all FIs.

V. General features for usability

Besides specific indicators and data points, workshop participants noted a general set of features and functionalities that the proposed climate risk dashboard should have to ensure its usability.

- **Interactive and explorable map view and benchmark data**

Participants noted that from a user perspective, the platform needed to be interactive and easy to explore. Relevant scenarios, time periods and risk views should be easy to select and navigate across. Participants also wanted to be able to create custom data visualisations, in particular, the ability to create custom maps was deemed an important feature as well as having benchmarks for all indicators (eg sector or country averages etc).

25 For example, Oxfam found in one report that the land area required for meeting carbon offset pledges would encroach on land required for crops to feed a growing world population. In fact, an area five times the size of India (~1.6 billion hectares) would be needed to get to net zero via tree planting alone. See A Sen and N Dabi, "Tightening the net: net zero climate targets – implications for land and food equity", *Oxfam Briefing Paper*, 3 August 2021. Available at https://policy-practice.oxfam.org/resources/tightening-the-net-net-zero-climate-targets-implications-for-land-and-food-equ-621205/.

- **Standard guidance on weighting multiple data sets**

Noting the combinations of various data sets involved, participants expressed the need for standard options and guidance on how relevant data sets should be treated and weighted. Though more advanced users could be offered the option to customise weightings for specific data sets and indicators, workshop participants stressed that the platform should come with a standard set of readily available indicators. This way, the user would only need to upload a portfolio according to a standardised template to receive a rich set of results.

- **Ability to export data**

Participants requested that data from the platform be exportable in Excel and comma-separated values (CSV) format for further analysis as required.

References

Basel Committee on Banking Supervision (BCBS) (2020): *Climate-related financial risks: a survey on current initiatives*, April, www.bis.org/bcbs/publ/d502.pdf.

—— (2021a): *Climate-related risk drivers and their transmission channels*, April, www.bis.org/bcbs/publ/d517.pdf.

—— (2021b): *Climate-related financial risks – measurement methodologies*, April, www.bis.org/bcbs/publ/d518.pdf.

—— (2022): *Principles for the effective management and supervision of climate-related financial risks*, June, www.bis.org/bcbs/publ/d532.pdf.

Financial Stability Board (FSB) (2021): *The availability of data with which to monitor and assess climate-related risks to financial stability*, 7 July, www.fsb.org/wp-content/uploads/P070721-3.pdf.

—— (2022): *Supervisory and regulatory approaches to climate-related risks: final report*, 13 October, www.fsb.org/wp-content/uploads/P131022-1.pdf.

Grantham Research Institute on Climate Change and the Environment (2022): "*What are stranded assets?*", 27 July, www.lse.ac.uk/granthaminstitute/explainers/what-are-stranded-assets/.

Network for Greening the Financial System (NGFS) (2020): *Guide for supervisors: integrating climate-related and environmental risks into prudential supervision*, May, www.ngfs.net/sites/default/files/medias/documents/ngfs_guide_for_supervisors.pdf.

Contributors

Steering group

BIS Innovation Hub Singapore Centre	Maha El Dimachki, Head, Singapore Centre (from October 2023)
	Benjamin Lee, Acting Head (from March 2023 to September 2023)
	Andrew McCormack, Head, Singapore Centre (until March 2023)
Monetary Authority of Singapore	Kenneth Gay, Executive Director, Enterprise Knowledge Department

Project group

BIS Innovation Hub Singapore Centre	Patrick Hoffmann, Adviser (from August 2023)
	Christian Weiss, Adviser (until July 2023)
	Joy Wann, Adviser (until January 2023)
Monetary Authority of Singapore	Harry Lee, Deputy Director and Head, Data Governance & Transformation Division
	Wei Chian Poh, Deputy Director, Data Governance & Transformation Division
	Richmond Lee, Associate, Data Governance & Transformation Division

We would like to thank Teresa Lin (Adviser, Hong Kong Centre), Kusuma Ayu Kinanti (Adviser, Strategy and Operations) and John Yeo (Adviser, London Centre) for their reviews of the report and their feedback. Furthermore, we would like to thank all participants of our engagement and scoping workshops as well as our industry partners for supporting this project.

Bank for International Settlements (BIS)

ISBN 978-92-9259-763-4 (online)