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OFFICE OF THE SUPERINTENDENT OF FINANCIAL INSTITUTIONS

Using Scenario Analysis to Assess Climate Transition Risk

Final Report of the BoC-OSFI Climate Scenario Analysis Pilot

Contents

1. Executive summary

- **The Bank of Canada and the Office of the Superintendent of Financial Institutions (OSFI) completed their climate scenario analysis pilot in collaboration with six Canadian federally regulated financial institutions**. The pilot has fully met its goals of (i) building the capability of authorities and participating financial institutions to do climate transition scenario analysis, (ii) supporting the Canadian financial sector in improving its assessment and disclosure of climate-related risks and (iii) contributing to the understanding of the potential exposure of the financial sector to climate transition risk. Furthermore, it has improved authorities' understanding of financial institutions' governance and risk management practices around climate-related risks and opportunities.
- **Scenario analysis is a useful tool for identifying potential risks in an environment of considerable uncertainty.** Climate transition risks are challenging to assess accurately given the long time horizons with high uncertainty about how policy, technology and socio-economic factors might evolve. Scenario analysis provides a flexible "what-if" framework to explore how the risks may manifest in the future.
- **In line with the objectives of the pilot, the Bank has developed a set of global climate transition scenarios to capture a range of risk outcomes that could be stressful to the Canadian economy and the financial system.** The climate transition scenarios are not meant to be forecasts or comprehensive. Rather, they explore different plausible but intentionally adverse transition pathways consistent with achieving specific climate targets.
- **The scenarios vary in terms of the ambition and timing of global climate policy and the pace of technological change.** They are consistent with global commitments of limiting global warming to below 2°C and rely conservatively on negative emissions technologies. In the scenarios, the transition relies on significant structural change at the industry level and not simply on hypothetical technological progress.
- **The scenarios describe a number of potential material risks to the economy and the financial system**. The analysis illustrated the important sectoral restructuring that the Canadian and global economies may need to undertake to meet climate targets. The analysis showed that every sector contributes to the transition and that the financial impacts vary across sectors. These impacts depend on how the sectors are affected by emissions and capital expenditures costs and on how the

demand for their products is affected by decarbonizing of economies. The scenarios also shed light on the risks of significant macroeconomic impacts, in particular for commodity-exporting countries like Canada. The economic impacts for Canada are driven mostly by declines in global prices of commodities brought by changes in global climate policy. Finally, the analysis showed that delaying climate policy action increases the overall economic impacts and risks to financial stability.

- **Using the scenarios, the pilot participants analyzed climate transition–related credit and market risks to selected elements of their asset portfolios**. The analysis focused mostly on the financial institutions' Canadian and US exposures and covered the 10 most emissions-intensive sectors in the economy, including agriculture, primary energy, electricity, energy-intensive industries and transportation.
- **The assessment of credit risk used a methodology that combines top-down and bottom-up approaches**. Borrower-level assessments by the financial institutions, using sectoral-level financial impacts based on the scenarios, capture nuances from the bottom up, while our top-down portfolio impact assessment extrapolates these borrower-level impacts to portfolio segments.
- **Pilot participants revealed that the bottom-up exercise helped them identify data gaps, explore new methodologies and develop a deeper understanding and awareness of the impacts of the climate transition on their portfolios. Participants also noted that the exercise required significantly more time and resources than they expected**. **Furthermore, the bottom-up approach highlighted some limitations and methodological challenges, raising potential issues of consistency and comparability that must be addressed in future exercises**. A common message we heard from a broad range of financial institutions was that there is a need to develop and standardize methodologies for climate risk assessment and to improve the availability of climate-related data.
- **From the authorities' perspective, the bottom-up component of the credit risk analysis provided better insight into the participants' methods and capabilities**. It also allowed authorities to address some existing data gaps. In particular, we provide estimates of the relationship between climate transition and credit risk using the financial institutions' borrower-level data and risk assessment expertise. While the estimated relationship is generally in the right direction, questions remain about the magnitude and robustness of some estimates.

- **The pilot project used a top-down approach to assess market risk**. Using financial data from the scenarios and a discounted dividend model, the authorities estimated the impacts on equity valuation at the sectoral level for each country/region along the alternative climate transition paths. The analysis showed decreases in equity valuations in the fossil-fuel sectors, while the electricity sector experienced gains. Also, the analysis suggested that delayed or sudden climate policy action could pose greater risks of financial market dislocation.
- **As part of the project, we surveyed the pilot participants on their governance and risk management practices and questioned a broader range of Canadian financial institutions on the level of preparedness for the analysis of climate-related risks**. We found that financial institutions are generally in the early stages of building climate-related risk assessment capabilities for transition risks, including the use of climate scenario analysis. The pilot participants recognized that efforts to mitigate and adapt to climate change can produce opportunities for organizations while managing their climate-related risks. All six pilot participants are also committed to enhancing their climate-related disclosure to align with the recommendations of the Financial Stability Board’s Task Force on Climate-related Financial Disclosure.
- **This pilot project represents an important foundational step in a longer path to understand and assess climate-related risks to the macroeconomy and the financial system**. The Bank and OSFI remain committed to better understanding and assessing climate-related risks to the Canadian economy and financial system and to supporting financial institutions in building their capacity for climate-related risk assessment and management.

2. Introduction

In November 2020, the Bank of Canada and the Office of the Superintendent of Financial Institutions (OSFI) jointly launched a climate scenario analysis pilot to better understand the risks to the financial system that could arise from a transition to a low-carbon economy.[1] The project involved the collaboration of six Canadian federally regulated financial institutions (FRFIs), including two banks, two life insurers and two property and casualty insurers.[2]

2.1 Pilot objectives

The objectives of the pilot were to:

- build the capabilities of authorities and financial institutions in climate scenario analysis and help the Canadian financial sector improve its assessment and disclosure of climate-related risks;
- increase understanding of the financial sector's potential exposure to a range of risks that may come with a transition to a low-carbon economy; and
- improve authorities' understanding of financial institutions' governance and risk management practices around climate-related risks and opportunities.

It is important to note that the project was not a climate stress-testing or a capital adequacy prudential exercise. Given that the practice of modelling climate-related risks is in its infancy, our hope is that this pilot supports the financial sector's own efforts to assess and disclose climate-related transition risk by developing resources and building capacity.

To this end, the Bank developed a set of intentionally adverse climate transition scenarios to guide the pilot analysis and support the scenario analysis efforts of other Canadian financial institutions. The Bank and OSFI are providing details on the

1 The Bank and OSFI are among the central banks and supervisors leading the use of climate scenario analysis, together with the Banque de France/Autorité de Contrôle Prudentiel et de Résolution, the Bank of England and a few others. At least 31 members of the Network of Central Banks and Supervisors for Greening of the Financial System (NGFS), of which the Bank of Canada is part, are currently conducting or planning similar exercises. For a case study of these exercises see NGFS, *Scenarios in Action: A Progress Report on Global Supervisory and Central Bank Climate Scenario Exercises* (October 2021).

2 The six FRFIs participating in the scenario analysis pilot were the Co-operators Group Limited, Intact Financial Corporation, Manulife Financial Corporation, Royal Bank of Canada, Sun Life Financial and TD Bank Group. These six FRFIs are also referred to as the "pilot participants" in this report.

methodologies used in this pilot to assess climate-related financial risk and sharing lessons learned to inform and support the broader financial sector going forward. Later in the report, we also discuss the results of a survey OSFI conducted that looked at current governance and risk management practices of the six Canadian FRFIs who participated in the scenario analysis study. We hope that sharing this information will provide insight into the pilot participants' governance and risk management practices around climate-related risks and opportunities.

Furthermore, as part of the lessons learned, we present the results of an additional questionnaire OSFI gave to a broad range of financial sector stakeholders. This exercise was designed to examine the feasibility and challenges of broader adoption of the pilot's methodological approaches. The questionnaire also looked at how prepared financial institutions are to assess climate-related transition risk.

This final report is accompanied by the release of two technical papers. The first is a Bank of Canada staff discussion paper that describes in detail the development and results of the climate transition scenarios. The second is a Bank of Canada technical report that lays out the financial risk assessment methodologies used in the pilot to assess credit and market risk. We are also publishing the climate scenario data developed for this exercise.

2.2 The need to understand the impacts of climate change on the financial system

Climate change looms as a potentially large structural change affecting the economy and the financial system. Clear physical risks are associated with climate change, including increases in the global average temperature and in the frequency and severity of extreme weather events (e.g., flooding and wildfires). These could result in significant macroeconomic and financial system impacts—some of which are already being felt.

Reducing these physical risks requires global action on climate change policies supported by technological progress and socio-economic change. While these efforts to decarbonize the economies create opportunities for innovation, investment and potential green growth, they also carry economic transition risks. Sudden changes in climate policies, technology or market sentiment could lead to economic dislocation and a reassessment of the value of a variety of financial assets. A late and abrupt transition to a low-carbon economy could lead to assets suddenly losing value and a rapid repricing of climate-related risks if they are not already sufficiently priced in by market participants. In turn, this could negatively affect the balance sheets of financial market participants, with potential consequences for financial stability.

Transition risks are of particular significance for Canada given its endowment of carbon-intensive commodities, the current importance of some of these carbon-intensive sectors for the Canadian economy, and the country's unique needs as a vast northern country for heating and transportation. Timely and clear climate policy direction and the correct pricing of risks, supported by climate-related financial disclosures, contribute strongly to mitigating these risks.

Climate risks are global and economy-wide in nature, and they are complex, varying across geographies and sectors. Scenario analysis plays a key role in helping us better understand how climate factors could drive changes in the economy and financial system (see **Box 1**).

Box 1:

Importance of scenario analysis in assessing climate-related risks

Scenario analysis is useful given the high degree of uncertainty around climate change. Climate risks are challenging to assess accurately. They are global and economy-wide in nature, and they are complex, varying across geographies and sectors. In particular, climate transition risks have long time horizons with high uncertainty about how policy, technology and socio-economic factors might evolve. These distinct characteristics are not well captured by more traditional risk assessment approaches that rely on top-down modelling and historical trends, are narrowly focused and assume the structure of the economy and financial system remain unchanged.

Scenario analysis is **not meant to be a forecast**. Rather, it is the process of examining and evaluating plausible future pathways under certain conditions and assumptions. The scenarios are hypothetical and represent a range of possible "what if" future states of the world. They are not designed to provide predictions of the most likely pathway. The scenarios are intended to help us better understand how climate factors could drive changes in the economy and financial system along different possible future paths. Scenarios related to transitioning to a low-carbon economy explore different pathways for reducing emissions and their implications for the economy and financial system.

The scenarios used for the purpose of this pilot are designed to be intentionally adverse. In line with the goals of this pilot exercise, we are particularly interested in transition scenarios that have the potential to be stressful to the economy and the financial system. Section 3 will describe in detail these climate transition scenarios, including two transition scenarios aligned with the Paris Agreement commitment of limiting global warming to below 2°C that differ in the timing and pace of policy, and a scenario with a more ambitious 1.5°C, or net-zero, goal.

As recommended by leading international organizations including the Task Force on Climate-related Financial Disclosure[1] (TCFD), established by the Financial Stability Board, and the Network for Greening the Financial System[2] (NGFS), at least 31 **central banks and regulators around the world have adopted scenario analysis** to better understand the macroeconomic and financial impacts of climate change.[3]

1 See TCFD, *Final Report: Recommendations of the Task Force on Climate-Related Financial Disclosures* (June 2017).

2 See NGFS, *Guide to Climate Scenario Analysis for Central Banks and Supervisors*, Network for Greening the Financial System Technical Document (June 2020).

3 See NGFS, *Scenarios in Action: A Progress Report on Global Supervisory and Central Bank Climate Scenario Exercises*, Network for Greening the Financial System Technical Document (October 2021).

2.3 Scope of the pilot exercise

During the pilot project, participating financial institutions analyzed and assessed credit and market risk related to selected elements of their balance sheets related to the transition to a net-zero/low-carbon carbon economy. Specifically, the bank participants analyzed credit risks to their wholesale loans portfolio, while the insurers analyzed credit risk to their bonds and corporate loans portfolios and market risk to their equity portfolio.[3]

For tractability, we assumed the financial institutions' balance sheets were static (i.e., kept unchanged) as of the end of 2019. We picked that date to abstract from any effects related to the COVID-19 pandemic. Considering the dynamic evolution of the balance sheet along the transition pathway could be desirable but would pose additional challenges given the length of the time horizon. It would significantly raise the number of assumptions needed, increasing issues of consistency and comparability across financial institutions.

The analysis focused mostly on the Canadian and US exposures of participating financial institutions, with some institutions also looking at their exposures outside of North America.[4] The pilot covered the 10 most emissions-intensive sectors in the economy: crops, forestry, livestock, coal, crude oil, gas, refined oil, electricity, energy-intensive industries and commercial transportation. Together, these sectors account for approximately 68 percent of Canada's greenhouse gas emissions. We broke down some of these sectors into more granular industries or subsectors because the transition can play out very differently across each.

The total credit exposures across all six pilot participants within the scope of the exercise were Can$239.3 billion. Banks accounted for 54.8 percent of those exposures, while insurers accounted for 45.2 percent. The exposures represented 5 percent of the banks' combined total balance sheet assets and 15 percent of the insurers' combined total balance sheet assets.

Chart 1 shows the breakdown of the exposures by sector. The largest exposures are to the oil and gas (29.9 percent) and electricity (29.2 percent) sectors, followed by the commercial transportation (16.0 percent) and energy-intensive industries (13.1 percent) sectors. Combined, these four sectors account for close to 90 percent of the total credit exposures within the scope of the exercise.

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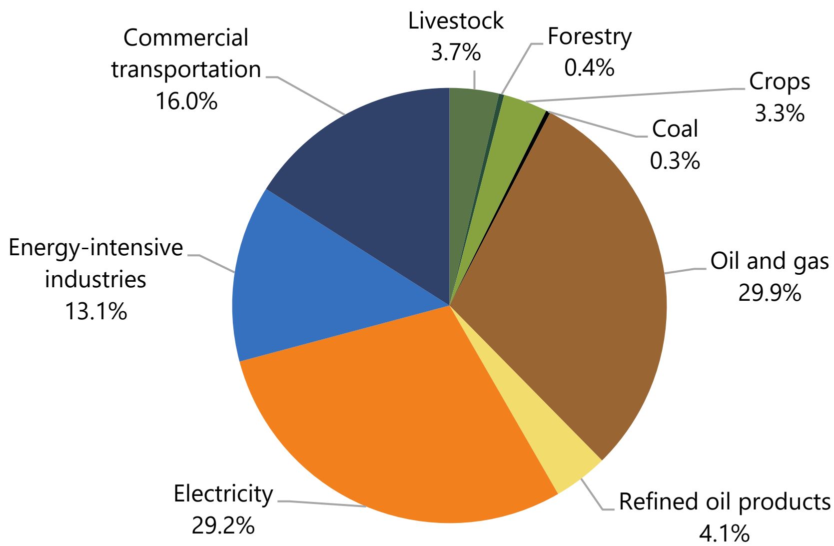
3 The analysis did not consider potential impacts on liabilities or other assets.

4 Please note that our climate scenarios are global, and although our focus is mainly on Canada and the United States, we also model the transition for other regions.

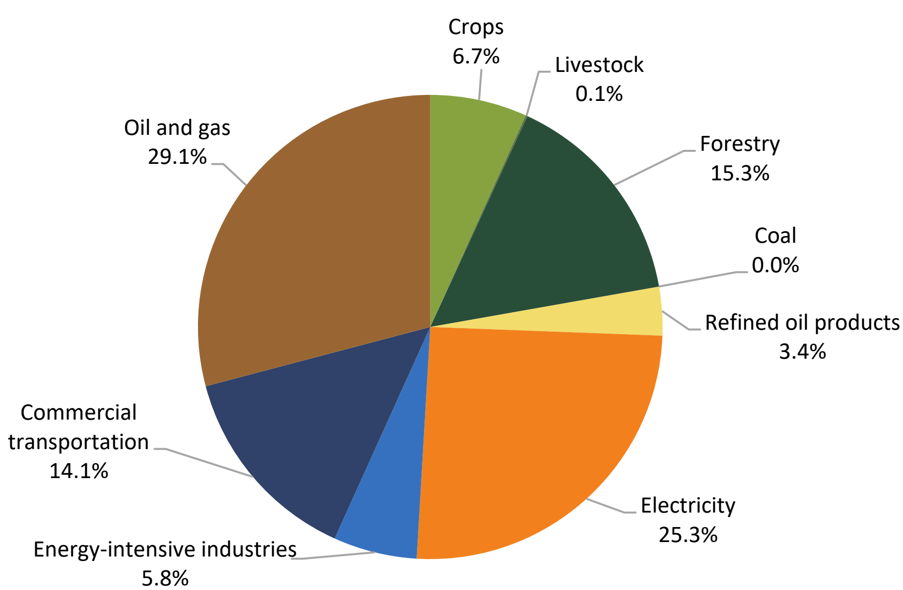
Chart 1: **Credit exposures in scope, by sector (2019)**



Note: Values may not add to 100 percent due to rounding.

The total equity exposures within the scope of the pilot exercise across the four insurers were Can$21.6 billion, representing 3 percent of their combined total balance sheet assets (see **Chart 2**). The main exposures are to the oil and gas and electricity sectors, followed by forestry and commercial transportation.

Chart 2: **Equity exposures in scope, by sector (2019)**



Note: Values may not add to 100 percent due to rounding.

3. The climate transition scenarios

3.1 Narratives and key assumptions

As stated previously, the current climate scenario pilot focused exclusively on the transition risk of climate change.[5] While it is equally important to assess the physical risks of climate change and the interaction between physical and transition risks, we have left this to future work.

To analyze climate transition risk, the Bank developed four climate scenarios over a 30-year horizon, from 2020 to 2050. The scenarios vary in terms of two key drivers of climate transition risk: first, the ambition and timing of global climate policy; and second, the pace of technological change and availability of carbon dioxide removal technologies.

The four climate scenarios are the following:[6]

- **baseline (2019 policies)**—a baseline scenario consistent with global climate policies in place at the end of 2019[7]
- **below 2°C immediate**—an immediate policy action toward limiting average global warming to below 2°C
- **below 2°C delayed**—a delayed policy action toward limiting average global warming to below 2°C
- **net-zero 2050 (1.5°C)**—a more ambitious immediate policy action scenario to limit average global warming to 1.5°C that includes current net-zero commitments by some countries

The scenarios are not meant to be forecasts or comprehensive. Rather, they explore different plausible but intentionally adverse transition pathways consistent with achieving specific climate targets. The scenarios rely conservatively on technologies that are not yet commercially available and/or could face scalability issues in the future. An overview of the scenarios and their key assumptions is presented in **Table 1**.[8]

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5 Transition risk is of significant importance to Canada, and assessing its impacts is more complex than assessing physical risk, which is better understood in risk assessment processes.

6 The latter three transition scenarios are consistent with the Paris Agreement commitment of limiting global warming to below 2°C. The 2015 Paris Agreement, signed by 195 countries, established a goal of holding the increase in global temperature within a range of 1.5–2.0°C above pre-industrial levels as well as a commitment to engage in adaptation planning and implementation. These goals were underscored by the recent Glasgow Climate Pact.

7 We chose the 2019 baseline to remove any effects related to the COVID-19 pandemic that could be confounded with the transition to a net-zero, or low-carbon, economy.

8 For a detailed description of the scenario narratives and their design, please see Y.-H. H. Chen, E. Ens, O. Gervais, H. Hosseini, C. Johnston, S. Kabaca, M. Molico, S. Paltsev, A. Proulx and A. Toktamyssov, "Transition Scenarios for Climate-Related Financial Risk Analysis," Bank of Canada Staff Discussion Paper No. 2022-1 (January 2022).

Table 1: Narratives and key assumptions of the scenarios

Scenario	Climate policy ambition and timing	Technological change
Baseline (2019 policies)	• The world follows a path consistent with climate policies in place at the end of 2019, implying a continued rise in emissions and an increase in average global temperature in the range of 2.9–3.1°C by 2100. • Forestry continues on a global trend of being a net source of emissions through mid-century.	• The pace of technological change is slow. • The availability of carbon dioxide removal (CDR) technologies is limited.
Below 2°C immediate	• Starting in 2020, collective global action is taken to reduce emissions toward a target of below 2°C by 2100. • Early investments, planning and management allow forests to become a small net sink by mid-century.	• The pace of technological change is moderate. • The availability of CDR technologies is limited.
Below 2°C delayed	• After a decade of following 2019 policy frameworks, collective global action to align with a below 2°C target begins in 2030. A steeper transition is needed to make up for the additional decade of a continued rise in emissions.[9] • Delayed investments, planning and management prohibit forests from becoming a net sink by mid-century.	• The pace of technological change is moderate. • The availability of CDR technologies is limited.
Net-zero 2050 (1.5°C)	• Starting in 2020, collective global action is taken to reduce emissions toward a 1.5°C target. Current net-zero commitments by some countries, including Canada, are modelled directly in this scenario. • Strong early investments enable forests to become a net sink by mid-century.	• The pace of technological change is fast. • The availability of CDR technologies is moderate, including bioenergy with carbon capture and storage.

These scenario narratives and the paths for global emissions and carbon prices are well-aligned with those of the scenarios developed by the Network for Greening the Financial System (NGFS),[10] to which the Bank contributed. Building on this, the Bank developed its own scenarios for this pilot to provide economic and financial data at the relevant geographic and sectoral level of granularity to assess the exposures of Canadian financial institutions. The scenarios are global and were developed for eight regions: Canada, the United States, Europe, Africa, India, China, Japan and the rest of the World.

The baseline scenario is intended to reflect market participants' expectations about climate policy and the transition at the end of 2019. We collected and modelled the

9 Given that climate change is driven by the accumulation of emissions in the atmosphere over time, we must compensate for these additional emissions by converging to a lower path of emissions through mid-century.

10 Please refer to the NGFS Scenarios Portal for more information. The NGFS scenarios serve as a reference for many central banks and supervisors to assess climate-related risks, promoting the comparability of results across institutions and jurisdictions.

policy frameworks in place at that time across different jurisdictions, including policies like renewable energy targets, fuel efficiency standards and carbon pricing schemes. But we did not impose any additional assumptions about how policies would evolve beyond what existing frameworks outlined.

In Canada, the 2019 policy framework is based on the “with measures” scenario of Environment and Climate Change Canada, as presented in *Canada’s Fourth Biennial Report on Climate Change*.[11] Canadian climate policies in 2019 were largely a product of the Government of Canada’s Pan-Canadian Framework on Clean Growth and Climate Change, including the following non-carbon price policies: Corporate Average Fuel Economy standards for both passenger and commercial vehicles, regulations on methane emissions, renewable shares in electricity generation, and the phase-out of traditional coal-fired generation of electricity.[12] In addition, Canada’s 2019 Pan-Canadian Framework outlined a federal backstop carbon pricing scheme that increased in price through to 2023.[13]

In the transition scenarios, additional climate policy may be required beyond the explicit policies mentioned above to meet the emissions targets. We capture this through a “shadow price of carbon.” Instead of directly imposing an exogenous path of carbon prices, our modelling approach aims to reduce emissions by a predetermined amount. We do this in the following way:

- First, we incorporate the non-carbon price policies as identified above that contribute to reducing emissions.
- Then, to fully meet the predetermined emissions path, we calculate a shadow price of carbon that captures the remaining implicit government climate policy required to come up with the rest of the mitigation.

As a result of the model’s capturing of the shadow price of carbon, the scenario’s carbon price path may differ from that stated by the government.

The scenarios assume that carbon pricing schemes are revenue-neutral, where proceeds are returned as lump-sum transfers to households in the same period.[14] The carbon pricing schemes target emissions of all greenhouse gases and do not discriminate

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11 See Government of Canada, *Canada’s Fourth Biennial Report on Climate Change* (Minister of Environment and Climate Change, 2019) for more details. The report was submitted to the United Nations Framework Convention on Climate Change.

12 To see the full list of policies included under the reference scenario, see Government of Canada, *Canada’s Fourth Biennial Report on Climate Change*, Table A2.39.

13 The Canadian government has more recently introduced a plan for carbon prices to rise through to 2030, committing Canada to cut its emissions by 40–45 percent relative to 2005 levels by 2030 and to ultimately reach net zero by 2050. Please refer to *Bill C-12* for more information.

14 Assumptions on the use of carbon tax revenues can affect estimates of transition risk. For example, redirecting significant portions of carbon tax revenue to government investment that promotes green growth and lower employment taxes may mitigate the negative impacts associated with carbon taxation and high energy costs. See the Phase 2 scenarios in NGFS, *NGFS Climate Scenarios for Central Banks and Supervisors* (June 2021).

across sectors or technologies. The scenarios assume no other government policy actions intended to smooth the transition. In addition, the scenarios assume modest contributions from nature-based solutions. Emissions and removals in forestry are modelled at the country or regional level, using historical estimates from the Massachusetts Institute of Technology and other sources where necessary. We then employ exogenous projections of forest-based carbon flux from the Global Timber Model.[15]

In terms of technology, the baseline (2019 policies) scenario and the below 2°C immediate and delayed policy action scenarios assume a slow pace of technological progress. In these scenarios, industries can take full advantage of technologies that are currently commercially available (e.g., electric vehicles or carbon capture and storage with traditional fossil-fuel energy generation). But industries cannot lean on technologies that are not yet commercially available or that face scalability issues (e.g., direct air capture). Furthermore, while the cost of technologies is evolving through the transition, the scenarios do not incorporate the invention of new technologies and development of new industries. The purpose is to look at scenarios where the transition relies on significant structural change at the industry level—which is thus potentially stressful to the economy and financial system—and not simply on hypothetical technological progress.[16]

In the net-zero 2050 (1.5°C) scenario, we assume that the pace of technological change is faster than in the other scenarios.[17] Under this scenario, a moderate amount of carbon dioxide removal technology is available, including bioenergy with carbon capture and storage (BECCS).[18] The faster pace of technological progress partially eases the transition in other parts of the economy and supports the achievement of the more ambitious global climate target.[19]

The accompanying Bank of Canada staff discussion paper describes in detail the scenario design and modelling approach summarized in **Box 2**.

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15 The scenarios assume the evolution of forest-based emissions follows the projections implied from the Global Timber Model across various global climate policy scenarios. See K. G. Austin, J. S. Baker, B. L. Sohngen, C. M. Wade, A. Daigneault, S. B. Ohrel, S. Ragnauth and A. Bean, "The Economic Costs of Planting, Preserving, and Managing the World's Forests to Mitigate Climate Change," *Nature Communications* 11, no. 5946 (2020). For more information, see Chen et al. (2022).

16 The scenarios assume limited reliance on negative emissions technologies and are aligned with the assumptions of the NGFS scenarios and the scenarios prescribed by the Net-Zero Banking Alliance convened by the United Nations Environment Programme Finance Initiative.

17 The carbon pricing required to achieve the 1.5°C target creates stronger incentives to develop and adopt new technologies.

18 BECCS is a potential net negative emissions technology. It refers to the process of converting biomass to energy and capturing and storing the carbon, thereby removing it from the atmosphere.

19 Similar assumptions are made by the NGFS, the International Energy Agency and the Canadian Institute for Climate Choices under their respective net-zero scenarios. See NGFS, *NGFS Climate Scenarios*; International Energy Agency, *Net Zero by 2050: A Roadmap for the Global Energy Sector* (May 2021); and Canadian Institute for Climate Choices, *Canada's Net Zero Future: Finding Our Way in the Global Transition* (February 2021).

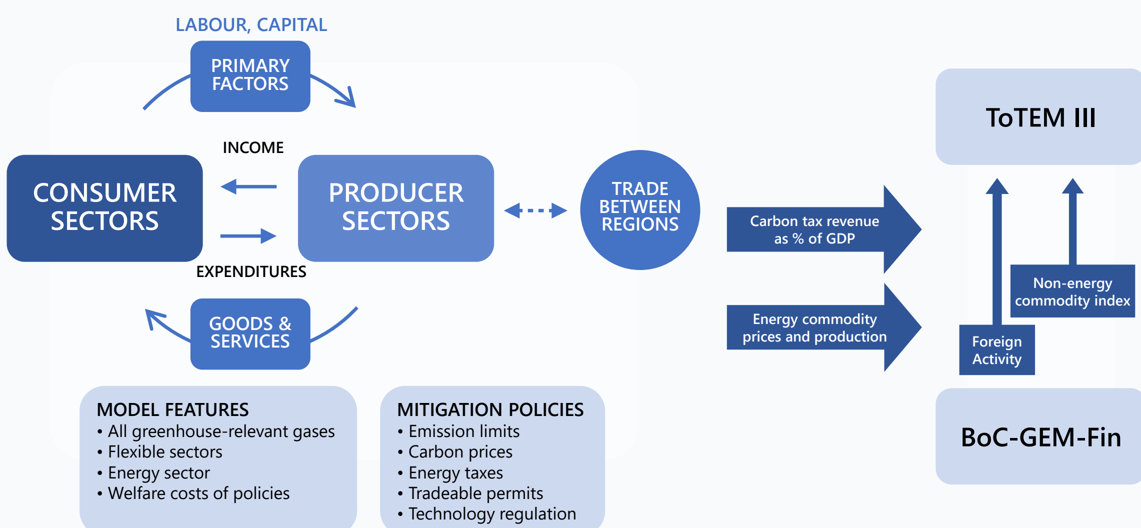
Box 2:

A suite-of-models approach

The Bank of Canada linked a computable general equilibrium energy-economy model with two macroeconomic models to develop the climate transition scenarios (see **Figure 2-A**). Recognizing the strengths and weaknesses of different models, we leaned on the comparative advantages of each model to help design the scenarios.

To develop the sectoral-level scenarios, we worked closely with the Massachusetts Institute of Technology (MIT) using its Emissions, Prediction and Policy Analysis (EPPA) model. MIT-EPPA is a recursive-dynamic multi-regional general equilibrium model of the world economy, which is built on the Global Trade Analysis Project (GTAP) dataset and additional data for greenhouse gas and urban gas emissions. The model tracks emissions as they relate to economic activity and has firms making cost-minimizing decisions over time. The MIT-EPPA model represents the world's economy across several countries or regions and sectors relevant to the Canadian financial system. In addition, the model has a rich representation of technologies (including traditional fossil fuels) as well as more advanced backstop technologies (including bioenergy with carbon capture and storage and others).

Figure 2-A: The suite of models



The MIT-EPPA model provides important information about the sectoral restructuring along the transition. This information played a key role in the assessments of market and credit risk for the sectors in the scope of this pilot exercise. However, to place the sector-level analysis in a larger macroeconomic context, we used two of the Bank's macroeconomic policy models to analyze the impact on the Canadian, US and global economies. These models are the Terms-of-Trade Economic

(continued...)

Box 2: (continued)

Model (ToTEM III), the Bank's main structural model for the Canadian economy,[1] and the Bank of Canada's Global Economy Model with Financial Frictions (BoC-GEM-Fin), a five-region model for the global economy.[2]

Both models are dynamic stochastic general equilibrium frameworks in which the behaviour of firms and households is largely micro-founded. The supply sides of both models are quite rich, with dedicated raw materials sectors responsible for producing commodities, and a variety of intermediate goods feeding into the production of final goods. This detailed supply structure makes the models useful laboratories for studying the macroeconomic effects of carbon pricing policies, which were introduced by allowing governments to impose taxes on firms' energy inputs. This specifically involves imposing tax-rate profiles on Canada and each region of BoC-GEM-FIN to match EPPA-generated paths for carbon tax revenues as a share of gross domestic product (GDP). In addition, the macroeconomic policy models took as inputs information on energy commodity markets from the MIT-EPPA model.

We emphasize that there are two-sided risks to the scenarios. For example, on the upside, the scenarios do not consider innovation in new products or services or the creation of new industries or sectors that might accompany the transition and productivity spillovers from investments in green technologies. On the downside, the macroeconomic models might fail to fully capture all the labour market adjustment costs and frictions along the transition. For instance, delayed climate action could lead to financial stress and disorderly adjustment of the economy in the short run (e.g., sharper declines in GDP and business investment as well as a rise in cyclical unemployment). We have left these issues for future work.

1 See P. Corrigan, H. Desgagnés, J. Dorich, V. Lepetyuk, W. Miyamoto and Y. Zhang, "ToTEM III: The Bank of Canada's Main DSGE Model for Projection and Policy Analysis," Bank of Canada Technical Report No. 119 (June 2021).

2 See C. De Resende and R. Lalonde, "The BoC-GEM-Fin: Banking in the Global Economy," *Bank of Canada Review* (Summer 2011): 11–21; and R. Lalonde and D. Muir, "The Bank of Canada's Version of the Global Economy Model (BoC-GEM)," Bank of Canada Technical Report No. 98 (September 2007).

3.2 Scenario highlights

Meeting emissions targets requires a rise in the shadow price of carbon (see **Chart 3**), reflecting the increased intensity of government climate policy consistent with the scenarios. The rise is nonlinear, reflecting the increasing challenges of reducing additional units of greenhouse gases.

Delayed action leads to a sharper transition. The below 2°C delayed scenario maintains the same target of limiting warming as that of the below 2°C immediate scenario, but it assumes policy actions do not intensify until 2030. Because of delayed action, emissions must fall rapidly to make up for lost time (see **Chart 4**), implying a sharper transition through mid-century. Comparing the net-zero 2050 (1.5°C) scenario with the below 2°C immediate scenario shows a front-loading of impacts in order to be consistent with the more ambitious target of limiting warming to 1.5°C.

Chart 3: Global GDP-weighted shadow carbon price

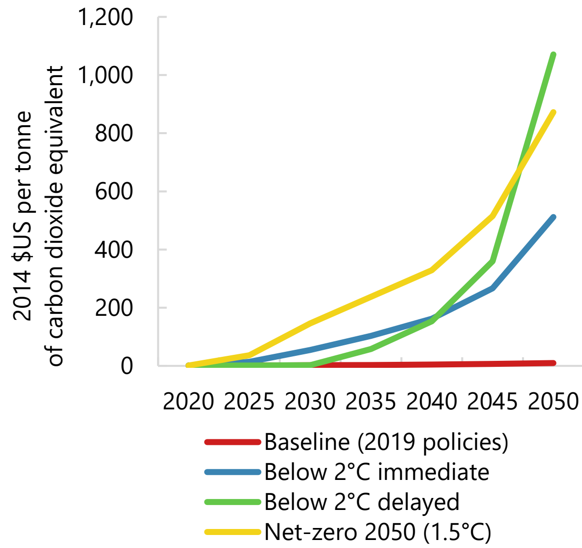
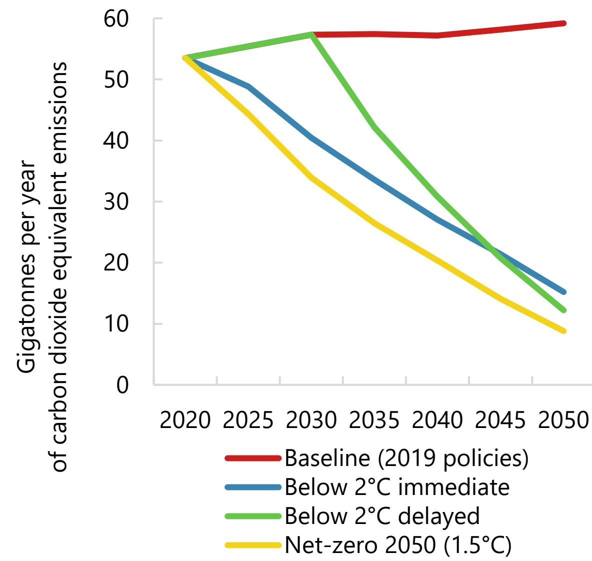


Chart 4: Global greenhouse gas emissions



A carbon price makes emissions-intensive energy commodities more expensive to consume. This higher cost acts like a negative demand shock for these commodities, pushing down the prices producers receive (see **Chart 5** and **Chart 6**). The carbon price changes the relative prices within the economy, encouraging substitution toward less emissions-intensive sources of energy.

Chart 5: Projected path for producer-received energy commodity prices
Below 2°C immediate, Canada

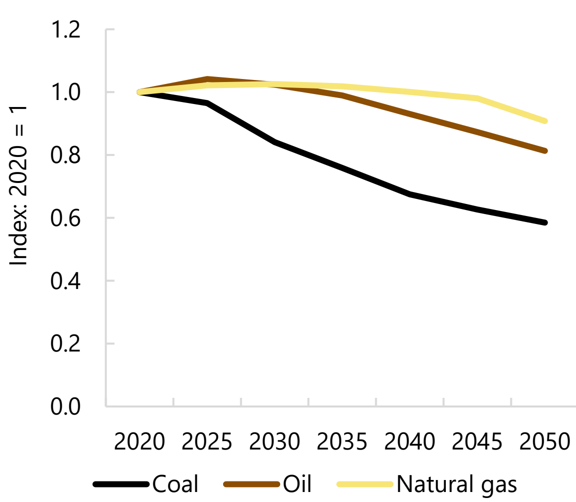
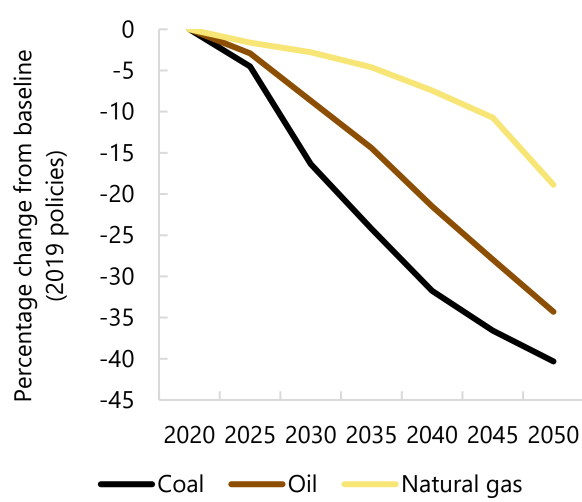


Chart 6: Change in producer-received energy commodity prices relative to baseline (2019 policies)
Below 2°C immediate, Canada

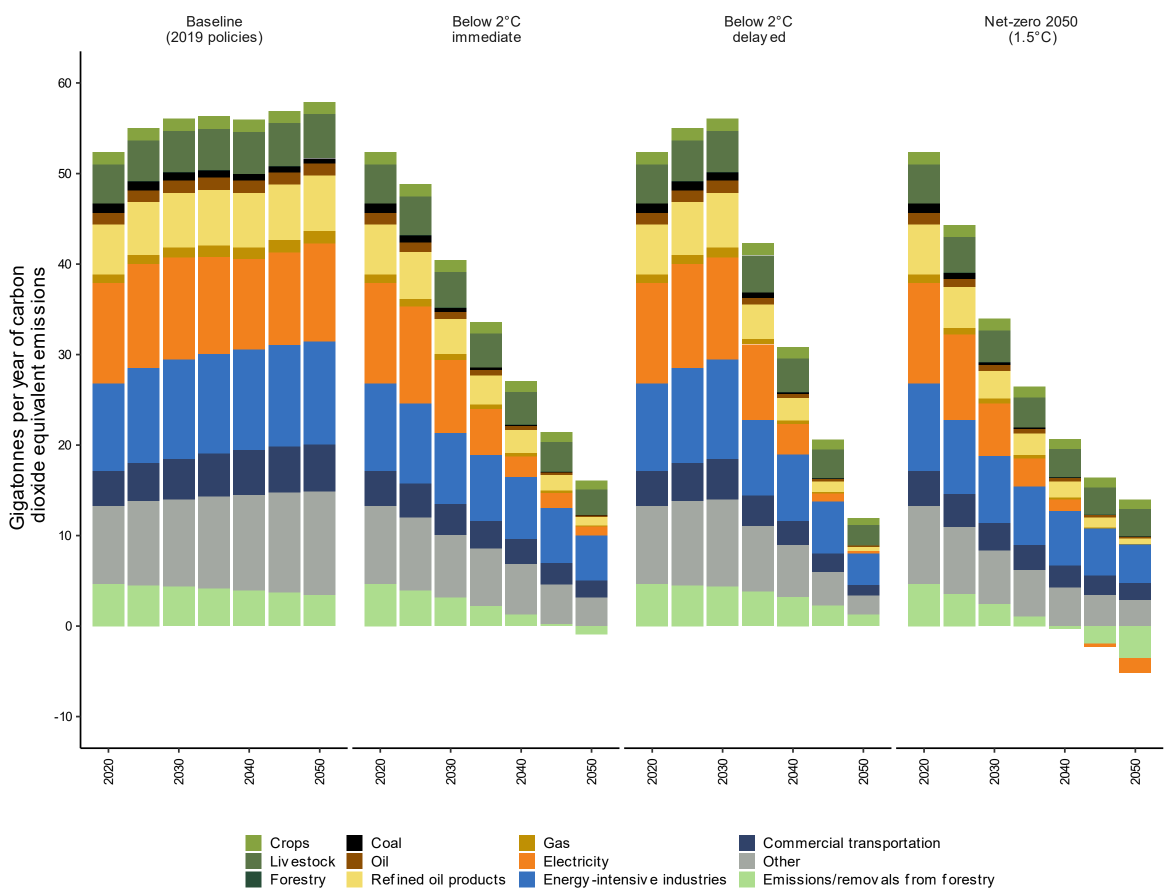


Sectoral impacts

Every sector contributes to reducing emissions to meet climate targets. The scenarios show not only sharp reductions in emissions in fossil-fuel sectors, such as coal, oil, refined oil and natural gas, but also contributions from other sectors, such as commercial transportation, energy-intensive industries, agriculture and electricity (**Chart 7**). Some sectors reduce emissions more than others, reflecting changes in the costs of fossil-fuel inputs, the availability and cost of low emissions technologies for that sector and other important sectoral differences captured in the scenarios.

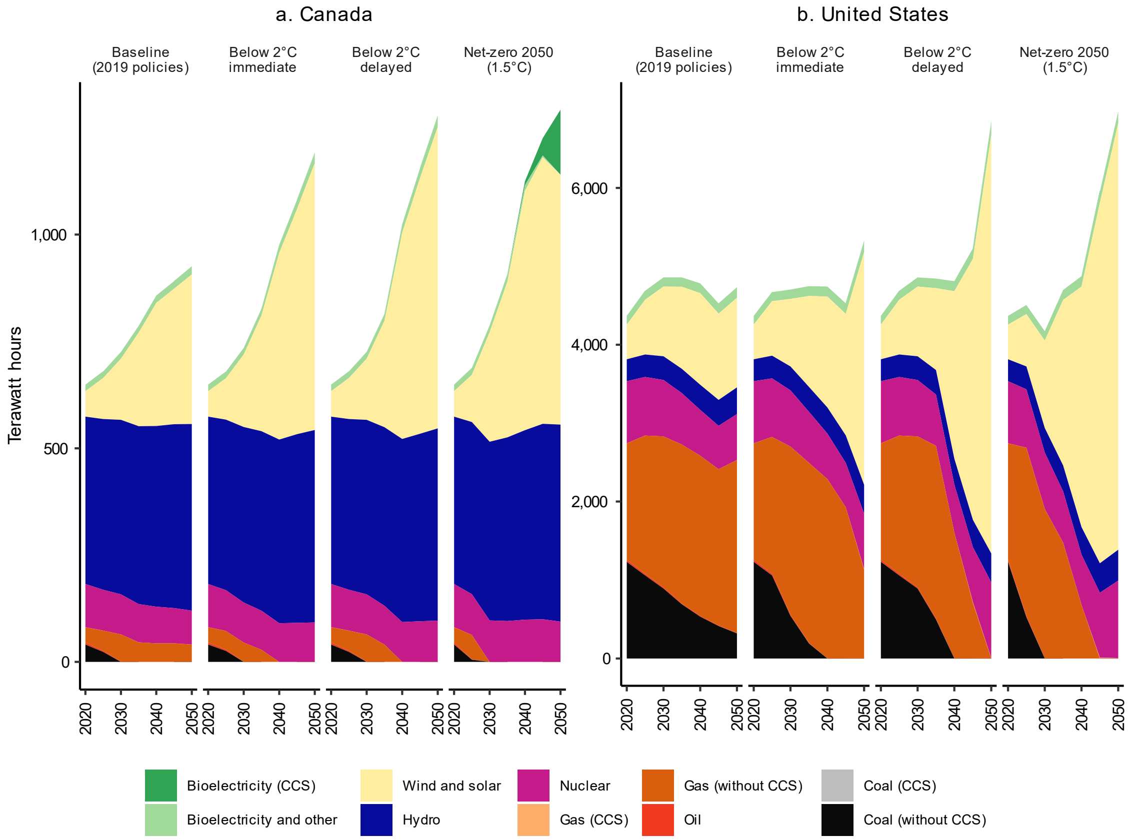
To achieve the most ambitious target of net-zero 2050 (1.5°C), the scenario relies on negative emissions produced through nature-based solutions in forestry, as well as on advanced technologies in the electricity-generating sector, such as BECCS. Together, this puts less pressure on industry to transition, with the net-zero 2050 (1.5°C) scenario falling roughly between the below 2°C immediate and delayed scenarios in terms of industrial emissions by mid-century.

Chart 7: Global emissions by sector



A sector's transition may look different across geographies. To shed light on this, we consider the evolution of the electricity sectors in Canada and the United States (**Chart 8**). In Canada, the electricity sector currently generates a majority of power from renewable sources. This means electricity is a source of energy with relatively low emissions intensity (compared with fossil fuels), which supports early electrification of the Canadian economy.[20] In contrast, the electricity sector in the United States is currently dominated by fossil fuels and faces a longer path to decarbonizing. Large investments need to be made to lower the emissions intensity of electricity generation in the United States before broad electrification of the US economy can take place.

Chart 8: Secondary energy-electricity generation



Note: CCS stands for carbon capture and storage.

20 Electrification refers to the process of replacing technologies that use fossil fuels with technologies that use electricity as a source of energy. As an example, one could think of passenger vehicles switching from using gasoline in internal combustion engines to using electricity in electric vehicles.

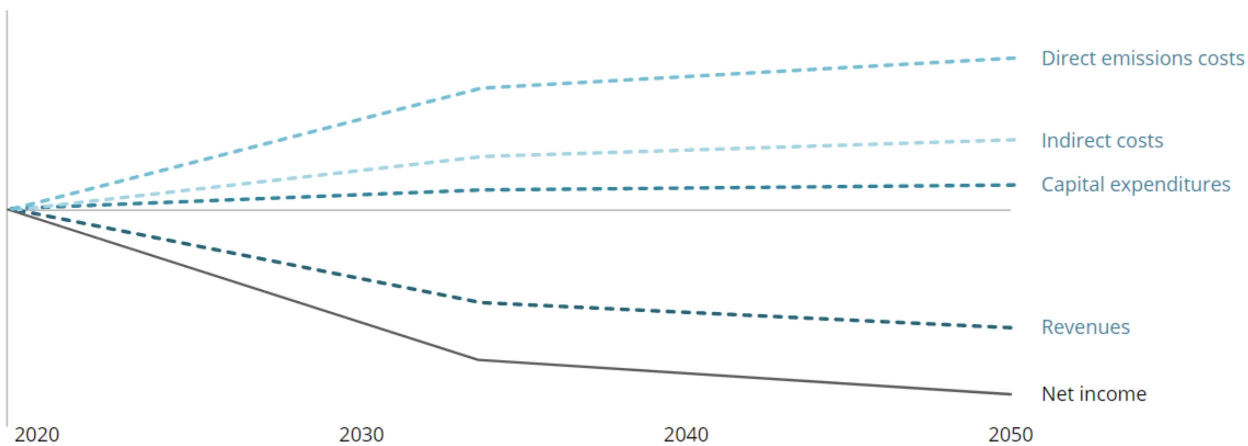
Mapping scenario variables to financial impacts

We mapped selected outputs from the scenarios developed in this pilot into risk factor pathways (RFPs), reflecting drivers of net income and financial risk at the sectoral level.[21] The RFPs reflect changes in direct emissions costs, indirect costs, capital expenditures and revenues along the transition path relative to the baseline scenario (**Chart 9**).

For example, an increase in a sector's costs associated with the release of greenhouse gases from burning fossil fuels is measured as direct emissions costs. Upstream sectors may pass on their direct emissions costs to other sectors, measured as indirect costs for those sectors. A sector may require investments in new technologies to become more efficient, increasing capital expenditures. Finally, revenues may fall because of reduced demand for the sector's output if it remains emissions intensive. The combined effect on the components of net income illustrates how the sector as a whole is affected through the transition and helps us evaluate the financial impacts on a given sector.

Chart 9: Illustrative risk factor pathways

Percentage change from baseline



Net income = Revenues – direct emissions costs – indirect costs – capital expenditures

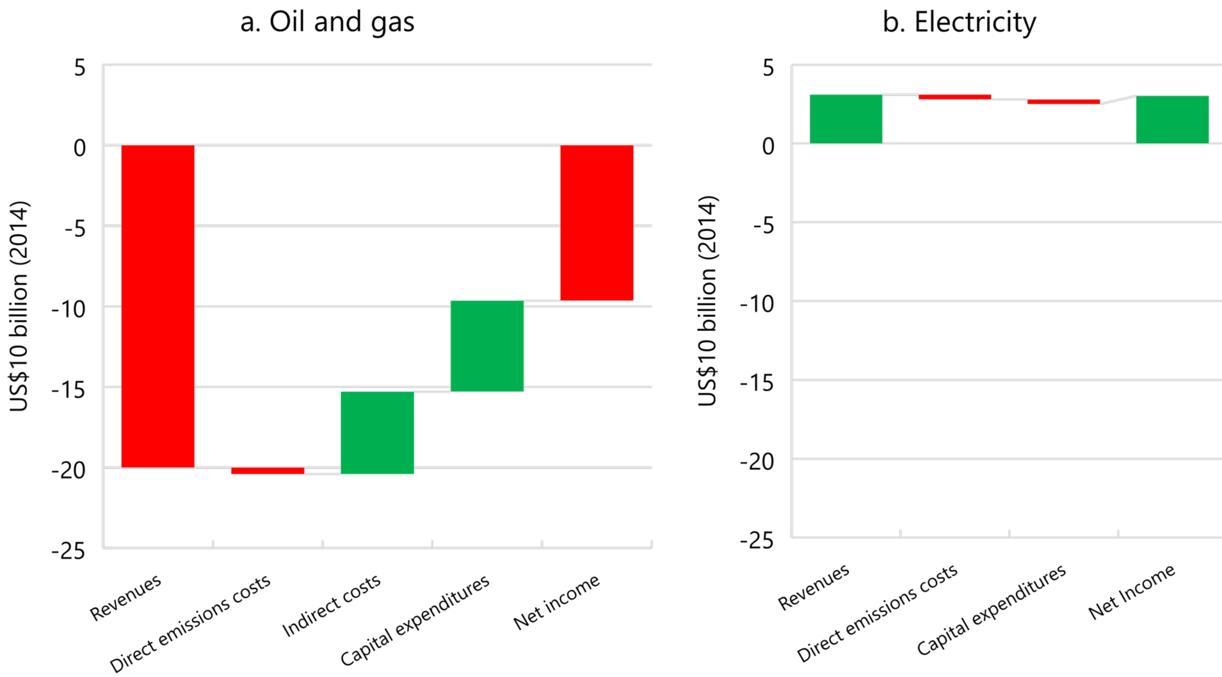
The scenarios have heterogeneous impacts on the income statements across sectors (**Chart 10**). Consider first the changes in the RFPs in Canada's oil and gas sector in the scenarios. Lower derived demand for refined fuel products implies lower demand for oil and gas. Together with lower fossil-fuel prices, this leads to a reduction in revenue. There is an increase in the direct emissions costs, and the decreased activity of this sector leads to lower capital expenditures and a reduction in aggregate indirect costs.

21 This follows methodology originally developed by Oliver Wyman, Mercer and the United Nations Environment Programme Finance Initiative in their own transition risk pilot assessment: see *Extending Our Horizons: Assessing Credit Risk and Opportunity in a Changing Climate: Outputs of a Working Group of 16 Banks Piloting the TCFD Recommendations* (April 2018).

Meanwhile, Canada's electricity sector experiences an increase in demand through electrification in the scenarios, leading to higher revenues. Investments in new low- or zero-emitting technologies raise capital expenditures, while the remaining emissions-intensive electrical utilities face higher direct emissions costs.

Chart 10: Change in components of net income for select sectors

Below 2°C immediate scenario versus baseline, Canada, 2050

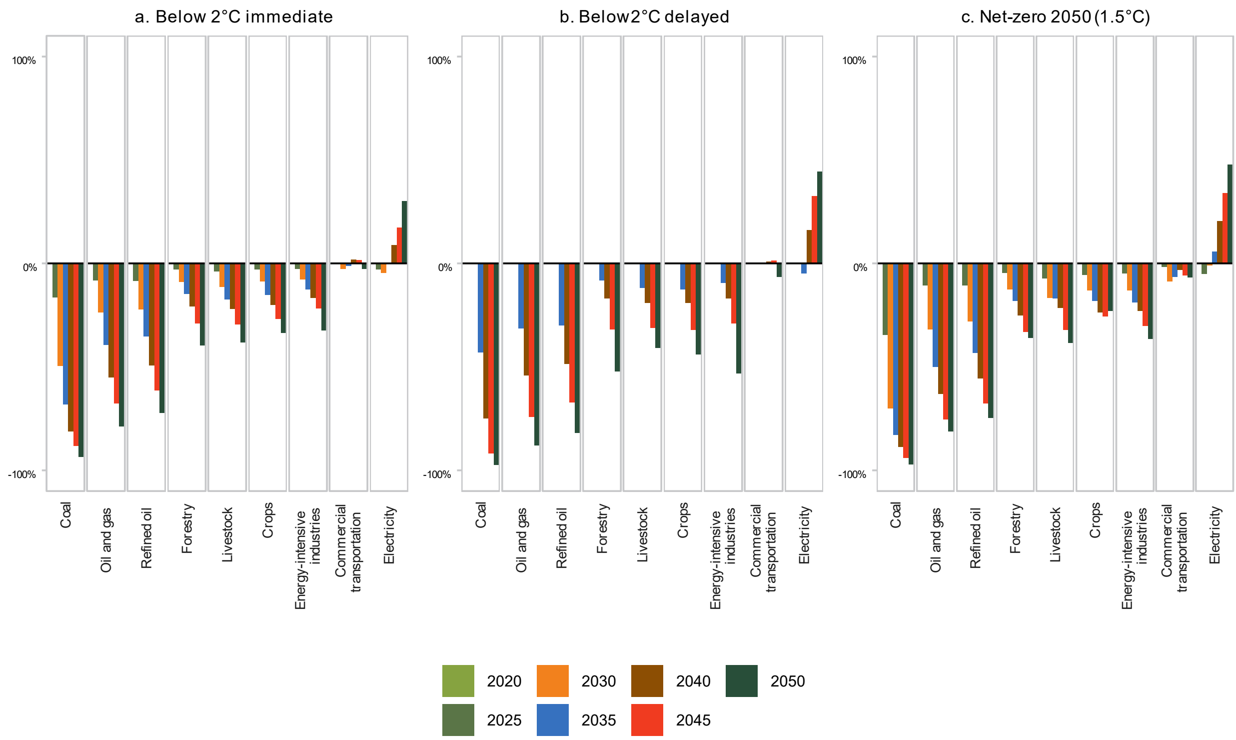


Note: Changes in net income are equal to changes in revenues minus changes in costs. For revenues and net income, red denotes a decrease relative to baseline, and green denotes an increase relative to baseline. For direct emissions costs, indirect costs and capital expenditures, red denotes an increase relative to baseline, and green denotes a decrease relative to baseline. Indirect costs are not available for the electricity sector.

Assessing the scenarios' financial impacts across sectors reveals diverse impacts from the transition to a low-carbon economy (**Chart 11**). We can group the sector impacts into three broad buckets:

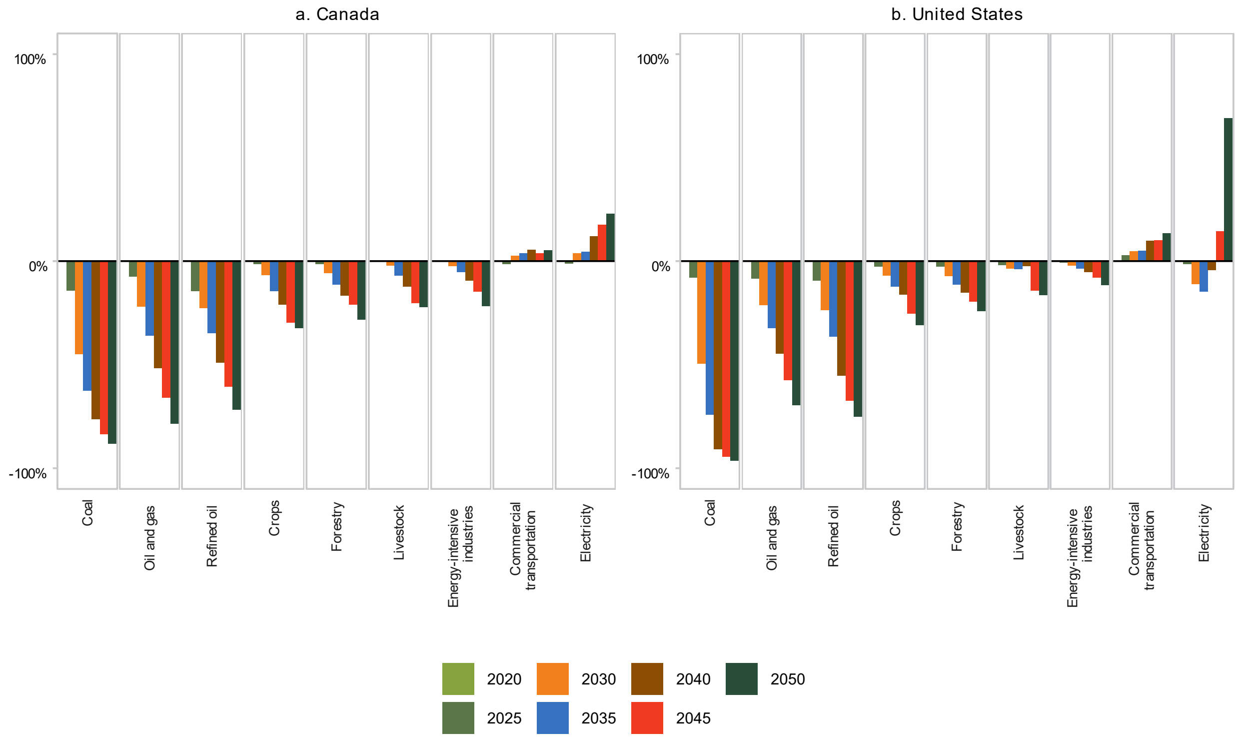
- those that experience a decline in demand as economies decarbonize
- those that experience a rise in demand through the transition
- others that experience challenges associated with increases in emissions costs and/or increases in capital costs to mitigate their exposure to the transition

Chart 11: Change in global sectoral net income relative to baseline (2019 policies) across scenarios



The scenarios show that financial impacts may also vary across regions. Consider the change in sectoral net income in the electricity sector between Canada and the United States under the below 2ºC immediate scenario (**Chart 12**). Here, the heterogeneous transition paths discussed above for the electricity sector can be seen to materialize in different impacts on net income. As mentioned, Canada's electricity sector relies heavily on renewables, allowing for early electrification and steady gains through mid-century relative to the baseline scenario (2019 policies). The United States, in contrast, goes through that costly transition period before electrification can take place. Once it does, the benefits materialize.

Chart 12: Change in sectoral net income under the below 2°C immediate scenario relative to baseline (2019 policies) for Canada and the United States



Macroeconomic impacts

As discussed in **Box 2**, to place the sector-level analysis in a macroeconomic context, we used two of the Bank's macroeconomic policy models to analyze the impacts of the adverse climate transition scenarios on the Canadian, US and global economies.

The Canadian economy is affected by the climate transition through three main channels:

- the domestic carbon pricing scheme and other domestic carbon-reduction policies
- reduced foreign demand for Canadian goods because of slower global economic growth following the implementation of similar policies in other countries
- lower commodity prices received by Canadian producers

In the transition scenarios, the increase in the domestic carbon price pushes up the prices that firms pay for fossil fuels, leading to lower demand for these products and impacting commodity-producing sectors. In addition, a portion of the costs are passed through to consumers, leading to higher prices for goods and services. Taken together, these effects weigh on gross domestic product (GDP). However, as assumed in the scenarios, the revenues from the carbon pricing scheme are transferred back to households, and this higher income offsets most of the adverse impacts.

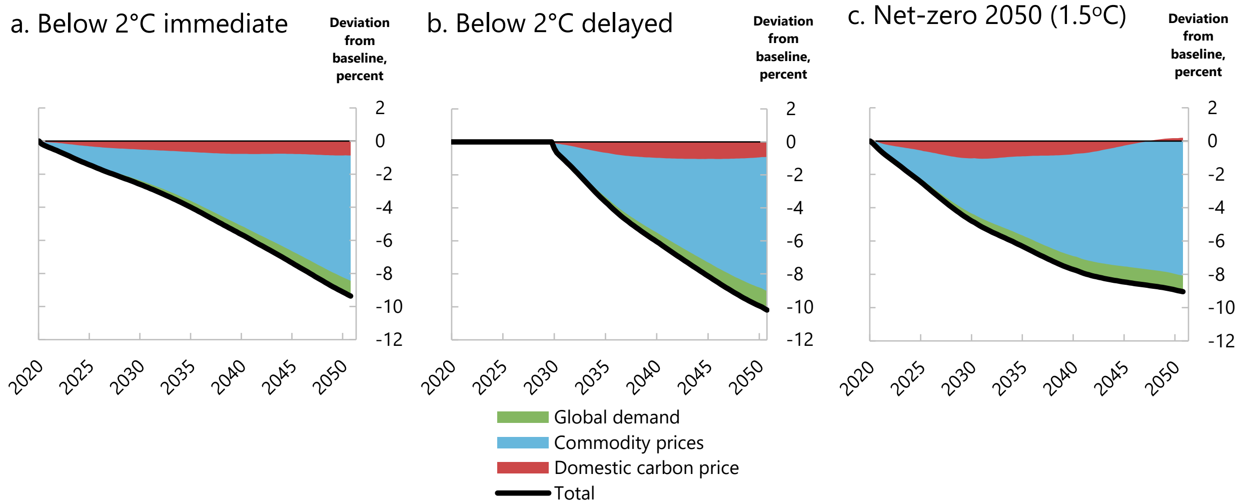
The impacts to the level of Canadian GDP are material across the transition scenarios, driven largely by global factors.[22] At the same time that climate policies are introduced domestically, other countries implement their own measures. This has two main effects:

- The rise in global efforts to combat climate change leads to lower foreign demand for goods and services, adding a further drag to domestic GDP.
- Global commodity prices decline as a result of lower global demand triggered by policy shifts around the world. This second effect weighs heavily on fossil-fuel-producing sectors and lowers the terms of trade of net energy-exporting regions.

The scenarios also reveal that the timing of policy matters, with delayed action requiring a sharper transition and larger macroeconomic impacts (**Chart 13**). In contrast to the 2°C immediate scenario, climate policy action is delayed by 10 years in the 2°C delayed scenario, requiring a steeper increase in the shadow price of carbon to meet the same level of climate ambition. This exacerbates the channels by which climate policy affects the macroeconomy, leading to a sharper and more material decline of GDP by mid-century. Comparing the below 2°C immediate scenario and net-zero 2050 (1.5°C) scenario, we see that the sharper increase in carbon prices required under the net-zero 2050 (1.5°C) scenario leads to a more front-loaded impact. In all scenarios, core inflation declines as lower foreign demand and commodity prices more than offset the cost-push effect of the carbon price increase. In reaction to disinflationary pressures, monetary policy adopts a more accommodative stance through a persistently lower policy rate.

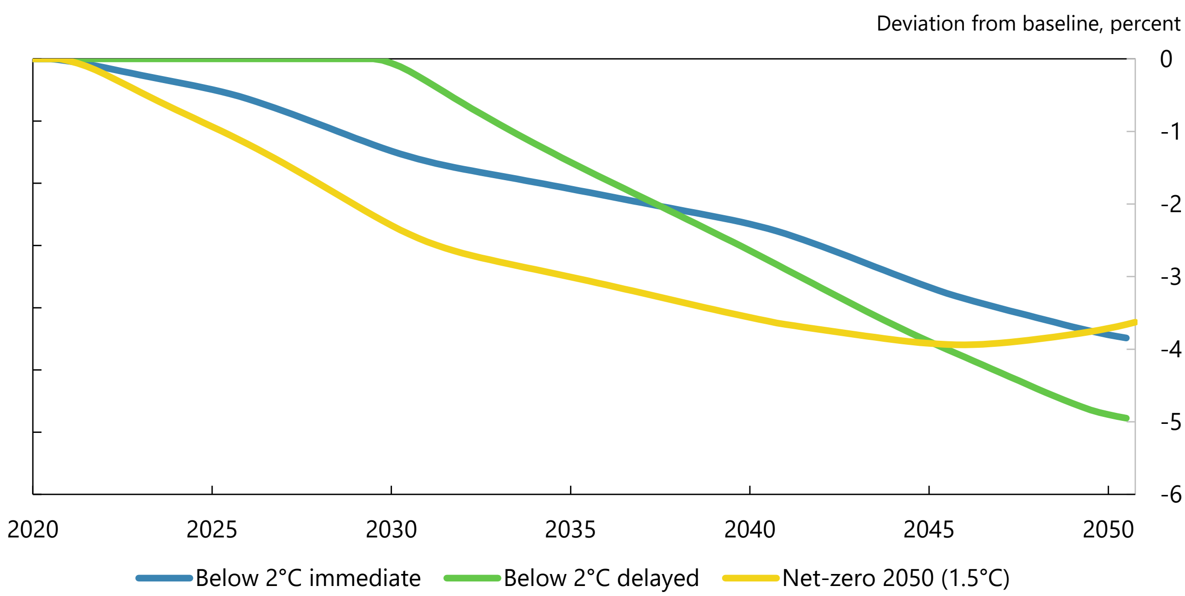
22 It is important to note that while the level of GDP changes relative to the baseline, GDP growth is still positive in the scenarios.

Chart 13: Decomposition of the level of Canadian GDP impacts across scenarios



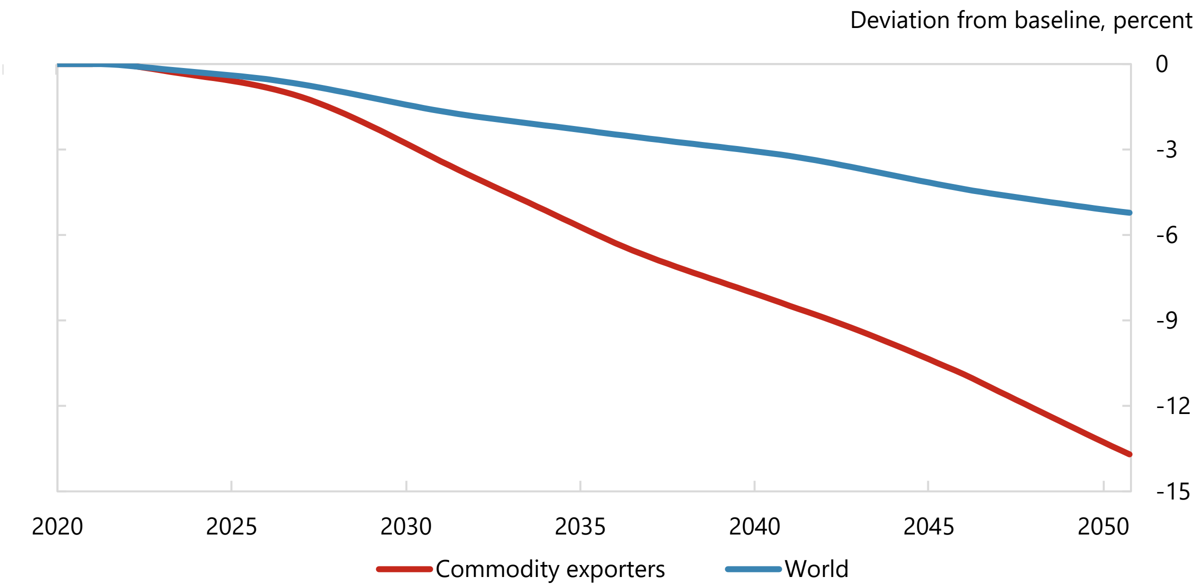
The impacts on the US economy along the transition scenarios are generally smaller than on Canada's (**Chart 14**). Carbon pricing in the United States acts like a negative supply shock, increasing both core and headline inflation. Faced with higher costs, firms invest less, lowering US output. Consumption also falls because of a decline in both incomes and wealth. However, since the energy sector does not account for as large a share of the economy in the United States as in Canada, the impact on investment and consumption is smaller.

Chart 14: GDP-level impact for the US economy in the transition scenarios



Commodity-exporting regions are most affected across the scenarios (**Chart 15**). Commodity prices decline as a result of lower global demand triggered by policy shifts around the world, particularly affecting the price of oil. These lower commodity prices transmit through the economies, weighing heavily on oil producers, lowering the terms of trade and thus weighing on output and inflation. These findings suggest that the transition to a lower-carbon economy should be more costly for commodity exporters like Canada relative to other economies.

Chart 15: GDP-level impact for the world, below 2°C immediate scenario



Finally, it is important to note that while the transition to a low-carbon economy may be costly, it must be viewed in the context of the physical risks avoided through climate mitigation. While we have left the assessment of physical risks for future work, the benefits of avoided physical risks to the global economy have typically been shown to exceed the costs associated with the low-carbon transition.[23]

3.3 Caveats

As previously discussed, the scenarios presented in this report do not aim to predict the most likely outcome. Rather, they explore plausible but intentionally adverse transition pathways that put pressure on industry to decarbonize.

Innovation and technological progress play a key role in easing the transition. The scenarios rely conservatively on technologies that are not yet commercially available

23 For more information, please see NGFS, *NGFS Climate Scenarios*.

and/or face scalability issues in the future. However, several technologies in early stages of development show promise in easing the transition for several sectors. As pointed out in a recent report by the Canadian Institute for Climate Choices (CICC), some emerging technologies could become increasingly attractive with continued innovation and declining costs.[24] These include geothermal energy, small modular nuclear reactors, hydrogen, second-generation biofuels and a wide range of clean technologies.[25] Several technical, market, cost and environmental challenges will need to be overcome, however. Furthermore, the scenarios do not consider innovation in new products or services or the creation of new industries or sectors that might arise through the transition and investments in green technologies. These represent opportunities for green growth. The CICC report outlines those that are relevant to the Canadian context. Innovation and investments in advanced technologies are essential in supporting the transition and in mitigating its costs.

Government policy can also play an important role in easing the transition. Our scenarios assume carbon pricing revenue is recycled back to households as lump-sum transfers. Alternative revenue recycling options could reduce transition costs, for example, through public investment in innovation that promotes green growth. Other government polices could also support the transition, for example, by promoting increased cross-sectoral labour mobility, skills development and retraining.

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24 See CICC, *Sink or Swim: Transforming Canada's Economy for a Global Low-Carbon Future* (October 2021).

25 For example, blue hydrogen could be produced alongside natural gas with carbon capture and storage, while providing a low-emissions source of energy for many downstream industries. Another promising technology is utility-scale battery storage as it continues to improve and become cheaper. These cost declines will make decarbonizing electricity systems easier.

4. Assessing credit and market risk along the climate transition pathway

As shown above, the transition to a low-carbon economy could have material impacts for the economy. It could imply strong economic dislocation, with significant negative financial impacts for some sectors (e.g., fossil fuels) and benefits for others (e.g., renewable electricity generation). In turn, these projected financial impacts could lead to a reassessment of the value of a variety of financial assets. In particular, alteration of projected earnings and expenses in many sectors driven by climate change could affect the debt repayment capacity and collateral of borrowers and increase credit risk for banks and other financial institutions. The sudden revaluation of equity in those sectors could also expose financial institutions to market losses. The speed at which such asset repricing would occur is uncertain, but its impacts could be important for financial stability and the safety and soundness of financial institutions.

In this section, we describe the methodologies used in the pilot project to assess credit and market risk. These methodologies allowed us to translate the projected economic and financial impacts of each scenario into credit and market risk impacts at the sector (or subsector) level. More details can be found in an accompanying Bank of Canada technical report.

Before we applied the methodologies, we first needed to define each sector or subsector so that financial institutions could map their counterparties to sectors or subsectors in a consistent way. To this end, we defined each sector or subsector using standard industrial classification systems. Our goal was to group related industries and activities that might be similarly impacted by the transition scenarios. Standard industrial classification system groupings were not designed with these considerations in mind, which implies that we needed to develop our own map based on granular industrial classification codes. Challenges the pilot project faced were the diversity of industrial classification systems used across institutions and the different degree of sectoral granularity captured by each one. To address these challenges, we developed a mapping based on several industrial classification systems, including the North American Industry Classification System (NAICS) and the Global Industry Classification Standard (GICS). The mapping is provided in **Appendix A**.

As discussed above, some sectors—including oil and gas, electricity, energy-intensive industries and commercial transportation—were further broken down into subsectors or industries, which we refer to as portfolio "segments."[26] A significant heterogeneity exists within these sectors in terms of the exposure to drivers of climate transition risk. Given this, we divided each of these sectors into segments that are largely homogeneous in terms of their exposure. We then constructed a heat map to help assess the relative sensitivities of each segment to the sector-level RFPs.[27] These sensitivities represent the responsiveness of the segment to each specific RFP relative to the average of the sector.

4.1 Credit risk analysis

Overview of the methodology

To assess credit risk, we built upon a methodology first proposed by the United Nations Environment Programme Finance Initiative (UNEP FI), Mercer and Oliver Wyman.[28] The methodology was developed as part of a pilot to better equip the banking industry to implement the recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD) of the Financial Stability Board.[29] It combines a top-down assessment with a bottom-up approach. A borrower-level calibration using sector-level financial impacts based on the scenarios captures nuances from the bottom up, while a top-down assessment of portfolio impacts extrapolates these borrower-level impacts to portfolio segments with homogeneous exposures to transition risk (see **Figure 1**).

Our approach can be broken down into the following steps:[30]

1. We used climate scenario variables to determine how credit risk drivers evolve over time at sector and geographic levels. As illustrated in **Chart 10** and **Chart 12**, the climate model variables were mapped into sector-level financial impacts for each geography. These RFPs are measured as changes relative to the baseline scenario, capturing the impacts of the transition. The RFPs reflect the main drivers of credit risk, including changes in revenues, direct emissions costs, indirect costs and capital expenditures. The approach assumes that 2019 borrower credit ratings reflect the baseline climate scenario.

26 Given that many companies in the pilot participants' portfolios were mixed oil and gas, participants found it useful to combine oil and gas into a single sector. However, to inform the borrower-level assessment, we provided both combined and separate RFPs.

27 See H. Hosseini, C. Johnston, C. Logan, M. Molico, X. Shen and M.-C. Tremblay, "Climate-Related Financial Risk Assessment Methodologies," Bank of Canada Technical Report No. 120 (January 2022) for a detailed discussion on how the heat map was constructed and used.

28 Please see UNEP FI, Mercer and Oliver Wyman, *Extending Our Horizons*; and D. Carlin and R. Fischer, *Beyond the Horizon: New Tools and Frameworks for Transition Risk Assessments from UNEP FI's TCFD Banking Program* (UNEP Finance Initiative, September 2020). The UNEP FI is a partnership between UNEP and the global financial sector to mobilize private sector finance for sustainable development.

29 TCFD, *Final Report: Recommendations of the Task Force on Climate-Related Financial Disclosures* (June 2017).

30 For further details on the credit risk methodology, see Hosseini et al. (2022).

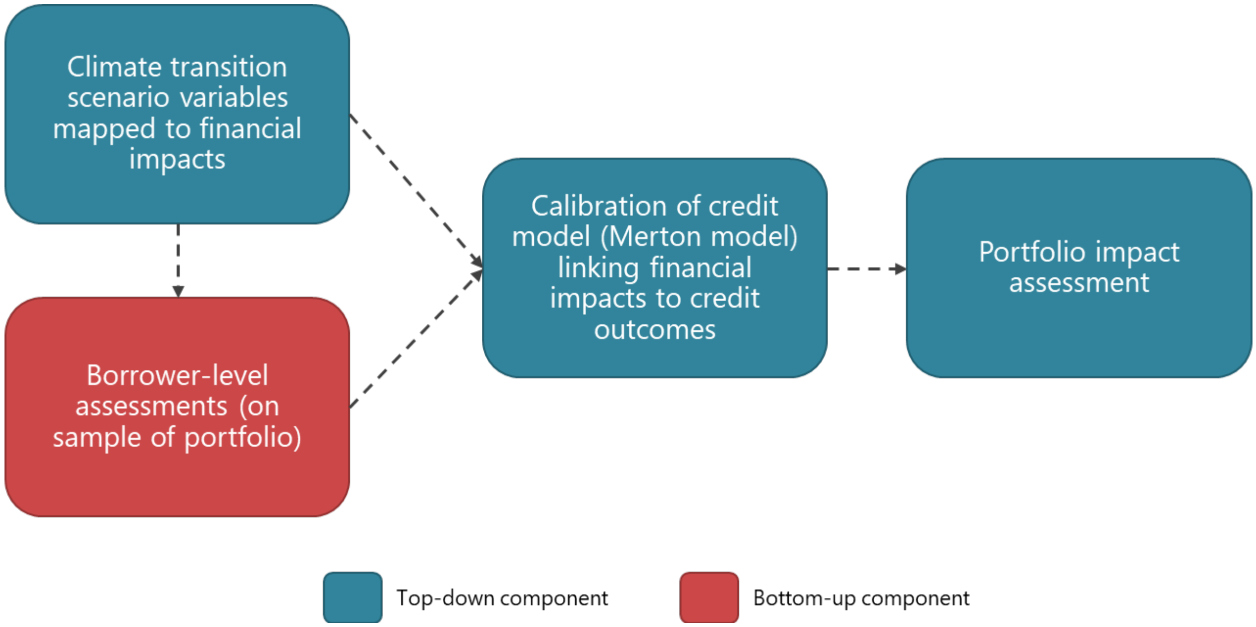
2. We asked financial institutions to select a minimum of five representative borrowers per segment in their portfolios. The choice of the number of representative borrowers balanced the benefits of higher precision in the estimated climate transition–credit risk relationship and the cost of the assessments for the financial institutions. We provided guidance on the selection criteria of representative borrowers so that the sampled borrowers were representative of the segment or sector regarding the distribution of credit ratings/probability of default (PD), distribution of exposure/loan size and other relevant borrower characteristics. The sample of borrowers represented 28 percent of the total credit exposure across all pilot participants within the scope of the exercise. Leveraging the sector-level RFPs, the scenario narratives and the heat map, the pilot participants used quantitative financial analysis of credit risk and expert judgment to assess the potential impact of the scenario on the PD for this sample of borrowers.[31]
3. Using the borrow-level calibration points provided by the pilot participants, we estimated a climate transition–credit risk relationship using a Merton-style model.[32] For each segment-geography pair, the model maps the RFPs along each transition scenario and the estimated heat map sensitivities of each segment into changes in the PDs. We used a Frye-Jacobs relationship to assess the loss given default (LGD) based on the stressed PDs.[33] We then used the pilot models to extrapolate the credit risk to the rest of the portfolio based on projected PDs, LGDs and exposures at default.

31 The borrower-level calibration required significant investment and expertise by the financial institutions, as well as relevant emissions and financial data for each sampled borrower. The amount of quantitative versus qualitative expert judgment used for the assessments varied across financial institutions. In terms of quantitative financial analysis, given the starting financial statements of the borrowers, the financial institutions applied the RFPs to compute the borrowers' transition-impacted financials. These financials were then translated into standard metrics of credit risk indicators, such as debt-to-EBITDA ratios, which were translated into credit ratings. Note, however, that financial institutions needed to make additional assumptions, such as how the free cash flow of the firm was going to be used (e.g., to repay debt, pay dividends or finance capital expenditures). These assumptions affect the accumulation of debt and thus the credit migration. Additional adjustments were also sometimes overlayed: for example, the extent of changes in business risk. Given the scope for additional assumptions by the analysts and experts in the early stages of the assessment process, we identified the need for further guidance in several areas to support consistency and comparability of the assessments across financial institutions. Areas of guidance included how to interpret and use scenario data, how to account for business risk, whether to consider borrowers' future operations and strategies that were unknown by the end of 2019, and how to treat borrowers' long-term contracts. For more details, see Hosseini et al. (2022).

32 In the Merton model, the PDs are related to the likelihood that a firm's future asset values could fall below a threshold value, specified by the value of the firm's liabilities. Climate transition risk (captured by the RFPs) introduces an additional systematic risk that shifts the firm's asset values. This shift in the distribution of asset values at a given point in time can be translated into an increase or decrease in PD, with idiosyncratic and other systemic factors remaining unchanged. For more details, see Hosseini et al. (2022).

33 For a description of the methodology, see J. Frye and M. Jacobs, "Credit Loss and Systemic LGD," *Journal of Credit Risk* 8, no. 1 (Spring 2012): 109–140.

Figure 1: Credit risk methodology



Relationship between climate transition and credit risk

In this section we discuss the estimated climate transition–credit risk relationship based on the bottom-up assessments by pilot participants. **Charts 16**, **17** and **18** are based on the combined borrower samples of the six pilot participants. For illustration purposes, we focus on the impacts on Canadian sectors (impacts to US sectors are shown in **Appendix B**).

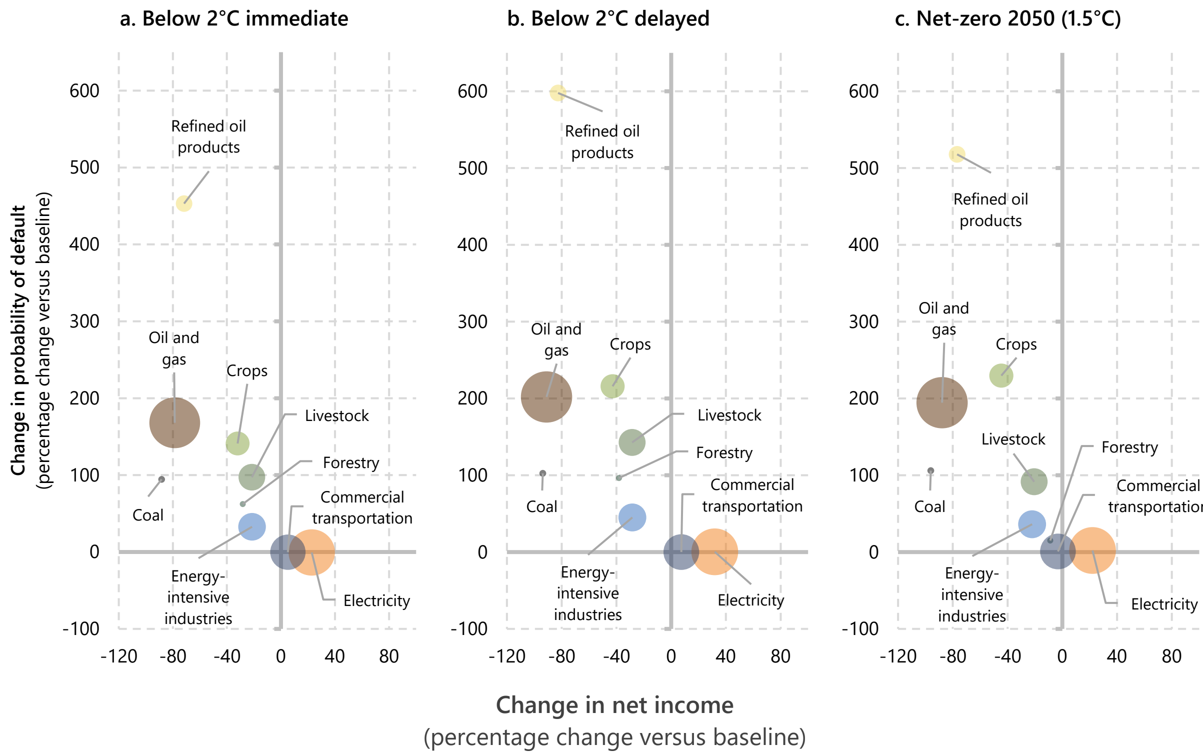
Chart 16 represents the estimated relationship between:

- the climate transition financial impact in each sector, measured as the percentage change in net income by 2050 versus the baseline, and
- the exposure-weighted average percentage change in PD for each sector (by 2050 relative to the baseline) projected by the estimated credit model.

The size of the bubble is proportional to the total exposure to the sector.

We can observe, as expected, an overall negative relationship between the magnitude of the financial impacts on the sector and the scale of the change in credit risk implied by the pilot participants' assessments: that is, borrowers in sectors that are more negatively affected by the transition scenarios are projected to have larger percentage increases in their PD. Equally, for more costly transition scenarios—in particular, in the below 2°C delayed action scenario—the increases in credit risk are generally larger.

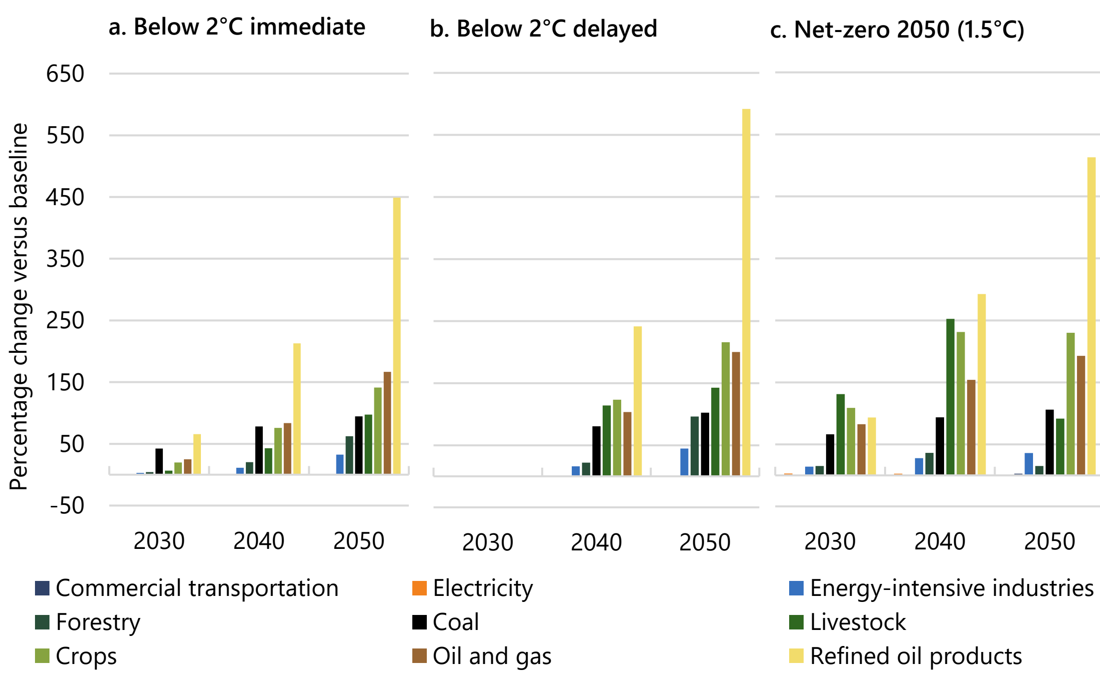
Chart 16: Climate transition–credit risk relationship, Canada, 2050



However, the climate transition–credit risk relationship may not be linear. As discussed above, transition scenarios might affect sectors differently, leading to different impacts on the various RFPs in each sector. This, in turn, has different impacts on the sectors' PDs. For example, in the below 2°C immediate scenario for Canada, the refined oil products sector sees its estimated PD increase by 450 percent by 2050 relative to the baseline, for a decline of 72 percent in its net income. At the same time, the crops sector sees an increase in the PD of 141 percent, for a decline of 32 percent of net income. The impact on credit risk for refined oil products relative to crops is therefore more than proportional to the relative decline in their net incomes. In contrast, the electricity sector sees barely any decrease in credit risk although it benefits from the transition. The analysis also suggested relatively small impacts on the PDs in the oil and gas and coal sectors relative to the projected magnitude of the decline in their net incomes, with several factors, discussed below, likely contributing to the misalignment.

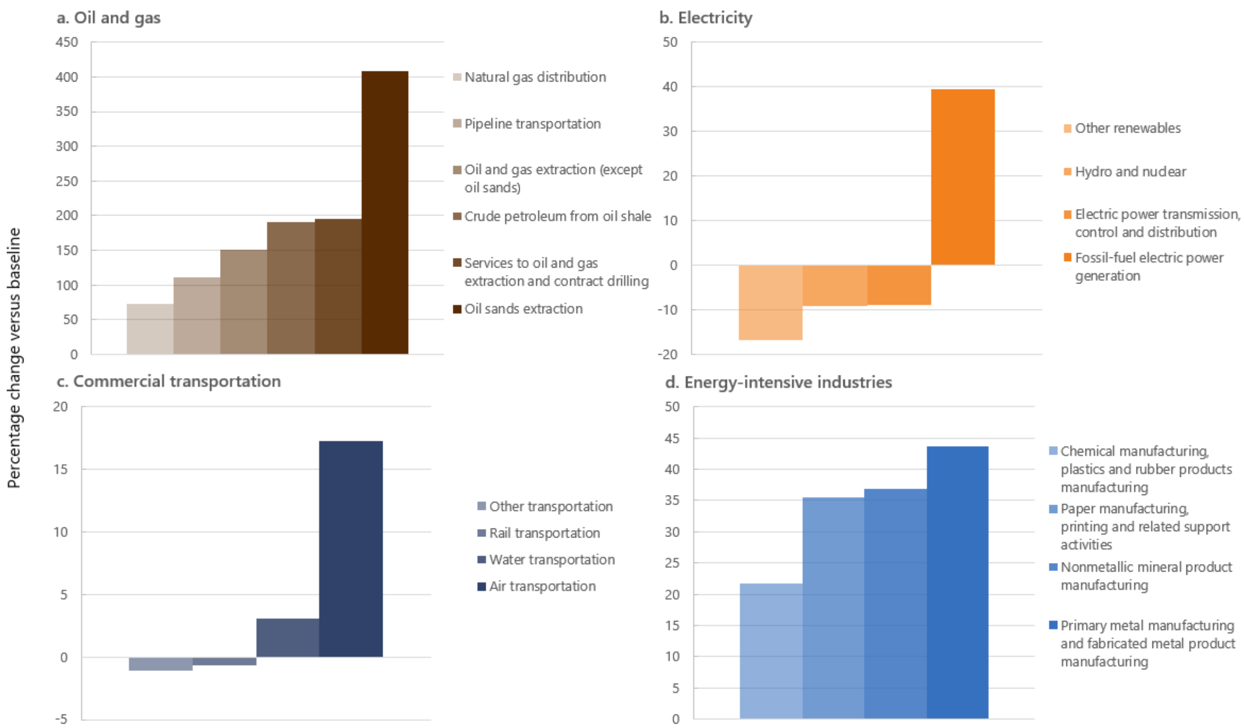
Looking at the evolution of the estimated percentage change in PDs over time and along each scenario relative to the baseline (**Chart 17**), we note that the increases are generally gradual, accompanying the evolution of the sectors' RFPs. Comparing the below 2°C immediate and delayed scenarios, we see more abrupt and larger increases in credit risk along the delayed action scenario across all sectors. Furthermore, comparing the below 2°C immediate and the net-zero 2050 (1.5°C) scenarios, we see that the more ambitious 1.5°C target leads to larger increases in credit risk across sectors, reflecting more pressure on industry to decarbonize. In the net-zero 2050 (1.5°C) scenario, the impacts on credit risk occur earlier in response to the more front-loaded nature of the increased price of carbon. It is also interesting to note that not all sectors respond in the same way to each scenario because they face different pressures and challenges to decarbonize along the transition. For example, under the net-zero 2050 (1.5°C) scenario, where the increases in carbon prices are more front-loaded, the livestock sector experiences early large increases in credit risk because of the challenges it faces reducing methane emissions in the shorter run and the consequent increase in its direct emissions costs. It is not until closer to 2050 that the livestock sector can reduce its direct emissions costs.

Chart 17: Change in probability of default in Canada across the transition scenarios



The sector-level analysis, however, obscured important differences across segments within the sectors. **Chart 18** shows the change in PD by 2050 under the below 2°C immediate scenario for each segment within the four multi-segment Canadian sectors in our analysis: oil and gas, electricity, commercial transportation, and energy-intensive industries.

Chart 18: Change in probability of default in Canada by 2050 under the below 2°C immediate scenario



In the oil and gas sector, the estimated credit risk impact on the oil sands extraction segment implied by the financial institutions' assessments is much larger than that on the other segments. This points to the fact that the segment is more sensitive to the changes in fundamentals brought on by the transition scenario. In contrast, the impact on the natural gas distribution segment is smaller than the average impact on the sector. The pilot participants mentioned factors that might explain this, including the fact that a significant number of companies in the segment are regulated and might be partially insulated from the projected decline in the price of natural gas, given the long-term nature of their contracts.

Turning to the electricity sector, the estimates point to both increases and decreases in credit risk across its segments. The estimated model shows an increase in credit risk for the fossil-fuel electric power generation segment driven by the steep increase in its direct emissions costs along the transition. This increase is accompanied by decreases in credit risk for the non-carbon-emitting segments (renewables, hydro and nuclear) as well as for electric power transmission, control and distribution. The latter segments benefit from the electrification process accompanying the transition to a low-carbon economy, leading to higher revenues but also requiring significant capital investments.

According to the financial institutions' assessments, the four segments in the commercial transportation sector show small and mixed credit risk impacts. On the negative side, air and water transportation segments see increases in their PDs. This is due to the decarbonization pressures put on these segments along the transition path. These segments are hard to decarbonize and may require large capital investments along the transition. On the positive side, ground and rail transportation might benefit along the transition because they are easier to decarbonize (e.g., through electrification), but they too require significant capital investments. Overall, the credit model estimates marginal credit risk improvements in these segments.

Finally, the estimated credit risk across segments within energy-intensive industries implied by the pilot participants' assessments is relatively similar. Given the challenge in decarbonizing these segments, the increase in direct emissions costs along the transition is the main driver for the increases in the PD.

Methodological lessons learned and limitations

Overall, the credit risk methodology described above has proven valuable to better understanding the climate transition–credit risk relationship and building the pilot participants' capabilities in scenario analysis. However, it also brought to light some limitations and challenges, including potential consistency and comparability issues. Below, we discuss some lessons learned by the pilot participants and the authorities.

The feedback collected from pilot participants showed that the bottom-up exercise helped them identify data gaps, explore new methodologies and develop a deeper understanding and awareness of the impacts of the climate transition on their portfolios. One participant mentioned that the exercise helped their analysts develop a deeper appreciation for the various impacts of the climate transition on their respective sectors while also providing a detailed framework on how to assess and evaluate these impacts moving forward. Other participants remarked that, overall, the methodology provided a reasonable framework for assessing transition risk in their portfolio.

However, several participants mentioned that the time and resources required to conduct the borrower-level assessment exceeded their expectations. Furthermore, several participants highlighted the importance and challenges of ensuring the representativeness of the borrowers in the sample, recognizing the trade-off between improving the precision of the estimates by increasing the sample size and the additional effort required. Many also highlighted the lack of sufficient data (e.g., emissions data), particularly outside of developed markets and public asset classes. One participant suggested that the disclosure of certain emissions details by issuers in

Canada would make transition risk data more readily accessible at the borrower level to use for assessments. This would enable more consistent understanding of each borrower in the context of any climate scenario.

From the authorities' perspective, the bottom-up component of the credit risk analysis provided a better insight into the participants' methods and capabilities. It also allowed authorities to address some existing data gaps by providing estimates of the climate transition–credit risk relationship using the financial institutions' borrower-level data and risk assessment expertise.

As shown above, the estimated relationship based on the pooled sample data of all pilot participants is generally in the right direction (i.e., an overall negative relationship between the magnitude of the financial impacts on the sector and the scale of the change in credit risk). However, the wide dispersion of the results across financial institutions caused us to question the robustness of some estimates at this very first attempt to assess credit risk related to climate transition. Comparing the climate transition–credit risk relationship that we estimated based on each financial institution's own sample data, we observe considerable variability across institutions. We provided guidance, for example, on how to map borrowers to sectors, the selection criteria for representative borrowers, the use of the scenario data versus expert judgment and several assumptions required for the analysis. However, this still left room for material differences in approaches and assumptions across institutions. The high degree of variability raises issues of consistency and comparability across financial institutions' assessments.

The variability might reflect several factors and challenges that must be overcome:

- **Challenges in the classification of companies and differences in the portfolios of the various financial institutions**. While we provided a mapping using standard industrial classification systems, as discussed above, many participants remarked that classifying companies that have multiple or mixed business lines represented a challenge (e.g., some power generation borrowers may have exposure to a variety of fuel sources). This was particularly true in the energy sector, where many companies are diversified. Differences in the classification of these companies could partly explain the variability across institutions and the potential underestimation of risks in some sectors or segments. For example, consider a company that has multiple business lines where some of its activities are not very exposed to transition risks while others are. If this company is classified as part of a high-transition-risk sector or segment, credit risk of that sector or segment may be underestimated.

- **Differences in analytical tools, capacity, expert judgment and assumptions across institutions**. These are further magnified by the long time horizon of the analysis and the need for many additional financial assumptions: for example, the extent to which borrowers will use free cash flow to repay debt along the transition. Unlike macroeconomic stress testing, which has a shorter time horizon (usually around two to five years), climate scenario analysis is still in its infancy, and standardized climate risk assessment methodologies are still to be developed and agreed upon.[34]

This pilot project was a first attempt to better understand and assess credit risk associated with the transition to a net-zero or low-carbon economy, and the scope of the analysis was subject to limitations (e.g., the coverage of only selected elements of the balance sheets, the exclusion of physical climate risks and the assumption of a static balance sheet). These limitations present opportunities for future enhancements and will be addressed in future work.

4.2 Market risk analysis

Overview of the methodology

To assess the impact of climate transition scenarios on the equity portfolios of pilot participants, we used a purely top-down approach. We estimated the impacts of the climate transition on equity valuation for each sector-geography pair using a discounted dividend model.[35] We calculated sectoral dividends under each climate transition scenario from projected sectoral value added along the transition pathway given assumptions on capital share of value added and the dividend distribution rate. We then discounted the streams of dividends using Morgan Stanley Capital International average historical returns.

In the analysis, for tractability we assumed that changes in global climate policy pathways are credible and incorporated into equity valuations immediately at the time of the policy path announcement. This implies that at the time of the global policy change, a discrete change in valuation can occur. However, we assume that economic agents have foresight over a 10-year rolling window of climate policy only, assuming

34 Macroeconomic stress tests are generally designed to assess the resilience of the financial system as a whole to short-term macroeconomic shocks. They are used in a regulatory context for the purpose of evaluating current liquidity and capital base needs and to inform liquidity and capital management for a period of two to five years. Climate scenario analysis is not, however, primarily a liquidity or capital management exercise. Its main goal is to understand and evaluate the sensitivity of a financial institution’s portfolio to physical and transition climate risks and aid in understanding how these risks and opportunities might plausibly impact the business over time, supporting the institution’s strategic planning.

35 We estimated geography-sector equity index values by discounting computed annual dividend flows within a 50-year, forward-looking window for each of the three climate transition scenarios from 2020 to 2100.

that policy remains constant from that point forward.[36] Our assumption implies a gradual adjustment in equity valuations following the discrete jump driven by the change in global climate pathways. It is also important to note that equity valuation impacts are driven by collective global climate policy action, not solely by climate policy announcements of individual countries.

Equity valuation impacts at the sector level

Chart 19 shows the equity valuation impacts on each sector for Canada following a shift in global climate policy from the baseline (2019 policies) scenario (results for US sectors are presented in **Appendix C**).

Not surprisingly, the equity valuation impacts vary by sector, geography and scenario, reflecting the different financial impacts of the alternative transition scenarios on sectoral value added. The biggest negative impacts are observed in the fossil-fuel sectors—such as coal, oil and gas, and refined oil—while the electricity sector experiences equity valuation gains. In the delayed scenario, a sudden change in the global climate policy path in 2030 results in an abrupt adjustment in asset values because the valuation of the sectors starts incorporating carbon price information from the new policy path. This is followed by a steeper path in equity values relative to the two immediate action scenarios. In the immediate action scenarios, a smaller adjustment happens in 2020 as the change in global policy path in 2020 gets priced in, followed by a smoother path. Abrupt changes in the valuation of assets pose greater risks to the financial system and financial stability. Finally, the introduction of negative emissions technologies, such as BECCS in the net-zero 2050 (1.5°C) scenario, may alleviate pressure on some industries that face challenges in abating and creates additional demand in the forestry and crops sectors by using their outputs in electricity generation. Together, this contributes to a partial recovery of equity values relative to baseline by mid-century for some sectors.

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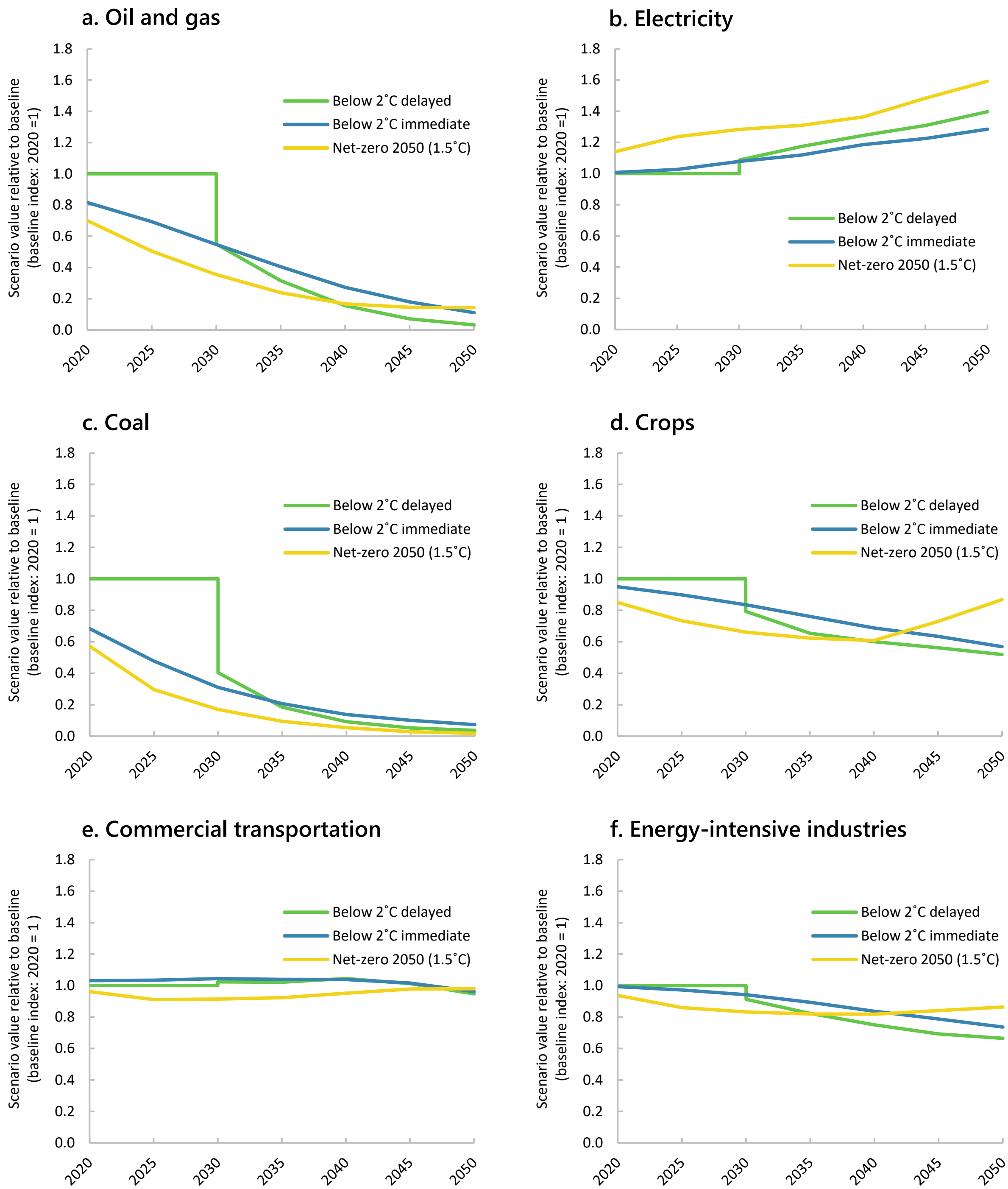
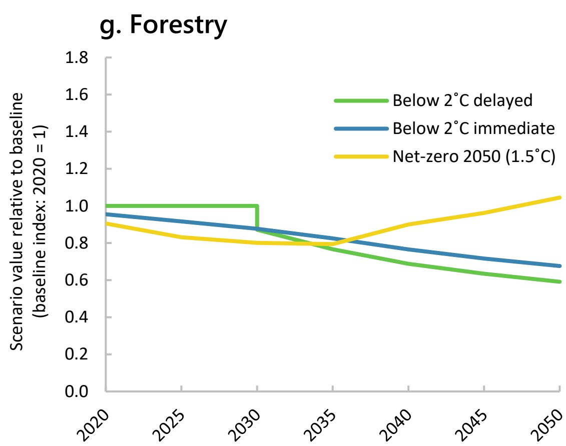
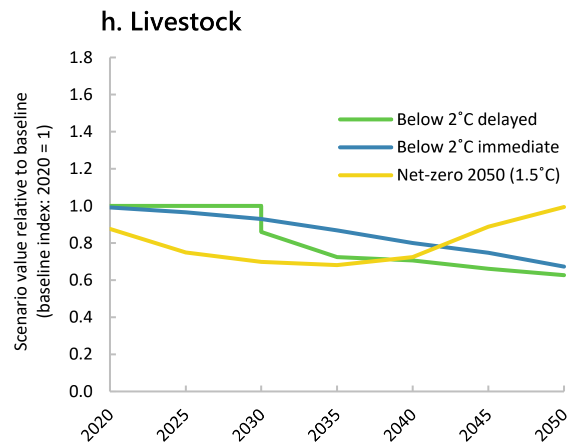
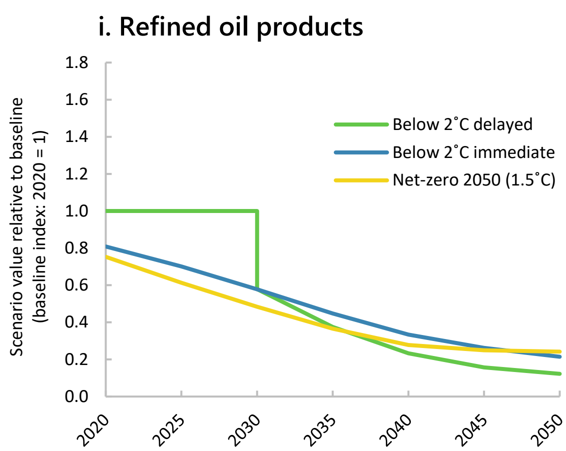
36 For example, in December 2020, the Canadian government introduced a plan committing Canada to reach net zero by 2050 that outlined a path for carbon prices until 2030. Please refer to *Bill C-12* for more information.

Chart 19: Equity valuation impacts on Canadian sectors following changing global climate policy









Methodological limitations and caveats

While the top-down approach used to assess equity risk ensured methodological consistency across financial institutions and lower resource costs, it limited the level of sectoral granularity of the analysis and ignored certain asset characteristic considerations. Given that the scenarios provided cash flows only at the sectoral level, the analysis was unable to distinguish the equity valuation impacts across subsectors or segments. Furthermore, the analysis did not capture differences between, for example, the risk-adjusted returns of private versus public equities.

It is also important to note that, for tractability, the analysis assumed that changes in global climate policy were permanent and credible and that economic agents possessed significant foresight. In reality, the path of global climate policy and the timing of policy changes are highly uncertain. This implies that markets might not fully price in changes in global climate policy immediately and that equities might be subject to frequent revaluations as new information becomes available.

Also note that the model only accounts for changes in equity valuations driven by shocks to their fundamental value. In addition, financial sector interlinkages and common exposures that make financial institutions vulnerable to fire sales and synchronous price dislocations could lead to disorderly market adjustments and systemic risk. Furthermore, uncertainty over the exposure of financial institutions, firms and households to climate-related transition risks could lead to overall tighter credit conditions and financial stress triggered by abrupt changes in global climate policy (as considered in the below 2°C delayed scenario).[37] This could further increase the short-run economic costs of the transition. **Box 3** illustrates the potential macroeconomic implications of this additional financial stress channel. In future work, the Bank and OSFI will conduct further analysis of the systemic risk channels related to the transition to a low-carbon economy.

37 Climate-related financial disclosures contribute to financial reporting transparency and the mitigation of this type of systemic risk.

Box 3:

A financial stress channel and its macroeconomic implications

As described in section 3, the climate transition scenarios developed for the pilot differ based on both the climate target and the speed of the transition to a low-carbon economy. Once announced, policies to curb emissions are increased steadily over time and are well understood by firms and households. As a result, the economy adapts smoothly, and resources have time to be reallocated across sectors. This approach is consistent with climate transition modelling, which traditionally has been used to assess optimal policy paths for emissions reductions. However, it omits important frictions (e.g., search and matching frictions in the labour market) and systemic financial risk channels that could increase the economic short-run costs of the transition. Below, we discuss how abrupt global policy changes could increase the risks of financial stress, particularly in countries with significant fossil-fuel exports, such as Canada.

The macroeconomic scenarios discussed in section 3 underscore how external changes in climate policy could have significant macroeconomic costs for Canada. Relative to the results presented in section 3, the abrupt shift in the global policy path in the 2°C delayed policy action scenario could have a much more acute impact in the short run if it triggered a disorderly reaction from financial markets.

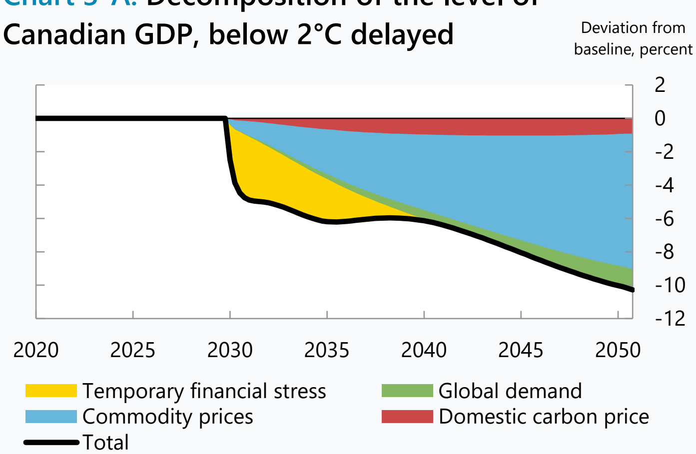
To assess the potential impacts of such a disorderly reaction, we developed an alternative version of the 2°C delayed scenario in which we capture the effects of financial stress using shocks to risk spreads, household wealth, and business and consumer confidence:

1. The increase in risk spreads captures uncertainties surrounding the exposures of firms, households and financial institutions to climate transition risks.
2. The shocks to household wealth capture the effects of fire sales and other mechanisms that might move asset prices out of line with fundamentals during episodes of financial-market disorder.
3. The shocks to business and consumer confidence capture the impact that such episodes tend to have on consumption and investment behaviour.

We calibrated shocks based on experience during previous stress events, namely the 2008–09 economic and financial crisis and the 2014–15 oil price shock.

Chart 3-A illustrates the impact of such a scenario and shows how market repricing could pull forward transition costs, making for an earlier and more volatile adjustment.

Chart 3-A: **Decomposition of the level of Canadian GDP, below 2°C delayed**



5. Governance and risk management practices

OSFI conducted a survey of current practices at the six pilot participants of the scenario analysis study. From the information gathered on governance and risk management practices relating to climate-related risks, the Bank and OSFI gained insight into:

- how the pilot participants' boards of directors and senior management oversee climate-related risks and opportunities;
- the extent to which climate-related risks and opportunities affect businesses, strategy, and financial and capital planning;
- how risk management processes incorporate the identification, assessment and management of climate-related risks; and
- how climate-related risks are reported to internal and external stakeholders.

This section summarizes the key themes from the participants' responses regarding their governance of and risk management practices for climate-related risks, including both transition and physical risks. The observations from this summary reflect the practices of the six pilot participants only and should not be interpreted or extrapolated to reflect the practices of the broader set of Canadian FRFIs or federally regulated pension plans. An additional questionnaire was provided to more organizations with exposure to climate-related risks, and the results are summarized in **Box 4** at the end of this section.

5.1 Methodology overview

This survey was designed to gauge the range of current risk management practices pertaining to climate-related risks. The summary of responses is not an assessment or endorsement of the quality of pilot participants' governance or risk management practices.

The survey was organized into five areas, where participants were asked to report on their current state of controls and practices rather than a target state, supported by any supplemental documentation.

- **Governance**: What are the current practices with respect to assigning responsibility for managing climate-related risks within the organizational structure?
- **Business models and business strategy**: What are the current practices with respect to implementing climate-related risks in the institution's business strategy, in the short, medium or long term?

- **Risk management oversight**: How does the institution incorporate climate-related risks when developing its overall approach for risk management oversight?
- **Risk management framework**: To what extent does the institution incorporate climate-related risks as drivers of existing risk categories in the risk management framework?
- **Reporting and disclosure**: How are climate-related risks reported within the organization and communicated to shareholders, supervisors and the general public?

5.2 Key themes

Governance and risk management

All six pilot participants are in the development stage of managing their climate-related risks. Some pilot participants are relatively ahead of their peers because of the nature and complexity of their business. While they have different levels of maturity and sophistication with respect to governance and risk management practices, all six pilot participants have increasingly recognized climate-related risk as one of their top risks. Furthermore, they are in the process of developing their understanding of the risks and accompanying financial impacts to make informed strategic and business decisions.

Work is underway to understand the impact of climate-related risks (physical and transition). This includes integrating climate-related risks when formulating and implementing their business strategy, further developing qualitative and quantitative tools to measure and monitor material risk, and becoming more transparent by enhancing their climate-related financial disclosure.

Climate-related risks versus opportunities

The six pilot participants also recognize that efforts to mitigate and adapt to climate change can produce opportunities for organizations while they are managing climate-related risks. The six pilot participants have started to explore climate-related investment opportunities (e.g., investing in renewable energy or sustainable real estate) and to assess opportunities to offer sustainable finance products and services to their clients. Integrating climate change has become a key element of business strategies and investment decisions.

Alignment with the TCFD recommendations

All six pilot participants are supporters of and committed to adopting the TCFD recommendations.[38] They either issue stand-alone annual TCFD reports or address their progress on implementing the TCFD guidance in their annual reports or sustainability/social impact reports.

In addition to adopting the TCFD recommendations and participating in the current scenario analysis pilot, some pilot participants participate in relevant international and voluntary industry-led initiatives, including the UNEP FI, to further develop methodologies for identifying and measuring climate-related risks.

5.3 Survey findings

Governance

Overall, governance frameworks with respect to climate-related risks have been established and the six pilot participants are working toward building robust practices within their organizations.

- Risk appetite frameworks:
  - Most of the six pilot participants have climate-related risks incorporated into their risk appetite frameworks (RAFs). Among the pilot participants, approaches with reference to RAFs vary, ranging from incorporating climate-related risks as a stand-alone risk to integrating elements of climate-related risks in other risk categories (e.g., strategic, credit, market, insurance or operational).
  - Most pilot participants have not incorporated quantitative climate-related risk measures (e.g., key risk indicators, limits) in their RAFs. Some pilot participants indicated that they have work underway to develop climate-related indicators and limits that will help inform quantitative climate-related risk appetite statements in the future.
- Roles and responsibilities:
  - Across the six pilot participants, various board committees have been set up to oversee the management of climate-related risks. Some pilot participants have dedicated committees for climate-related risks, while others cover climate-related risks in committees overseeing a broader range of risk issues.

38 TCFD, *Final Report* (June 2017).

- Senior management at all pilot participants is actively engaged in managing climate-related risks, and roles and responsibilities are assigned according to the governance framework. Pilot participants set up multiple steering committees and working groups to respond to climate-related risks among their organizations.
- First-line-of-defence management plays a key role in risk taking and ultimately owns the climate-related risks arising from business activities; however, not all pilot participants have established clear roles and responsibilities for the first line of defence or have formally documented them. For the pilot participants that assigned roles and responsibilities to the first line of defence, these roles and responsibilities include performing climate analytics, undertaking monitoring and control procedures and implementing client-focused climate solutions.
- Executive remuneration at most pilot participants is linked to the organizations' performance, including environmental, social and governance factors.
- The governance process is reviewed regularly to ensure that risks are properly captured. Governance processes may evolve to further define roles and responsibilities as climate-related risk management practices mature.

Business model and strategy

All six pilot participants have indicated that they are adapting their business models and strategies to a changing climate. They are in the process of identifying risks arising from climate change for key sectors, geographic areas and related products and services for markets where they are active or considering becoming active.

- Understanding climate-related risks:
  - All six pilot participants have been undertaking efforts to measure their exposure to climate-related risks while recognizing challenges in measuring such exposure. They have implemented in-house capabilities to analyze physical risk and transition risk. Some pilot participants have participated in various national (e.g., this scenario analysis pilot) or international (e.g., UNEP FI pilots) initiatives to enhance their methodologies.
  - Some pilot participants have also identified reputational risk that may arise if the FRFI or other associated parties violate environmental regulations or best practices.

  - The pilot participants recognize that, as a prudent practice, greater scrutiny is required for transactions in certain high-emitting sectors. More restrictions have been imposed for lending or investment activities in these areas.
  - Implementing changes to business models and strategies mainly coincide with evolving risk management practices, while large-scale strategy changes are still in development.
- Understanding climate-related opportunities:
  - The six pilot participants have also explored climate-related opportunities (e.g., investing in renewable energy or sustainable real estate) and assessed opportunities to offer sustainable finance products and services to their clients. Some pilot participants have increased their business targets in recognition of such business opportunities.
  - While not all pilot participants have established key performance indicators in their business strategies, the majority have set targets for their operations related to greenhouse gas emissions, use of renewable energy sources, and carbon-related asset metrics. Some pilot participants have also committed to long-term targets (e.g., net-zero initiatives). Some pilot participants have also set up business targets for offering sustainable financing services.

Risk management oversight

The six pilot participants have initiated efforts to integrate climate-related risks into their overall risk oversight functions. Climate-related risks have been identified as a top risk or a key driver to existing risk categories for all six pilot participants. As a result, they have developed governance frameworks to oversee climate-related risks. Climate-related risks and opportunities are escalated to the board and senior management, as appropriate.

Risk oversight is achieved through the “three lines of defence” approach:

1. Most pilot participants recognize that first-line-of-defence management should be responsible for the climate-related risks arising from business activities. However, not all pilot participants have established clear roles and responsibilities for the first line of defence, nor have they formally documented them.
2. All pilot participants have incorporated climate-related risks into the oversight responsibilities of their risk management functions. Responsibilities include identifying, assessing, measuring, monitoring and reporting climate-related risks. Some pilot participants have more dedicated resources for climate-related risks, while some are in the process of building up the capacity.

3. While pilot participants recognize that Internal Audit should provide an independent review of risk management controls, processes and systems and of the effectiveness of the first- and second-line-of-defence functions, some have yet to determine how Internal Audit can incorporate its review of climate-related risks in the audit plan.

Risk management framework

While the six pilot participants recognize the need to incorporate climate-related risks as drivers into the risk management framework, most of them are still in the early stage of developing these capabilities. Most pilot participants view climate-related risks as risks manifesting in existing risk categories (e.g., credit, market, liquidity, operational and insurance risks; see **Table 2**). Overall, physical risk is better understood in the risk assessment processes, while the impacts of transition risk on pilot participants' exposure are more complex. Insights gained from the BoC-OSFI Climate Scenario Analysis Pilot will likely further this development.

Table 2: Climate-related risks in participants' risk management frameworks

Credit risk management	Most of the six pilot participants are still in the early stage of developing capabilities and incorporating climate-related risks as drivers into their risk management framework and have prioritized these efforts given the urgent and transverse nature of these risks. Generally, collateral valuation does not take into account climate-related risks. Loan pricing frameworks do not explicitly reflect credit risk appetite and business strategy with regard to climate-related risks.
Operational risk management and operational resilience	For most pilot participants, climate-related risks are captured broadly in their operational risk framework. Risk factors are frequently included in the business continuity plans/business resilience programs in response to climate-related risks. Most participants have assessed some aspects of climate-related risks and their impact on operational resilience.
Market risk management	Less than half of the pilot participants consider climate-related risk factors in their market risk frameworks.
Liquidity risk management	Most pilot participants do not consider climate-related risks directly in their liquidity risk management or buffer calibrations.
Insurance risk management	For pilot participants with insurance underwriting activity, some respondents include climate-related risks in their insurance underwriting processes, while others address climate-related risks on a portfolio basis.

Materiality assessment, due diligence and risk quantification	Most pilot participants integrate climate-related risks into their strategic planning. Most conduct climate-related due diligence on institutional clients. Some include climate-related risks in their assessment of materiality. Pilot participants are in different stages of developing their capabilities to quantify climate-related risks.
Capital adequacy	Most pilot participants assess the impact of climate-related risks on capital adequacy through the financial condition testing exercise or through capital planning for traditional risk categories (e.g., credit, market and operational).
Stress testing / scenario analysis	All pilot participants incorporate climate-related stress testing or scenario analysis either in their enterprise-wide stress-testing programs or through participating in the current scenario analysis pilot. While all pilot participants conduct climate-related stress tests to some degree, current practices and capabilities for physical risk assessment are more developed than those for assessment of transition risk.

Reporting and disclosure

All six pilot participants recognize the potential materiality of climate-related risks and the need for robust climate-related reporting and disclosure practices. They have made progress on discussing climate-related risks in internal reporting. Moreover, they are collectively committed to aligning with the TCFD recommendations to disclose clear, comparable and consistent information about climate-related risks and opportunities.

- Reporting:
    - Most pilot participants do not have a specific holistic approach to data governance for climate-related risks, but some have made adaptations to their IT systems for data analytics and have begun performing data gap assessments.
    - Most pilot participants have considered adapting their IT systems to systematically collect and aggregate the necessary data to assess their exposures to climate-related risks. However, some intend to instead rely on external vendors and data sources to assess climate-related exposure.
    - Some pilot participants cannot provide information on the impact of climate-related risks on their business models, strategies and risk profiles or generate aggregated and up-to-date climate-related risk data reflecting exposure to the risk.

  - The boards and senior management receive reports that capture and escalate existing metrics and targets for all pilot participants. Some reports are reviewed and approved by the boards before being published as per the TCFD recommendations.
- Disclosure:
  - All six pilot participants are supporters of the TCFD and are committed to adopting its recommendations. They have taken steps toward implementation, as reflected in their respective annual climate-related reports.
  - Some pilot participants have obtained limited assurance on select indicators (e.g., greenhouse gas emissions) through a third party, while others currently do not plan to acquire third-party verification.

Box 4:

Key takeaways from the broader financial sector questionnaire

In addition to surveying the six pilot participants, OSFI provided a questionnaire to a broader range of financial sector stakeholders to better understand the level of preparedness for climate-related risks. OSFI received 51 responses from small and medium-sized federally regulated financial institutions (FRFIs), asset managers, pension plans, industry associations, rating agencies and other service providers. The questionnaire results indicate a wide range of practices in managing climate-related risks.

Capacity for preparedness

- The financial sector is beginning to consider climate-related risk. But respondents indicated they are still in the early stages of incorporating these considerations into their decision making and management of risks, noting that "it is ongoing education" and a ''steep learning curve."
- While respondents showed a low level of maturity in climate-specific expertise and capabilities, most indicated they have concrete plans to expand their capacity in the next two years to perform climate-related risk analysis.
- Respondents indicated that a lack of modelling capacity impedes their ability to quantify and translate results of climate scenario modelling into potential financial impacts—with a key challenge being the long time horizons. Respondents also identified the challenges of understanding how climate-related risks interact with or differ from more traditional risks.

(continued...)

Box 4 (continued)

Governance

- The incorporation of climate-related risks into risk appetite frameworks varied across respondents:
    - Organizations that explicitly and formally articulate climate risks support them with qualitative or quantitative measures or statements. In some cases, these align with or are reported in the organizations' public climate ambition and strategy.
    - Climate risks that are not explicitly captured in risk appetite frameworks are embedded in other risk categories—with organizations treating them as ''transversal risk factors'' driving other traditional risks.
    - In a few reported cases, organizations include climate-related risks in remuneration policy and practices to incentivize behaviour. However, these are implemented at executive levels.

Disclosure

- Most respondents have taken first steps in putting TCFD recommendations into effect, with implementation in early stages and planned as a multi-year journey.
- Respondents generally find that the most useful types of disclosures from corporate entities include:
    - concise and specific information on risk and opportunity metrics
    - targets related directly to the strategy and financial performance of the entity
- They report that the development and usability of climate-related risk and opportunity disclosures are limited by:
    - poor and unverifiable data
    - inconsistent and non-transparent methodologies, taxonomies and reporting standards for developing climate-related metrics and targets
- However, respondents generally recognize the strong value of standardized methodologies for assessing climate-related risks.

6. Lessons learned from the pilot exercise

This section summarizes key lessons learned from the conduct of the pilot exercise in terms of both developing the climate scenarios and assessing the financial risk of climate transition to a low-carbon economy. In doing so, it draws on OSFI's survey and questionnaire findings, which provided valuable insights into financial institutions' current climate-related governance and risk management practices and preparedness. We also reflect on direct feedback from pilot participants on their own lessons learned from the pilot project experience. To situate the takeaways from this pilot project within the broader learning context of using scenario analysis to assess climate-related risk, we also draw on lessons learned from other financial authorities that have conducted similar analyses.

6.1 Climate scenario development component

This pilot project provided financial authorities and participating financial institutions with a foundational experience in using climate scenario analysis to identify, assess and understand climate-related transition risks to the Canadian economy and financial system. It improved awareness of and capabilities in the application of climate scenario analysis, while recognizing this as a new and growing field of analytical activity.

The climate transition scenarios developed for this exercise pointed to a number of potential material risks to the economy and the financial system. Through its rich set of sectoral information, the analysis illustrated the important sectoral restructuring that the Canadian and global economies could need to undertake to meet climate targets. While the analysis showed that every sector needs to contribute to the transition, significant negative financial impacts emerged for some sectors (e.g., fossil fuels) and benefits emerged for others (e.g., electricity). The results of the climate scenario analysis also shed light on the risks of significant macroeconomic impacts, driven largely by global channels and of particular significance for commodity-exporting countries like Canada. Finally, the analysis showed that delayed climate policy action increases the overall economic impacts and the risks to financial stability of a sudden repricing of assets.

It is important to acknowledge that several key assumptions and methodological considerations influence the estimates of the macroeconomic and financial impacts from the transition. These include uncertainties associated with long time horizons, the availability of technologies, the recycling of revenues from carbon pricing schemes back into the economy, and the level and nature of climate policies adopted at the global level.

The pilot project apprised the Bank of the methodological and design choices and challenges related to scenario analysis development, including in terms of understanding the implications of different assumptions and parameters, and the value in offering a range of possible outcomes. The technical reports on the scenarios' development and financial risk assessment methodologies that accompany this report will help build the capacities around climate scenario analysis.

6.2 Financial risk assessment component

Overall, the financial risk assessment component of the project increased authorities' and financial institutions' understanding of the financial sector's potential exposure to risks associated with a transition to a low-carbon economy. It helped build pilot participants' capabilities in climate risk assessment by exploring novel risk assessment methodologies that incorporate long time horizons. The process allowed participants to increase their understanding and awareness of the economic and financial implications of the climate transition for their portfolios, including identifying sectors expected to be more at-risk as well as those that could benefit and to what degree. The assessment also provided a forum for institutions to exchange expertise and compare thinking on climate-related transition risk to inform individual analyses.

As corroborated by OSFI's survey and questionnaire findings, financial institutions are generally in the early stages of building climate-related risk assessment capacities, including through scenario analysis. Findings also confirmed that institutions consider climate-related transition risks to be particularly complex to analyze. The exercise represented a constructive starting point to further support financial market participants' assessment of transition risks and will help inform their thinking on how to identify and measure transition-related impacts moving forward.

The bottom-up component of the credit risk analysis allowed financial institutions to identify data gaps, fostering the importance of data collection within institutions. Financial authorities in turn were able to address their own data gaps by using pilot participants' borrower-level data and risk assessment expertise. However, this bottom-up component of the credit risk analysis highlighted some challenges:

- Pilot participants stressed that the time and resources required to assess the transition risks exceeded their expectations.
- The assessments of the participating financial institutions varied greatly, despite the guidance we provided on how to use financial impacts generated from the top-down scenarios development component to complete the risk assessments. This made the consistency and comparability of results particularly challenging.

Such variation could be attributed to several factors, including differences in participants' internal analytical tools and capacities and in how they interpreted and used scenario data and narratives to inform expert judgment. The process for classifying borrowers and selecting representative borrowers and the availability and quality of counterparty data (e.g., emissions data) may also be factors in the variability of results.

While the top-down analysis of market risk required fewer resource costs, we conducted it at a lower level of sectoral granularity and abstracted from some important considerations, including channels of transmission of systemic risk (e.g., common exposures and fire sales).

Overall, the financial risk assessment component of the pilot project revealed opportunities for future enhancements to support a deeper understanding of the implications of transition risks. Directions for future work include developing and standardizing climate risk assessment methodologies and practices, improving data collection efforts and incorporating systemic risk considerations into the analysis.

7. Conclusion and next steps

This pilot project represents an important foundational step on the path to building our capacity to understand and assess how climate-related risks affect the Canadian financial system. Ultimately, the ongoing development of climate-related scenario analysis will provide authorities with an assessment of the financial system's vulnerabilities due to climate change.

As discussed above (e.g., see **Box 3**), there are channels through which climate transition risks could lead to financial stress across the system. For example, abrupt changes in global climate policy could lead to (i) fire sales because of common exposures to climate-sensitive assets across financial institutions or (ii) a tightening of financial conditions and financial stress because of opacity in climate-related financial reporting. These risks could be further propagated through financial sector interlinkages. Enhancing the understanding and assessment of climate change impacts on system-wide market and credit risks will allow the Bank and OSFI to improve how we assess system-wide vulnerabilities.

A core goal of the pilot was to build up the capacity of authorities and financial institutions for conducting climate scenario analysis, which is a natural prerequisite for system-wide assessments. The pilot project involved only a small set of participants and focused on a small fraction of the financial institutions' balance sheets and did not consider these potentially important channels of systemic risk. A recent NGFS report on the practices and experiences from a range of central banks and supervisors conducting climate scenario analysis corroborates a key takeaway from the present pilot exercise—namely, that climate scenario analysis is a new and growing field of analytical activity.[39] The experience of other central banks and supervisors indicates that developing awareness and capabilities around climate-related risks is as important as assessing the risks themselves, emphasizing the considerable value in conducting climate scenario analysis at this juncture.

The Bank and OSFI remain committed to better understanding and assessing climate-related financial risk to the Canadian economy and financial system and to supporting financial market institutions in building their climate-related risk assessment and management capacity. The lessons learned and results generated from this joint pilot project on climate scenario analysis provide constructive insights that will help inform

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39 Please see NGFS, *Scenarios In Action: A Progress Report on Global Supervisory and Central Bank Climate Scenario Exercises* (October 2021).

the Bank's and OSFI's respective work programs in this area. Future work will address some of the limitations of the current analysis by:

- incorporating physical risks,
- expanding the scope of the analysis to include other financial institutions and other assets,
- exploring systemic risk considerations, and
- working toward improving and standardizing risk assessment methodologies.

This work will allow us to better understand and quantify potential climate-related financial stability risks.

Authorities will work toward developing capabilities in top-down climate scenario analysis to assess potential systemic risks while supporting financial institutions' building of their own climate risk assessment and disclosure capacity. In the near term, OSFI will follow up on the discussion paper it published in 2021 with the development of prudential guidance on risk management expectations, scenario analysis and disclosure.[40]

40 OSFI, *Navigating Uncertainty in Climate Change: Promoting Preparedness and Resilience to Climate-Related Risks* (January 2021); see also OSFI, "OSFI Launches Consultation on Climate-Related Risks in the Financial Sector" (press release, January 11, 2021).

Appendices

A. Mapping exposures to sectors using NAICS and GICS industrial classification systems

Sector	NAICS	GICS
LIVE	112	30202010, 30202030
FORS	113	15105010
CROP	111	30202010, 15105010
COAL	2121, 213117, 213119	10102050, 15104050, 15104020
OIL	213111, 213118, 2111	10102010, 10102020, 15104020, 10101010, 10101020
GAS	2212, 213111, 213118, 2111	551020, 10102010, 551050, 551030, 10102020, 15104020, 10101010, 10101020
ELEC	2211	551010, 551050, 551030, 55105020
HYDRO	221111	55105020
NUCLEAR	221113	551010, 551050, 551030
FOSSIL FUELS	221112	551010, 551050, 551030
OTHER (i.e., geothermal, solar, tidal, wind)	221119	551050
TRAN	488, 492, 481, 493, 483, 487, 486, 482, 485, 484	201010, 203020, 20305010, 20201070, 20305020, 25301020, 10102010, 25301030, 203030, 20305030, 551030, 10102040, 20304010, 20304020, 203010
EINT	322, 323, 325, 326, 327, 331, 332	151020, 45103010, 201010, 201020, 201030, 303010, 303020, 352010, 352020, 15101010, 15101020, 15101030, 15101040, 15101050, 15103010, 15103020, 351030, 15105020, 15104010, 15104020, 50202020, 15104025, 15104030, 15104045, 15104050, 50202010, 20104010, 20106020, 20201010, 20201060, 25101010, 25101020, 25201020, 25201030, 25201040, 25201050, 252020, 25302020, 35101020, 50201040, 45103020
FOOD	311, 312	30202010, 30201010, 30201020, 15101020, 30101030, 30202030, 30201030, 15101050, 302030
ROIL	324	10102050, 15101010, 151020, 15101020, 10102010, 10102030

OTHR	339, 334, 336, 333, 2122, 2123, 314, 315, 316, 335, 321, 238, 236, 237, 2213, 337, 313, 213117, 213119	50201010, 201010, 20106015, 15104010, 25203010, 25101010, 25102010, 201020, 25301010, 10102050, 452010, 201030, 20106010, 151020, 25201010, 15104025, 15101020, 15104020, 20104010, 45203015, 45203010, 45203020, 20201050, 15101030, 25203020, 15105010, 15104030, 35101010, 35102015, 35101020, 20104020, 20305020, 25201020, 25201030, 25201040, 303010, 25201050, 20106020, 352030, 15103010, 25102020, 50202010, 551030, 20201060, 10101020, 15103020, 303020, 15104040, 50201040, 60102030, 45301010, 45301020, 15104045, 25302020, 15104050, 452020, 25203030, 551040, 60102010, 252020
SERV	541, 561, 611 517, 448, 518, 522, 523, 441, 447, 515, 519, 711, 713, 721, 443, 453, 532, 811, 452, 551, 812, 813, 623, 624, 722, 814, 446, 562, 445, 621, 622, 442, 444, 451, 524, 454, 712, 521, 533, 115, 491, 531, 413, 414, 419, 526, 911, 912, 913, 914	50201010, 201010, 30202010, 203010, 20305010, 50101010, 25504010, 45103010, 40203010, 25504050, 50201020, 50201030, 25301010, 20201010, 25504020, 201030, 402020, 45102020, 25503010, 40101010, 40203030, 15104020, 60102010, 60101010, 20201070, 30101010, 25302010, 20201050, 40203040, 30101020, 30101030, 15105010, 25503020, 15104030, 35102010, 35102020, 60101050, 35102015, 351030, 25504030, 25504060, 60101030, 25301020, 20202010, 30101040, 60101020, 40301010, 10102010, 50101020, 502030, 255020, 45102030, 40203020, 45102010, 25301030, 40301020, 352030, 35102030, 40204010, 50202010, 40301030, 40201030, 60101040, 20201060, 10101020, 10102030, 10102040, 40201020, 30202030, 15104040, 40301040, 50201040, 20304010, 60102030, 60102020, 60102040, 40101015, 40301050, 20202020, 60101060, 25301040, 60101070, 20201080, 15104045, 25302020, 40201040, 60101080, 25504040, 15104050, 45203030, 401020, 201070, 20304020, 50102010, 255010, 201050

B. Estimated climate transition–credit risk relationship for the United States

Chart A-1: Climate transition–credit risk relationship, United States, 2050

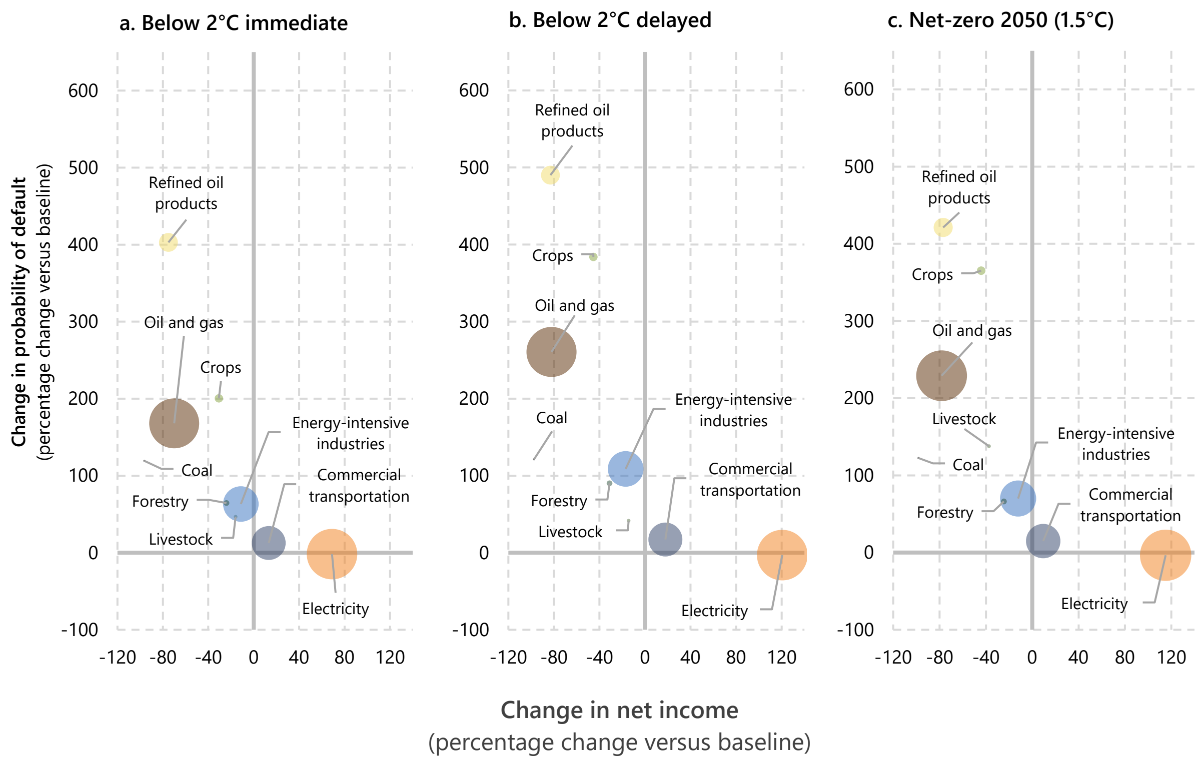


Chart A-2: Change in probability of default in the United States across the transition scenarios

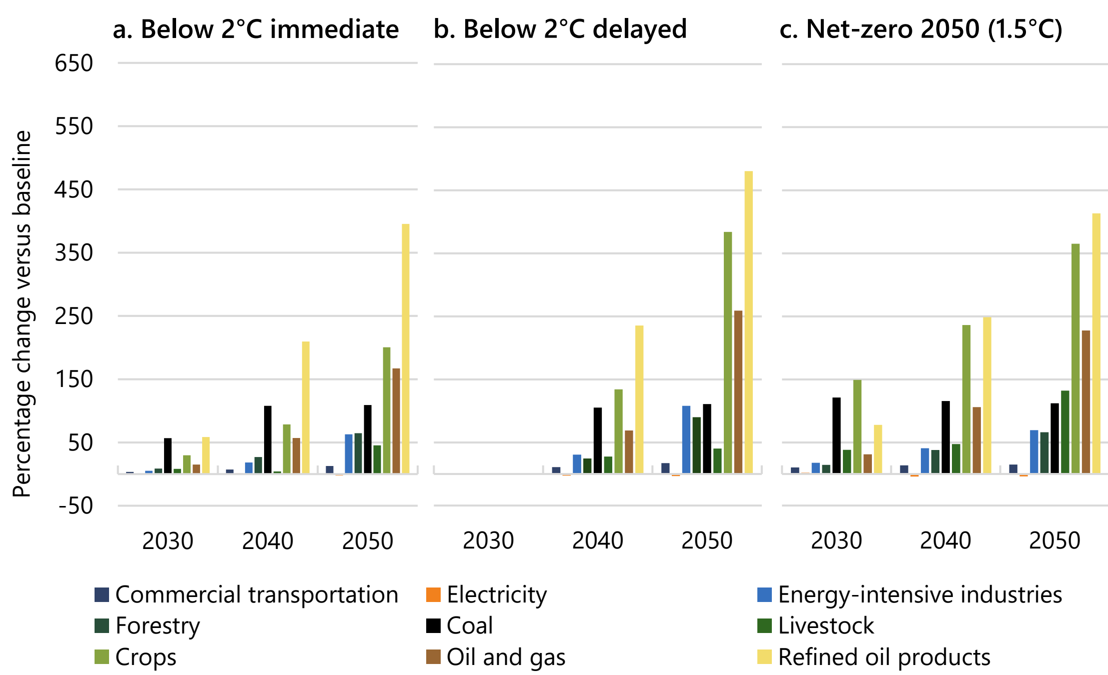
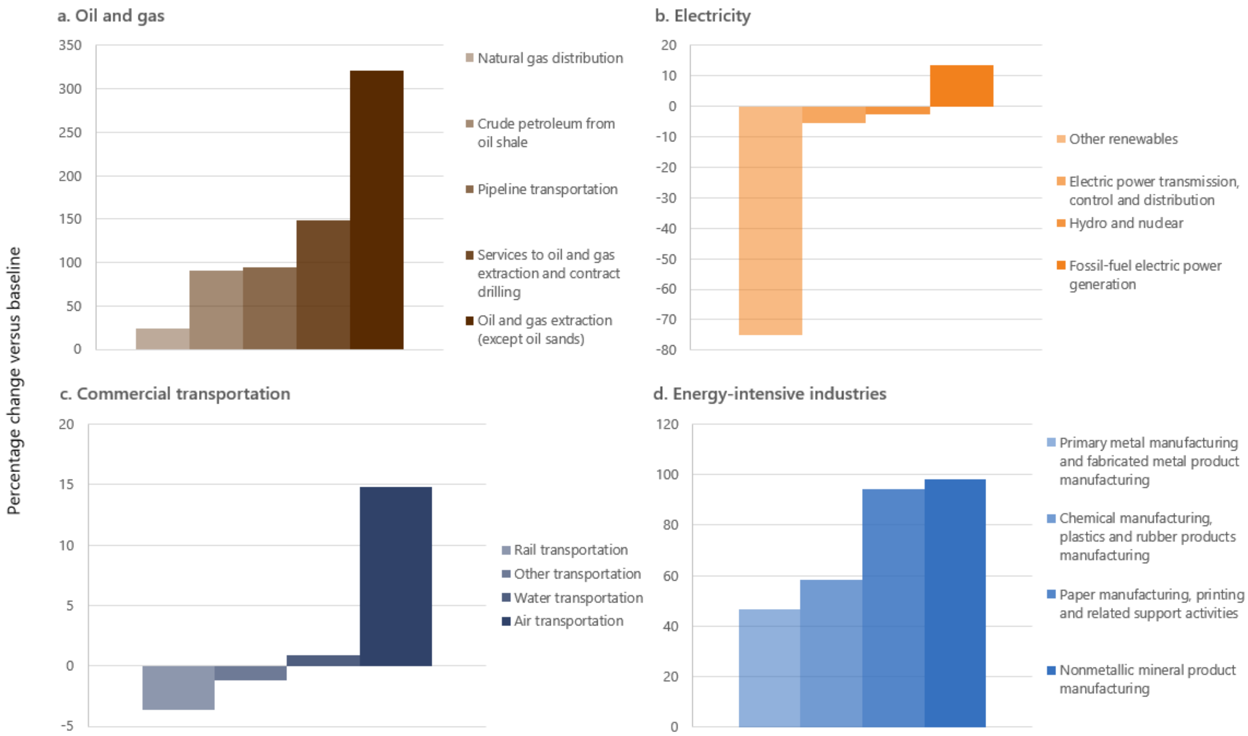
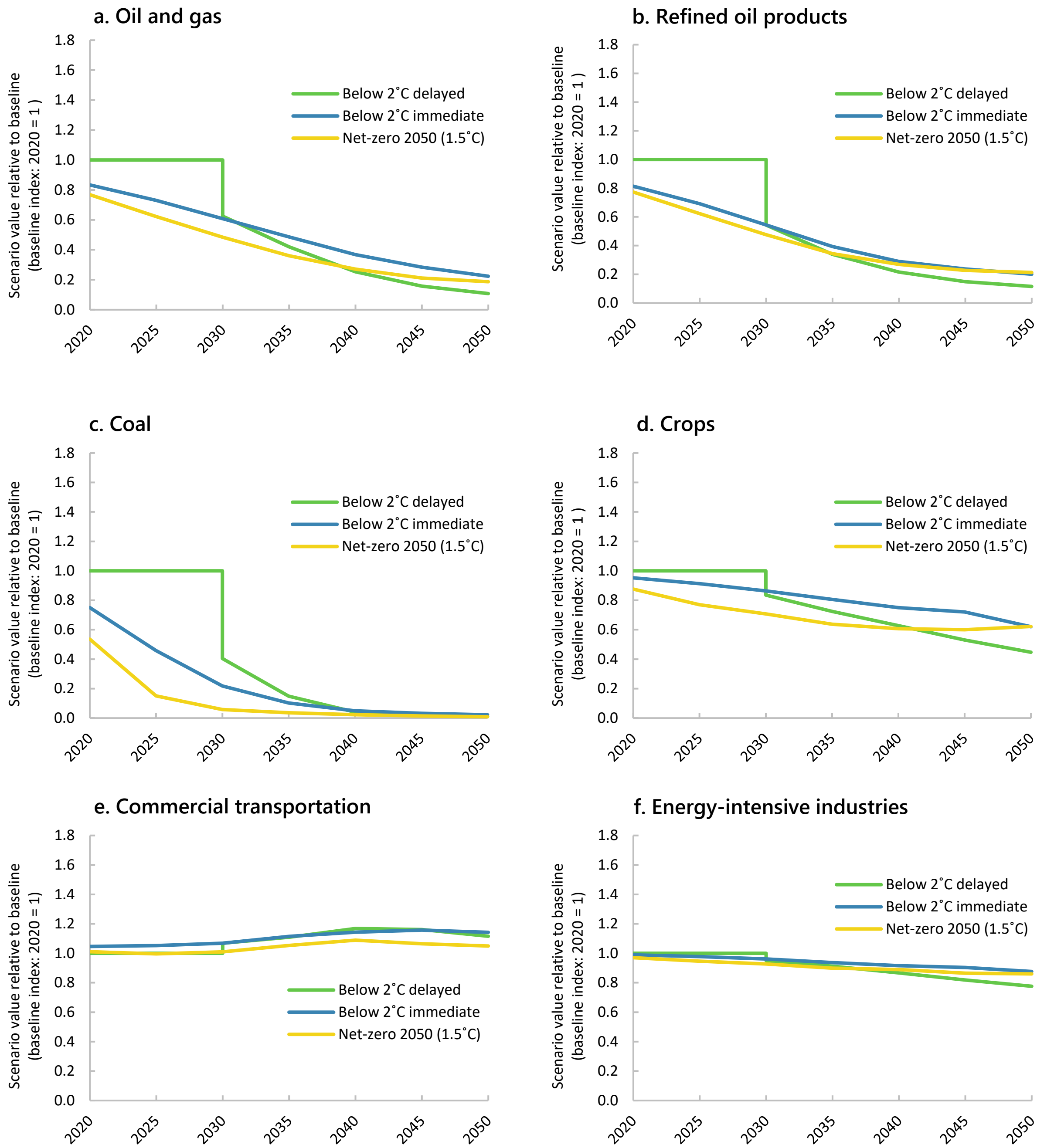


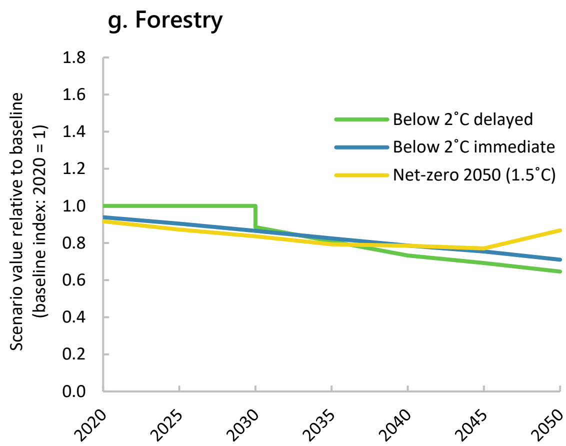
Chart A-3: Change in probability of default in the United States by 2050 under the below 2°C immediate scenario

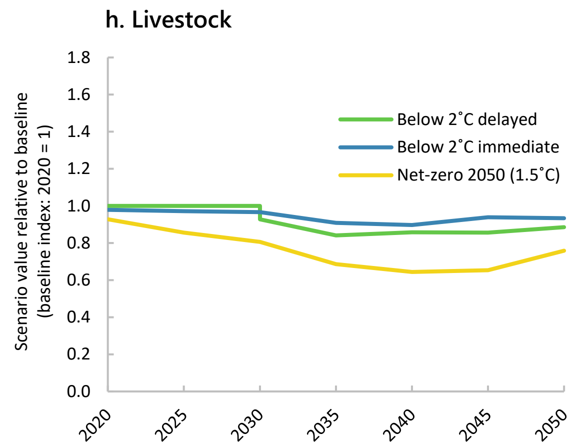


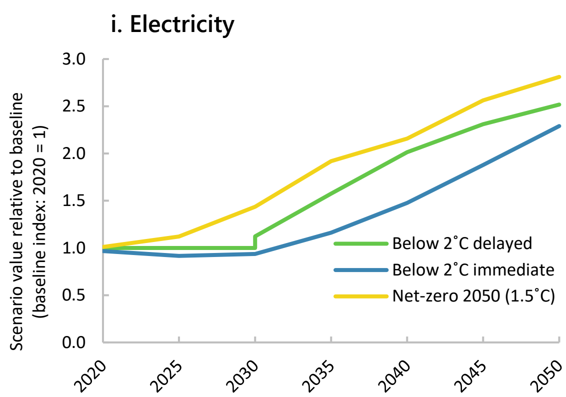
C. Estimated equity valuation impacts by sector for the United States

Chart A-4: Equity valuation impacts on US sectors following changing global climate policy




g. Forestry
Scenario value relative to baseline (baseline index: 2020 = 1)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2020
2025
2030
2035
2040
2045
2050
Below 2˚C delayed
Below 2˚C immediate
Net-zero 2050 (1.5˚C)


h. Livestock
Scenario value relative to baseline (baseline index: 2020 = 1)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2020
2025
2030
2035
2040
2045
2050
Below 2˚C delayed
Below 2˚C immediate
Net-zero 2050 (1.5˚C)


i. Electricity
Scenario value relative to baseline (baseline index: 2020 = 1)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2020
2025
2030
2035
2040
2045
2050
Below 2˚C delayed
Below 2˚C immediate
Net-zero 2050 (1.5˚C)