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EXTENDING OUR HORIZONS

Assessing credit risk and opportunity in a changing climate: Outputs of a working group of 16 banks piloting the TCFD Recommendations

PART 1: Transition-related risks & opportunities

April 2018

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PERSPECTIVES FROM THE ORGANIZATIONS IN THE WORKING GROUP

Many of the environmental challenges that the world faces today, first- and foremost climate change, can be traced back to one fundamental root cause: short-termism. Financial markets can become a catalyst for action on sustainability, but for that they need to become more long-term oriented. The beauty of the TCFD framework is that it encourages organizations to consider and disclose long-term impacts. This change in perspective is what we need to achieve sustainable development. That's why as UN Environment we are excited to be working with such committed leaders in the finance industry.

ERIK SOLHEIM
Executive Director
UN Environment

RBC believes climate change is one of the most pressing issues of our time and we have an important role to play in supporting the transition to a low carbon economy. We are committed to advancing best practices in climate-related disclosures, assessing climate-related risks and opportunities, and supporting our clients in doing the same.

DAVID MCKAY
President & Chief Executive Officer
Royal Bank of Canada

Joining the UNEP FI TCFD Pilot Working Group has provided a valuable opportunity to collaborate with leading global banks and other experts as we start on the journey of climate change stress testing. The ultimate goal is to combine scientific scenarios and climate risk information with financial risk management techniques to better understand the risks and opportunities to NAB's loan portfolio. This encompasses defining risk appetite, forming strategies that support low carbon transition, and improving disclosures to regulators, shareholders and other stakeholders. NAB also sees real benefits for our customers, our regulators and community stakeholders who are considering their strategies and response to climate change.

DAVID GALL
Chief Risk Officer
National Australia Bank

As a bank, we are a major actor in the transformation of the economy towards a carbon free world. Given the importance of considering risks related to climate change, Societe Generale participates in the UNEP FI workgroup with an open and inclusive approach. This initiative allows us to further develop quality methodologies to evaluate these risks for a better integration of climate related challenges in the steering and management of the banking industry.

MICHALA MARCUSSEN
Group Chief Economist
Societe Generale

For markets to respond appropriately to climate change, we must first lay the analytical groundwork for assessing climate risk and opportunities. This report sets forth a new methodology that bridges climate science, risk management practices, and industry credit expertise. Collaboration across these disciplines has sparked this innovation in climate risk assessment. Increasing awareness of climate risk within the financial services industry will ultimately generate broad-based benefits for the economy and society as a whole.

As a management consultancy focused on breakthrough impact, it has been our privilege to contribute to the industry and to society through these first steps, and we hope it will lead to continuing efforts by all stakeholders, with benefits for generations to come.

JOHN COLAS
Partner & Vice Chairman
Oliver Wyman Financial Services Americas

The impacts of climate change tend to be increasingly relevant to financial institutions. The TCFD recommendations bring insights on how to consider and disclose these impacts. The pilot project with UNEP FI takes an important step and brings proposals on how the sector can assess their exposure to climate-related risks and opportunities.

DENISE PAVARINA
Executive Director & TCFD Vice-Chair
Bradesco

While we are still in the early stages of testing this approach, we expect it will be a useful framework to inform our ongoing discussions with customers regarding their climate-related risks and opportunities. Our participation in this working group along with our peer banks aligns with our purpose of shaping a world where people and communities thrive.

KEVIN CORBALLY
Chief Risk Officer
ANZ

We value the importance of the discussions of the UNEP FI working group on the TCFD and are committed to finding the best ways to incorporate the recommendations of each pillar in our disclosures and reports. In addition to this, the aim is to intensify our evaluation of the risks and opportunities involving the scenarios of climate change, guaranteeing safety and transparency for our clients and investors. The results of this working group demonstrate our pioneering spirit towards the development of a low carbon economy, combining the sophistication of complex models with the flexibility of adjustments in various stages of the tool.

ALEXSANDRO BROEDEL LOPES
Chief Financial Officer
Banco Itaú

The collaborative effort to pilot some of the recommendations by the Task-Force on Climate-related Financial Disclosures is invaluable for advancing best practice of climate risk analysis. I am convinced that we can close data and know-how gaps over time by working jointly across financial and non-financial industries as well as in research.

LISELOTTE ARNI
Managing Director, Environmental & Social Risk
UBS

Anticipating how the transition to a lower-carbon economy could impact our portfolio, will help us better advise our customers to manage the related risks and opportunities. Working within the UNEP FI TCFD Pilot Working Group, Barclays is able to tackle the challenges associated with understanding the financial impacts of climate change. This is the start of a longer-term process for the industry to explore approaches to climate stress testing and we look forward to continuing to work with UNEP FI and its members to find possible solutions.

JON WHITEHOUSE
Head of Government Relations & Citizenship
Barclays

This is a key milestone to better understand how climate change impacts banking activity. We are very proud to be part of a collective endeavour promoted by UNEP FI to set the fundamentals of an open methodology that can now be used by the whole industry worldwide. The great challenges that we experience today require more than ever the greatest collaboration.

ANTONI BALLABRIGA
Global Head of Responsible Business
BBVA

Climate change is a priority for Banco Santander. Participating in the UN Environment helps us better understand how climate change can affect our business. The increased information this initiative brings to light on how banks asses the risks and opportunities derived from climate change is an important contribution to the transition to a low carbon economy.

FEDERICO GÓMEZ
Head of Sustainability
Santander

Integrating climate analyses into financial institutions' work is a positive development that will allow for smarter long-term planning and more transparent reporting to stakeholders. The public methodology is an important step toward this goal and Citi's commitment to contributing to a strong, sustainable global economy. We are proud of the hard work that Citi and our industry colleagues have put toward these efforts thus far and look forward to continue working with them.

BRANDEE MCHALE
Director of Corporate Citizenship
Citi

Rabobank's participation in the UNEP FI pilot on the implementation of the recommendation of the TCFD is in line with our mission of Growing a Better World Together. By partnering with leading international organizations like UN Environment we aim to make a serious contribution to tackling the challenges brought about by climate change. Assisting in the realization of the Paris Agreement is part of our operational compass. Adequately managing the associated transitional risks is part and parcel of this commitment.

BAS RÜTER
Director of Sustainability
Rabobank

Meeting the challenge of climate change requires ambition, commitment and collaboration. With the aid of UN Environment and our expert partners, and working with our peer banks on this pilot project, we have made strong progress in understanding the issues and potential approaches for banks in their assessment of transition risks, and in delivering the TCFD recommendations. There is still much to do and we look forward to working with our partners on this critical initiative.

VASUKI SHASTRY
Global Head, Public Affairs & Sustainability
Standard Chartered

If banks understand and integrate climate risk, we will improve overall credit risk and responsible decision-making. The UNEP FI pilot has been essential to realize the hard work ahead required from us as banks to truly understand the risks and opportunities associated with climate change. DNB will continue to integrate the methodologies developed into our daily activities as the financial sector is part of the solution.

IDA LERNER
Group Executive Vice President for Risk Management
DNB

TD Bank Group understands that it is increasingly important to grasp climate-related risks and opportunities to better serve our clients. The Financial Stability Board's recommendations on climate-related financial disclosures can help provide important guidance and a consistent approach to assessing impacts, helping to improve decision making and long-term planning. As one of 16 global banks participating in the UNEP FI's pilot study of the recommendations, TD is committed to supporting the transition to a prosperous, low-carbon economy.

ANDREA BARRACK
Vice President, Global Corporate Citizenship
TD Bank Group

ACKNOWLEDGEMENTS

The pilot project was led by a Working Group of sixteen banks convened by the UN Environment Finance Initiative:

UN Environment Finance Initiative and Oliver Wyman would like to express their gratitude to the Potsdam Institute for Climate Impact Research (PIK) and the International Institute for Applied Systems Analysis (IIASA) for their invaluable research, help, and guidance throughout the process and to the International Energy Agency (IEA) for their support.

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DISCLAIMER

Oliver Wyman was commissioned by the UN Environment Finance Initiative ("UNEP FI") Working Group, which includes the following sixteen banks: ANZ, Barclays, BBVA, BNP Paribas, Bradesco, Citi, DNB, Itaú, National Australia Bank, Rabobank, Royal Bank of Canada, Santander, Société Générale, Standard Chartered, TD Bank Group, and UBS (the "Working Group"), to assess climate-related transition risks and opportunities for banks' corporate credit portfolios.

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PROJECT INTRODUCTION

This report is the result of a collaboration of sixteen of the world's leading banks under the UN Environment Finance Initiative (UNEP FI) to pilot the recommendations published by the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD). Through this collaboration, banks set out to develop and test a scenario-based approach for assessing the potential impact of climate change on their corporate lending portfolios as recommended by the TCFD. As an inaugural exercise, the output of this process is intended to provide a first, but critical step, in a longer process of responding to the TCFD recommendations.

The TCFD recommendations urge banks to use scenario analysis to assess and disclose the "actual and potential impacts" of climate-related risks and opportunities on their business as well as how they manage them. In this framework, climate risk can be divided into two risk categories: physical risk and transition risk. To assess both sides of climate risk, the sixteen banks formed a Working Group to test the impacts of climate risk under three scenarios (representing a 1.5°C, 2°C, and 4°C global average temperature increase by the end of the century), supported by two consultancies: Oliver Wyman and its sister company Mercer on transition risk and Acclimatise on physical risk.

This report focuses on transition risk, which is associated with the transition to a low-carbon economy and constitutes the first in a two-part series publishing both the transition risk and physical risk assessment methodologies developed through the Working Group's collaboration.

Oliver Wyman, a leading global management consultancy and Mercer, a leader in investment management consulting, supported the development of the methodology outlined in this report. Oliver Wyman brought deep expertise in risk management and stress testing from the financial services sector while Mercer, an active member of the TCFD, provided its framework for considering climate change investment risks and opportunities from its 2015 "*Investing in a Time of Climate Change*" study. Developing a widely applicable and rigorous methodology for assessing transition risk relied heavily on the active participation of Working Group members' sustainability, credit risk, stress testing, and finance teams. Participants from the sixteen banks provided input into this report and continue to pilot and refine the methodology as a result of their six month collaboration.

EXECUTIVE SUMMARY

To avoid the most disruptive outcomes of climate change, nearly 200 countries have agreed—through the 2015 Paris Agreement[1]—to strengthen the global response to climate change in order to limit "the increase in the global average temperature to well below 2°C above pre-industrial levels". To achieve this objective, a transition to a low-carbon global economy is required. From the perspective of the market, a low-carbon transition translates into a new and uncertain landscape of commercial risks and opportunities. These new risks and opportunities need to be understood, assessed, and translated into effective strategies if companies are to adapt to, benefit from, and contribute to a low-carbon economy.

The TCFD recommendations provide both corporates and financial institutions with a **consistent, high-level guidance to assessing and disclosing climate-related risks and opportunities**. They require organisations to adopt a forward-looking, scenario-based approach to climate impact assessments, extending their horizons decades into the future. It is expected that implementing the recommendations will generate new sources of information for market actors and policymakers, influence the allocation of capital, and facilitate the transition to a more sustainable, low-carbon economy.

While providing high-level guidance, the TCFD has left it to the various industries to develop and pilot the specific approaches, methods, and scenario inputs best suited to their specific needs and exposures.

This report synthesizes the efforts of a Working Group of sixteen international banks convened by the UN Environment Finance Initiative (UNEP FI) and supported by Oliver Wyman to develop a methodology for assessing the risks and opportunities associated with the transition to a low-carbon economy (the "transition-related" impacts associated with climate change). As such the methodology addresses the *Strategy* element of the TCFD recommendations around the use of **scenario analysis** for forward-looking assessments of transition-related impacts.

The key aim of the methodology is to help banks assess the transition-related exposures in their **corporate loan portfolios** where they may have concerns about the potential policy and technology related impacts of a low-carbon transition, as well as an appetite to explore and capture the associated opportunities. It is also through their lending activities, including corporate portfolios, that banks can play the most influential and impactful role in catalysing the transition to a low-carbon economy.

Corporate loan portfolios are short term compared to the time horizon of a low-carbon transition, providing banks with flexibility to adjust such portfolios over time. However, banks should not wait to assess the potential impacts and opportunities of climate change. If deemed necessary, changing the exposures and risk profile of a corporate loan portfolio takes time: assessing risks and growth prospects, developing a coherent strategy, and building capabilities and relationships to affect the profile of the client base require advanced action. Additionally, understanding climate risks and opportunities will allow banks to engage with their customers to help them manage the transition to a low-carbon future..

The methodology identifies how a low-carbon policy and technology transition to mitigate climate change could impact the credit risk of a bank's corporate loan portfolio, as well as its commercial strategy: **it helps build awareness of climate risks and opportunities**.

Assessing transition-related risks

While comparisons can be made with macro-economic stress testing commonly employed by banks, climate scenario analysis or "stress testing" has a somewhat different application. Macro-economic stress testing, generally defined as comprehensive, firm-wide scenario

1 United Nations Framework Convention on Climate Change, "The Paris Agreement," December 2015

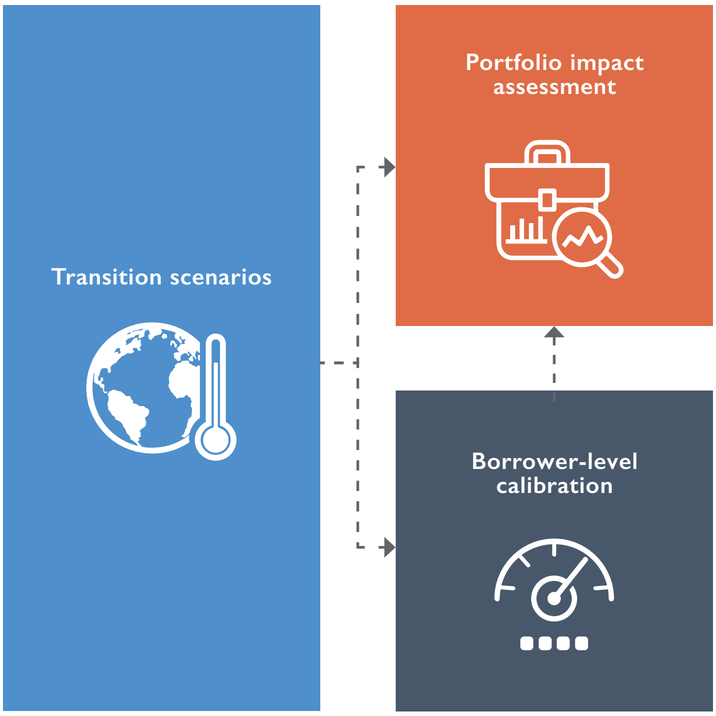
analysis, is intended to estimate capital needs and manage capital over one to five years. A climate transition response, however, will evolve over decades. Analysis over this long time horizon is rather intended to assess the sensitivity of a bank's current business to plausible climate-related transition scenarios at different points in time over the extended horizon.[2] The exercise is not a precise forecast but **a sensitivity analysis which can be used to inform strategic planning and portfolio composition and to ensure institutions are sufficiently climate aware**.

In addition to an extended time horizon, assessing climate-related transition risk presents **unique challenges** for financial institutions:

- **Limited information** is available to assess how a climate transition scenario might impact the creditworthiness of specific borrowers and industries
- **Substantial coordination** within organizations is required to execute an effort with such scope: expertise from sustainability, credit risk, industry, stress testing, finance, and investor relations must be brought to bear
- Finally, to be most useful and instructive for banks and the market, the methodology must be **repeatable, systematic, and consistent**, while allowing for company-specific customization where data are available

To address these challenges, the methodology leverages the most relevant tools for quantifying climate-related transition risk and combines them into a **holistic approach for transition risk assessment**. The methodology is anchored in analyses of particular temperature-based scenarios, including a 2°C scenario as well as 1.5°C but flexible to a range of such scenarios. It combines portfolio-level and borrower-level risk assessment.[3] As shown in Figure 0.1, a borrower-level calibration module captures nuances from the bottom up while a top-down portfolio impact assessment module extrapolates these borrower-level impacts to portfolio segments with homogeneous exposures to transition risk. As a result, only a sample of name-level analyses is required to estimate portfolio risk exposure, reducing both time and resource requirements. Note the impact of the transition scenarios can be positive, negative, or neutral depending on the sectors, the geographies, and the scenarios.

Figure 0.1: Overview of the transition risk modules



Transition scenarios describe an evolving economic environment in a consistent manner across time, sectors, and geographies. Scenarios provide detailed outputs which help assess the economic impact on sectors.

Portfolio impact assessment uses a systematic and repeatable approach to extrapolate the risk assessed by the other modules (i.e. transition scenarios and borrower-level calibration) to the remainder of the portfolio.

Borrower-level calibration addresses the lack of empirical data on corporate exposure to transition risk by using industry experts and tailored assessment to estimate the scenario's impact on individual borrowers. Calibration specifies the relationship between economic scenarios and credit outcomes.

Source: Oliver Wyman

2 See Box 1 for more detail on the differences between macro-economic and climate scenario analysis

3 See Box 2 for more detail on the alternative approaches considered

By linking the three modules, banks can address the major challenges inherent to modelling transition risk:

- **Transition scenarios** provide plausible views of how transition risk might evolve across sectors over the next few decades
- **Borrower-level calibration** allows each bank to tailor the approach and overcome a lack of empirical data to estimate changes in credit outcomes
- **Portfolio impact assessment**, together with the scenarios, provides a structured analytical framework that makes the approach repeatable, systematic, and consistent and helps coordinate and integrate analysis and judgment across a bank

The Working Group's piloting of this approach yielded valuable insights. In particular, the testing underscored the need for a methodology that can **accommodate different scenarios and bank exposures to risk**. For instance, there are multiple ways to achieve a 2°C scenario; each path can lead to vastly different sector impacts depending on the underlying scenario assumptions, such as the feasibility of wide-scale carbon capture and storage technology (CCS). Specific scenarios may prove more relevant for probing particular bank vulnerabilities. For example, in some scenarios, the oil and gas sector can benefit from a rapid phase out of coal; a scenario that stresses high-carbon power generation companies may therefore not be as stressful, in the short-term, for oil and gas exploration and production counterparties. Findings like these emphasized the importance of developing a methodology compatible with different scenarios and scenario sources which will provide different views of how the future may look. While the methodology described in this report focuses on temperature-based scenarios to align with the TCFD recommendations, it can be adapted to **bespoke, event-based scenarios** such as a sudden policy change or a technological breakthrough. These events may lead to greater risk to the banks in the short term as **banks and companies will have less time to adapt and adjust to the new environment**. Broadly, as in macro-economic stress testing, banks should identify **their own vulnerabilities** and test various scenarios to probe them.

The piloting of the approach also highlighted that there is a need for **further collaboration** between the different stakeholders, such as banks, industry groups, and scenario modelling teams. This collaboration will help standardise approaches and practices so that results can be disclosed and compared across banks along a variety of dimensions, including sectors, geographies, and scenarios. Collaboration can also improve the assessment by creating feedback between the physical and economic scenario descriptions, and the assessments done by the banks. Increased scenario details and further granularity, for example, would improve the assessment.

A major advantage of the proposed approach is its adaptability: **the methodology is extensible to multiple sectors, a variety of scenario sources, different risk factors, and timeframes**. Such flexibility will prove useful as banks refine their approach to risk assessment, as financially-oriented climate scenario sources develop, and as disclosure guidelines, reporting and best practices evolve.

As the first exercise of its kind, this methodology provides **a foundation to build upon in future work**. Implementation of TCFD recommendations will naturally require multiple phases as practices evolve and new data emerges from industry practitioners, corporates, policy makers, and climate modellers. We see a number of **potential paths for further development of the approach**. This includes creating financially-oriented transition scenarios tailored to the vulnerabilities of the institutions, developing data and analytics for borrower-level climate risk analysis, enhancing the portfolio impact assessment methodology, and integrating transition risk assessment in the organization.

Assessing transition-related opportunities

While a transition scenario could elevate credit risks for banks, it could also present **opportunities to further serve clients**. For example, products and services that have a lower emissions profile or contribute to greenhouse gas reductions could become more competitive, increasing financing demand for their production or for their purchase. Such opportunities might include investment in energy efficiency technologies, new energy generation and production sources, low-emissions products and services, or low-carbon infrastructure. Not only could banks position themselves to meet the growing demand for low-carbon corporate lending in such segments, but they could also **help clients from more carbon-intensive industries adapt to the new environment**.

Assessment of opportunities, like any strategic assessment, is more than a quantitative or statistical exercise; it needs to consider **both qualitative and quantitative elements** regarding the future market and competitive landscape, as well as internal capabilities. To that effect, the approach aims to compare the assessment of the market with the strengths and capabilities of an institution.

Transition scenarios can provide a guidepost for strategic planning intended to help identify potential low-carbon market opportunities. The attractiveness of the market for low-carbon investment in particular segments and sectors need to be assessed by considering two key drivers: the segment's response to policy, and technology considerations.

Potential market size is not enough to make opportunities actionable; banks also need to consider their ability to capture those markets. To gain a deeper understanding of which segments are actually within an institution's grasp, banks require an individualized assessment of their own capabilities by assessing three major drivers of their potential market share: the competitive landscape, their risk appetite, and their operational capacity. The ultimate goal is to compare market assessment and capabilities side-by-side to determine the most promising areas for banks.

1. INTRODUCTION: PREPARING BANKS FOR THE LOW-CARBON TRANSITION

On June 29, 2017, the Task Force on Climate-related Financial Disclosures (TCFD) published a set of recommendations for the voluntary disclosure of climate-related risk and opportunities by financial institutions and other corporations. Chaired by former New York City Mayor Michael Bloomberg on behalf of the G20's Financial Stability Board (FSB) led by Mark Carney, Governor of the Bank of England and Chairman of the FSB, the industry-led TCFD elevates the profile of climate risk and opportunity assessment to the executive agenda.

In the months since its release, many of the world's leading financial institutions have pursued efforts to understand and implement the TCFD recommendations. Over 250 organizations[4] have signed onto the recommendations, and national governments, such as France and Sweden, have embraced the TCFD's aims. The need for climate risk assessment on the part of financial institutions is no longer theoretical.

To advance all banks' efforts, this report details the results of a collaboration to develop and test a proposed methodology for assessing transition risk on bank lending portfolios. Transition risk, one of the two pillars of climate-related risk detailed by the TCFD, is the risk associated with a transition to a low-carbon economy. For banks, transition risks could manifest in a variety of ways that will eventually impact the health of their borrowers, and the risk of their lending portfolios.

To stimulate a low-carbon transition, governments will need to take actions, for example by implementing cap and trade markets or ramping up fuel efficiency standards. Such actions will naturally impact the economics of borrowers. Current and future policy changes translate into corporate financial impacts, by, for example, capping production, incentivizing investment in more efficient technologies, or increasing corporate costs. In the future, policies will continue to evolve, resulting in a changing set of financial impacts across industries.

As the economy transitions toward low-carbon energy production and consumption, as well as low-carbon land-use, "winners and losers" will emerge across borrowers in a portfolio. Technological improvements can lead to cost declines and ultimately transform industry market demand for products such as renewable energy and battery storage. In the future, other disruptive technological innovations may be possible, causing sudden declines in demand for carbon-intensive products.

As the effects of climate change continue to manifest, the risk related to transition will increase. Yet the financial impact of such events on bank performance is difficult to assess. Banks need a framework and a new set of tools to identify these risks in a variety of potential contexts. Such tools will help banks to manage exposure and adjust portfolios in response to transition risks, as well as appropriately account for and disclose these risks to investors.

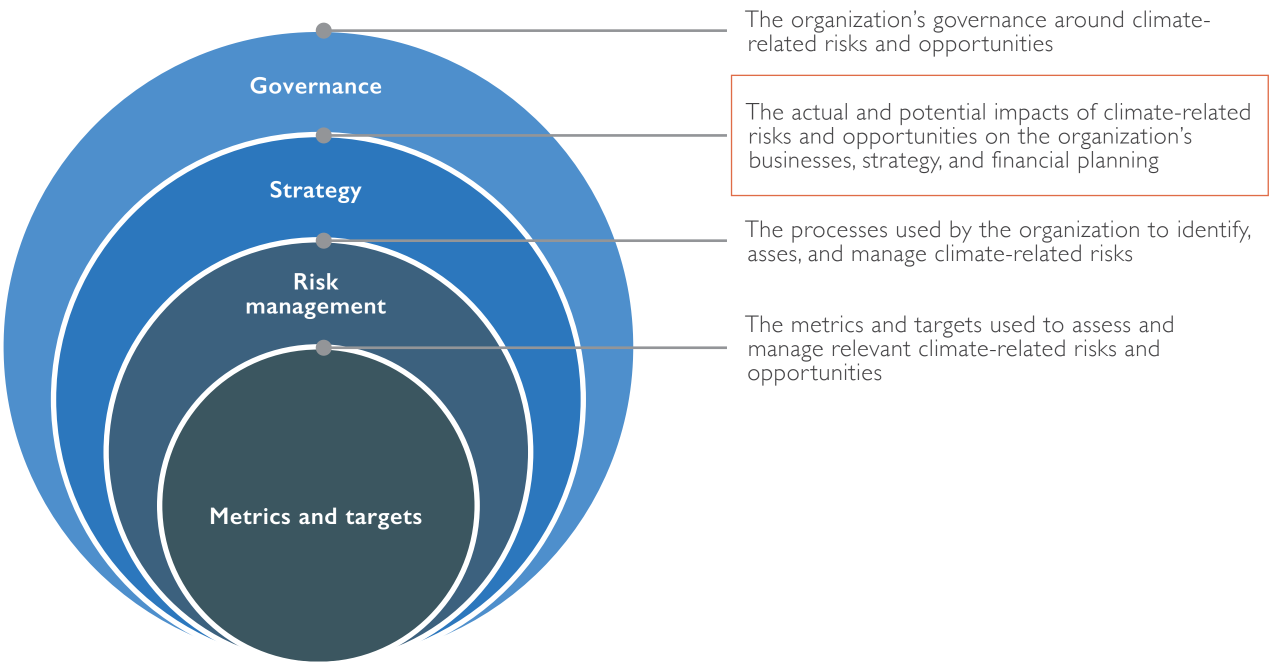
1.1. A GROWING NEED FOR CLIMATE SCENARIO ANALYSIS

To assess transition risk, the TCFD recommends banks to perform scenario analysis, which it defines as a "what-if" analysis of one potential state of the world under which a low-carbon transition could materialize. A scenario is therefore a plausible "hypothetical construct" of the future, not a precise forecast or a predictive model. Such analyses are useful for strategic decision-making and understanding the range of future transition-related impacts. The purpose of climate scenario analysis is to understand and disclose risks and inform decision making. Climate scenario analysis is at the heart of the Strategy element of the

4 Source: TCFD website (as of April 2018)

TCFD recommendations (see Figure 1.1), which aims to disclose "the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning where such information is material, (..) by taking into consideration different climate-related scenarios, including a 2°C or lower scenario." A "2°C or lower scenario" lays out a trajectory "consistent with holding the increase in the global average temperature to 2°C above pre-industrial levels". The scenario analysis is expected to inform the "metrics and targets used to assess and manage climate-related risks and opportunities" (Metrics and Targets element of the TCFD recommendation in Figure 1.1)". The scenario analysis is expected to inform the "metrics and targets used to assess and manage climate-related risks and opportunities" (Metrics and Targets element of the TCFD recommendation in Figure 1.1)".

Figure 1.1: Core elements of the TCFD recommendations



Source: TCFD, "Recommendations of the Task Force on Climate-related Financial Disclosures", June 2017

Though the TCFD provides the general guardrails for disclosing transition risk, the recommendations are not prescriptive. Decisions on methods of analysis, scenario inputs, and granularity of disclosures are all left to institutions. The interpretation and implementation of the TCFD recommendations requires effort and ingenuity on the part of companies. Banks therefore have an opportunity to shape climate risk disclosures, and ensure the analyses they generate are useful to their institutions, stakeholders, and to the market.

Yet scenario analysis of a transition to a low-carbon economy is about more than just disclosure; transition risks are already an evolving reality for the banks and their clients. Just in the past year, climate policy has evolved in ways that could impact bank portfolios. In China, state-led support for electric vehicles has led to significant reductions in associated technology costs and State announcement of intentions to ban gas and diesel cars. In Europe, the Emissions Trading Scheme's carbon price reached into the double digits for the first time in six years. Meanwhile, in the United States, the Clean Power Plan, if it proceeds, would impose the first CO_2 emission performance standards on power plants. Understanding the impact of potentially more aggressive policies and disruptive technologies on banks' portfolios is critical from a risk management perspective.

Climate risk is not currently ignored by banks; institutions already perform ad-hoc analyses to probe particular climate vulnerabilities. Methodologies range from assessing specific loans to identifying stranded asset exposures for major oil and gas counterparties. However, there is no single off-the-shelf, comprehensive approach for evaluating transition risk at a portfolio or institutional level that describes the risk in terms of financial losses. Since the financial crisis, institutions have spent years, built up teams, and significantly expanded risk management budgets to enhance their macro-economic stress testing capabilities. While we do not expect climate change risk measurement to receive the same level of singular attention at banks in the near term, we nonetheless expect that the development process will require multiple iterations, experimentation, and concerted effort across institutions to evolve a set of clear best practices. This document describes a meaningful but nonetheless initial step towards building such a best practice methodology.

1.2. THE CHALLENGE FOR BANKS

Despite similarities, the assessment of transition risk presents unique challenges compared to traditional risk evaluation. To develop a comprehensive methodology for assessing climate-related transition risk, banks have to overcome six key challenges.

First, limited empirical data exists to measure the strength of the climate-credit risk relationship. Banks lack historical data with which they can assess the impact of climate risk on credit losses. No long-term policy experiments have occurred at the scale that would be required for a 2°C transition, and the financial impacts of more binding policy constraints on industries, including those reliant on fossil fuels, for example, remain untested. As a result, methodologies to quantify transition risk need to heavily rely on expert judgments and assumptions, while making the best use of informative, though not definitive, insights from climate scenarios on the potential economic effects under different scenarios.

Second, long time horizons for transition impacts challenge the way banks usually manage risk. Transition impacts will likely be experienced over intergenerational time horizons: transition scenarios often project impacts over 30–100 years. Specific transition risks may not materialize over the one- to five-year periods that banks typically use to conduct business planning and stress testing exercises. Credit experts do not currently focus on risks that might impact borrowers one or two decades in the future, and bank corporate portfolios tend to contain loan maturities of far shorter-term than these horizons. Nonetheless, changing the risk profile of a corporate portfolio is not an overnight exercise. Assessing risks, developing a coherent strategy, and building capabilities and relationships to capture a different market require advanced action. A medium to long term modelling horizon can inform strategic planning and portfolio construction and allow banks to engage with their customers to help them manage the transition to a low-carbon future.

Third, transition risks vary across sectors, both in terms of how, and how much, they impact specific industries. In some industries like automobile manufacturing, early producers of low-carbon electric vehicles may possess a competitive advantage if a transition scenario materializes. In other industries, such as coal, investment in carbon capture or similar technologies may merely temporarily slow a continuing decline in demand from policy-related costs and less competitive prices. Such differences make scenario information at an aggregate, economy-wide level insufficient for informing transition risk analysis. To make the exercise tractable and accurate, banks require a methodology that can be both used flexibly across sectors while capturing major differences in sector risk.

Fourth, the methodology needs to be systematic, repeatable, and consistent in order to be useful for disclosure. The approach used by banks should follow an organized, systematic analytical structure. It should also be repeatable, preventing banks from having to reinvent the wheel for each assessment, or across economic sectors, geographies, and scenarios. Finally, the approach should yield results that can be compared across banks along a variety of dimensions, including sectors, geographies, and scenarios.

Fifth, banks need to tailor transition risk assessments to their own organizations. A purely generic, top-down analysis of transition risk is fundamentally inadequate. For instance, relying simply on variations in high-level macro-economic variables would be insufficient to assess nuances in risk exposure. Top-down analysis may neither capture bank-specific portfolio considerations, nor banks' own assessment of the magnitude and nature of these risks. Transition risk assessment should reflect the knowledge of institutional experts to foster ownership and mainstream adoption of these analyses. Further, risk materiality often varies substantially from bank to bank due to portfolio exposures. Customization at an institutional level must play a role in a transition risk methodology.

Finally, conducting quality scenario analysis requires major coordination across the organization. Transition risk analysis requires a range of industry, credit risk, and sustainability experts from across the bank. In such a cross-functional exercise, ownership and governance, as well as differences in techniques and skill sets, can lead to coordination challenges. The approach should make the work required by banks manageable, with clearly defined inputs and outputs, in order to facilitate execution across complex organizations. Furthermore, as banks approach disclosures additional expertise will be required from finance, strategic planning, legal, and investor relations.

1.3. LEVERAGING AND INTEGRATING THE RESOURCES AT BANKS' DISPOSAL

In the context of these significant challenges to transition risk assessment, banks should turn to the best use of the resources at their disposal to assess transition risk. While individually these tools have limitations that prevent them from being able to address scenario analysis needs, in aggregate they create a meaningful framework for assessment.

- **Transition scenario models**: A wide range of energy system, economic, and integrated models, which this report refers to in aggregate as transition scenario models, provide relevant scenarios for analysis. These models are capable of producing an internally consistent picture of how transition risk could evolve over time and across sectors and geographies, and they can generate relevant macro-economic metrics for risk analysis. They have been used in studies ranging from the Intergovernmental Panel on Climate Change (IPCC) assessment reports to sector-specific analyses of climate change impacts.

  Despite these benefits, transition scenario models face significant limitations in corporate risk analysis. Models often employ aggregated and high-level representations of energy-economy interactions, lacking specific quantification of scenario impacts at a company or industry level. Additionally, transition scenario models are oriented toward use in macro-economic and policy assessment environments, requiring additional interpretation for financial analysis.

- **Credit and sustainability experts** within banks are able to identify the link between scenarios and the creditworthiness of the borrowers. Using experts for bottom-up assessment has significant precedent in risk management. Banks' borrower risk assessments are institution-specific processes that drive the competitiveness of their businesses. Analogous exercises, such as regulation-driven macro-economic stress-testing, also embed institution-specific risk assessments that reflect expert input.

  Expert judgment alone, however, risks yielding inconsistent results. Experts could identify a variety of futures, and a wide range of methods, to assess risk at a borrower-level, making judgments difficult to compare across sectors and institutions. Furthermore, such an assessment on its own is unlikely to be scalable at an institutional level. The workload created by a borrower-by-borrower assessment of impacts could quickly overwhelm experts when applied to the whole of a portfolio.

- Finally, a variety of well-established **techniques for credit risk modelling** can help establish the link between scenarios and credit risk. In the past decades, bank risk management functions have expanded dramatically, creating methodologies, tools, and frameworks to assess and manage various institutional risks. In particular, since the financial crisis, regulators around the world have pushed for banks to develop advanced stress testing infrastructure to ensure they can sustain systemic, macro-economic shocks as well as idiosyncratic shocks. While there are differences, these stress testing exercises are similar to scenario analysis in that both exercises consider the impact to the bank of a hypothetical scenario unfolding over time (see Box 1 for more detail on the differences between macro-economic and climate scenario analysis).

  Applying these techniques to transition risk, however, demands additional effort. These frameworks will require new data sources and a modified conceptual apparatus for linking climate risk drivers and the creditworthiness of borrowers.

These tools must be combined to make the best use of their strengths while also completing what they lack. The methodology outlined in the following sections identifies a way to tackle transition risk by integrating the three different tools described above. Through this approach, banks can use the tools at their disposal to overcome the challenges posed by the significant scope of the transition risk assessment mandate.

BOX 1: Climate scenario analysis

Understanding the differences between macro-economic and climate scenario analysis

Clear parallels exist between macro-economic stress testing and climate scenario analysis. Both use scenarios and are undertaken to estimate a firm's level of risk. Despite these high-level similarities, macro-economic risk and climate risk assessment have a number of significantly different features. The scope, time frame, and use of risk assessment exercises vary widely.

Since the 2008 global financial crisis, the term "stress testing" has generally been used to qualify a comprehensive, firm-wide scenario analysis. In such analyses, most elements of the profit and loss statement and balance sheet are estimated under a set of macro-economic scenarios designed to test the bank's resilience to a specific shock. Macro-economic stress testing is generally used in a regulatory context for the purpose of estimating capital needs and planning capital management for a period of two to five years.

Climate scenario analysis is not, however, primarily a capital management exercise. Where macro-economic stresses are assumed over a period of only a few years, climate-related transition risks will materialize over decades. During this time, banks' portfolios and capital structure will change, introducing significant uncertainty, and making analysis of transition-related capital needs secondary if not irrelevant.

One might attempt to mechanically forecast the evolution of corporate portfolios to evaluate capital adequacy. However, the impact from numerous institution-specific assumptions on the portfolio evolution and the risk assessment would likely dwarf impacts from the climate transition scenario. This would negatively impact the ability to understand and interpret the results of the analysis (as they are impacted more by anticipated management actions on the portfolio than climate risks). These types of assumptions would also prevent comparability between banks, reducing the ability for financial institutions to provide standardized, consistent disclosures.

In our view, rather than evaluating the adequacy of the current capital base, a useful purpose of this exercise is instead to understand and evaluate the sensitivity of a bank's current portfolio to climate transition scenarios. Capturing projected impacts on the current business profile can facilitate strategic planning and portfolio construction. In other words, we see climate scenario analysis more as a "what-if" or a "sensitivity analysis" under different transition scenarios rather than holistic stress testing exercise as undertaken for modern capital management analyses.

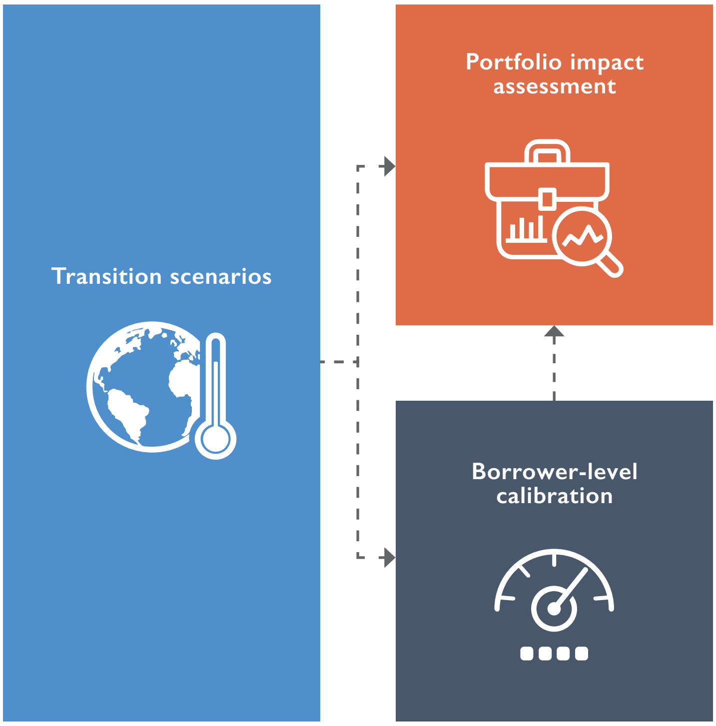
Armed with the understanding of climate scenario analysis, banks might still choose to test alternative portfolio constructs or to model a dynamic portfolio for strategic planning. Either exercise could use the same methodology as the current portfolio impact assessment outlined in this document.

And, of course, enhanced disclosures will inform stakeholders and the public financial market will provide important feedback.

2. AN INTEGRATED APPROACH FOR TRANSITION RISK ASSESSMENT

The proposed transition risk assessment methodology encompasses three integrated modules, as shown in Figure 2.1.

Figure 2.1: Overview of the transition risk modules



Transition scenarios describe an evolving economic environment in a consistent manner across time, sectors, and geographies. Scenarios provide detailed outputs which help assess the economic impact on sectors.

Portfolio impact assessment uses a systematic and repeatable approach to extrapolate the risk assessed by the other modules (i.e. transition scenarios and borrower-level calibration) to the remainder of the portfolio.

Borrower-level calibration addresses the lack of empirical data on corporate exposure to transition risk by using industry experts and tailored assessment to estimate the scenario's impact on individual borrowers. Calibration specifies the relationship between economic scenarios and credit outcomes.

Source: Oliver Wyman

Each of the modules serves a distinct purpose in evaluating transition risk in this methodology. Together, they combine to form a holistic approach for transition risk assessment:

- **Transition scenarios**: Transition scenarios describe an evolving economic environment in a consistent manner across time, sectors, and geographies. Each transition scenario provides detailed outputs which help assess the economic impact on sectors.

  Variables from transition scenario models are used to determine how risk evolves over time at sector and geographic levels. Scenarios provide a consistent reference point, and common parameters, that experts use to assess the impact of transition across institutions, geographies, and sectors during the borrower-level calibration. The scenario variables are also summarized into "risk factor pathways", representing corporate credit risk drivers: direct and indirect emissions costs, changes in revenue, and required low-carbon investment. "Risk factor pathways" are differentiated across economic sectors in scenario model outputs, and further differentiated into more granular segments through customized sensitivities. In the portfolio impact assessment, these "risk factor pathways" allow extrapolation from calibrated borrower-level impacts to the whole of the portfolio.

- **Borrower-level calibration**: Borrower-level calibration addresses the lack of empirical data on corporate exposure to transition risk by using industry experts and tailored assessment to estimate the scenario's impact on individual borrowers. Calibration specifies the relationship between climate scenarios and credit outcomes.

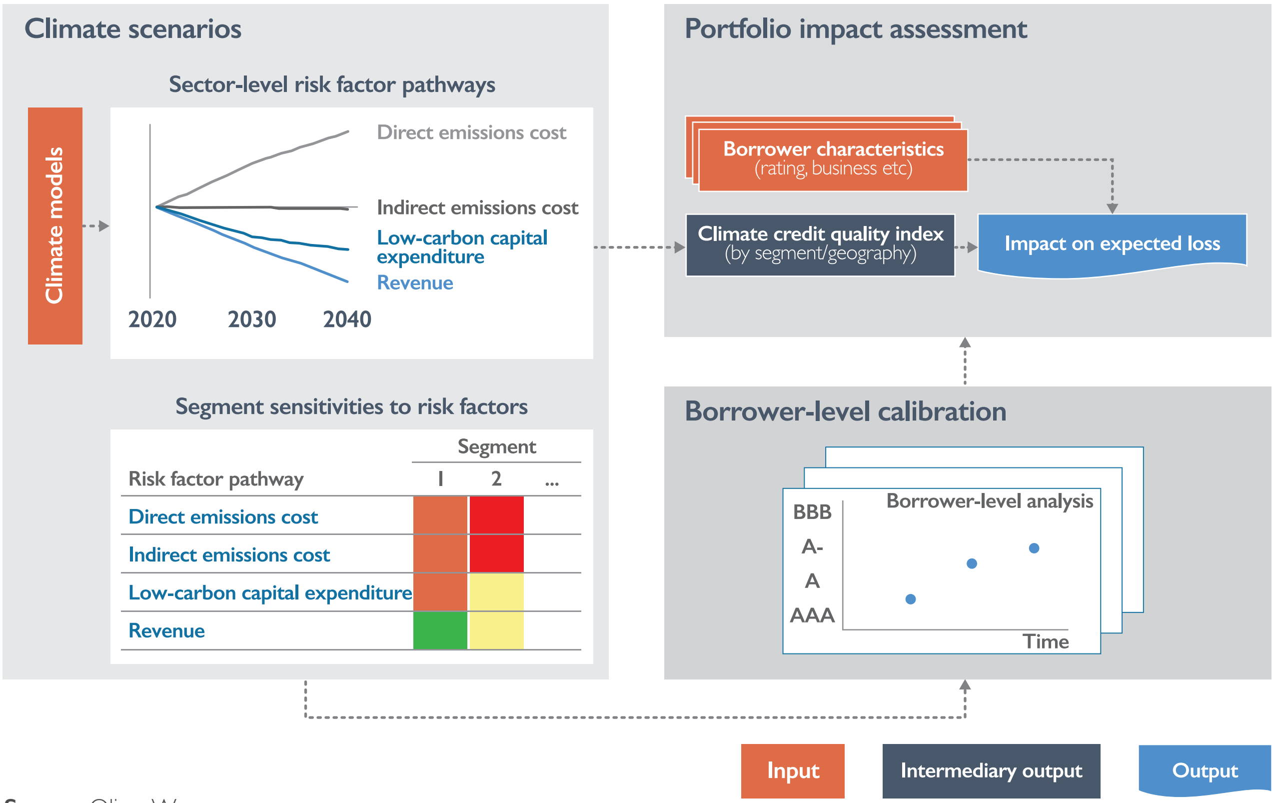
  The borrower-level calibration builds on scenario variables, bridging information gaps using expert judgment and in-house credit risk tools to assess the changes to the probability of default of particular borrowers. This assessment provides the primary basis for identifying the magnitude of the scenario's impact on the creditworthiness of borrowers, incorporating quantitative and qualitative considerations. This analysis is only conducted on a subset of cases, allowing for manageable workload.

- **Portfolio impact assessment**: The portfolio impact assessment uses a systematic and repeatable approach to extrapolate the risk assessed by other modules to the remainder of the portfolio.

  Portfolio impact assessment provides a structured quantitative method for combining bottom-up expert judgment from calibration with top-down parameters provided by scenario models. Changes in creditworthiness from a handful of borrowers are extrapolated to the overall portfolio using a "climate credit quality index", derived from the risk factor pathways and the calibration points, and a Merton-type framework.[5]

An overview of the proposed approach is diagrammed in Figure 2.2

Figure 2.2: Proposed methodology overview



Source: Oliver Wyman

By combining these modules, the proposed methodology provides a consistent structure for translating expert insights into transition impacts on borrowers while grounding that judgment in a reference scenario. These judgments are then extended to the whole of the sector using credit risk assessment methods in a way that ensures the analysis is consistent, repeatable, and systematic. The methodology is therefore a blend between sector-level and borrower-level modelling (see Box 2 for more detail around modelling options). Expert judgment is deployed in multiple components of the analysis, but this approach incorporates expert judgement in a structured, repeatable, and transparent manner, without overburdening expert resources.

By linking each module, banks can address the major challenges inherent to modelling transition risk (described in Section 1.2), as shown in Table 2.1.

5 Merton, Robert C., 1974, *On the Pricing of corporate debt: the risk structure of interest rates, Journal of Finance 29, 449–470*

Table 2.1: Challenges associated with bank transition risk assessment

CHALLENGE	SOLUTION	ASSOCIATED MODULES
Limited empirical data	▪ Provide transition models outputs that project plausible views of sector-level transition risk ▪ Leverage expert judgment to inform assessments of impact from scenarios to borrower and segment impacts	▪ Transition scenarios ▪ Borrower-level calibration
Risk analysis over extended time horizons	▪ Use scenarios to demonstrate how risk factors could evolve over long time horizons	▪ Transition scenarios ▪ Borrower-level calibration
Varying sector relationships to risk	▪ Take advantage of climate scenario models with geographic and sector granularity ▪ Further differentiate risks across segments through tailored sensitivities	▪ Transition scenarios
Systematic, consistent, and repeatable	▪ Provide a consistent basis for expert judgment, as well as a standardized method for obtaining portfolio impacts	▪ Portfolio impact assessment ▪ Transition scenarios
Bespoke bank requirements	▪ Allow expert judgment and bank-specific risk methodologies to drive assessment of risk magnitude at borrower level	▪ Borrower-level calibration
Improved coordination	▪ Use reference scenarios and a structured analytical methodology to coordinate and integrate judgments across a bank	▪ Portfolio impact assessment ▪ Transition scenarios

In the following section, the three modules of the methodology are explored in greater detail.

BOX 2: Modelling transition risk: top-down or bottom-up?

Throughout development of the methodology, several alternative transition risk assessment approaches were considered. Each method offers a trade-off between feasibility and analytical rigor, while approaching transition risk from a different standpoint. The three main methods considered, categorized as top-down or bottom-up, are:

Top-down approaches:

- **Macro-economic level modelling**: Assessing impact of climate scenario on the loan book through national-level variables, similar to macro-economic stress testing
- **A sector-level approach**: Assessing impact of climate scenario on the loan book through the performance of economic sectors

Bottom-up approach:

- **Borrower-level analysis**: Directly assessing impact of climate scenario on borrower-level financials or credit risk factors

Macro-economic level modelling was first ruled out for being unable to capture the nuances of transition risk. Since transition risk can have greater distributional effects across and within sectors than an overall economic impact, a macro-economic analysis would not effectively capture these risks.

A sector-level approach would capture sector-level distributional effects. As a top-down approach, however, it would still ignore relevant differences within a sector and would be unable to differentiate effectively and reflect borrower level characteristics.

A comprehensive borrower-level analysis would be able to capture those nuances. This type of approach however, would be difficult to develop and implement. First, no comprehensive climate risk assessment of borrowers, such as an indicator of climate resilience, currently exists and the availability of relevant attribute data at a borrower-level is limited, especially for smaller, non-listed companies. Additionally, directly linking transition scenarios to credit rating models poses significant challenges given that these credit rating models typically do not use emission and energy system variables as inputs, and transition scenario models do not yet produce the types of variables used by credit rating models. In practice, bottom-up analysis would currently require an extensive and case-by-case evaluation for much of the portfolio. Such extensive workload would overburden analysts and increase the risk of inconsistencies.

The proposed transition risk methodology is a blend between sector-level and borrower-level modelling. The bottom-up, borrower-level calibration captures borrower-specific nuances. Top-down portfolio impact assessment extrapolates the borrower-level information to segments which are homogenous in their sensitivity to transition risk. In practice, only a sample of "manual" borrower-level analyses is necessary to determine sector exposure, reducing both required time and resources, while maintaining the integrity and accuracy of the analysis. Furthermore, limited manual intervention is required when running a different climate transition scenario from the same source or adding a new borrower to the portfolio.

These three methods, as well as their assessments, are summarized in the figure below.

	Macro economic-level	Sector-level	Borrower-level
Description	▪ Assess impact of climate scenario on the loan book through national-level variables	▪ Assess impact of climate scenario on the loan book through the performance of economic sectors	▪ Directly assess impact of climate scenario on borrow-level financials or credit risk factors
Top-down vs. bottom-up	Top-down	Top-down	Bottom-up
Feasibility and assessment	▪ Will not effectively capture all transition risk credit impacts, e.g.: ▫ Sector concentrations ▫ Impacts on asset values (e.g. GDP measures flow/ activity, not stocks/value) ▫ Results of redistribution of productive capacity	▪ Expected to capture main transition sensitivities as they will largely be sector-specific	▪ No existing, comprehensive climate risk assessment of borrowers ▪ Limited availability of relevant attribute data ▪ Direct linkage of climate scenarios to existing credit risk models is challenging

Higher granularity

A mix of sector-level and borrow-level modelling can be used to capture climate risk

2.1. TRANSITION SCENARIOS

2.1.1. Understanding transition scenarios and their sources

Transition scenarios are used by researchers, policymakers, and, increasingly, corporations to analyse how the world might achieve a particular temperature outcome. In climate and energy research, transition scenarios have been leveraged to inform the most effective policies for mitigation, the economic burden of those policies, and the prerequisites for achieving particular temperature targets. Scenarios illustrate the connections and dependencies across technologies, policies, geographies, and economic outcomes as the world strives toward a particular climate mitigation goal.

A transition scenario can be decomposed into a few common components, the warming outcome of transition-related actions being chief among them. Transition scenarios are designed to test how the world might arrive at a common temperature, radiative forcing, or carbon concentration outcome, assuming a specific link between emissions and climate impacts.[6] Temperature targets are most frequently specified as warming in degrees Celsius above pre-industrial levels. As temperature targets decrease, the physical impacts of climate change are reduced, but more aggressive and disruptive policies are required to achieve the necessary transitions in energy and land-use systems.

To study how the world can get to a particular temperature change outcome, a starting policy, technology, and socioeconomic environment is specified that dynamically evolves over time. Usually models are calibrated with a set of starting assumptions that incorporate a series of global or regional policies, a business-as-usual sociodemographic projection, and a set of energy use and production technology assumptions. In a particular scenario, energy and land use evolve over time to reduce emissions in response to policy, which in turn leads to the achievement of a particular temperature target.

Transition scenario sources, however, vary widely across many dimensions. Transition scenarios are produced using a range of models managed and developed by academic institutions, non-governmental organizations, and corporations. The availability and utility of data for financial risk analysis therefore varies widely by model type. Identifying what makes a scenario source useful for financial analysis is an important component of transition risk analysis.

To identify the most useful scenario sources for financial assessments of transition risk, the leading public sources were evaluated based on the following criteria on scenario outputs:[7]

- **Scenario availability**: Ideally, for financial assessment of transition risk, a baseline, 2°C, and lower than 2°C scenario should be analysed. Multiple temperature targets enable the study of how more aggressive assumptions can impact risk. A consistent baseline, or reference, scenario is necessary to understand the incremental risk of transition scenarios relative to business as usual. Since more severe transition risks are likely to evolve over longer time horizons, scenarios should project impacts to at least 2040.
- **Output breadth**: Ideally, reference scenarios would cover all regions of the world where banks have exposures and all sectors of economic activity where transition risk is most material. Analytical breadth varied widely across sources. Among major scenarios analysed, only certain climate models, for example, contain detailed representations of land use, including agriculture. In other instances, valuable scenario sources did not have complete regional representations.

6 These links are usually provided through separate climate models, which are capable of modelling world climate responses to emissions scenarios at a more granular level of detail. The temperature-related outcome of the model may be a constraint for the way the model optimizes other variables, or simply a modelled output.

7 Note these criteria are focused on the required outputs from climate scenarios. They do not aim to assess the techniques or analytical approaches. Such evaluation was outside the scope of this methodology design. We expect continued evaluation and enhancement of scenario sources to be a key area of continued further development.

Additionally, guided by the TCFD recommendations, scenario sources were assessed for availability of the most critical financial risk variables, including energy prices, carbon prices, emissions, investment needs, and energy demand by fuel type.

- **Output granularity**: Though some models may cover the entire world, they do not always report the results of this analysis in a granular way. Scenario sources should also report economic and emissions results at a sector level, so that the major differences in sector relationships to risk drivers are captured. Additionally, regional or country level outputs are useful for capturing differences in transition risk across jurisdictions and levels of economic development.
- **Update frequency**: Since important socioeconomic and policy inputs into transition risk models will evolve in the real world, frequent publication of scenario model outputs is necessary. To avoid disruption or obsolescence, selected scenario models should be maintained actively by a group with a mandate to continuously publish.[8]

Based on these criteria, two publicly available, and widely referenced, scenario sources were deemed most appropriate for the purposes of this transition risk analysis exercise:

- **The IEA World Energy Outlook**: An annual scenario analysis publication that projects carbon emissions, technology development, and energy sector trends based on current and emerging policy frameworks. The scenarios are produced using the World Energy Model, a partial equilibrium model designed to explore how energy use and production will evolve over time under alternative policy assumptions.
- **Integrated assessment models (IAMs)**: A suite of integrated energy-economy-climate models developed by the scientific community. These models explore the relationship between emissions, the climate outcome until 2100, and socioeconomic developments including a detailed representation of the energy and land-use systems. The scenarios generated through IAMs have been relied upon in various Intergovernmental Panel on Climate Change assessments, which is the international body for assessing the science related to climate change.

2.1.2. Using scenarios for transition risk assessment

No matter how strong the scenario source, these scenarios are not used to produce the definitive view of the future but rather plausible, hypothetical possibilities. Scenarios have very long time horizons and capture complex interactions between policy, technology, and economic sectors that are inherently difficult to predict. Transition scenarios are thus not forecasts, but internally consistent pathways of plausible futures based on a body of research and an agreed-upon, forward-looking narrative. There are a virtually unlimited number of ways to get to a particular target temperature outcome. Policies, socioeconomic states, and technology development pathways could vary widely, causing a range of differences in how a transition happens over time.

Even if transition scenarios do not produce the definitive view, they provide a consistent and plausible picture of progress toward a low-carbon transition. Thus, in scenarios with sector and regional outputs, information can be compared between sectors and geographies while referring to the same state of the world. Additionally, scenarios provide variables that illustrate dynamic interactions in a consistent way. For instance, emissions will decline over time as sector investment in low-carbon technology increases in response to a carbon price. Energy demand, and thus sector revenue, will change as certain forms of energy increase in price. As a result of rising commodity prices, world or regional economic output in the form of GDP or consumption may decline relative to a business-as-usual scenario. Simultaneously, land use may change as demands for increased carbon sequestration require policies aimed at increased afforestation or reduced deforestation. Such policies simultaneously cause rises in food prices as production becomes more intensified. State-of-the art transition scenario models are capable of capturing these dynamic interactions across space and time.

The use of scenario analysis in the face of uncertainty is already an integral part of banks' risk toolkits. As previously mentioned, scenarios are very common in stress testing exercises.

8 This analysis was agnostic on specific policy inputs used, as these may be easily changed in future generations of transition scenario models, and often evolve within modelling groups over time.

However, in this case, climate change transition scenarios were initially developed for different purposes; the best way to use them is therefore not immediately apparent for financial risk analysts. Scenario outputs must be translated to allow for assessment of transition risk in financial terms.

2.1.3. Bridging the gap between climate scenarios and financial risk assessment

Transition scenario models produce outputs often initially intended for policy analysis or research. As such, they describe the main dynamics that could impact sectors through policy, technology, or market impacts. To analyse these dynamics for corporate financial analysis, however, transition scenario outputs need to be financially interpreted. To this end, scenario model outputs can be summarized as a set of focused risk drivers that describe the major corporate performance dynamics in a transition scenario.

The main dynamics described in scenarios that have corporate performance impacts at a sector-level fall into three categories:

- **Policies** can lead to additional costs or gains in revenue by borrowers through taxes or subsidies, impose quantity regulations that decrease demand for borrower products, or mandate capital improvements that require additional investment.
- All of these policies act on a portfolio of **technologies**. Policies can make technologies relatively more competitive by changing their costs. Increased deployment of low-carbon technologies will help some industries and harm others, cutting into their market share. All increases in technology deployment come at a cost, requiring greater capital expenditure.
- The **market** finds equilibria in response to transition dynamics. Prices will change as companies find ways to pass through increased costs. Consumers will, in turn, respond to price changes by modifying which products they buy. These impacts will, ultimately, affect the total emissions the economy outputs and thus the policies required to further reduce emissions in subsequent periods.

Risk factor pathways are a way to interpret these economic scenario impacts in corporate financial terms. Each risk factor pathway is a driver specifying risk changes from a climate scenario compared to a baseline or reference scenario, in this case a 4°C scenario, where only current policies are expected to continue. As such, risk factor pathways were developed from scenario outputs with the intention of meeting several criteria. They must:

- **Enable a financial interpretation for corporate risk exposure analysis**: Risk factor pathways should indicate financial loss or gain for corporates across an economic sector and geography that is intuitive and based on analysis of the scenario.
- **Allow common comparisons across sectors**: To achieve consistency, the structure of the risk factors should be applicable to multiple economic sectors (though the specific values they take are expected to differ across sectors). If these metrics were not common risk drivers, differing risk analysis frameworks would have to be developed for different sectors.
- **Apply to multiple scenarios from various models**: The metrics used to generate risk factor pathways should be common outputs of leading transition scenario models. This allows additional flexibility for future transition risk analysis to occur across multiple scenarios and model sources.

Importantly, these risk factor pathways are always expressed as a change relative to a baseline scenario. In other words, the approach assumes that current borrower credit ratings reflect a baseline climate scenario.

Based on these starting principles, four risk factor pathways were developed at the sector/geography level to encompass major drivers of financial risk:[9]

- **Incremental direct emissions cost**, or the increased costs of emitting CO_2 and other greenhouse gases relative to a baseline scenario. In transition scenario models, increased costs are driven by the amount of emissions per period, and the associated carbon-equivalent price. In the real world, these increased costs might be levied as a direct tax on emitters, or through cap-and-trade.
- **Incremental indirect emissions cost**, or the increased costs of production inputs relative to a baseline scenario. During a low-carbon transition, carbon-intensive fuels will increase in price due to pass-through of direct emissions costs. Increased fuel costs will directly impact sectors that use carbon-intensive fuels for economic activity. Increased fuel costs can be further passed on through downstream goods, indirectly incurring subsequent cost increases. Scenario models usually only report increases in fuel prices, but analysis can identify increases of other intermediate goods costs used in production down the chain.[10]
- **Incremental low-carbon capital expenditure**, or the increased costs associated with the need for capital investment to transition to a low-carbon economy. In scenarios, capital expenditure increases to ensure sufficient production capacity exists to meet demand in subsequent periods. Capital expenditure must also increase to meet energy efficiency mandates assumed by the scenario.
- **Change in revenue**, or changes in price and consumer demand. As costs increases, an increasing proportion of costs may be expected to be passed on to consumers. Consumers, in turn, will respond to increased prices by decreasing their demand for certain goods and increasing their demand for others, leading to a change in revenue.

Together, the combined risk factor pathways provide a picture that is meaningful for assessing probability of default for corporates exposed to these risk factors. Each risk factor has an impact on borrowers' cash flow, and the sum of these risk factor pathways indicate how future cash flows might change due to climate transition risk. A borrower's cash flow is directly linked to the borrower's ability to pay off debt without adversely impacting future financial performance. Excess cash can be allocated to loan interest payments, decreasing the probability that a borrower will default by failing to pay back a loan. Note however that, even after combining output variables, the resulting risk factor pathways are still based on economic models and are thus an imperfect proxy for borrower-level financial or accounting impacts. They should be interpreted as a summary of the scenario for a specific region and sector.

Risk factor pathways provide a picture of transition risk that can be interpreted at a glance. For example, Figure 2.3 shows how risk factor pathways evolve in the European Union's oil and gas sector under a 2°C transition scenario in the REMIND model, an integrated assessment model developed by the Potsdam Institute for Climate Impact Research (PIK). In this case, one expects both oil and gas, as fossil fuels, to experience risk increases.

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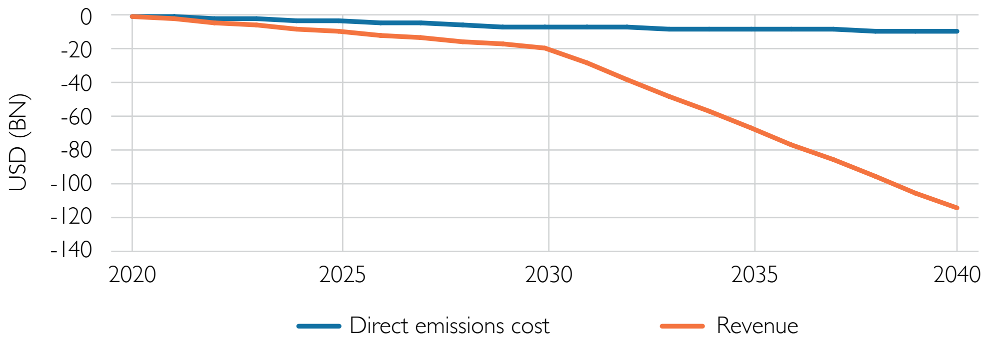
9 During the pilot, sector definitions were developed to be compatible with the level of granularity of variable reporting provided by the transition scenario models. Outputs allowed definition of fourteen high-level sectors for use in the pilot: energy, oil and gas, oil, gas, coal, electricity, agriculture and forestry, crops, forestry, livestock, renewables, transportation, industrial processes, and residential and commercial buildings. An additional layer of "segment" granularity for risk analysis is defined and customized by banks as further discussed in section 3.1.1. Ten high-level geographies were defined.

10 For example, using input-output models to project the change in other intermediate good prices based on a pass-through of fuel prices.

Figure 2.3: European Union oil and gas risk factor pathways from the REMIND model 2°C scenario



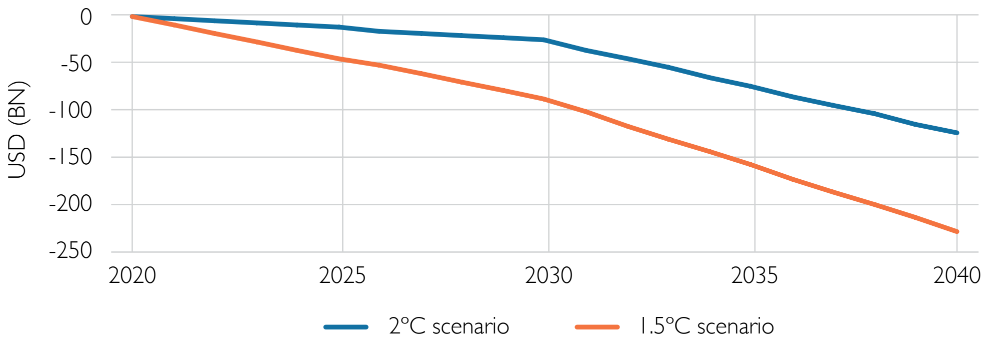
Source: Potsdam Institute for Climate Impact Research; Oliver Wyman analysis

In this scenario, the cost of upstream emissions for the oil and gas sector slightly and steadily increases relative to the baseline scenario in response to an increasing carbon price (incremental costs are shown as a negative value here). Throughout this period, the sector is not exposed to indirect emissions costs (since oil and gas production is upstream).

Instead, changes in sector risk are driven by reductions in sector revenue relative to the baseline scenario, with a small gap in revenue compared to the baseline in 2030, then an increasingly wide gap afterwards. This pattern can easily be explained through analysis of the scenario. During early periods, there are few cost-effective alternatives to oil and gas based fossil fuels, particularly in the transportation sector. Over time, the cost of alternative fuels decreases, and the infrastructure to support their distribution and use expands, making them more competitive. Revenue has a non-linear response to increased competition relative to oil and gas increase in cost. As more competitors enter the market, revenue declines much more rapidly than costs increase, implying an increasingly high elasticity of fossil fuel demand.

The combination or sum of the risk factor pathways provides a one-dimensional summary of how risk changes over time for the sector as a whole, and can be interpreted in a manner similar to the major transition-related changes in sector profitability or cash flow,[11] as seen in Figure 2.4. The curvature of the aggregated risk factor pathways reflects the dominance of revenue risk driver impacts. Also in this chart, one can see the incremental adverse impacts on the oil and gas sector in a 1.5°C scenario. Since the 2°C and 1.5°C scenarios are compatible in terms of macro-economic and policy assumptions, aggregated risk factor pathways helps to quantify the increase in sector risk experienced under more rigorous temperature targets in a consistent manner. Simply put: a more aggressive climate target (1.5°C vs. 2°C) generates higher transition costs.

Figure 2.4: European Union combined oil and gas risk factor pathways, REMIND model

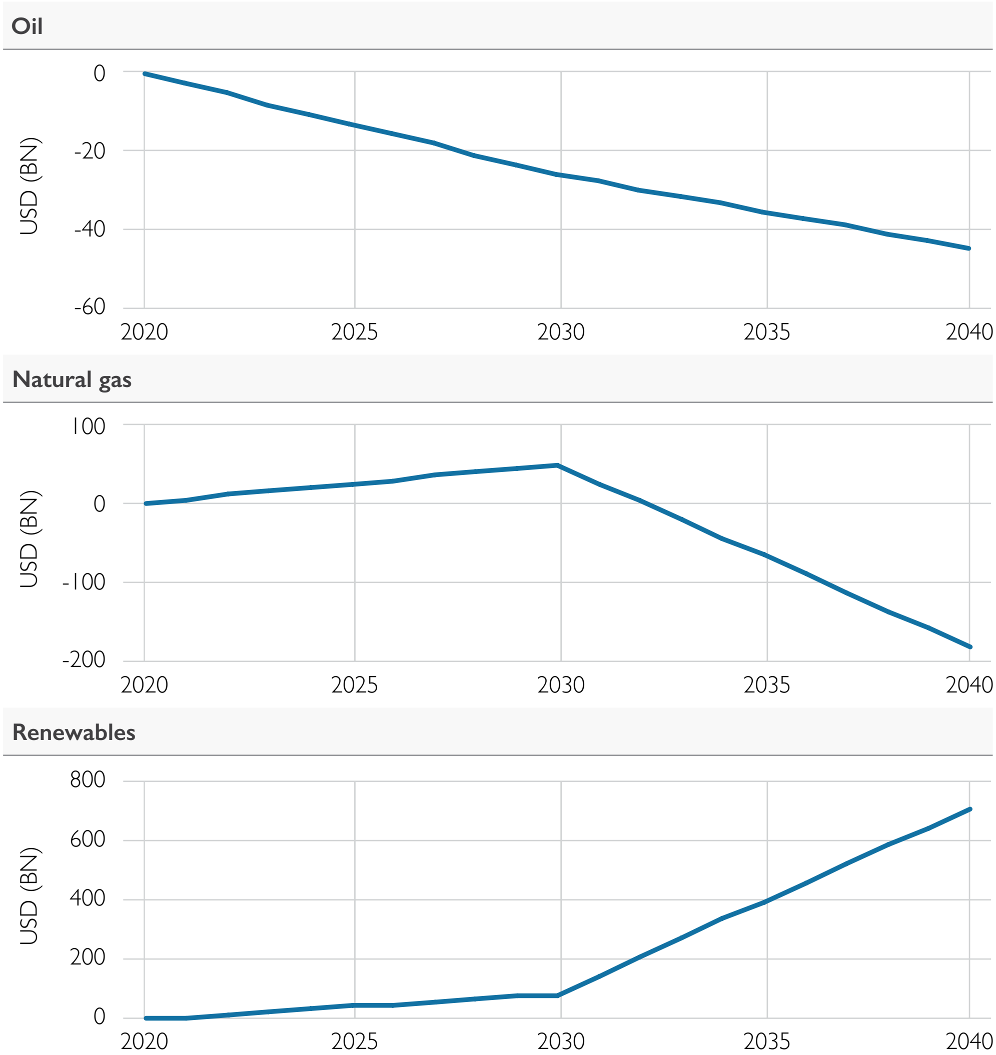


Source: Potsdam Institute for Climate Impact Research; Oliver Wyman analysis

11 Note this does not exactly represent impact on income or cash flow as cash timing issues and capitalization of investment are not addressed

Such "snapshots" of sector risk can be derived for all sectors and geographies covered in the transition scenario models.[12] Figure 2.5 shows one such example for Asia.

Figure 2.5: Asia combined oil and gas risk factor pathways, REMIND 2°C scenario



Source: Potsdam Institute for Climate Impact Research; Oliver Wyman analysis

In Asia, risk evolves across different energy sources in an intuitive manner. Oil demand drops off steadily under the transition scenario. Much of this transition is to natural gas-based sources of energy, which receive a temporary bump in utilization as a bridge fuel. Renewables, on the other hand, are immediately deployed, but take longer to see an aggregate net positive impact due to the scale of investment required. Before 2030, renewable investments nearly balance increases in revenues; in later periods, increased revenues from new capacity dominate.

12 See Appendix A for more detail on the granularity available in the transition scenarios models

Box 3: Translating scenarios from two of the world's leading transition scenario models

From PIK (REMIND) and IIASA (MESSAGEix-GLOBIOM)

Note: For this pilot, the Working Group obtained scenarios from two of the leading interdisciplinary research institutions focused on modelling the global response to mitigating climate change: the Potsdam Institute for Climate Impact Research (PIK) and the International Institute for Applied Systems Analysis (IIASA). Contributing scientists included Elmar Kriegler and Christoph Bertram (PIK) and Keywan Riahi and David McCollum (IIASA).

PIK and IIASA develop scenarios using integrated assessment models (IAMs), which combine representations of global land-use and energy systems with internally consistent socio-demographic and economic projections to understand strategies and impacts related to climate policy and technology transition over the course of the 21st century. The scenarios developed by these energy-economic-land use-emissions models, namely the REMIND-MAgPIE model from PIK and the MESSAGEix-GLOBIOM model from IIASA, have been deployed by institutions around the world to understand transition impacts on the whole-of-economy and specific sectors, primarily for policy-related purposes The United Nations Framework Convention on Climate Change (UNFCCC) for example, uses the scientific knowledge synthesized every few years by the Intergovernmental Panel on Climate Change (IPCC), which relies heavily on IAM scenario results in its assessment.

PIK and IIASA are leading members of the Integrated Assessment Modelling Consortium,[13] which was founded in 2007 to facilitate research and model development across the IAM community and to serve as a body for cooperating with other communities. Until now, collaboration efforts have focused on working with policymakers and other research communities, such as physical climate modellers and impacts and adaptation modellers. Using scenarios developed by the IAMC, researchers have studied a wide range of transition-related themes, including the impact of the global mitigation policy landscape, the effect of a climate-related transition on particular sectors, the influence of technologies on mitigation policy requirements, and linkages between mitigation policy and sustainable development. As the modelling community has matured, it has also begun to work toward establishing collaborations with other key user communities, namely non-state actors, including in the financial sector. The current TCFD pilot project with the Working Group banks has been a critical step in this direction.

The collaboration between the Working Group banks and PIK and IIASA represents a first-of-its-kind effort in response to the TCFD recommendations. To model financial risk impacts, scenario researchers, Oliver Wyman, and the Working Group identified relevant outputs from PIK's and IIASA's transition scenario models. Researchers, via Oliver Wyman, then helped the banks understand and interpret outputs from their models; during this process, the financial risk factor pathways, as well as assumptions required for calculation, were vetted with the researchers to ensure that the interpretations are consistent with underlying (quantitative) scenario assumptions and (qualitative) scenario narratives.

As this work progressed, possibilities for further bridging the gap between financial risk modelling and climate-economic modelling presented themselves. Modellers identified additional information that might be output to better inform future risk modelling exercises, such as more detailed and financially oriented investment information. Other potential avenues for IAM improvement include more detailed national/regional and sectoral representations, particularly in downstream or energy end-use sectors such as transportation and manufacturing. An advantage of the proof-of-concept approach described in this report is that it is generalizable enough to incorporate more detailed IAM outputs as they become available going forward. Moreover, as the current collaboration strengthens, scenario modellers may also work with financial institutions to develop customized scenarios with built-in policy assumptions that are explicitly intended for financial stress-testing purposes.

Through this pilot, the first steps toward building a bridge between the financial and scientific modelling communities demonstrated that closer collaboration can yield important lessons that improve both parties' understanding of the impacts of transition risk.

13 Read more about the IAMC at www.globalchange.umd.edu/iamc/

At present, scenario models only provide transition risk outputs at a sector level. Banks, however, are interested in understanding differences in scenario impacts within sectors where there are major variations in borrower characteristics. Understanding risk is perhaps even more important at a more granular segment level within a sector, where groups of companies share homogeneous exposures to transition risk drivers.

To bring sector-level risk down to the segment level, analysts must define **relative sensitivities** of segments to each transition risk driver. Relative sensitivities specify the impact of transition risk drivers on one segment relative to others. For electric utilities, for example, coal-fired power plants will have a higher sensitivity, or higher potential for adverse impact, to direct emissions cost than a nuclear or renewables-focused generation company. In some sectors, where there are winners and losers, relative sensitivities must also identify the direction of impact relative to the sector as a whole. For example, electric vehicle producers may see an increase in revenue even though car manufacturers as a whole may see a decline.

While relative sensitivities provide constraints on the relative relationships of a segment to a particular transition risk driver, they do not quantify the specific magnitude of the risk driver's impact on the segment. In the case of electric utilities, one need only identify that coal-fired power plants are worse off in terms of direct emissions than their renewable counterparts when setting relative sensitivities; one does not need to know by how much. The magnitude of these differences, expressed as a **calibrated sensitivity**, is always identified through borrower-level calibration, as described in the following section.

2.2. BORROWER-LEVEL CALIBRATION

Outputs from transition scenarios cannot be directly translated into impacts on the creditworthiness of borrowers. Under a specific scenario, the probability of default of a borrower is impacted by a number of drivers, both quantitative (such as emission costs) and qualitative (such as adaptability to the new environment).

While the scenarios provide a high-level view on some of these drivers, they do not specify:

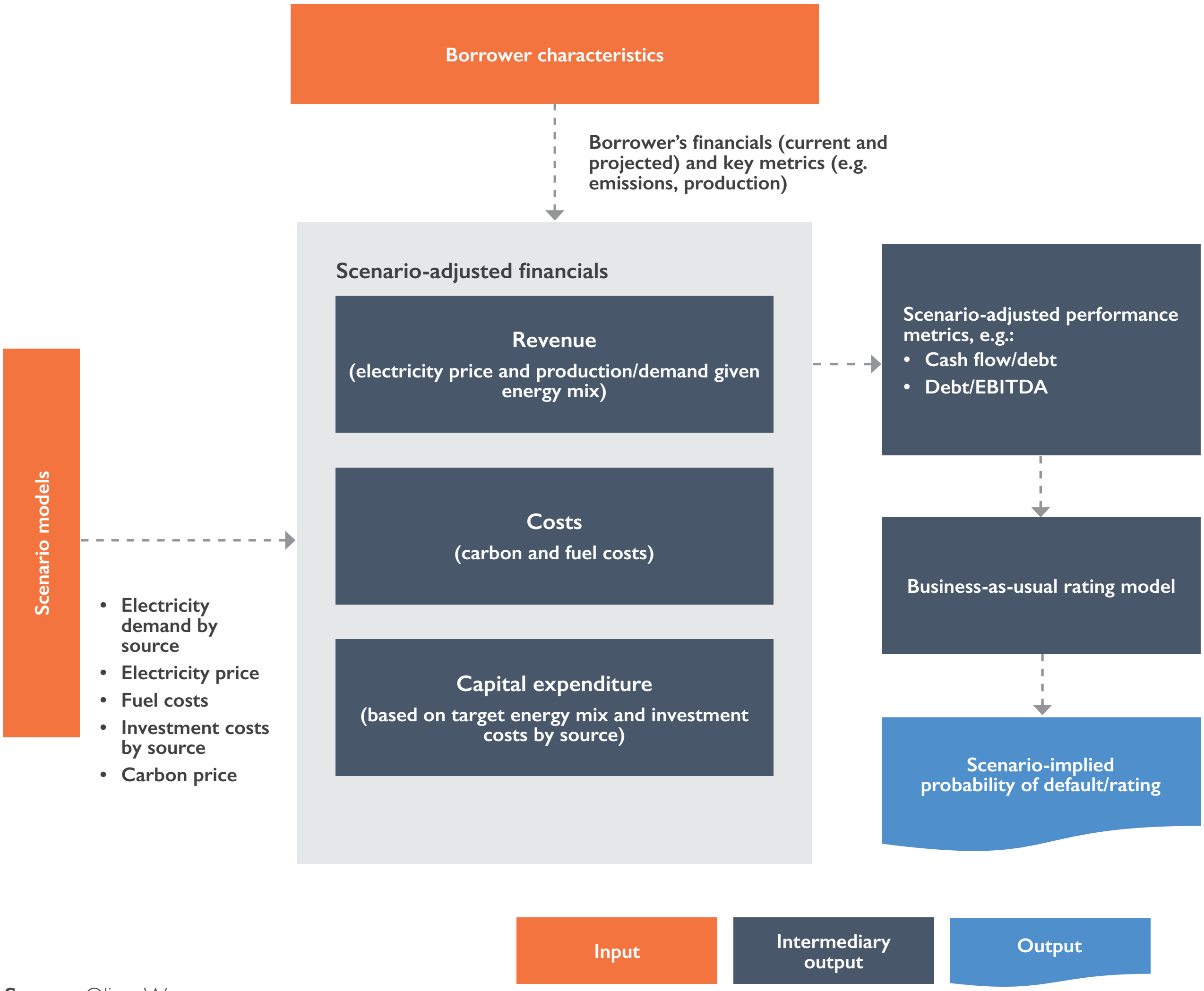
- Financial impact at a borrower-level
  - Given scenarios are articulated at a sector level, they do not provide a view on how material the impacts on costs/revenues or cash-flows are for borrowers relative to their overall performance and risk profile
  - Not all financial drivers can be derived from the scenario (e.g. corporate leverage)
- Qualitative considerations such as adaptability of a specific borrower to a low-carbon environment

Borrower-level calibration builds on the variables provided by the scenario models and bridges information gaps, using expert judgment. Calibration defines, for various levels of transition risk, the potential impact on specific borrowers. To assess the magnitude of these impacts, credit and sustainability experts within the banks use their experience and the tools at their disposal to determine the link between the scenario and their borrowers.

Calibration empowers experts to interpret a transition scenario, and specify the potential impact that sector and economic changes may have on the creditworthiness of select borrowers. A number of representative borrower cases are selected for a segment containing borrowers with generally homogeneous exposures to transition risk drivers. Based on scenario outputs and supplementary research, banks use credit risk experts' experience, judgment, and analytical tools to assess the potential impact of the scenario on the probability of default (PD) for this handful of borrowers. Each of these "calibration points" will provide the information base for extrapolating borrower-level impact to the rest of the portfolio (see next section).

Banks can use quantitative or qualitative methods for assessing changes in PD for specific borrowers. For a quantitative assessment, banks might have rating models they can leverage to determine transition-induced credit changes. Banks can estimate the impact of the scenario on specific rating factors that are used as inputs into the rating models. An example of this process in the utility sector is provided in Figure 2.6.

Figure 2.6: Adjusting rating factors for unregulated power generation utilities using scenario variables (simplified example, illustrative)



Source: Oliver Wyman

Scenario models provide variables that inform regional carbon costs, electricity demand, fuel costs, and investments in the power generation sector. An expert performing calibration can use these variables to estimate the scenario-implied financials of a specific borrower. Flowing the scenario's electricity price, demand, cost, and capital expenditure through a pro forma analysis of the company's balance sheet allows the expert to assess impact on key financial performance metrics, such as cash flow/debt or debt/EBITDA.

Note that, even using a quantitative approach, expert judgment is required. In this specific case, the analyst must make assumptions, especially about the future energy mix of the company: the company might either decide to pay the additional carbon cost or invest in low-carbon power generation.

Financial performance metrics are typically used as rating factors in "business-as-usual" rating models. They are often complemented by qualitative considerations such as the borrower's competitive position and the industry outlook, which can also be informed by scenarios.

Note that a quantitative approach such as the one described above is not feasible for all sectors. For end-use sectors in particular (e.g. airlines, car manufacturers), a more qualitative assessment is often necessary given the transition scenarios currently provide fewer relevant variables compared to the energy sectors (see Section 5 and Appendix A for more detail).

Calibration reflects the view that, once scenarios are articulated into relevant industry level metrics, credit risk experts are ultimately best-positioned to quantify the potential impact of scenario on the creditworthiness of borrowers. The low-carbon transition will influence the financial and economic conditions credit risk experts consider when making rating decisions.

Such assessments are not foreign to credit experts, who regularly take changes in policy and the macro-economic environment into account in making rating decisions.

This process also allows for customization across banks. Through calibration, in-house experts are empowered to use the risk assessment tools that are most relevant for assessing scenario impacts, while ensuring the assessment is consistent with the bank's view of risk. Calibration also allows experts to reflect their understanding of the reaction of individual companies to a transition scenario, based on the company's operating characteristics. A US car manufacturer with existing electric vehicle capacity, for example, might be impacted differently from traditional automobile manufacturers based on their ability to adapt to change and compete. Calibration also affords the banks the opportunity to assess the most critical exposures in their portfolio in a customized manner, ensuring that the results of their analysis reflect their biggest transition-related concerns. As a result, detailed calibration approaches are expected to vary across banks.

At the conclusion of the calibration process, bank experts have developed a set of calibration points specifying the impact of the climate scenario on particular borrowers' PD at a given point in time. This set of calibration points provide the basis for extrapolating the impact of climate transition risk from individual borrowers to an entire portfolio.

2.3. PORTFOLIO IMPACT ASSESSMENT

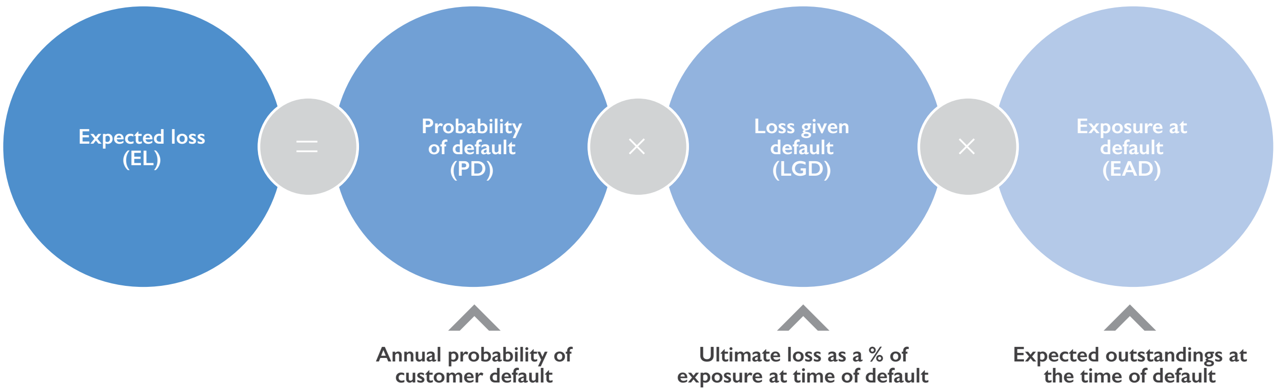
Scenarios provide sector-level risk factor pathways and experts provide borrower-level calibration points, but an additional module is required to integrate the two. This integration occurs through portfolio impact assessment, during which borrower impacts are extrapolated to a segment, using risk factor pathways as parameters and sensitivities as constraints.

2.3.1. Linking expected loss to transition impacts on portfolios

From the perspective of banks, expected loss is an essential metric for understanding credit risk and thus the focus of these modelling efforts. Expected loss is the amount that a bank is expected to lose on its lending exposure in the normal conduct of business and in the current environment, i.e. under a baseline scenario. It reflects the probability that a borrower will default and the expected amount the bank stands to lose should that borrower default. Transition risk is measured as the change in expected loss under a transition scenario. In other words, the methodology aims to capture the expected loss conditional on a given transition scenario.

Expected Loss is calculated for each borrower as the product of Probability of Default (PD), Loss Given Default (LGD), and Exposure at Default (EAD) (Figure 2.7).

Figure 2.7: Expected loss calculation



Probability of Default (PD) is the probability of a borrower defaulting over a one-year time period.

Loss Given Default (LGD) is the percentage of an exposure a bank expects to lose if a default occurs. Loss given default is ultimately a function of the value and type of collateral a borrower puts up to back a loan.

Exposure at Default (EAD) is the expected amount of financial exposure the lender has to the borrower at the time of default, taking into account interest and principal payments. Exposure at Default is usually expressed as a dollar amount and varies based on the lending terms offered to the borrower.

The methodology described in the remainder of this section focuses primarily on assessing the evolution of PD under different transition scenarios. The assessment of LGD is expected to be sector-specific, requiring custom assessment of impacts by the type of collateral backing a particular loan, and is discussed in Section 2.3.3. EAD is assumed to remain constant for the purposes of this analysis, allowing the results to be interpreted as an assessment of the sensitivity of the current portfolio to transition risk.

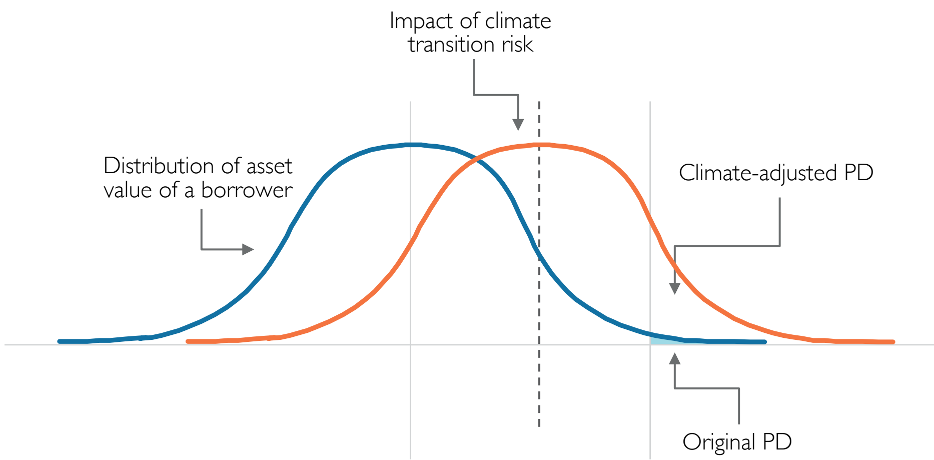
2.3.2. Assessing probability of default (PD)

Over the past decades, banks have developed and adopted a body of financial theory to assess exposure of their portfolios to credit risk. These existing frameworks can be leveraged, with modification, to assess transition-induced changes in PD.

A Merton-like framework is used to theoretically ground the calculation of transition-related PD impacts. Originally developed in the 1970's by Robert Merton, the Merton model for structural credit risk is often used within financial institutions to understand the risk of a borrower defaulting.[14] Banks, brokerages, and investors around the world have historically leveraged this model in their credit analytics.

The framework relates PD to the likelihood that the firm's future asset values could fall below a threshold value, specified by the value of the firm's liabilities. The distribution of the firm's future asset values is therefore crucial to determining a change in PD. If the distribution of future firm asset values is widened, through an increase in variance, or shifted, through a change in mean, the PD is affected. This Merton framework can be modified to assess transition risks.

Figure 2.8: Illustration of the adjusted Merton framework for climate risk



14 Merton, Robert C., 1974, *On the Pricing of corporate debt: the risk structure of interest rates, Journal of Finance 29, 449–470*

In the proposed framework, a low-carbon transition is assumed to shift the firms' asset values in response to the introduction of additional systemic risk related to transition risk. With idiosyncratic and other systemic factors remaining unchanged,[15] an increase or decrease in PD can be measured at a given point-in-time based on a shift in the distribution of asset values. This methodology adapts the Merton framework to assess PD impacts as a shift in the distribution of asset values; Figure 2.8 illustrates an adverse impact. This shift is determined by a combination of the risk factor pathways, sensitivities, and calibration points. The modified equation is expressed in Equation 2.9.

Equation 2.9: Model calibration equation

$$PD_i|c^* = \Phi[\Phi^{-1}(PD_{i,\,TTC}) - \underbrace{\frac{1}{\alpha_k} \cdot \sum_r \left(s^r_{j,k} \cdot f^r_k\right)}_{\text{Climate credit quality index for segment-geography } j}]$$

Where:

$PD_i \vert c^*$	Probability of Default for borrower *i* under a climate scenario *c**
Φ	Standard normal distribution
$PD_{i,\,TTC}$	Original through-the-cycle Probability of Default for borrower *i*
$s^r_{j,k}$	Calibrated sensitivity to the risk factor *r* in segment-geography *j* and sector *k*
f^r_k	Risk factor pathway *r* in sector *k*
α_k	Calibration factor for the sector *k*

This equation essentially shifts the through-the-cycle PD of the borrower over time, based on the value of the "climate credit quality index". This climate credit quality index is the sum of the products of the risk factor pathways and segment sensitivities, multiplied by a calibration factor.

The climate credit quality index incorporates the results from each previously described methodology module. Risk factor pathways determine how risk evolves over time, and the relative contribution of each driver to risk at the sector level. Calibration points are used to solve for the unknown parameters in the "climate credit quality index":

- A single calibration factor (α_k)by sector, which determines the overall magnitude of climate risk impacts on the sector
- The value of each of the calibrated sensitivity parameters ($s^r_{j,k}$), subject to the rank-ordering constraints specified by experts

The calibration factor "alpha" is first estimated using a least-squares optimization that fits the risk factor pathways to the calibration points. From a theoretical perspective, "alpha" has a dual interpretation. First, it normalizes the impact of risk factor pathways to be interpretable as an impact to a random variable with a unit normal distribution, which is required in the Merton framework. Second, it identifies the magnitude of the scenario impact, effectively assessing the strength of the climate-credit risk relationship at the sector level for a given portfolio.

15 Systemic market factors not directly driven by the transition scenario, such as macro-economic conditions, are assumed to remain unchanged. Idiosyncratic impacts, which occur through random, firm-specific events, are also assumed to be unchanged.

After determining the magnitude of sector impacts, calibrated sensitivity values are fit to calibration points. Experts qualitatively evaluate relative sensitivities to provide a relative ranking of risk factor impacts on segments in a given sector (see Section 3.1.2 for more detail on sensitivity assessment). This qualitative assessment needs to be translated into a quantitative magnitude. The approach uses the risk factor pathways, the relative constraints supplied by relative sensitivities, and the calibration points to find the best fit values for segment sensitivities during calibration.

Once all these parameters are calibrated, a scenario-implied probability of default can be estimated for all borrowers in a segment based on their starting ratings, using Equation 2.9. The methodology uses outputs from a common and internally consistent scenario for parameters, but the calibration process allows for customization. The framework can be applied across all sectors, and it can accommodate a range of sensitivities, segment definitions, and calibration points supplied by bank experts.

2.3.3. Assessing loss given default (LGD)

The assessment of LGD, the second element of expected loss, is largely driven by the type and the value of collateral provided for a specific facility as well as potential asset value of the firm. An example of such a relationship is in oil and gas reserve-based lending, where collateral based on reserves can have sharp value declines due to such assets becoming "stranded", or unexploitable. Assets can become stranded, for example, if extraction costs rise above the price of oil due to a drop in demand and price in a transition scenario. Banks should identify cases where sector-specific LGD assessment is necessary, and thus where customized assessments must be developed. This type of assessment is expected to be a focus of next-generation exercises for the most material exposures.

Simple and cross-sector approaches may also be used, for instance by forecasting LGD based on its relationship to PD, but at the risk of being less rigorous. Examples include:

- Directly assessing the LGD based on the stressed PD using the Frye-Jacobs relationship,[16] which provides a single parameter, generic relationship between PD and LGD
- Forecasting LGD based on a correlation between PD and LGD. Unlike the previous option, using this method requires an assessment of parameters to assess the magnitude of the linkage between PD and LGD

* * *

16 Frye, J. and Jacobs, M., "Credit loss and systematic loss given default", Journal of Credit Risk (1–32) Volume 8/Number 1, Spring 2012.

A consistent yet adaptable approach

The purpose of the proposed methodology is to provide a systematic, consistent, and repeatable approach for assessment of transition risk in corporate lending. The methodology offers a consistent structure for translating expert insights into transition impacts on borrowers, by grounding that judgment in the context of well specified and consistent scenarios. The three components of the methodology aim to strike a balance between standardization, through use of a common climate scenario, and customization, through incorporation of expert judgment. Yet the approach is also adaptable for a number of potential future use cases.

The approach is:

- **Applicable across multiple sector and segment definitions**. By changing scenario parameters, sensitivities, and calibration points, the methodology can be repurposed for any sector.
- **Compatible with a range of scenario models**. Outputs from multiple integrated assessment models and other climate-economic models can be adapted and used as inputs in the proposed methodology. All scenarios produced by the compatible models can be run through the proposed methodology.
- **Implementable using different timeframes and risk factors**. Banks might use a similar methodology applied to shorter or longer transition timeframes. Of particular interest may be using the approach to model an event-based scenario (such as a sudden carbon price regulation) or an overshoot scenario, in which CO_2 concentrations or temperatures temporarily exceed target levels before being reduced, leaving less time for companies to adapt. By adjusting the risk factors, the proposed framework could also be adapted to other risks, including climate physical risk.
- **Self-improving through time**. As banks accumulate more borrower and scenario data and extend borrower-level analysis, the methodology is expected to continue to evolve and improve.

This methodology and the associated bank pilots described in the next section provide a starting point for future transition risk analysis. Yet the flexibility at the core of this approach allows for adaptation as banks' needs change and the risk tools at their disposal continue to evolve.

3. OPERATIONALIZING THE APPROACH: LESSONS LEARNED FROM BANK PILOTING

The development of the methodology benefited from the input of the sixteen banks in the Working Group, who continue to test and implement the approach. These pilots are being conducted on banks' own portfolios in the sector groups selected for this study, spanning oil and gas, electric utilities (power generation), metals and mining, transportation, and agriculture and forestry. The piloting process surfaced refinements throughout, which were incorporated into the methodology.

To launch these pilots, banks were provided scenario outputs and sector-specific risk factor pathways developed in conjunction with two of the leading groups of global climate mitigation scenario modellers, the Potsdam Institute for Climate Impact Research (PIK) and the International Institute for Applied Systems Analysis (IIASA) (see Appendix A and Box 3 for more detail). Note the scenario provided to the banks is an example of a 2°C scenario, but the methodology is compatible with a wide range of transition scenarios. Banks are expected to test several transition scenarios to probe vulnerabilities. The risk factor pathways, the segments, the relative sensitivities, and the calibration points were combined in an Excel-based tool to calculate the scenario-implied PD. In addition to these parameters, banks needed to collect portfolio data on borrower-level LGDs, EADs, and through-the-cycle PDs to run this tool. This chapter describes the process steps involved in developing bank-customized inputs (segments, relative sensitivities and calibration points). The chapter concludes by bringing these implementation steps together, and demonstrating results, through bank case studies.

3.1. PILOTING THE TRANSITION RISK METHODOLOGY

In piloting the methodology, banks undertake three major steps:

- Defining sectors and segments
- Evaluating relative segment sensitivities to risk factor pathways
- Determining borrower-level calibration points

The following sections describe the practical steps banks need to take to execute the methodology, as well as key lessons learned during each phase of piloting. The chapter concludes by bringing these implementation steps together, and demonstrating results, through bank case studies from the sector pilot groups.

3.1.1. Defining sectors and segments

Appropriate segmentation is important for obtaining accurate results, since borrowers within a segment will be assigned a consistent risk assessment, or level of climate stress, during portfolio impact assessment. The segmentation scheme should have three characteristics:

1. **Homogeneity in risk**: The methodology relies on the assumption that each segment is largely homogeneous in exposure to climate risk drivers, and borrower calibration points are representative of these risks. Portfolios vary widely across banks, requiring some flexibility to ensure homogeneous segments.
2. **Materiality to banks**: Since calibration requires a minimum number of cases per segment, banks may want to avoid unnecessary workload by ensuring that each segment has a potential portfolio exposure that is material to the bank. Dollar-based exposure and the number of borrowers by sector vary widely across banks, requiring flexibility to ensure segment materiality.

3. **Comparability across institutions**: Banks must achieve a balance between above-mentioned portfolio-specific considerations and standardization to facilitate comparability across institutions.

The following section describes the scheme used to strike this balance and the practical considerations for developing an appropriate segmentation scheme.

The pilot playbook

In order to strike a balance between customization and standardization, three levels of borrower classification are used.

"Sectors" provide the highest level of classification and form the primary basis for standardized comparison of parameters across institutions, while ensuring compatibility with definitions used in the transition scenario models. As such, sectors should be defined using a widely available and easily mappable classification scheme. The Working Group used the *International Standard Industrial Classification* (ISIC), following a survey to determine the most commonly used classification scheme with the highest concordance to other prevalent schemes. Sector definitions provide the basis for data collection and shared understanding across banks; this common starting point ensures results can be compared across institutions.

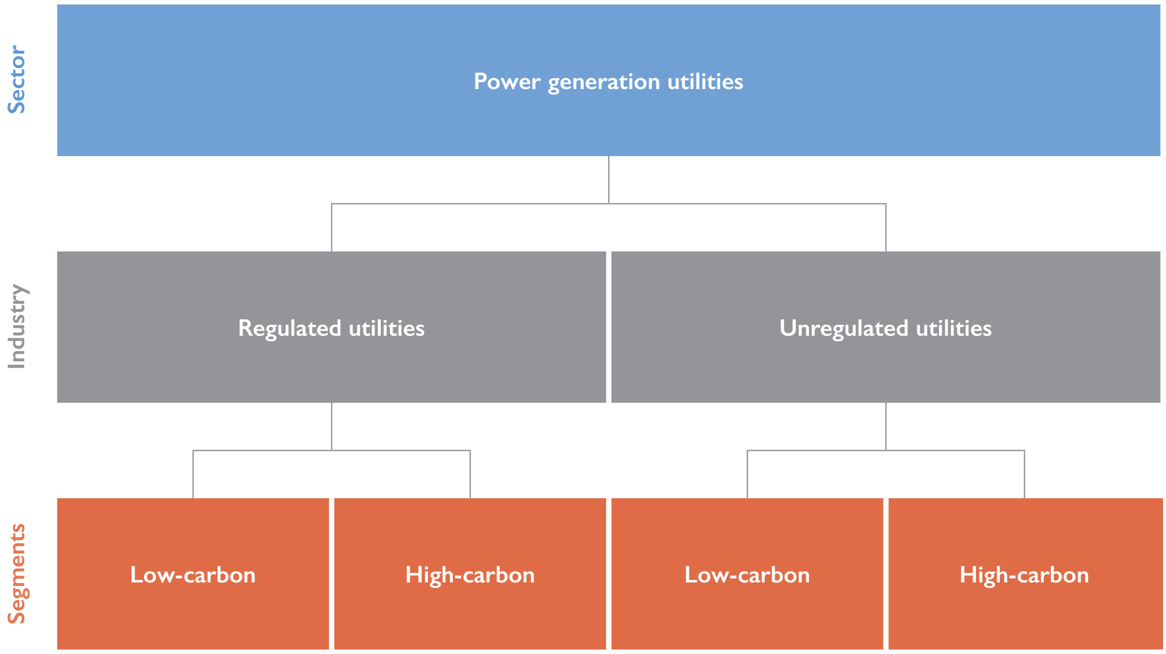
An intermediate **"Industry"** classification adds a layer of standardization based on commonly identifiable industry characteristics. Industries are defined as groups of borrowers that share common characteristics identifiable through classification codes. Full standardization across banks at the industry level is not required, but clearly defined industries may be useful for comparing results at a more granular level and identifying defensible ways to further segment a sector. At minimum, industry segmentation provides a useful starting point for thinking about how groups of borrowers might react to climate risk, based on fundamental differences in industry activities.

"Segments" provide the final level of classification. Segments incorporate transition-specific considerations that are not easily identified through commonly-used classification schemes, but divide the portfolio into homogeneous groups based on exposure to climate risk drivers. For instance, both coal-fired and solar generators of electricity would fall under the same ISIC code: "electric power generation, transmission and distribution". Within this modelling framework, however, borrowers with such different exposures to transition risk drivers (e.g. direct emissions costs) should ideally be placed in different segments.

Banks can customize the segment level to reflect their view of transition risk in a sector/geography and the materiality of their portfolio exposures. Segments capture "winners and losers" within a sector: the differences between borrowers who will benefit from the low-carbon transition and those who will be adversely impacted. For instance, electric vehicle production leaders could be positively impacted by a transition scenario, while traditional automobile manufacturers could be negatively impacted. A firm's exposure within resulting segments should be material to minimize the number of cases that experts must calibrate. As a result, while banks are encouraged to share learnings about helpful segmentation definitions, segments should be defined in a manner that is useful and relevant for each institution.

As an example, some banks decided to use the segmentation seen in Figure 3.1 for the power generation utility sector.

Figure 3.1: Segmentation scheme for the power generation utilities sector



The sector is first split between regulated and unregulated power generation utilities. Regulated utilities are able to pass costs through to the consumers and are therefore less exposed to transition risk. The revenue of unregulated utilities, on the other hand, is largely determined by market forces. Unregulated and regulated utilities are expected to react differently to a transition scenario.

Furthermore, banks segmented unregulated and regulated utilities by the energy mix of each utility. The higher the carbon dependency of a utility, the more transition risk it will encounter as it will have to choose between investing in low-carbon generation capacity or bear the emissions cost burden.

Insights from the pilot

Developing the segmentation scheme across banks yielded two conclusions:

- The final segmentation scheme may differ by institution/region
- The segmentation process is iterative

Segmentation should reflect both homogeneous borrower-level responses to transition risk drivers and a material portfolio exposure. Since banks can differ significantly in terms of risk appetite, underwriting strategy, and geographic and sectoral distributions, full standardization of segment definitions could adversely impact banks' abilities to conduct a homogeneous and material risk analysis. With a fully standardized segmentation scheme, some banks may find themselves over-segmenting in areas, effectively forcing a borrower-by-borrower bottom-up assessment using very granular segments. Further segmentation would lead to immaterial exposures and overextend credit experts with minimal benefit. In other cases, different geographic or economic considerations can cause some segments to have responses to transition risk that are not materially different from other segments.

For some large and diverse portfolios, banks could also under-segment their portfolios if they were to use a fully standardized scheme. In some cases, banks may have particular borrower segments that are exposed to relatively higher transition risks than the rest of industry. For example, exploration and production of shale was an important segment of oil and gas for a few banks but irrelevant for others.

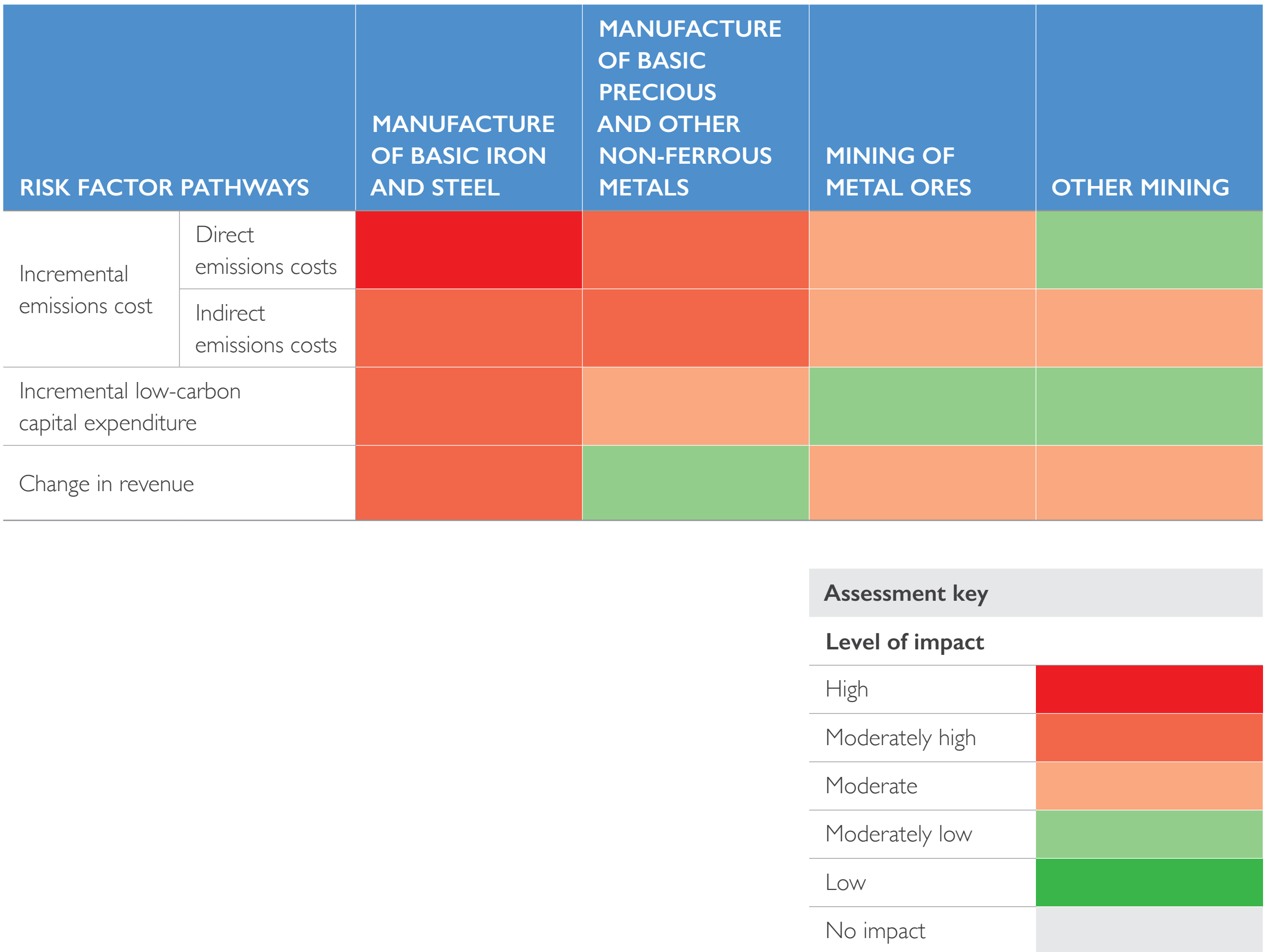
To develop a defensible segmentation scheme, banks should tap into bank expertise and surface refinements as they develop experience with this framework. During borrower-level calibration, banks may find that segments do not actually reflect meaningful transition risk differences. For example, some institutions merged initially diverse segments after identifying similar transition risk responses during calibration. Other institutions tested alternative segmentation schemes as more data became available or the experts garnered a better understanding of how segments might respond. In general, bank experts may wish to explore various ways of assessing their portfolios through alternative segment definitions.

Defining sector segments is not a linear process, especially during the early stages of piloting. Bank experts need to drive this process forward, leveraging their knowledge to define segments aligned with the banks' understanding of segment risk and materiality. Bank experts should aim for material and homogenous segments, knowing that iteration may be needed as they evaluate segment sensitivities and conduct borrower-level calibration.

3.1.2. Evaluating relative segment sensitivities

To bring sector-level risk factor pathways down to the segment level, banks provide a qualitative assessment of the segment's exposure to each of the risk factor pathways relative to the sector as a whole. During calibration, these relative segment sensitivities constrain the relative magnitude of the risk factor pathway's impact on a segment. To assess relative sensitivities, banks can assign a high, moderately high, moderate, moderately low, low, or no impact of the risk factor pathway on each segment compared to the sector average, as seen in Figure 3.2.

Figure 3.2: Relative sensitivity heat map for the metals and mining sector (illustrative)



Sensitivities assigned to each segment provide an ordinal ranking of risk factor impacts with clear interpretations. This relative scaling of adverse impacts – high, average relative to the sector, or low – needs to be assessed for all four transition risk drivers: direct and indirect emissions cost, low-carbon capital expenditure, and revenue. For instance, steel and iron producers are likely to have a high adverse impact with respect to direct emissions relative to the rest of the metals and mining sector, due to the carbon-intensity of the segment's emissions. Guiding questions, as well as quantitative metrics, can be used to help direct and inform the assessment of relative sensitivities in a consistent and repeatable manner.

Relative sensitivities can be associated with sector characteristics that do not widely vary across scenarios. Thus, for example, sensitivity to emissions costs could be based on the current carbon-intensity of emissions. Low-carbon capital expenditure could be assessed based on the need to invest in or replace capital to reduce carbon emissions. Sensitivities to revenue could be assessed by examining price elasticities or cross-elasticities of demand.

Bank experts can choose to supplement their knowledge with external studies or reports on the effect of a low-carbon transition on particular industries or segments. To assist with analysis, publicly available carbon databases, input-output analytics, and economic research are typically useful.

Table 3.1 provides a suggested assessment key for defining segment sensitivities to risk factor pathways, which was used during the pilot. This qualitative assessment is designed to evaluate observable segment characteristics and can be supported by external sources.

Table 3.1: Assessment guide for relative sensitivities

RISK FACTOR	GUIDING QUESTION	EVALUATION SCALE	SOURCES FOR ANALYSIS
Incremental direct emissions costs	How large of an impact would emissions costs have on segment based on current emissions intensity?	▪ **Highly adverse impact:** Segment has higher emissions per unit of production relative to others in the sector ▪ **Moderately adverse impact:** Segment has moderate emissions per unit of production relative to other segments in the sector ▪ **Low adverse impact:** Segment has lower per unit of production relative to others in the sector ▪ **No impact:** Near zero emissions segment	Carbon intensity of production
Incremental indirect emissions costs	Is the segment's supply chain likely to become more expensive due to climate policy, based on its current mix of inputs?	▪ **High:** Segment is highly reliant on carbon intensive inputs (e.g. oil, cement, steel, coal) relative to others in the sector ▪ **Moderate:** Segment is moderately reliant on carbon intensive inputs relative to others in the sector ▪ **Low adverse impact:** Segment is less reliant on carbon intensive inputs relative to others in the sector ▪ **No impact:** Negligible carbon intensive inputs into production	Input-output database analysis, e.g. World Input Output Database
Incremental low-carbon capital expenditure	To compete in a lower carbon economy, will the segment have to invest in new fixed capital?	▪ **High:** Segment requires higher investment in low-carbon capital required to compete relative to others in the sector ▪ **Moderate:** Segment requires moderate investment in low-carbon capital to compete relative to others in the sector ▪ **Low adverse impact:** Segment requires lower investments in low-carbon capital to compete relative to others in the sector ▪ **No impact:** Segment will not rely on low-carbon capital to compete	Marginal abatement cost curves
Change in revenue	Could the segment experience decreases in demand, due to competition with low-carbon alternatives or an increase in price from a cost pass-through?	▪ **High:** Segment experiences highly adverse demand responses relative to others in sector ▪ **Moderate:** Segment experiences moderately adverse demand responses relative to others in sector ▪ **Low adverse (or positive) impact:** Segment experiences limited adverse impacts, or demand increases relative to others in sector ▪ **No impact:** Segment revenue will not change	Industry price elasticity of demand Industry price cross-elasticity of demand relative to high-carbon producers

Source: Oliver Wyman

3.1.3. Determining borrower-level calibration points

During calibration, bank experts translate the transition scenario into PD impacts on a subset of segment borrowers. The output from this analysis is a series of calibration points, which quantify the scenario's impact on borrowers' PDs at given periods relative to through-the-cycle PDs.

Calibration is the most important step for obtaining an accurate financial representation of scenario impacts, but it is also the most sensitive to expert judgment. The first part of this section provides the general guidelines for conducting a calibration analysis. The second section shares some key insights from credit risk analysts piloting this process.

The pilot playbook

Three steps are necessary to conduct borrower-level calibration:

1. Selecting representative borrower cases
2. Contextualizing the scenario impact on borrowers
3. Translating scenario changes into PD changes

Selecting representative borrower cases

To calibrate borrower-level impacts, banks need to assess the scenario's impact on the PDs of "representative" borrowers. Since borrower cases are used to extrapolate to segment impacts, selecting representative cases is critical for avoiding sample bias. Two criteria are particularly important:

- **Representative of potential climate-related impacts**: Within segments, sector experts should identify further nuances in company response to climate risk drivers. For instance, a utility with 100% coal-fired generation may end up in the same "fossil-based generation" segment as a utility with only 30% coal exposure and 70% natural gas exposure. Unrepresentative sampling biased toward companies with 100% coal exposure would overestimate segment risk.
- **Representative starting ratings**: The cases selected should represent the variation in through-the-cycle ratings within the sector. Different through-the-cycle ratings can indicate variations in a company's ability to respond to a transition-related shock. Since ratings take underlying corporate financials into account, lower-rated companies may be more sensitive to changes in the risk environment, while higher-rated companies may be more resilient.

To obtain the best results, banks need to assess the impact of the scenario on the PDs of at least five representative borrowers in each segment (though more is preferred). Analysis of five borrowers per segment enables a unique solution to the calibration formula, which contains five parameters per segment (see Equation 2.9).

Contextualizing the scenario impact on borrowers

To calibrate borrower-level impacts, experts need to understand how the transition scenario will impact client financials. Developing a holistic understanding of the scenario helps experts identify the best methods, and information sources, for calibration.

Experts are provided with scenario data to help them understand changes in the macro-economic environment and their sector. These changes can be described qualitatively or quantitatively, by summarizing transition scenario outputs. Understanding the whole scenario, rather than isolated metrics, helps experts unfamiliar with transition risk contextualize the scenario's impacts within a broader framework. This broad understanding is essential since scenarios often output economic variables that do not have a plug-and-play financial interpretation. Understanding the scenario context generally helps experts identify the most appropriate assessment methodologies.

Banks can leverage two sources to understand what a scenario means for their borrowers: direct scenario outputs and supplemental literature. Many scenarios directly output time-series variables including price, demand, energy mix, emissions, land use, GDP, policy, population, and investment that are relevant for understanding scenario impacts. Supplemental sources can help shore up gaps in these indicators, as well as identify impacts at a more granular level of analysis.

Since transition scenario models currently output high-level sector variables, additional information may be needed to supplement bank experts' understanding of low-carbon transition impacts at a borrower and segment level. Relevant transition literature can come in the form of other scenarios with the same temperature target, CO_2 price, or ex-post analyses of scenario or historical impacts at the segment or borrower-level.

As an example, Table 3.2 provides an illustration of select supplementary scenario sources in the oil and gas sector.

Table 3.2: Select external study selections in the oil and gas sector

SEGMENT	ESTIMATED METRIC	REFERENCE TRANSITION SCENARIO METRIC	KEY DYNAMICS CAPTURED	REFERENCE STUDY
Oil sands	Mid-range incremental cost of carbon tax to oil sands producers	USD 30 CO_2e/tonne (currently planned carbon tax)	Cost	Special Report: What does the carbon tax mean for the Canadian oil sands?[17]
		USD 50 CO_2e/tonne (potential future carbon tax)	Cost	
Oil refineries	Decline in regional profit margins (Singapore)	USD 14 CO_2e/tonne carbon tax	Profitability	Singapore to become more eco-friendly with carbon tax[18]
Oil reserves	Estimated unburnable proven and probable reserves (company-specific data available)	IEA 450 scenario through 2050	Revenue	Oil & carbon revisited: Value at risk from "unburnable" reserves[19]
Oil refineries	Reduction in BAU capital investment in E&P (company-specific data available)	IEA 450 scenario through 2035	Capital expenditure	2 degrees of separation: Transition risk for oil and gas in a low-carbon world[20]

When analysing supplemental literature that differs from the scenario's risk factor pathways, experts should most heavily weight sources that are compatible with the transition scenario. Experts should be aware that many policy and technology combinations can be assumed in a 2°C scenario, across a number of economic environments. The timing and magnitude of transition impacts often differs substantially by scenario source. Information used from supplemental sources with different implied transition risk factors should therefore be applied carefully to avoid inconsistencies in results. Supplementary information that is consistent with the scenario should be given greater emphasis by experts. For example, experts might identify supplementary sources with similar socioeconomic developments, policy instruments, and temperature or emissions targets as the transition scenario under examination.

17 www.td.com/document/PDF/economics/special/Canadian_Oil_Sands.pdf

18 www.straitstimes.com/opinion/singapore-to-become-more-eco-friendly-with-carbon-tax

19 cape.ca/wp-content/uploads/2014/07/2013-HSBC-Unburnable-carbon.pdf

20 www.carbontracker.org/reports/2-degrees-of-separation-transition-risk-for-oil-and-gas-in-a-low-carbon-world-2/

Translating scenarios into probability of default

Armed with an understanding of the impact of the scenario on a segment, experts then translate the scenario into an impact on a borrower's probability of default (PD) or credit rating.

Experts may conduct this assessment using quantitative or qualitative means, or a mix of both methods. Regardless of the method chosen, however, expert judgement will be required to sense-check results and generate valid assumptions.

In some cases, quantitative assessments can leverage an existing rating or credit assessment model, which can be related to scenario changes in transition-related metrics. Most banks have rating models that use a series of variables (rating factors), including financial ratios, to assess the PD of borrowers. In some cases, experts can estimate the impact of the scenario on rating factors for an individual borrower (i.e. debt/EBITDA or industry outlook as illustrated in the utility example in Section 2.2) by directly using scenario variables, making assumptions about the macro-economic environment's impact on these factors, or conducting a pro forma analysis of the firm's balance sheet to obtain scenario-adjusted rating factors. A full quantitative analysis is not always possible, however, for all sectors given the data provided in transition scenarios.

Qualitative assessments rely more heavily on expert judgment and should be leveraged when no applicable rating model, combined with scenario data, can directly inform the change in PD.

When translating scenario impacts, bank experts should keep in mind that the methodology was designed to flexibly meet needs of a range of institutions. Sector experts across a bank are expected to utilize a mix of quantitative and qualitative approaches, depending on the specific sector and scenario information available.

Insights from the pilot

In completing early calibration exercises, Working Group experts quickly identified two key factors to achieving success:

- Considering the effort required, experts must be set up with the right resources and processes for calibration, including experienced team members, scenario information, and process guidelines. Throughout, experts must be empowered to experiment with evaluation methods to obtain results; setting ground-rules is important, but changes to the evaluation methodology will arise throughout the assessment process.
- The calibration exercise should be iterative and feed back into the rest of the transition risk assessment process, including the segmentation process. Since this is the first time banks have undertaken the calibration exercise, methods and results should be discussed and challenged amongst industry and credit experts within each bank to refine the calibration process. Banks can challenge results through a variety of channels. Sector results can be compared across teams, and other internal experts can be consulted. Banks can compare results across institutions, if appropriate, and at minimum should sense-check that the results are commensurate with the transition scenario. Cross-institutional conversations about calibration methods and challenges proved helpful over the course of this pilot. When challenging these results, banks may find that they need to revisit prior steps. Experts may determine that the initial segmentation was not at an appropriate level of granularity or that the sensitivities were under- or over-estimated. In a few cases during the pilot, segments were collapsed after a similar level of credit risk was assessed during calibration. Banks could also discover that the borrowers chosen for the calibration process were not representative of the segment.

Ultimately, calibration has the greatest room for improvement as banks gain experience. New quantitative methods for bottom-up borrower risk assessment may be developed as banks seek to link scenario outputs more closely with existing credit risk tools.

3.2. CASE STUDIES AND RESULTS

At the time of the writing of this report, banks were testing and piloting the methodology. The rest of this section discusses preliminary results of the piloting process. Case studies from three institutions in three regions are presented for the following sectors: power generation utilities, metals and mining, and oil and gas.

3.2.1. The pilot transition scenario

This section illustrates the results delivered by one of the two transition scenario models used during the pilot process: the REMIND Integrated Assessment Model (IAM) 2°C scenario developed for the European Commission-sponsored CD-LINKS project.[21] CD-LINKS scenarios provide a basis for analysing the linkage between sustainable development goals and low-carbon transition policies.[22] It is important to note that the selected scenario is just one example of a 2°C scenario. Given the number of assumptions required in transition scenario models, many different 2°C scenarios with different economic impacts can and should be tested. The proposed methodology is compatible with a range of transition scenario models and transition scenarios.

In the baseline scenario, business-as-usual policies continue in a world that follows historical trends. Beyond today's implemented polices and policy commitments, no further action is taken to address climate change. In the 2°C scenario, these same business-as-usual policies also continue until 2020. Starting in 2020 however, a globally-consistent carbon price is layered onto reference scenario policies to trigger technological and economic changes.

The 2°C scenarios used in the pilot limit warming to 2°C above pre-industrial levels with 66% certainty throughout the 21st century, whereas the 1.5°C scenarios achieve a reduction of warming to 1.5°C in 2100 with 50% likelihood after a temporary overshoot. While some scenario elements are presented through the end of the century, the pilot was conducted using outputs through the year 2040.

In the following section, major elements of the REMIND CD-LINKS 2°C scenario are described at a global level to contextualize the case study results: including policy, socioeconomic, climate, energy, and land use patterns. All scenario descriptions are presented here at a world level, though regional outputs were used by pilot institutions.[23]

Policy changes

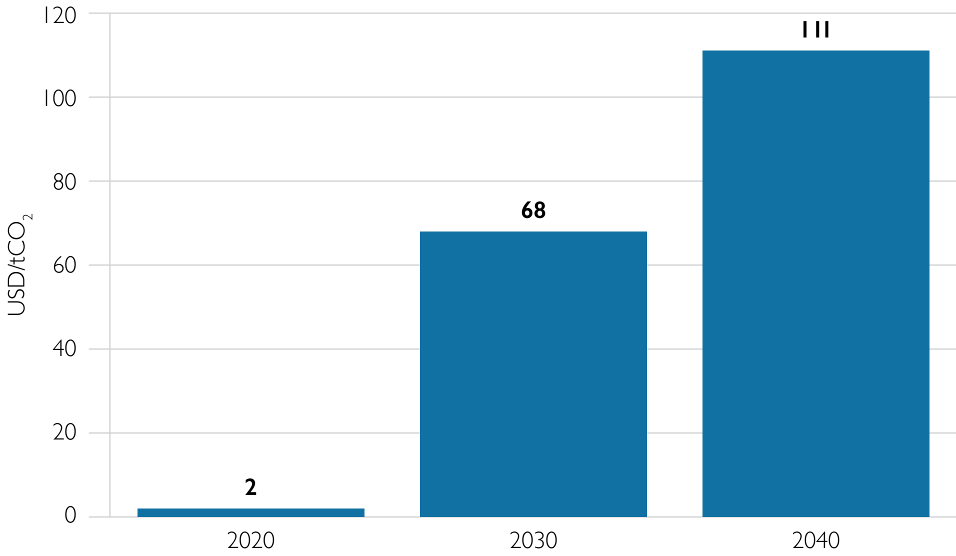
The main policy instrument after 2020 in the REMIND CD-LINKS 2°C scenario is a global carbon price that is consistent across regions. Within this scenario, the carbon price increases throughout the century, starting at a baseline carbon price of USD 2/tCO_2eq in 2020, and rising to over one-hundred dollars in 2040 (Figure 3.3).

21 More information on the CD-LINKS project can be found at www.cd-links.org/

22 The scenario variables were not publicly available at the time of writing. Once published, the scenario variables will be available at db1.ene.iiasa.ac.at/CDLINKSDB

23 For more information on the models and scenarios used, please refer to: McCollum, Zhou, Bertram, de Boer, Bosetti, Busch, Després, Drouet, Emmerling, Fay, Fricko, Fujimori, Gidden, Harmsen, Huppmann, Iyer, Krey, Kriegler, Nicolas, Pachauri, Parkinson, Poblete-Cazenave, Rafaj, Rao, Rozenberg, Schmitz, Schoepp, Van Vuuren, Riahi (2018-accepted). *"Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals"*. *Nature Energy* (forthcoming).

Figure 3.3: Carbon prices in the REMIND CD-LINKS 2°C scenario, all regions



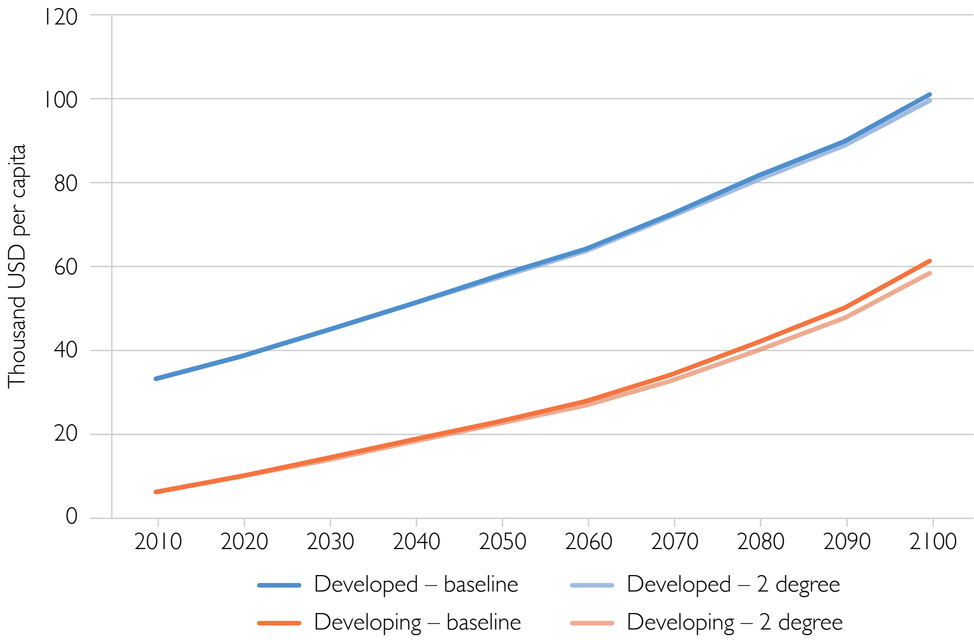
Assumed availability of carbon sequestration options, including reverse emissions (i.e. reduction of atmospheric CO_2 by afforestation or bioenergy combined with carbon capture and sequestration (CCS)), increase the permissible emissions from fossil fuels and thus reduce carbon prices required for achieving a given net emissions target. Other studies have shown that if these options remain unavailable, either for socio-political or technical reasons, carbon prices will need to be much higher to achieve the same net emissions (and thus temperature) target.

From an economics perspective, this represents a transition scenario where policy changes are efficient at a global level through use of harmonized carbon pricing. In reality, sector-specific or geography-specific policies are likely to be driven by distributional concerns, such as placing a higher burden through specific policy instruments on developed countries or particular emitting sectors. If these alternative policies are implemented, transition impacts on particular industries, geographies, and the overall economy would likely worsen compared to this scenario.

Socioeconomic development

Overall, the REMIND CD-LINKS scenarios occur in a "middle-of-the-road" world, where social, economic, and technological trends do not shift markedly from patterns of the recent past.[24] Figure 3.4 illustrates GDP per capita evolution in the reference and 2°C scenario for developed and developing regions. Developing and developed region per capita GDP increases through the century, with developing countries reaching current OECD levels by the second half of the century. Global economic growth is similar in both the 2°C and reference scenarios, reflecting the economic efficiency of a global carbon price.

Figure 3.4: GDP per capita, by developed and developing countries in the REMIND CD-LINKS 2°C and baseline scenarios



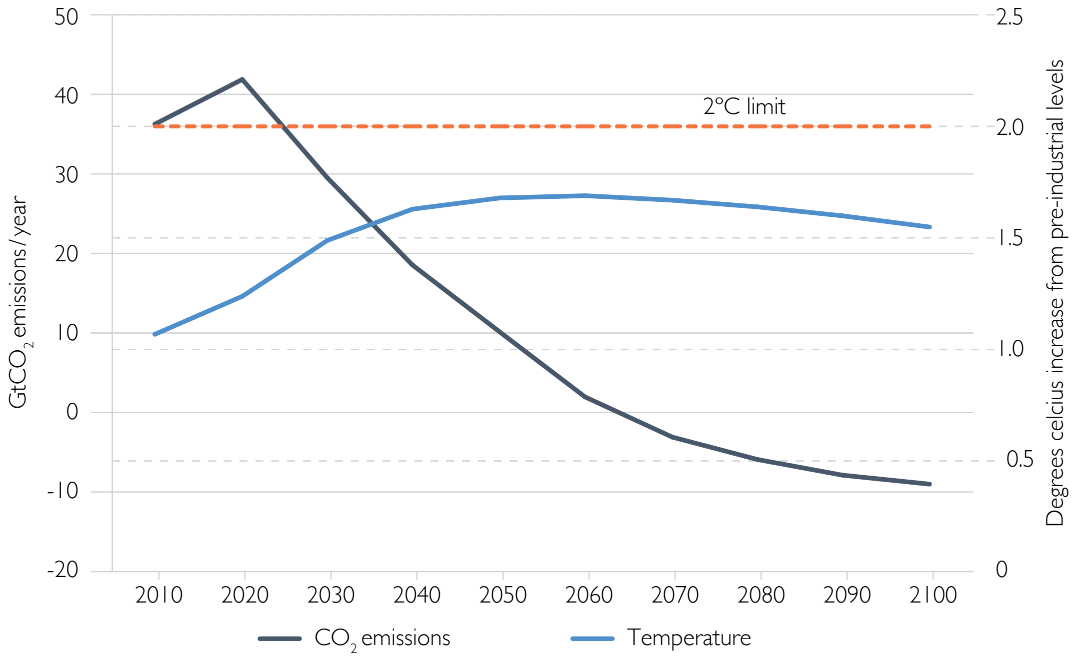
Temperature change and emissions trajectories

In the 2°C scenario, average global temperature increases peak at just under 1.8°C above pre-industrial levels toward the middle of the century.[25] Carbon dioxide emissions peak in 2020 and decline rapidly before turning negative due to sequestration and reverse emissions technologies in 2070, as illustrated in Figure 3.5.

24 This refers to shared socioeconomic pathway 2, see more at dx.doi.org/10.1016/j.gloenvcha.2016.05.009

25 This temperature time series represents the median outcome of the MAGICC climate model, such that a 1.8°C peak temperature corresponds to a 66% likelihood of not exceeding 2°C

Figure 3.5: Global average temperature and carbon dioxide emissions in the REMIND CD-LINKS 2°C scenario

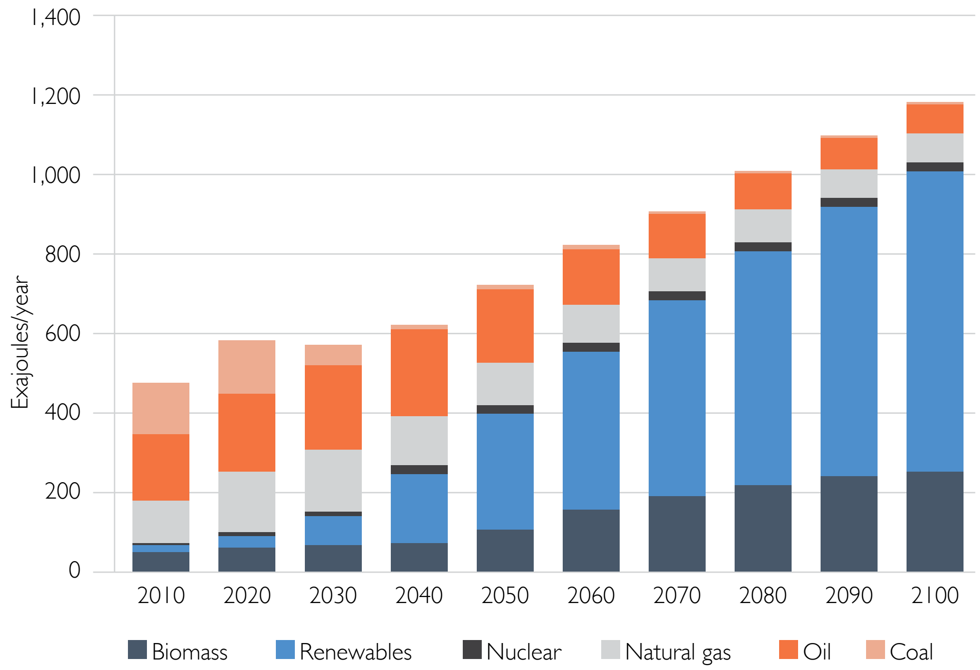


Source: Potsdam Institute for Climate Impact Research

Energy mix

The energy sector mix shifts rapidly in the 2°C scenario, as the world transitions away from fossil fuels and to renewable technologies. Figure 3.6 shows the projected change in global primary energy supply throughout the century.

Figure 3.6: Global primary energy mix in the REMIND CD-LINKS 2°C scenario, using the direct equivalent accounting method

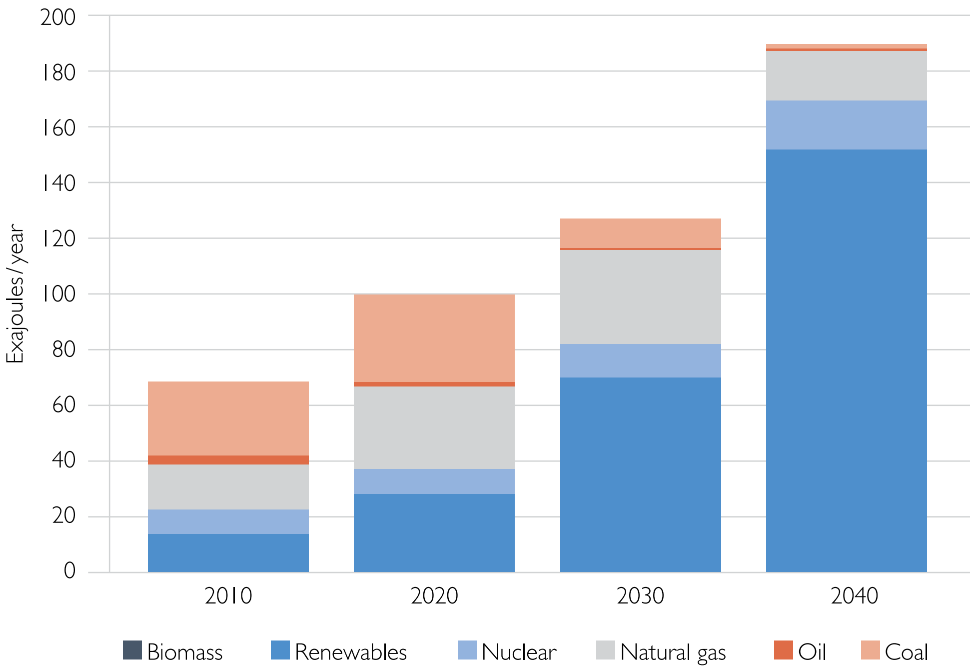


Source: Potsdam Institute for Climate Impact Research

Renewables and coal see the largest near-term transition impacts. By 2040, coal declines dramatically to only 2% of the total energy mix. Conversely, in 2040, renewables account for over a quarter of total primary energy supply. Fossil fuel use continues throughout the century, peaking in 2020 and declining thereafter. Oil in particular remains a sticky part of the economy during early periods. By the end of the century, however, half of all remaining fossil fuel use is natural gas. The complete transition away from fossil fuels would have to be much more rapid under the assumption that no reverse emissions can be achieved through afforestation and bioenergy with carbon capture and storage (BECCS).

Figure 3.7 depicts the evolution of the electricity sector, which generally sees the most rapid decarbonization in 2°C scenarios. Renewables quickly come to dominate the generation mix by 2040. In some developed regions, coal use within the electricity sector drops to virtually zero within ten years of the initiation of transition policies.

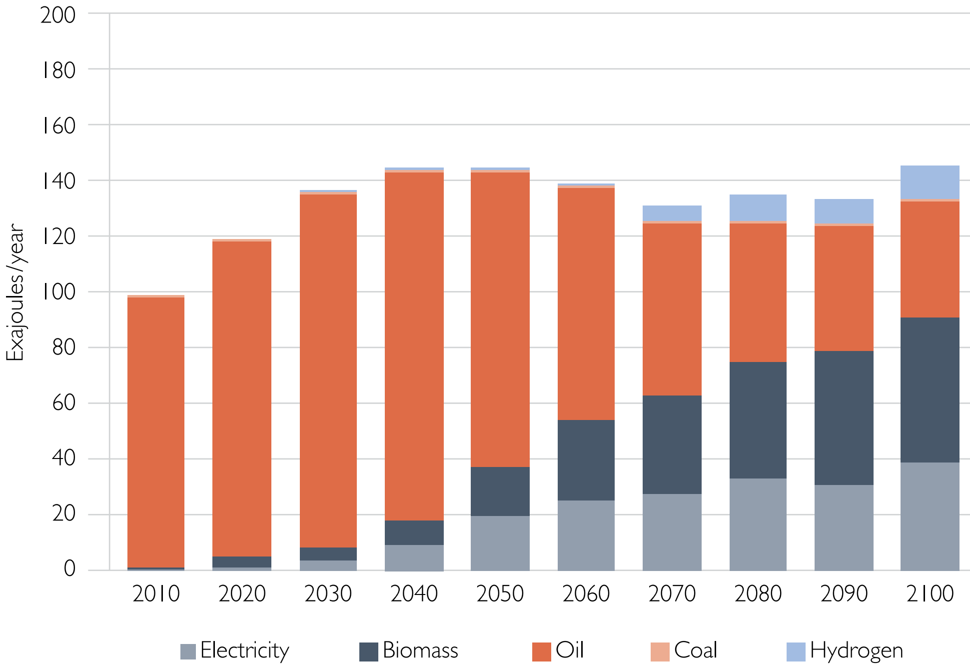
Figure 3.7: Electricity generation mix in the REMIND CD-LINKS 2°C scenario



Source: Potsdam Institute for Climate Impact Research

The transportation sector realizes a transition away from fossil fuels gradually and incompletely. Oil remains dominant within the transportation sector during the first half of the century due to the challenges of ramping up alternatives, such as biofuels, electricity, and hydrogen. Figure 3.8 details the change in transportation energy mix.

Figure 3.8: Transportation sector energy mix in the REMIND CD-LINKS 2°C scenario



Source: Potsdam Institute for Climate Impact Research

Land use change

In the 2°C scenario, land use changes help to advance low-carbon transition goals by reversing deforestation and increasing sequestration potential. Carbon sequestration both by afforestation and bio-energy with carbon capture and storage (BECCS) increases rapidly, particularly after the year 2040. Methane and nitrous oxide emissions peak in 2020, declining thereafter throughout the century. Methane is driven by livestock production, while nitrous oxide is primarily driven by fertilizer use. Within the scenario, emissions from both livestock and farming operations are penalized through the carbon price.

In general, land use changes provide a carbon sink. Forested lands, both managed and natural, increase slowly throughout the century under the 2°C scenario. Deforestation reverses after 2020. Due to land scarcity, and the area requirements for both afforestation and bioenergy plantations, non-energy crop and livestock prices increase steadily, doubling by the end of the century.

3.2.2. Piloting results

At the time of the writing of this report, all banks in the working group were testing and piloting the methodology. The rest of this section discusses preliminary results of the piloting process. Case studies from three institutions are presented for the following sectors: power generation – utilities; metals and mining; and oil and gas.

BARCLAYS CASE STUDY:
UTILITIES IN EUROPE AND THE US

Barclays has applied the pioneering and experimental transition risk assessment method to calculate the climate-adjusted probability of default (PD) for the electric utilities (utilities) credit portfolio in the United States and Europe.

PORTFOLIO ASSESSMENT SCOPE

In this calibration exercise, a total of 35 electric utility entities were assessed in detail, each across four possible stress test scenarios giving a total of 140 entity level stress tests (80 in the US and 60 in the EU).

The REMIND 2°C scenario developed for the European Commission-sponsored CD-LINKS project, is the transition climate scenario used to describe policy, socioeconomic, climate, energy, and land use patterns over time.

The following describes the scope of the utilities portfolio assessed:

1. **Sub-sectors:** power generation, power transmission & distribution, integrated utilities, electricity production & distribution.
2. **Countries:** Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, the UK, and the USA.
3. **Products:** liquidity facility, loans, revolver/term loans, revolving credit facility, swingline, letter of credit, municipal letter of credit, and standby letter of credit.

PORTFOLIO SEGMENTATION

Segmentation is the process of sub-dividing the sector into homogeneous groups based on exposure to climate risk drivers that are not currently captured through commonly-used classification schemes. In this case, the utilities sector has been sub-divided into four segments based on two key factors:

- Regulated or unregulated entities - to reflect the assumed greater ability of regulated utilities to pass onto consumers the climate related operating costs and capital expenditure deemed reasonable by regulators, relative to the unregulated utilities.
- Low or high carbon intensity - to reflect current dependence on carbon intensive power generation assets based on the positioning of their generation mix percentage versus the target generation mix at regional level (US or EU).

SEGMENT SENSITIVITIES

Evaluating segment sensitivities involves the qualitative assessment of a segment's exposure to risk factor pathways relative to the sector as a whole. The table below identifies the sensitivity of each segment to each risk factor:

Table 3.3: Segment sensitivity to risk factor

SEGMENTS	RISK FACTOR PATHWAYS			
	DIRECT EMISSIONS COSTS	INDIRECT EMISSIONS COSTS	LOW-CARBON CAPEX	REVENUE
Regulated - high carbon*	Moderate	Moderate	Moderately high	Moderate
Regulated - low carbon	Low	Low	Moderate	Moderately low
Unregulated - high carbon	Moderately high	Moderately high	High	Moderately high
Unregulated - low carbon	Low	Low	Low	Low

* applies to the US, not to the EU

CALIBRATION

Probability of Default (PD) calibration was undertaken by credit risk officers to understand how the transition scenario will impact the credit standing of the entities assessed. The output from this analysis is a set of calibration points, which identify the impact on utilities' through-the-cycle PDs in a particular period relative to their 2017 baseline PDs. Barclays' approach consisted of a bottom-up, quantitative-based stress test supported by qualitative assumptions where required.

Five representative utility cases were selected for each segment and region based on the following factors: materiality of exposure, granular generation mix, and geographic location. Each utility case underwent a 'static stress test' where no transition response was registered as well as an "adaptive stress test" to capture possible transition response. These stress scenarios assess the financial performance of the utilities, through impact to earnings, cash flows, and balance sheet.

- The **static stress test** assumes no capital expenditure (capex) requirement to change generation mix and reflects revenue/cost assumptions (in particular cost of emissions) that apply as of 2030/2040 compared to the 2017 baseline. In addition, carbon intensive utilities' total power supply has been subjected to a haircut according to reliance on fossil fuels, reflecting the displacement of some generation capacity in the merit order/supply curve (i.e. declining ability to address demand on the market in an economic way).
- The **adaptive stress test** reflects revenue/cost assumptions that apply as of 2030/2040 on the 2017 baseline and assumes overnight capex requirements (with adequate learning discount rates applied) to change utilities' generation mix to get closer to or match the assumed regional generation mix in 2030/2040. This capex then builds into debt. The capex reflects the shift required in the installed capacity assuming: (i) no new coal, oil, and nuclear; (ii) new gas fired output capped at the regional mix in a given year; (iii) any additional capacity requirement catered via renewable sources.

Portfolio calibration was achieved by extrapolating to the wider portfolio the PD calibration results using the Portfolio Assessment Tool designed by Oliver Wyman. The tool relies on data sourced and a scenarios conditions defined by the Potsdam Institute for Climate Impact Research (PIK) and the International Institute for Applied Systems Analysis (IIASA), which Barclays has not challenged as part of this exercise.

RISK ASSESSMENT RESULTS

Based on two key credit metrics (funds from operations to debt, and debt to EBITDA), four different stressed through-the-cycle PDs (TTC PDs) have been calculated: 2030 static, 2030 adaptive, 2040 static, and 2040 adaptive. For each year, the average of the static and adaptive PD has been used as the final stressed TTC PD, and these have been used as calibration points in the calibration of the entire portfolio. The observed results appear reasonable, despite the stress tests' use of conservative assumptions.

Under the "2040 - 2°C scenario", the climate stressed Exposure at Default-weighted average portfolio PD is 2.2x greater in the US and 2.3x greater in the EU relative to baseline. However, given the majority of the utilities are investment grade, stressed average PDs result in a portfolio that remains largely in the investment grade or high non-investment grade credit categories.

Barclays believes that the initial results of this experimental assessment could be further enhanced and refined with the mitigation of certain limitations faced. Some of these being: a lack of or inconsistent entity data and disclosure, reliance on relatively few credit metrics, low visibility on capital structures going forward, and the absence of assumptions on potential government subsidies as well as capacity payments. Where applicable, the case study incorporated a "most conservative view" that included fully debt-funded overnight capex aggregated to entities' baseline debt. It should also be noted that the results and conclusions reflect the content of Barclays' current portfolio, and should not be considered as a reflection of the full and wider markets in the US and in the EU.

Table 3.4: Results by segment (2°C scenario)

	HIGH CARBON INTENSITY	LOW CARBON INTENSITY
Regulated	▪ For US entities reliant on fossil-fired (especially coal) generation, substantial effort is required to shift generation mix. However, the overall transition appears manageable. ▪ Despite the assumption that carbon emissions costs are passed-through to ratepayers, sizable capex requirements stress cash flows and challenge credit quality. ▪ Segment is irrelevant in the EU since regulated utilities are pure transmission and distribution entities, with no or negligible generation capacity.	▪ Credit metrics for US power generators deteriorate more acutely relative to unregulated low-carbon peers due to a lower share of renewable generation capacity. ▪ Climate related transition risks are very limited on pure transmission & distribution entities. ▪ Transition from centralized to distributed generation will urge substantial capital investment in network development and adaptation. This will increase their regulatory asset base, subsequently positively impact earnings and cash flows, thus credit metrics.
Unregulated	▪ In the 2020s, US and EU utilities in this category who do not adjust their generation mix benefit from higher power price forecast, and fuel cost declines driven by lower demand. ▪ Such entities eventually suffer in the 2030s as carbon costs cause significant parts of their generation capacity to become uncompetitive (pushed out of merit order). ▪ However, debt required to accommodate entities that decide to transition sooner is later compensated by their future ability to grow along market. ▪ Requirement to achieve four-fifths renewable output by 2040 significantly stresses financial metrics, potentially causing a handful of entities to face significant financial difficulties under this conservative scenario.	▪ Such entities appear to be favorably positioned as stress applied to their PD is mostly manageable. ▪ Entities deemed likely to grow sales along market show credit metrics deteriorating slightly more than peers due to capex-related stress required to accommodate additional capacity needed to meet demand.

CONCLUSION

The benefits of this methodology include the early identification of entities "at risk" that could benefit from further engagement and support. Its flexibility allows future development of the calibration exercise, to stress a more comprehensive set of metrics and allow more granular analysis.

The project was a good example of cross-team collaboration, involving colleagues from a range of business units and support functions, including and not limited to: (i) government relations, citizenship, sustainability; (ii) environmental risk; (iii) credit risk; (iv) portfolio management; (v) stress testing; (vi) data and reporting; (vii) quantitative analysis; and (viii) relationship coverage.

Data challenges occur both internally and externally. The required credit portfolio metrics take time to extract from internal systems. In addition, use of a "most conservative view" under the adaptive scenario was taken to maintain a degree of consistency while minimising arbitrary assumptions. The quality of the stress tests run would also be significantly improved if the utilities were to disclose standardised climate relevant risks and data, e.g. current generation mix, the expiry date of the licenses of their nuclear capacity, etc. This coincides with the TCFDs recommendations for a standardised framework to promote alignment and consistency for climate-related financial disclosures.

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BANK #2 CASE STUDY: METALS & MINING

To pilot a scenario-based assessment of transition risk, one Bank brought together relevant modellers, analysts, and credit professionals. The various teams were drawn together from their separate industry disciplines to provide appropriate subject-matter expertise, reflecting the importance of the pilot and to support the UNEP FI Working Group

PORTFOLIO SEGMENTATION

This Bank categorized its metals & mining portfolio into a total of nine segments, in line with industry classification codes: black coal mining; copper ore mining; gold ore mining; iron ore mining; nickel ore mining; other metal ore mining; mineral sand mining; alumina manufacturing; and iron and steel manufacturing. The sample size represents more than 60% of the bank's exposure at default and risk-weighted assets within its mining and metals portfolio.

SEGMENT SENSITIVITIES

Leveraging the expertise of its technical directors, this bank determined the degree of impact that each of the four risk factor pathways would have on each of the segments. The four factors are:

Table 3.5: Segment sensitivity to risk factor

SEGMENTS	RISK FACTOR PATHWAYS			
	DIRECT EMISSIONS COSTS	INDIRECT EMISSIONS COSTS	LOW-CARBON CAPEX	REVENUE
Black coal mining	Moderately high	Moderately high	Moderately high	High
Copper ore mining	Moderately low	Moderate	Moderate	Moderately high
Gold ore mining	Moderately low	Moderate	Moderate	Moderate
Iron ore mining	Moderate	Moderately high	Moderate	Moderately low
Metal ore mining N.E.C.	Moderately low	Moderate	Moderate	Moderate
Mineral sand mining	Low	Moderately low	Moderate	Moderate
Nickel ore mining	Moderately low	Moderate	Moderate	Moderately high
Alumina production	High	High	High	Moderately high
Basic iron & steel manufacturing	High	High	High	Moderately high

CALIBRATION RESULTS

Table 3.6: Segment sensitivity to risk factor

Tier 1	Tier 2	Tier 3
Investment Grade (IG)	**Strong Sub-IG**	**Weak Sub-IG**
BBB- and above	**BBB- to BB**	**Below BB**

- Tier 1: No change from current PDs for the predicted 2030/2040 PDs for groups BBB- and above (**Investment Grade**). This segment is considered to have high resilience to climate change.
- Tier 2: One notch downgrade from current PDs for the predicted 2030/2040 PDs for groups below BBB- to BB (**Strong Sub-Investment Grade**). This segment is considered to have moderate resilience to climate change.
- Tier 3: Two notch downgrade from current PDs for the predicted 2030/2040 PDs for groups below BB (**Weak Sub-Investment Grade**). This segment is considered to have low 'resilience' to climate change.
- Thermal Coal: An additional one notch was added to reflect the higher level of disruption customers are likely to experience in this industry. Lower resilience to climate change relative to other industries.

IMPACT ON CREDITWORTHINESS OF BORROWERS

The loss impact on the black coal sector is driven by the thermal segment as compared to the metallurgical segment. For non-coal segments the impact on losses are on average 2.0 to 2.5x lower than for the coal segments. The PD profile by segment over the stress horizon increases on average between 1.4 to 2.0x by 2040.

OVERALL INSIGHTS FROM THE MODEL

Modelled outcomes reinforced the requirement for a subjective assessment that considers the attitude of the companies' management towards climate change and actions being taken by the customers in response to climate change risk.

The project is a good first step to facilitate further conversations with our customers about climate change risk and opportunities. We would expect the model inputs and calibration to evolve over time to include more sophisticated assessment of how our customers may respond to these risks and opportunities.

BANK #3 CASE STUDY:
OIL & GAS IN THE UNITED STATES

PORTFOLIO

One of the banks in the Working Group conducted the analysis using a sample of oil and gas exploration and production companies in its U.S. reserves-based lending (RBL) portfolio. The RBL sub-sector within oil and gas was selected because this sub-sector is particularly sensitive to changes in price and demand.

The bank segmented the portfolio into three sub-segments – conventional, shale, and offshore. Generally, US shale has slightly higher production costs than conventional and offshore has the highest production costs. Shale companies accounted for over half of the companies in the portfolio and a big majority of the bank's exposure, while offshore companies accounted for only a small fraction of its portfolio and exposure.

SCENARIO IMPACTS

Scenario analysis is not a forecast of the future, but a tool to help navigate a high degree of complexity and uncertainty. Using scenario-analysis as an effective tool in the context of climate change requires conceiving of and testing scenarios representing very different pathways to get to the same outcome – limiting global warming to 2°C or 1.5°C. By testing different pathways to get to the same temperature target, a bank can understand the range of potential impacts on a given sector and its credit ratings. It can identify and hence start monitoring the most important drivers of potential impact. This bank's testing results in the oil and gas sector are a good illustration of how scenario analysis can reveal the range of conceivable future outcomes:

In this specific case the bank used the REMIND model's 2°C and 1.5°C scenarios. These scenarios describe a particularly strong reduction in the use of coal as the pathway to achieving 2°C and 1.5°C respectively. Under the assumptions of these scenarios, oil and gas serve as short-term substitute fuels as the world quickly transitions away from coal. In addition, demand for transportation grows rapidly and oil is assumed to remain an important transport fuel that is not easily substituted in the short-term. Consequently, under this particular 2°C scenario, US oil demand would increase between 2020 and 2030 and only start to fall between 2030 and 2040. As a result, under these assumptions, credit ratings for oil and gas explorers and producers in this US portfolio would not be affected and there would be no increased risk of default. Testing different conceivable pathways to staying within a 2°C warming limit that rely less on coal reduction the bank would potentially see stronger impacts on oil and gas companies' credit ratings as the demand for oil and gas would need to decrease more to achieve the same temperature target.

Differentiating between conventional, shale, and offshore companies, particularly under the 1.5°C coal-reduction focused scenario, more cost efficient oil and gas producers are expected to be in a stronger position to weather the changes.

In a 1.5°C scenario, offshore companies, which have the highest operating costs, would potentially see a one notch downgrade in the 2020-2030 period. Between 2030 and 2040 demand for oil and gas would then fall much more sharply and the price differential between the 1.5°C and the 4°C baseline scenarios would widen. In 2040, under this scenario the bank would expect to see credit rating changes primarily for shale players and offshore companies. Shale and offshore oil and gas tend to have higher production costs than conventional oil and gas companies, which make them more sensitive to reductions in price and demand.

4. TRANSITION OPPORTUNITIES: EXPLORING AN INSTITUTIONAL STRATEGY

While a 2°C transition could elevate credit risks for banks, it could also present opportunities to further serve clients. For example, products and services that have a lower emissions profile or contribute to greenhouse gas reductions could become more competitive, increasing financing demand. Such opportunities might include investment in energy efficiency technologies, new energy generation and production sources, low-emissions products and services, or low-carbon infrastructure. Not only could banks position themselves to meet the growing demand for low-carbon corporate lending in such segments, but they could also help clients from more carbon-intensive industries adapt to the new environment.

The TCFD recognizes this dynamic by recommending that banks not only use scenarios to analyse transition-related risk, but also to assess these opportunities. Yet assessment of transition-related opportunities requires a different tack from risk assessment. Assessment of opportunities, like any strategy assessment, is more than a quantitative or statistical exercise; it needs to consider both qualitative and quantitative elements regarding future market and competitive landscape, as well as internal capabilities.

Transition scenarios can provide a guidepost for strategic planning intended to help identify potential low-carbon market opportunities. Note, in this section, opportunities are defined narrowly, in line with the scope of this exercise, as the increased demand for corporate lending driven by additional low-carbon investment under a transition scenario. However, a similar framework can be used for opportunities outside of corporate lending.

The ultimate goal is to compare market assessment and internal bank capabilities side-by-side to determine the most promising areas for banks.

The following pages provide early thinking on a three-part proposed approach:

- First, the attractiveness of the market for low-carbon investment in particular segments and sectors is assessed
- Second, bank capabilities are assessed to determine which high-potential low-carbon segments are most aligned with bank strengths
- Finally, capabilities and the market assessment are compared to identify the strategies required for banks to capture opportunities

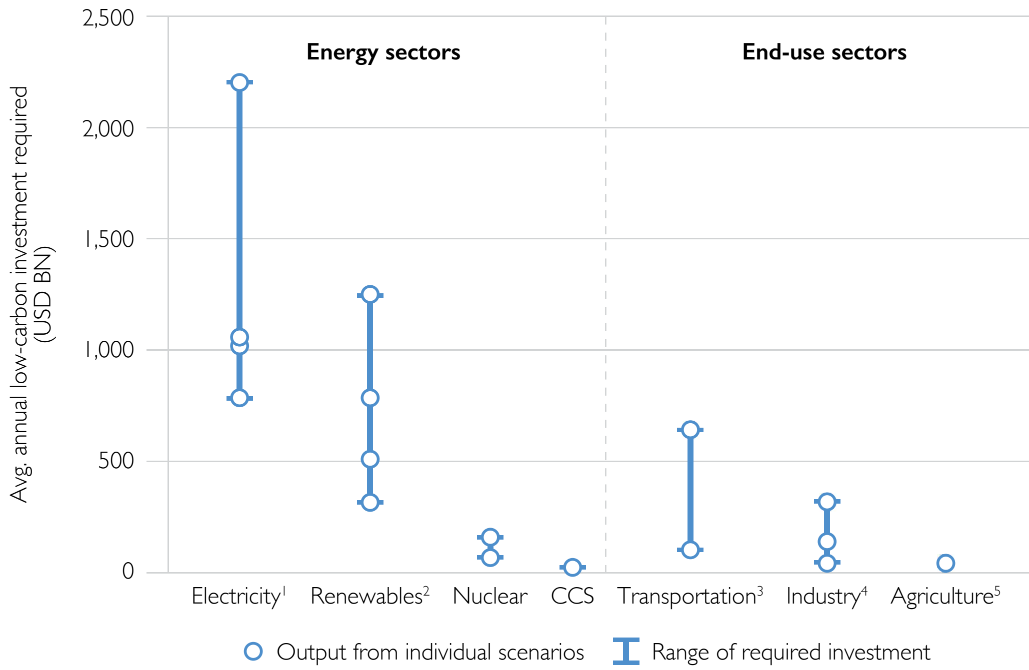
4.1. ASSESSING THE MARKET

4.1.1. Grounding opportunity assessments in scenario analysis

Scenarios can be leveraged to understand the ranges of investment potentially required to realize a low-carbon transition. Since assumptions vary across scenario models, no single scenario is meant to definitively predict how a low-carbon future will materialize. Yet, in aggregate, scenarios provide a useful foundation for analysing the relative growth of lending markets across sectors, time periods, technologies, and geographies, based on an analysis of plausible futures.

Many scenarios identify the capital investment required to meet transition temperature targets. Aggregating these estimates across a range of commonly used scenario sources can provide a high-level picture of how investment markets might evolve in a 2°C scenario as seen in Figure 4.1.

Figure 4.1: Average annual world investment by sector for a 2°C transition



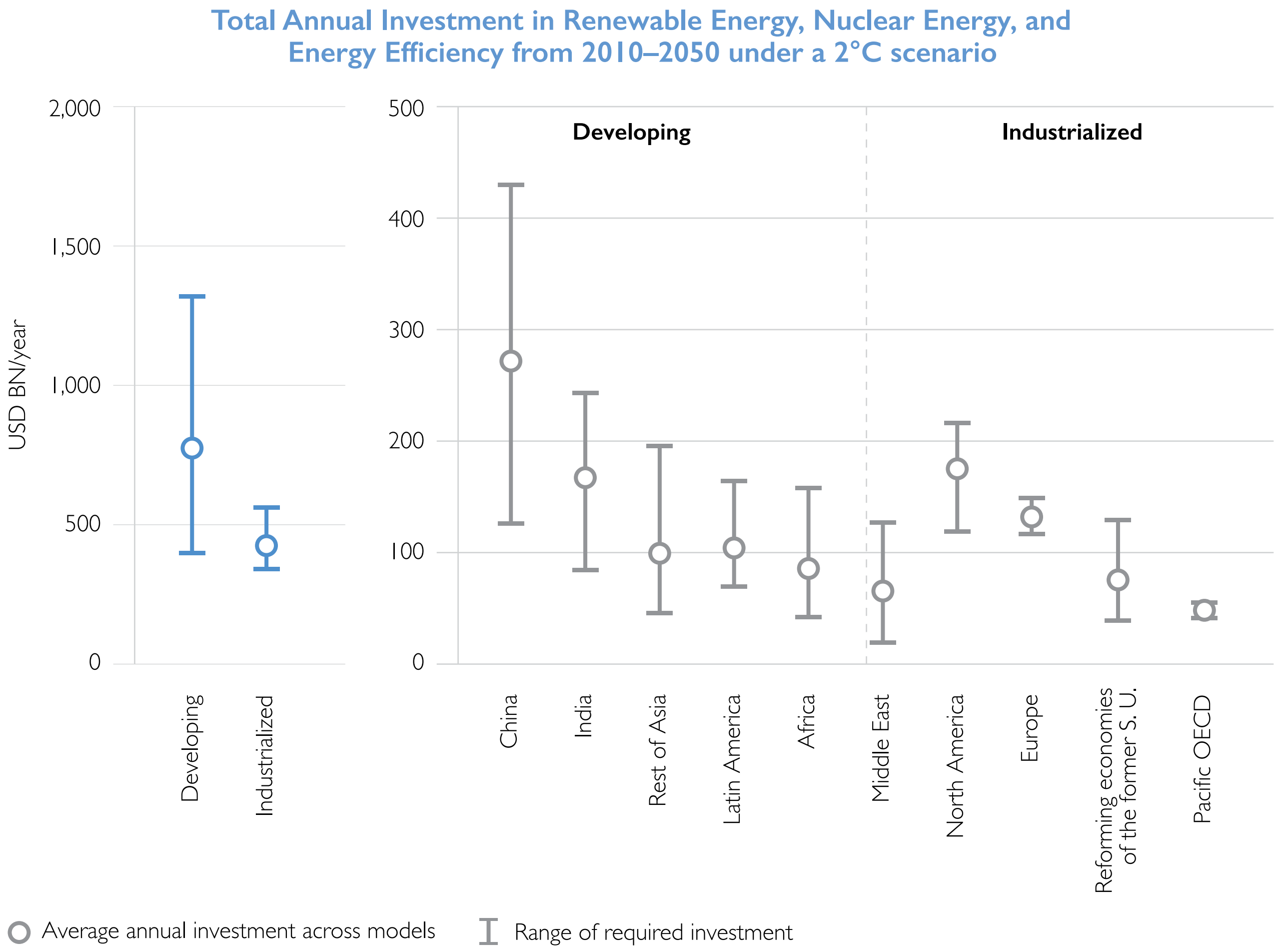
1. Includes both low-carbon (e.g. renewable) power generation and non-low-carbon infrastructure
2. Non-biomass renewables subset of electricity and low-carbon energy supply
3. Includes efficiency and EV investment
4. Includes efficiency and investment in on-site combustion retrofits
5. Includes agriculture and forestry

Source: Potsdam Institute for Climate Impact Research and International Institute for Applied Systems Analysis (CD-LINKS scenarios); International Energy Agency, "World Energy Outlook: 2017"; IEA, "Energy Technology Perspectives, 2015"; UNFCCC, "Investment and financial flows to address climate change," 2007; Oliver Wyman research and analysis.

Policy, technology, and market assumptions can differ substantially across scenarios, and even when these drivers are harmonized, investments across models and sectors may differ markedly (see Figure 4.2).[26] But scenarios help get a sense, at a high level, of the investment needs across sectors. For instance, more investment will be required in renewables than in nuclear and CCS technologies to achieve a 2°C transition. Similarly, in non-energy sectors, scenarios frequently identify incremental transportation investment needs that exceed those of industrial processes, and agriculture.

26 Figure reproduced with permission from McCollum D, et al, "Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals," (forthcoming).

Figure 4.2: Global average annual energy investments by category from 2016 to 2050 according to six global IAMs run in the CD-LINKS project.



Source: McCollum D, et al, "Energy investments under climate policy: A comparison of global models," Climate Change Economics, Vol 4, No. 4, (2013).

Scenarios are also a good source for understanding relative regional investment requirements. One such analysis across five different integrated assessment models demonstrates the potential range of regional investment required under a single 2°C transition scenario that assumes reference policies from the baseline scenario through 2020 and then a globally harmonized carbon price thereafter. Though regional investments range widely, investments across developing markets are consistently higher than in industrialized regions.[27]

27 McCollum D, et al, "Energy investments under climate policy: A comparison of global models," Climate Change Economics, Vol 4, No. 4, (2013).

Additional uses of scenarios for opportunities assessment are also possible. Identifying the incremental investment required to meet more rigorous mitigation targets, for example, will help determine the sensitivity of sector investment demand to transition ambitions. Comparison of scenarios across various transition timeframes could surface market timing considerations.

Analysing scenarios, however, only gets banks part of the way toward developing an actionable strategy to capture transition-related opportunities. Some of these limitations are data-related. Scenario comparisons can be imprecise, limited by inconsistencies in sector and geographic definitions. Many outputs of scenario models are also unpublished.

Most importantly, such scenarios ultimately have limited utility for answering the most pressing bank questions in setting a low-carbon investment strategy. Namely, most scenarios can neither tell banks what segments and industries within a sector will require more investment in a low-carbon transition, or which future is likely to materialize. Scenarios offer a starting, order of magnitude assessment of sector-level investment needs, but further analysis is required to make this information useful.

4.1.2. Assessing segment market attractiveness

To develop a valuable transition-related opportunities assessment, banks can identify the most likely winners from a low-carbon transition at a level of granularity relevant for decision-making. Each industry is likely to contain winners and losers, and competition can often occur within a given industry and region. Market analysis will need to be conducted at a more granular level than scenario models allow to appropriately target companies; once identified, specialized expertise will be required for banks to capture these opportunities.

Under this proposed framework, banks use a scorecard approach to assess the attractiveness of each segment within a given target geography. This approach identifies the "best bets" for future investment, qualitatively assessing each segment's relationship to the major drivers of low-carbon market size and the ability of banks to capture that market. A scorecard approach provides a simple assessment before forming a go-to-market strategy, without overburdening banks with quantitative analysis.

In the market assessment, banks should consider two key drivers: the segment's response to policy, and technology evolution. For policy, banks should identify whether likely policies could disrupt the segment's target market, causing increases in demand for lending. Such demand might increase due to either increased consumption of a segment's products or a need to retrofit existing technology to comply with emergent regulations. In terms of technology, banks should evaluate whether the product being offered within the particular segment offers a compelling solution to transition challenges.

Such an analysis is expected to be largely qualitative, supported by guiding questions and informed by analysis of scenarios as well as additional sources. In Figure 4.3 some suggested guiding questions for conducting this analysis, and potential sources of additional information to support it, are provided.

Figure 4.3: Market opportunities assessment – Scorecard (illustrative)

DRIVER	EVALUATION CRITERIA	GUIDING QUESTIONS	INDICATORS	EXAMPLE ASSESSMENT
Policy impact	Will future policies have a meaningful impact on the segment's potential market? ▪ **H** – High positive impact on segment's potential market ▪ **M** – Moderate positive impact on segment's potential market ▪ **L** – Low or adverse impact on segment's potential market	Is the segment's industry likely to be adversely affected by carbon costs?	▪ Industry carbon intensity	
		Is the segment's industry likely to be a target of specific regulations, e.g. efficiency or emissions cap, regulations?	▪ Policy announcements ▪ Country strategic plans	
		Is the segment likely to receive subsidies?		
		Does the segment export to other geographies where policies might expand markets?	▪ Export data ▪ Export country policies	
Technology evolution and relative performance	Will the segment's product be a competitive solution to transition challenges? ▪ **H** – Highly competitive solution ▪ **M** – Moderate increases in demand ▪ **L** – Low increase or decline in demand	Does the segment produce a product or technology that could substitute for adversely impacted technologies?	▪ Market and product analysis	
		Do other low carbon segments compete directly with this segment?	▪ Market technology scan	
		Is the product's market likely to become highly fragmented, or consolidated by particular players?	▪ Market concentration ▪ Intellectual property and patents	
		Is the segment cost competitive with carbon-intensive alternatives?	▪ Cost and/or price differentials	

Source: Oliver Wyman

The above assessment guide helps point out potentially attractive segments. For example, an analysis of the Wind Independent Power Producer (IPP) segment in India might reveal promising features. Using the questions above, banks might identify the potential for further policy-related disruption in the electricity sector based on emerging policies like the "Generation Based Incentive Mechanism". Wind IPP companies in India could offer a highly cost-competitive solution with government support. Market fragmentation might make selecting particular winners difficult, however, requiring a strong level of due diligence.

Throughout, this analysis is partly informed by scenarios and scenario models. Scenario outputs sometimes capture more detailed interactions between competing technologies, for example, which may help inform judgments about segment attractiveness. Additionally, when constructing scenarios, modellers rely on experts who make judgments about policy and technology fundamentals. Specific scenario technology and policy inputs often reflect leading research into underlying economic and political environments. Where possible and warranted, such inputs might be leveraged to help make conclusions about relative segment attractiveness.

Scenarios may also aid with triage. Given the higher level of effort required for segment- and geography-specific market assessment, banks may wish to focus initially on areas where scenarios identify consistently high investment demand at a regional and sector level.

4.2. IDENTIFYING BANK CAPABILITIES

Yet market size is not enough to make opportunities actionable; banks also need to consider their ability to capture those markets. To gain a deeper understanding of which segments are actually within an institution's grasp, banks require an individualized assessment of their own capabilities.

A second scorecard, focused on bank capabilities, accompanies segment-level market assessment. This scorecard should focus on the three major drivers of banks' potential market share: the competitive landscape, their risk appetite, and their operational capacity. An example scorecard, which identifies potential sources of information and guiding qualitative questions for analysis is shown in Figure 4.4.

Figure 4.4: Bank capabilities assessment – Scorecard (illustrative)

DRIVER	EVALUATION CRITERIA	GUIDING QUESTIONS	INDICATORS	EXAMPLE ASSESSMENT
Competitive landscape	Is the bank in a strong position in the segment relative to other players in the market? ▪ H – Bank is competitively positioned to be a market leader ▪ M – Bank is positioned to keep pace with others in the industry ▪ L – Bank faces significant challenges to competing with others in the market	What is the bank market share in the segment?	▪ Market share vs. competition ▪ Competitive research	
		How fragmented is the market within the segment? How mobile is the competitor structure (e.g. newcomers)?		
Risk appetite	Is the segment's risk profile aligned with the bank's risk appetite? ▪ H – Segment is in strongly aligned with bank objectives ▪ M – Segment is loosely aligned with bank objectives ▪ L – Segment is misaligned with bank objectives	What is the expected evolution of the risk profile (e.g. evolution of the probability of default) of the segment?	▪ Segment historical performance ▪ Transition risk analysis	
		Is the future segment's risk profile aligned with the bank's risk appetite?	▪ Risk appetite statement	
Operational capacity	Does the bank have the tools and expertise to act on the segment opportunity? ▪ H – Bank has currently available internal resources and experts ▪ M – Bank does not have currently available resources, but predicts the ability to acquire necessary resources ▪ L – Bank does not currently have nor will be able to acquire necessary resources	Is the bank active in parts of the investment ecosystem adjacent to the segment?	▪ Review of bank capabilities ▪ Size of investment team	
		Does the bank have talent capacity to onboard new clients in the segment? Does the bank have specialized expertise among RMs, investment team to cover the segment?		
		Does the bank have excess financial capacity to extend capital to others in the segment?		
		Does the bank have a sufficiently advanced and functional data environment to assess and serve the segment?		

Source: Oliver Wyman

When assessing the **competitive landscape**, banks can consider whether their institution already has leading edge relative to other lenders, whether there is an opening for increased involvement due to market fragmentation, and whether there are barriers posed to market entry or scale. This assessment should give a sense of the current and future market position of the bank relative to its immediate competition.

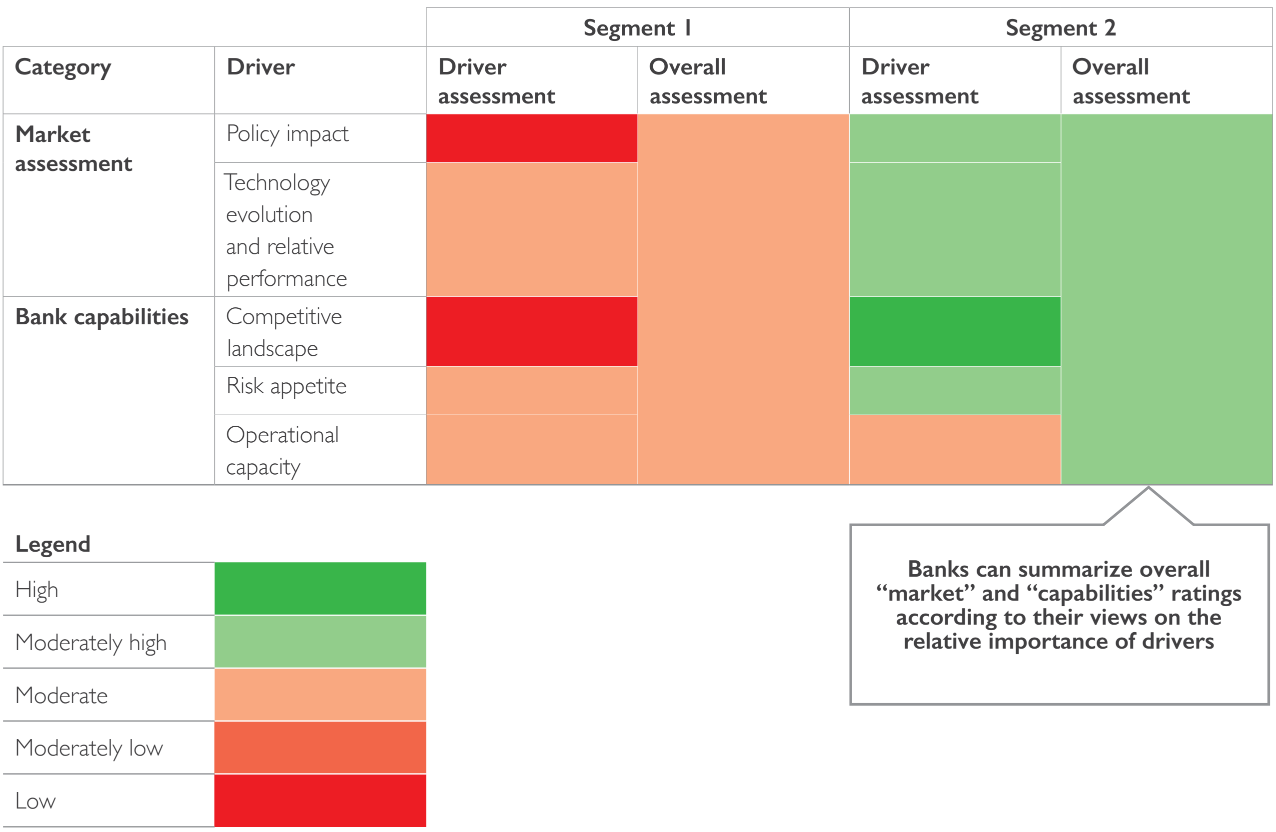
Pursuing the segment should also be aligned with the bank's **risk appetite**. Here, the transition risk analysis described extensively in Chapters 2 and 3 provides a further linkage to scenario analysis. A segment with investment market potential might nonetheless have an unattractive risk profile. For example, carbon capture and storage based lending might be directed to the fossil generation-focused utilities market, which could increase in risk under a transition scenario. Or companies in a segment could be too small or too young for bank lending. The risk profile coming out of scenario-based transition risk analysis should be compared to the bank's risk appetite statement to determine whether investment in the segment is aligned to bank interests.

Finally, banks should consider their **operational capacity** to capture the segment opportunity. Data, talent and expertise, and financial bandwidth are all fundamental for being able to capture markets. Operational capacity assessments can help identify if the bank would need to make substantial additional resources or strategic investments to realize particularly attractive opportunities.

4.3. SURFACING THE HIGHEST POTENTIAL OPPORTUNITIES

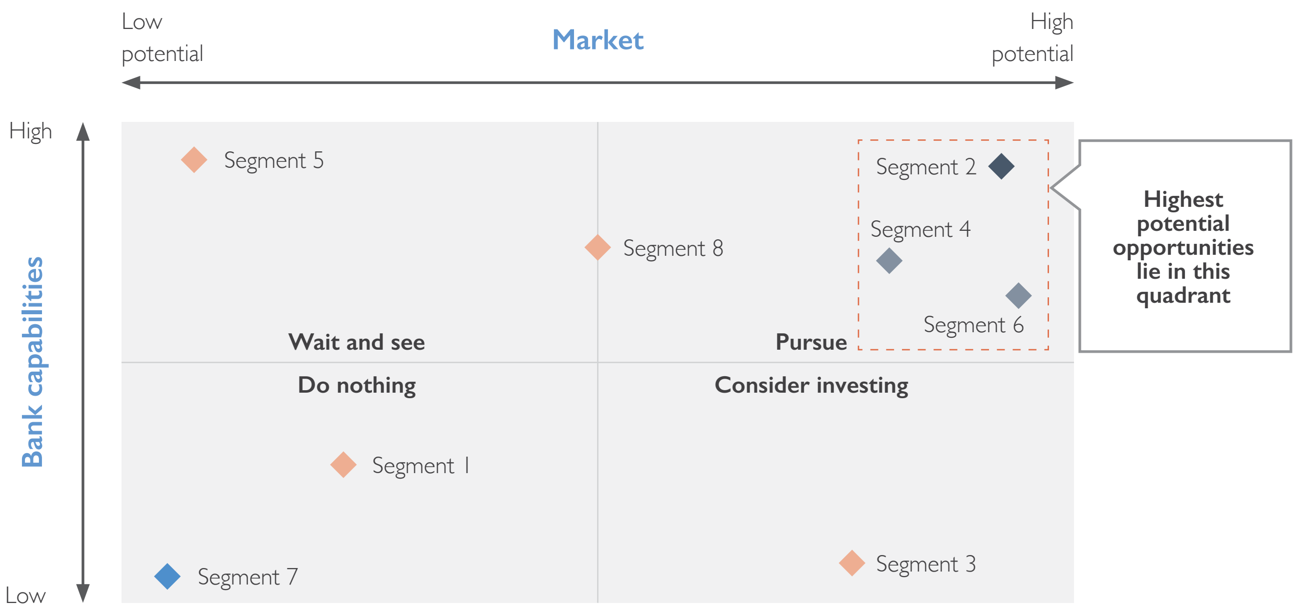
Viewing market opportunities and capabilities side-by-side can form the basis for a strategic discussion on opportunity identification. Comparing these two scorecards, alongside qualitative and quantitative information surfaced during the analysis, can yield a more complete understanding of segment-specific opportunities. Impacts might be compared at a specific "driver" level, or rolled up into high-level assessments of the capabilities and market scorecards as shown in Figure 4.5.

Figure 4.5: Illustrative comparison of scorecard results



Banks can also use this comparison to create a two-dimensional chart comparing market opportunities and bank capabilities across two axes. Plotting results of the segment analysis can help to provide high-level guidance on bank strategic action as shown in Figure 4.6.

Figure 4.6: Illustrative snapshot analysis of bank capabilities and market assessment



As seen in this figure, results from the scorecard assessment suggest potential bank strategies. For segments that both excel in their market potential and bank's ability to capture them, shown in the upper right quadrant, banks might choose intentional pursuit or increased investment. For segments that lag in capabilities, but show good market potential, banks will likely weigh carefully the need for internal investments to make market opportunities feasible. Conversely, where bank capabilities are substantial, but the market shows currently low potential of developing, a strategy of watching and waiting to determine how the market plays out, or even staged divestment, may be prudent. Finally, where both capabilities and market potential are low, banks may choose the status-quo.

This strategic analysis should be seen as the beginning of a broader discussion. It provides structure to a strategic discussion around expansion in a low-carbon world, either by lending to the winners of the low-carbon transition or by helping clients adapt to the low-carbon economy. But it is only the starting point for deeper bank due diligence and strategic planning.

The transition to a low-carbon economy will without doubt lead to a reconfiguration in lending opportunities. Under a transition scenario, some markets will even more rapidly expand than forecasted at present. Leading banks may choose to position themselves to not only lie at the cutting edge of that change, but also drive it through increased financing to certain segments. Additionally, banks can play an instrumental role in helping their long-term clients, especially from the carbon-intensive industries, adapt to the new environment. The approach to assessing opportunities suggested in this chapter could provide a launching point for those discussions.

5. FUTURE DIRECTIONS: DEVELOPING THE NEXT GENERATION OF TRANSITION RISK ANALYSIS

This transition risk methodology is envisioned as the first foundational step in an evolving process of creating best practice transition scenario risk analysis. It provides a foundation for transition risk analysis by outlining a systematic, consistent, and repeatable framework, while taking advantage of both climate research and bank credit and sector expertise. Throughout, the framework allows flexibility to incorporate expert judgement, detailed borrower-level financial analysis, and alternative scenarios.

Yet this first step is just the beginning of a longer and iterative journey that needs to further incorporate practical lessons learned through implementation of the framework. Over the course of this work, several avenues for future development were identified. In this final section, a vision for the future generation of transition risk analysis is outlined through four key ideas.

Idea 1: Building out climate scenario models to support financial risk analysis

Most publicly available scenarios are primarily intended for a different purpose from financial risk assessment. The most sophisticated scenario models, such as the ones assessed in IPCC reports are intended as energy-economy-climate models with policy and research applications. As a result, critical outputs for financial analysis are often unpublished or unavailable.

Over the course of the methodology development process, significant advancements were made toward building a bridge between the scenario modelling practices of the scientific community and the credit risk analysis practices of the financial sector. During this process, scenario modellers worked with financial system experts to develop a risk interpretation of their scenarios, while also expressing interest in continuing this work in future generations. In particular, specific sector-level variables were extracted from scenario models in order to inform risk assessment across different economic scenarios.

This process also highlighted a number of areas for future development, further discussed in Box 3, which include: improved model granularity, ex post calculations to generate new financial risk variables, and redesign of model reporting to track additional sector variables. Ultimately, this work would help to improve granularity of the risk factor pathways (both in terms of geographies and sectors) and reduce reliance on assumptions and expert judgment. For example, transition scenario models are currently largely focused on the energy sector but there are limited variables relevant to end-use sectors. Therefore the revenue risk factor pathways for end-use sectors rely on assumptions and require alternative sources (see Appendix A). In the future, scenario models may be able to provide a more comprehensive set of variables relevant for financial analysis. Similarly, scenario models generally operate at either 5- or 10-year time steps; but modelling one-year or intra-year time steps is a possibility for the next generation of models, especially early in the scenario (e.g. from today to 2030).

One example area of enhancement would be to provide additional information on the size and scale of the modelled segments over time, that when combined existing outputs used to estimate changes in costs and revenues for sectors, would help to evaluate the corresponding materiality of cost and revenue impacts. This added detail could help to enhance model calibration and reduce reliance on expert judgement.

Over the course of this pilot, the group did not identify a unique "right" set of policy, technology, and market input assumptions for stress testing bank portfolios. No perfect scenario exists that completely meets the financial sector's needs. In the future, additional collaboration with modellers could also yield a richer set of scenario-based policy and technology stressors that banks could use to examine their individual vulnerabilities to transition risk. For instance, banks could run short- term, event-based scenarios such as a sudden policy change or a technological breakthrough or an overshoot scenario, in which CO2 concentrations or temperatures temporarily exceed target levels before being reduced, leaving less time for companies to adapt.

Idea 2: Developing data and analytics for borrower-level climate risk analysis

The borrower-level calibration exercise is a time-intensive but important component of the transition risk methodology; it also has the greatest potential for further enhancement. Such enhancements should focus on creation of granular borrower-level data to better evaluate climate-related impacts, and the advancement of analytics that translate scenarios into borrower-level impacts.

In terms of borrower-level risk assessment, the underwriting process offers an opportunity to request and analyse additional climate-related information from borrowers, especially as corporates start to implement the TCFD recommendations. This additional information could include energy-use mix, carbon emissions, low-carbon investment, and other variables relevant for borrower-level risk assessment. Such variables would be helpful:

- To inform underwriting decisions
- To refine and tailor the assessment of the scenario on borrower-level credit risk (e.g. PD)

Additionally, as banks continue to work with the methodology, best practice analytics will emerge for assessing the link between scenario outputs and borrower-level credit risk across various industry segments. For example, for some segments there may be enough scenario information and borrower data to incorporate scenario impacts through credit rating models and evaluate the impact on credit risk. In other areas, qualitative judgment based approaches may continue to be required though firms may develop better process, governance and review and challenge to get the best answer. The best techniques will differ across segments and likely across financial institutions.

Idea 3: Methodology enhancements to the portfolio impact assessment

The methodology used in the portfolio impact assessment module borrows from the latest set of approaches that financial institutions have used for credit portfolio modelling and for macro-economic stress testing. It applies these concepts in the context of climate change and calibrates the approach through borrower-level analysis. While the methodology is grounded in the now common Merton-model framework of credit risk assessment, there are a number of simplifications and estimated parameters that were used in this initial version to minimize complexities, to make the approach understandable to a range of stakeholders, and to facilitate initial piloting. Some technical areas for potential further development and review include:

- Refinement of the quantitative techniques for solving calibration parameters including the error minimization function
- Refinement to sensitivity constraints and range of viable values for sensitivities
- Review of the requirements for segment calibration including number and type of required calibration examples
- Consideration of alternative techniques and parameters for evaluation of the cumulative impact of the risk factors over long-term scenario horizons
- Incorporation of scenario conditional rating migration pathways into loss forecasts
- Enhancements to parameter segmentation to reflect learnings about climate risk sensitivities

As institutions pilot and implement the approach, we anticipate continued review and refinement across these technical elements of the methodology.

Idea 4: Integration of transition risk assessment in the organization

The methodology outlined in this document provides for scenario-based assessment of transition risk. However, institutions need to go beyond risk assessment and disclosure to properly manage transition risks. As climate risks materialize, institutions would benefit from their broader incorporation into a range of business management and risk management processes at financial institutions. While specifics may differ across institutions depending on particular profiles, potential examples of areas for integration include:

- Integration across other risk measurement processes including physical risk
- Embedding into risk identification processes
- Incorporation of climate risk considerations in underwriting and credit rating processes
- Consideration of climate-related limits and exposure monitoring
- Climate risk-related portfolio management and structuring
- Consideration within business planning and strategic planning

* * *

These ideas for enhancements point to a future where transition risk analysis becomes mainstream as a cornerstone of the risk analyst's toolkit. Through this project, banks have built the foundations of this future, where rigorous tools and approaches are brought together and applied to the challenge of transition risk assessment; and where transition risk is elevated as a strategic concern. To build on these foundations, senior engagement from the organizations will be required: climate risk will need to become a bank-wide, senior management and board-level priority.

COMING SOON FROM ACCLIMATISE: AN APPROACH FOR ASSESSING PHYSICAL CLIMATE-RELATED RISKS AND OPPORTUNITIES

By Acclimatise

Introduction

Regardless of the success and rate at which global greenhouse gas emissions are controlled, some man-made climate change is locked into the earth's climate system over coming decades, and changes are already underway. Physical risk, one of the two pillars of climate-related risk addressed by the TCFD, is the risk resulting from climate variability, extreme events, and longer-term shifts in climate patterns which are already underway. For banks, physical risks could manifest in a variety of ways that can eventually impact the financial health of their borrowers, and the credit risk in their lending portfolios.

Climate change can also present opportunities for the clients to which banks lend. Some clients will need additional investment to undertake actions that increase their climate resilience. This, in turn, leads to lending opportunities for banks. Further, an expanding and global market is developing for climate-related products and services, and companies, such as engineering and technology providers, are identifying opportunities to capitalise on the shifting market trends. For banks, this can translate into opportunities to do more business.

To support banks to consider the physical risks and opportunities of climate change to their loan portfolios, a sector-based methodology is being developed and tested with the sixteen banks involved in the pilot project. This section provides an outlook of the methodology, with full details being published in a report focused on physical risk and opportunity in summer 2018.

The assessment of sectors' and companies' performance, incorporating changing climate risk exposures at the level of banks' portfolios, is novel and innovative. As such, the pilot project has identified areas for further development to improve future assessments in line with the TCFD recommendations. These include, amongst others:

- Banks' lack of location-specific data on their borrowers' facilities and operations,
- A lack of published research linking climate change impacts on sectors to borrower financial performance and company credit risk.

Sectors addressed in pilot project for physical risk and opportunity

The impacts of a changing climate will affect commercial and retail borrowers. Many economic sectors and businesses face a changing risk landscape, from Small and Medium Enterprises (SMEs) to multi-national corporations. The degree to which any sector is vulnerable to climate change depends on its level of climate sensitivity. Four sectors were chosen to pilot the physical risk methodology, due to their high climate sensitivity and materiality within banks' lending portfolios. These sectors are characterised by their reliance on physical assets, complex value chains or natural assets. Table 6.1 presents the sectors and sub-sectors included in the pilot project, along with a summary of key physical risks facing borrowers in these sectors. In the physical risk methodology, these risks are framed in terms of potential financial impacts on borrowers, and related potential impacts on the credit risk in banks' lending portfolios.

Table 6.1: Sectors covered by the methodology and the key physical risk banks' borrowers in these sectors may face

SECTOR	SUBSECTOR	KEY PHYSICAL RISKS
Energy	Oil and gas	Physical damage and downtime from extreme events (e.g. tropical cyclones impacting offshore assets) Changes in production/output from incremental changes in climate (e.g. rising temperatures causing loss of output from Liquified Natural Gas (LNG) facilities and refineries)
	Power utilities (power generation, power transmission)	Physical damage and downtime from extreme events (e.g. wildfires impacting power transmissions lines) Changes in production/output from incremental changes in climate (e.g. changing rainfall patterns affecting hydropower generation) and extreme events (e.g. drought impacting the availability of cooling water for thermal power production)
Transport	Infrastructure (ports)	Physical damage and downtime from extreme events (e.g. storm surge impacting port infrastructure) Changes in production/output from incremental changes in climate (e.g. climate-driven changes in agricultural production and consequently trade flows through ports)
Agriculture	Crop production Animal husbandry Forestry/timber production	Changes in production/output from incremental changes in climate (e.g. warmer temperatures, changing rainfall patterns affecting crop yields) and extreme events (e.g. extreme temperatures impacting livestock)
Real estate	Retail mortgages Commercial property	Physical damage and change in property value from extreme events (e.g. flooding affecting homes)

Key components of the physical risk methodology

The physical risk methodology explores a range of potential climate futures out to 2040, representing different global climate change mitigation ambitions. In the near-term and mid-term, changes in climate due to past and present-day greenhouse gas emissions are already locked into the climate system, and the physical risks are already being felt. However, over the longer-term the degree of physical risk faced by borrowers is partly determined by which emissions trajectory is followed. To explore a range of potential climate futures, the methodology assesses physical risks for two scenarios:[28] 2°C and 4°C (the latter being the current trajectory based on present-day emissions), corresponding to Representative Concentration Pathways (RCPs) 2.6 and 8.5 respectively. The timescales covered by the assessment go out to 2040.

The methodology considers the impacts on borrowers' financial health of extreme (acute) climate-related events and incremental (chronic) climate change. The impacts of extreme events on borrowers are typically framed in terms of asset damage and downtime. The impacts of incremental climate change, such as gradual shifts in temperatures and rainfall patterns, can lead to changes in output/production. These performance metrics can be positive (e.g. increases in output) or negative (e.g. more downtime) and can affect borrowers' revenues and costs. These changes in borrower financial performance, in turn, can potentially affect the credit risk in banks' lending portfolios.

Insurance is a key consideration in assessing borrower exposure to extreme events. Insurance can mitigate climate risks to borrowers. However, the influence of a changing climate on the insurance market is multifaceted and complex. In the future, insurers may increase insurance premiums and/or introduce caveats as risks increase, or withdraw cover all together for some types of event in some locations. The methodology aims to explore how these future scenarios could play out.

28 Change in global average temperature by 2100 relative to the pre-industrial era

Key components of the physical opportunities framework

The TCFD reports describe "climate-related opportunity" as "the potential positive impacts related to climate change on an organization". At present, there are no agreed methodologies for identifying and assessing opportunities arising from, and in response to, the physical impacts of a changing climate. Working with the sixteen banks, the pilot project is developing a framework for assessing these opportunities and their potential impact on lending portfolios.

A taxonomy of climate-related opportunities can assist banks in understanding the potential investment needs of their clients, and the role of banks in providing investment for climate resilience. This is not an area which has been extensively researched and there are very few published examples which speak directly to the interests of the financial services sector. The pilot project is developing a taxonomy of opportunities relevant to banks.

Market analysis data for banks exploring the demand and timescale for capital driven by the impacts of a changing climate is not readily available. Most of the available analysis has been published by international development banks and development partners, or by governments in national and sectoral climate change risk assessments and adaptation plans. In the pilot project, the framework explores how such information can be used to assess opportunities, although the limitations will require banks to rely on judgements and assumptions.

Capital requirements to meet the challenges of a changing climate will vary across sectors and will be influenced by global, regional and national market conditions, and by policy and regulatory drivers. The framework recognizes the variations and uncertainties in these factors, and the need for banks to assess future impacts on their business by sectors and markets, rather than at an aggregated, business or economy-wide level.

Opportunities will depend on banks' specific strategies and business models. A generic, top-down analysis of opportunities will not capture the specific portfolio profiles of each bank and the bank's own assessment of the scale and value of these opportunities. The framework assists banks in identifying those opportunities, which should be evaluated consistent with their internal strategies and procedures. Assessment of the opportunities should incorporate the views of sectoral experts within a bank and reflect its capacity to respond to changes in market conditions.

APPENDIX A: GENERATING THE RISK FACTOR PATHWAYS

Risk factor pathway calculations rely directly on transition scenario model outputs. During the pilot, risk factor pathways for 2°C and 1.5°C scenarios based on the Integrated Assessment Models REMIND and MESSAGE were developed.[29] Risk factor pathways are derived for fourteen sectors, across energy, end-use sectors, and agriculture and forestry for ten geographies.[30]

Table 7.1 provides a definition of the sectors used in this piloting process. Both modelling frameworks used employ a soft-coupling of an energy-economy model (REMIND and MESSAGE) with a land use model (MAgPIE and GLOBIOM, respectively).

Table 7.1: Sector definitions

SECTOR		DEFINITION
Energy	Oil and gas	Upstream oil and gas industries (e.g. production, extraction, conversion, transportation)
	Oil	Upstream oil economic industries (e.g. production, extraction, conversion, transportation)
	Gas	Upstream gas industries (e.g. production, extraction, conversion, transportation)
	Coal	Upstream coal production industries (e.g. coal mining)
	Renewables	Renewables generation industries (e.g. independent power producers; may also be used to indirectly proxy for renewables manufacturing and installation)
	Electricity	Electric utility generation, transmission, distribution and storage industries
	Energy	All supply-side energy industries
End-use	Industrial processes	All manufacturing and industrial production industries (e.g. metals and mining, other than coal)
	Transportation	All transportation services industries (e.g. freight, passenger services)
	Residential and commercial buildings	All residential and commercial buildings industries
Agriculture and forestry	Crops	All cropping production industries
	Livestock	All livestock production industries
	Forestry	All timber and forestry-related industries
	Agriculture and forestry	Crops, livestock and forestry related industries

Table 7.2 provides details on how the risk factor pathways are calculated for these sectors.

29 Similar risk factor pathways could be developed based on the data from the IEA's World Energy Outlook or from other scientific integrated assessment models (e.g., WITCH, AIM/CGE, IMAGE, GCAM, POLES)

30 Extensive documentation for these and other integrated assessment models can be found at the following site: themasites.pbl.nl/models/advance/index.php/ADVANCE_wiki.

Table 7.2: Risk factor pathways calculations

<table>
<tr><th>CATEGORY</th><th>SECTOR</th><th>DIRECT EMISSIONS COST</th><th>INDIRECT EMISSIONS COST</th><th>LOW-CARBON CAPITAL EXPENDITURE</th><th>REVENUE</th></tr>
<tr><td rowspan="7">Energy</td><td>Oil and gas</td><td rowspan="3">Product of emissions and carbon pricing, by energy source</td><td rowspan="5">Not applicable</td><td rowspan="4">Not captured</td><td rowspan="7">Product of price and demand, by energy source</td></tr>
<tr><td>Oil</td></tr>
<tr><td>Gas</td></tr>
<tr><td>Coal</td><td rowspan="7">Product of emissions and carbon pricing, by energy source</td></tr>
<tr><td>Renewables</td><td>All renewables investment</td></tr>
<tr><td>Electricity</td><td>Product of fuel demand and price, by fuel type</td><td>All non-thermal technology investment and CCS</td></tr>
<tr><td>Energy</td><td>Not applicable</td><td>All energy supply side investment</td></tr>
<tr><td rowspan="3">End-use</td><td>Industrial processes</td><td rowspan="3">Product of sector energy demand and price</td><td rowspan="3">Energy efficiency and other low carbon investment</td><td rowspan="3">Sector-specific revenue (derived from incremental costs and price elasticity assumption)</td></tr>
<tr><td>Transportation</td></tr>
<tr><td>Residential and commercial buildings</td></tr>
<tr><td rowspan="4">Agriculture and forestry</td><td>Crops</td><td rowspan="2">Product of carbon-equivalent methane and nitrous oxide emissions and carbon price</td><td>Not captured</td><td rowspan="3">Annual investment, derived from supplementary scenario source</td><td>Product of non-energy crop price and demand</td></tr>
<tr><td>Livestock</td><td>Product of crop feed and price</td><td>Product of livestock price and demand</td></tr>
<tr><td>Forestry</td><td>Not captured</td><td>Not captured</td><td>Revenue from lumber and sequestration through international scheme</td></tr>
<tr><td>Agriculture and forestry</td><td colspan="4">Sum of crops, livestock, and forestry</td></tr>
</table>

	Directly calculated from the climate variables (no or minor assumptions required)
	Requires additional assumptions based on external sources
	Not applicable or not captured

Source: Oliver Wyman

As can be seen in Figure 5.2, the transition risk models provide a comprehensive coverage of the energy sector. However, for end-use and agriculture and forestry sectors, fewer relevant variables were provided by the models during the pilot project, especially with regards to low-carbon investment and revenue. In these cases, additional assumptions were made based on external sources. Assumptions were derived from foremost sources of data (including IPCC Annex 1 emissions, the Food and Agriculture Organization of the United Nation's international prices, UNFCCC Investment and Financial Flows, and the IEA World Energy Outlook 2017) and vetted with the scenario modellers.

Each available risk factor pathway was calculated across 10 geographies. Table 7.3 lists the regions used throughout the piloting process, based on common regional aggregations used within the integrated assessment modelling community.

Table 7.3: Regional definitions

REGION	COUNTRIES
OECD 1990 countries, EU members and candidates	Albania, Australia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Fiji, Finland, France, French Polynesia, Germany, Greece, Guam, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, Malta, Macedonia, Montenegro, Netherlands, New Caledonia, New Zealand, Norway, Poland, Portugal, Romania, Samoa, Serbia, Slovakia, Slovenia, Solomon Islands, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States of America, Vanuatu
Reforming economies of the Soviet Union	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan
Asian countries, excepting the Middle East, Japan, and Former Soviet Union states	Afghanistan, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, China Hong Kong SAR, China Macao SAR, Democratic People's Republic of Korea, East Timor, India, Indonesia, Lao People's Democratic Republic, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Singapore, Sri Lanka, Taiwan, Thailand, Viet Nam
Middle East and Africa	Algeria, Angola, Bahrain, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Cote d'Ivoire, Democratic Republic of the Congo, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kenya, Kuwait, Lebanon, Lesotho, Liberia, Libyan Arab Jamahiriya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Oman, Qatar, Reunion, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Syrian Arab Republic, Togo, Tunisia, Uganda, United Arab Emirates, United Republic of Tanzania, Western Sahara, Yemen, Zambia, Zimbabwe
Latin America	Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Suriname, Trinidad and Tobago, Uruguay, Venezuela
World	All countries
People's Republic of China	People's Republic of China
India	India
United States of America	United States of America
European Union 28	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

Source: Adaptation of Merton framework to climate risk

APPENDIX B
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