6

Climate Risk Measurement and Management

Learning Objectives

After completing this reading you should be able to:

- Identify approaches to measuring climate-related risks and the available metrics and tools.
- Understand both why and how climate risks are different from other risk types.
- Describe the basic risk types: operational, credit, liquidity, insurance underwriting, market and sovereign risk.
- Identify the standard tools and techniques for measuring, modeling, and managing the basic risk types.
- Describe the Climate Value at Risk (CVaR) framework.
- Understand how existing tools and techniques can be applied, adapted, or amended to incorporate climate risk.
- Explain how climate risk can be incorporated into existing Enterprise Risk Management (ERM) frameworks.
- Explain how climate change could be incorporated into the different aspects of risk management, such as risk identification, measurement, and monitoring.
- Describe how climate risk can be incorporated into risk governance frameworks, risk appetite statements, and risk culture.
- Understand the climate risk implications for corporate culture and governance.
- Evaluate the rationale for the different types of climate models and explain the justification for the models' varying levels of certainty.

This chapter describes how climate risk is measured and managed, covering both types of climate risk, physical and transition (as described in Chapter 3). After an introduction, this chapter covers in detail how climate risk transmits into more traditional risk categories at the company level, including operational risk, credit risk, liquidity risk, and underwriting risk. It then covers how climate risk can be a systemic risk with potential threat to financial stability, transmitting either through one of the previously mentioned channels or through market dislocations (market risk) or effects on countries (sovereign risk).

The chapter goes on to describe available data and analytical tools for measuring both physical and transition risks, building on material from Chapter 3. Finally, this chapter examines how climate risk can be, and is being, integrated into existing enterprise risk management (ERM) processes, ranging from governance structures and strategy setting to risk evaluation and disclosure. The material in this chapter sets the stage for Chapter 7, which builds on these topics by looking specifically at the application of scenario analysis to climate risk management.

Chapter Outline

Key Learning Points

- **Measuring and defining** climate risk is a prerequisite for being able to manage it—even more acutely so than for many other kinds of risks.
- Climate risk affects many **company-level risks,** including operational, credit, liquidity, and underwriting risks.
- Climate risk can also constitute a **systemic risk** and a potential threat to **financial stability** through its impacts on entire sectors and swathes of the economy.
- **Corporate greenhouse gas emissions** are classified by scope. The classifications are as follows: Scope 1 (direct emissions), Scope 2 (emissions from energy inputted) and Scope 3 (indirect emissions from supply chains and products).
- Understanding transition risks requires data beyond current emissions, notably on **emission trajectories,** as well as data on a number of drivers ranging from policy and technological changes to consumer preferences and market sentiment.
- Physical risks can be analyzed at the asset level, or, for ease of use, through **company-level scores**. Asset-level analysis is more thorough but also more difficult; scores are easier to use and integrate but can sometimes suffer from methodological opacity or lack of cross-comparability between providers.
- Climate risk can be integrated into **enterprise risk management** in all its facets. This includes risk governance, strategy, risk assessment, review, and disclosure.

CLIMATE RISK MEASUREMENT AND MANAGEMENT

6.1 Introduction to Climate Risk Measurement and Management

Risk management is a structured approach to monitoring, measuring, and managing exposures to reduce the potential impacts of uncertain occurrences, and it has long been practiced by non-financial corporations and financial institutions alike. Climate risk affects corporations and portfolios in various ways. As with other kinds of risks, **climate risk management,** when practiced proactively, can help to mitigate the impacts of climate change, both from physical impacts and transition impacts, on a financial institution's portfolio or corporation's operations.

To understand and manage climate risk, it is helpful to examine how climate risk affects various types of financial risk, such as operational, market, insurance, liquidity, and credit risk. This is not only because risk managers are more familiar with these "traditional" categories of risk, but rather it is because climate change transmits through these various types of risk, so understanding these transmissions channels is helpful. For analytical clarity, this chapter starts by looking at company-level "micro" climate risk transmission (Section 6.2) and then goes on to discuss climate change as a macro phenomenon, with the potential to be a source of systemic risk and pose a threat to financial stability (Section 6.3).

The old cliché that "You can only manage what you can measure" is just as true for climate risk as it is for other types of risk, though compared to other types of risk, a greater variety of data is often required. Understanding transition risk not only requires solid data on the amount of greenhouse gas emissions attributable to a particular company or asset but also an understanding of the evolving climate policy landscape, technological changes, and evolving consumer and broader societal preferences, as well as market sentiment. Understanding physical risk requires forward-looking climate models and historical weather data, as well as information on physical geography, adaptive infrastructure, market responses, cross-correlations, and distributions (see schematic for an example, and Section 6.4 for details).

EXAMPLE: DATA FOR UNDERSTANDING PHYSICAL RISK TRANSMISSION INTO FINANCIAL PORTFOLIOS

This example, a generalized version of the transmission chain of physical risk into financial assets, as presented for the US mortgage market in Chapter 3, highlights the different types of data and information needed to account for climate risk in a financial context, to measure it, and then manage it. Weather and climate data and models are needed to understand the physical hazards; topographical maps and geolocation data to understand exposure; and data on flood defenses and other adaptive measures to understand vulnerability.

In jurisdictions where mortgages tend to be retained on bank balance sheets, banks need access to this information to track their risk exposure and conduct risk management. In jurisdictions such as the United States, where mortgages tend to be securitized and sold onwards in financial markets, this adds an additional layer of complexity. Ultimately, end investors need access to climate risk exposure data to be able to adequately gauge the riskiness of their holdings.

Source: Author.

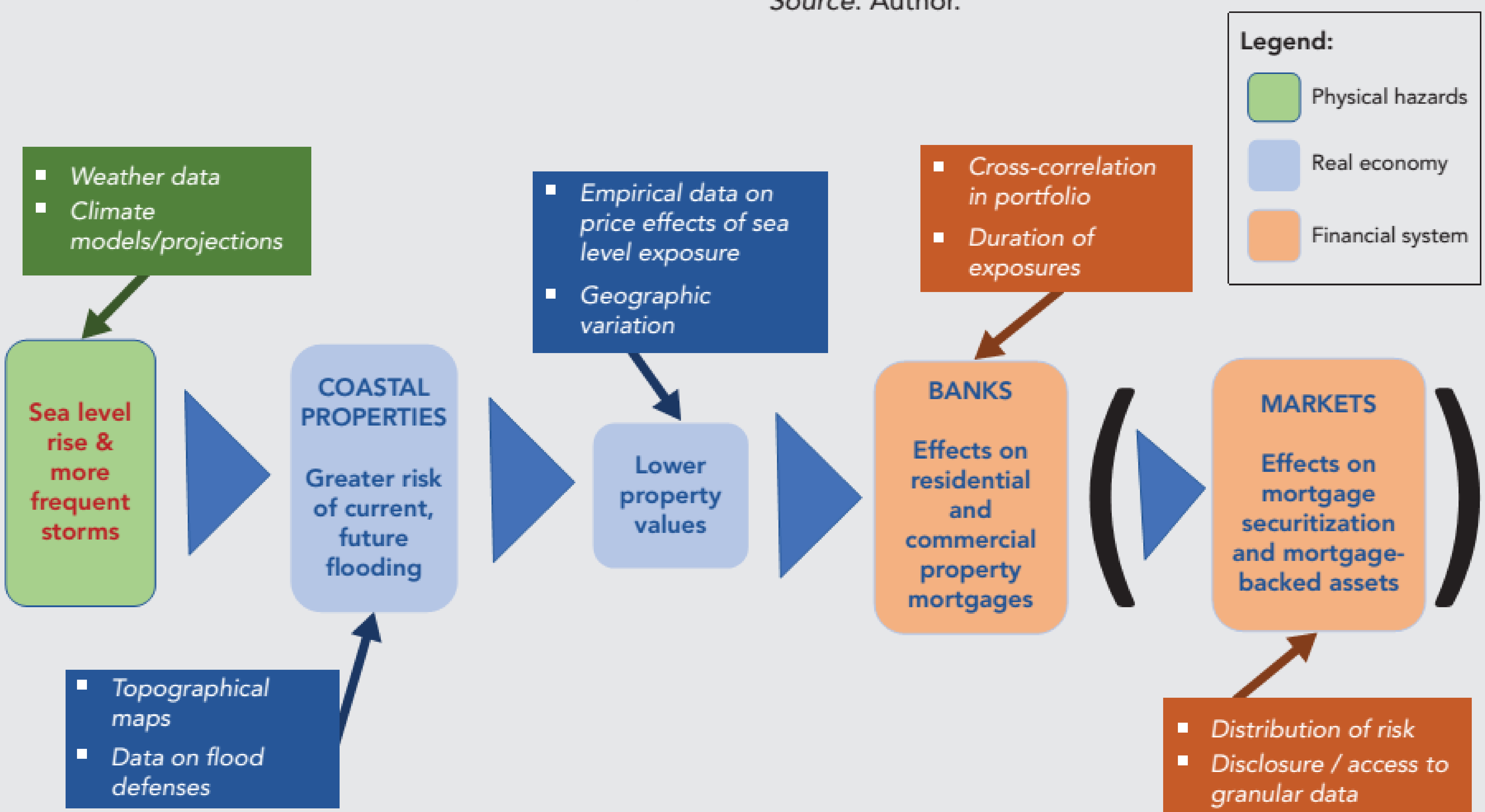

Figure 1

6.2 Introducing Climate Risk Transmission: Micro and Macro Level

Climate risk drivers can transmit to financial risk through a number of risk types, ranging from operational risk and credit risk to market risk. This section contextualizes the classification of these risks before the transmission channels are covered in much more detail in Section 6.3 and Section 6.4.

Many classification schemes of climate risk transmission channels come from central banks (and umbrella organizations made up of them, such as the Basel Committee for Banking Supervision or the Network for Greening the Financial System). Given these institutions' focus on the health of the macroeconomy, including maintaining price stability and employment, their schemes distinguish between microeconomic, macroeconomic, and financial consequences and drivers (see graphic).

The NGFS schematic clearly shows how both transition and physical climate risks can cause microeconomic and macroeconomic effects. At the micro level, individual firms and households can be impacted by property damage, business interruption, loss of income, changes in demand, and falls in asset valuation through asset stranding. The macroeconomy can be affected by shifts in prices, changes in productivity, socioeconomic changes, or labor-market frictions. These can then cause financial risks to manifest.

However, the micro- and macroeconomic split, with financial risk relegated to a separate category, de-emphasizes the effects on the broader financial system, notably to financial stability, as well as any feedback effects between the economy and the financial system.

Due to this chapter's focus on corporations, both non-financial and financial, with less emphasis on households or on the macroeconomy, Section 6.3 focuses on company-specific risks, whereas 6.4 combines macroeconomic risks with systemic risks and those that potentially threaten financial stability. The following section focuses on six main risk categories, some primarily at the company level, some primarily affecting markets, and some at the macro level. The summary table below highlights these risks, which are then analyzed in greater detail in the following sections.

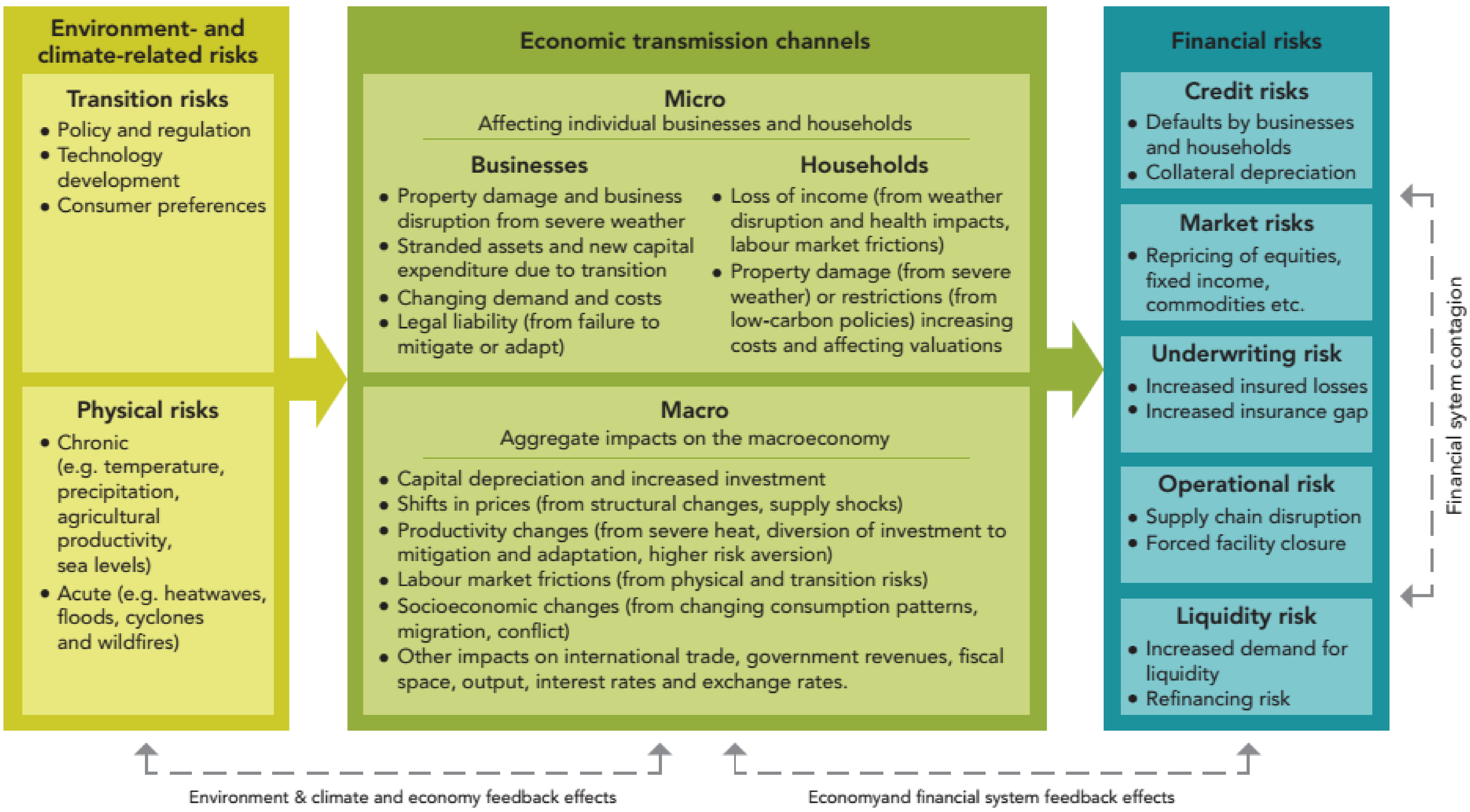

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Figure 2

Table 1

Risk Type	Risk Metrics	Micro-level: How do *climate risk drivers* cause company-specific risks?	Macro-level: Potential for *climate* to cause systemic / financial stability risk?
Operational risk	• Proportion of facilities in risky areas • Level of company preparedness	**Physical risk** leading to more frequent, more severe extreme weather can cause property damage and business interruption, both to a business' own facilities and to supply chains. Heat can also affect worker productivity. **Transition risk** can transmit to operational risk in case of abrupt policy changes leading to facility shutdowns.	**LIMITED**—Only under a specific set of circumstances, such as where a sector has high geographic concentration
Credit risk	• Probability of default (PD) • Loss given default (LGD) • Exposure at default (EAD)	**Physical risk** causing property damage and business interruption can lead to loss of revenues and lower profits, worsening a firm's financial position and increasing probability of default. **Transition risk** causing asset stranding can worsen a firm's financial position, increasing its probability of default, and increasing the loss given default for a lender given the lower asset valuations.	**SIGNIFICANT**—Sector-wide asset stranding or changes in demand can impact sector revenues and increase sector-level PD, posing financial stability risks in the case of important sectors and for exposed financial institutions.
Liquidity risk	• Loan to deposit ratio (banks) • Liquidity ratios • Bid-ask spread (markets)	Abrupt **physical and transition risk**-related events such as natural disasters or abrupt policy changes can prompt sharp repricing and sudden market re-evaluation of firms' viability, leading to liquidity shocks. This can lead to widening of bid-ask spreads. Abrupt climate events can prompt large demand for deposit withdrawals at banks, raising their loan-to-deposit ratios.	**SIGNIFICANT**—A "climate Minsky moment" could cause abrupt and wide enough repricing and dislocation to constitute a market liquidity shock.
Underwriting/ insurance risk	• [Change in] insurance premiums • Availability of insurance	**Physical risk** can lead to higher insurance premiums for corporations, or, in more severe cases, for certain facilities in extremely vulnerable areas to become uninsurable, with no insurance available. **Transition risk** can lead to less insurance availability, as some insurers refuse to underwrite certain kinds of activities and facilities, such as thermal coal power plants.	**SIGNIFICANT**—If a number of insurers withdraw or refuse coverage, this might leave firms completely without coverage, potentially amplifying risks to financial stability.

(continued)

Risk Type	Risk Metrics	Micro-level: How do *climate risk drivers* cause company-specific risks?	Macro-level: Potential for *climate* to cause systemic / financial stability risk?
Market risk	• [Weighted average] carbon intensity • [Climate] Value at Risk • Portfolio risk scores	**Physical and transition risk** can become more widely incorporated in asset prices, both through abrupt repricing as well as more gradually. Large-scale shifts in input and product markets affect non-financial corporations. Shifts in asset prices increase the risk of financial institutions' portfolios.	**SIGNIFICANT**—Climate risk is expected to produce sector- and market-wide repricing of many if not most assets and commodities, causing dislocation and potential systemic risk.
Sovereign risk	• Proportion of budget revenues from fossil fuels • Vulnerability to physical climate risks	**Physical risk** can cause countries that are particularly vulnerable, such as Bangladesh, to have higher costs of damage and lower GDP growth, hampering long-term ability to repay. **Transition risk** can heavily affect countries reliant on fossil-fuel production for a substantial proportion of GDP and of government tax revenue.	**MIXED**—Many countries have diversified economies and geographies, but some countries are heavily exposed to physical or transition risk and are likely to be severely affected.

6.3 Micro (Company-Level) Climate Risks

An important way in which climate risk manifests as financial risk is through its effects on microeconomic company-level risks such as operational, credit, liquidity, and insurance risk, each of which are examined in turn in this section. (Some of these channels can also pose a systemic risk, which is discussed in Section 6.3 alongside other non-company-specific transmission channels).

6.3.1 Operational Risk

Operational risk is the risk inherent in doing business, and it reflects potential losses from inadequate or failed internal processes, systems, human error, or outside events such as extreme weather or terrorist attacks. These various causes of operational risk tend to be regarded as subcategories, and they include external risk (from outside events); systems risk; people risk (from human error); internal process risk; and legal, strategic, and reputational risks.

Operational risk, being multifaceted, can be somewhat harder to measure. But metrics include the proportion of facilities in vulnerable locations (for external risk) and various measures of company preparedness.

One of the strongest effects of climate risk on operational risk is through its effect on external risk. Acute climate change hazards, such as wildfires, storms, or floods, or chronic climate hazards, such as sea level rise, can damage or destroy the factories, supply lines, or warehouses needed by a corporation or the offices, data centers, or bank branches of a financial institution. However, unlike some definitions of external risk that consider events such as natural disasters to be ones that have negative impacts that are beyond a given company's control, climate models combined with detailed data can allow at least some degree of anticipation on what physical facilities will be affected by these external risks.

To the extent that climate risk transmits into operational systems risk, it does so in ways similar to external risk. Physical climate hazards such as floods or fires can affect data centers and other system infrastructure, thus causing systems risk to a corporation or financial institution.

Climate risk can manifest through people risk in a few different ways. Inadequate staff training or management attention toward physical and transition climate effects can lead to these issues being ignored or underplayed within an institution's operations, potentially leading to losses. Another way climate risk can become people risk is more direct—through the harmful effects of excess heat on worker productivity and acuity (see ILO research mentioned in Chapter 3).

Transmission of climate risk into internal process risk is similar to that for people risk—if a bank's or other corporation's internal processes and procedures do not take sufficient account of climate risk, it can end up affecting portfolios and facilities more deeply than anticipated.

Three other categories of operational risk are particularly important when analyzing climate risk. One of these categories is legal risk. As described in much greater detail in Chapter 3, legal and liability risk can end up significantly affecting financial institutions and non-financial corporations if they are held liable for a) neglecting to manage climate risks, b) failing to adequately disclose their exposures to such risks, or c) contributing to climate change. Another category is strategic risk, where poor business decisions around failing to align business practices with the net-zero transition or adapt to the physical impacts of climate change can cause significant risks compared to competitors that do mitigate and adapt. And the third category is reputational risk, which can severely affect institutions working with "dirty" industries that come to be seen as having lost their social license to operate (see the example on Goldman Sachs in Chapter 3).

6.3.2 Credit Risk

Credit risk measures the creditworthiness, or ability a borrower has to pay back, a loan.

Key metrics for gauging credit risk, especially for banks, include the **probability of default (PD)** and the **loss given default (LGD)** (i.e., the proportion of value recovered after a default). The third key metric used under the Basel supervisory framework for banks is exposure at default (EAD). We focus primarily on PD, as this is the most general measure of credit risk and it is applicable beyond banks (e.g., to

VISUALIZATION OF CLIMATE AFFECTING OPERATIONAL RISK AND ITS SUBCOMPONENTS

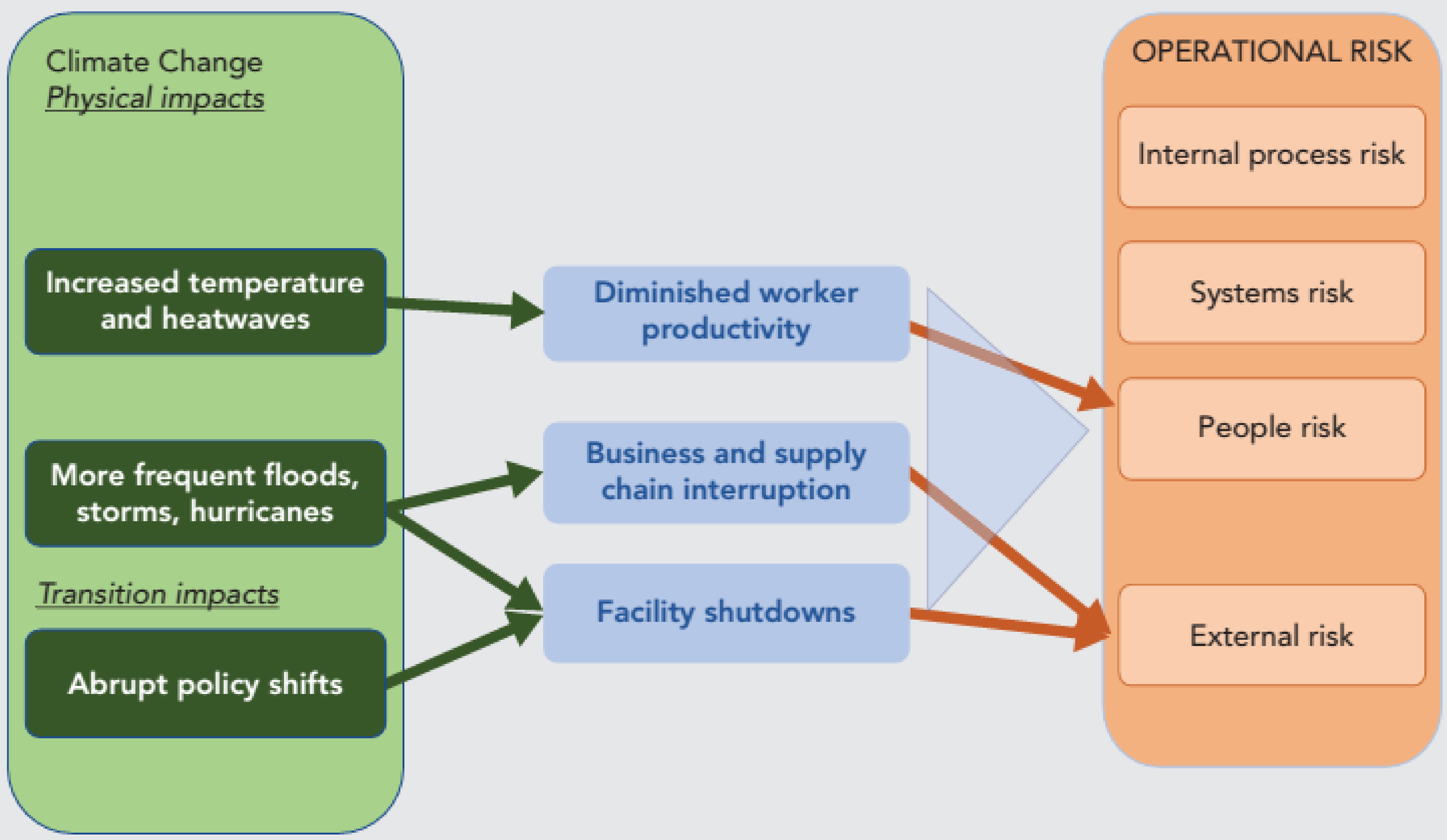

Figure 3

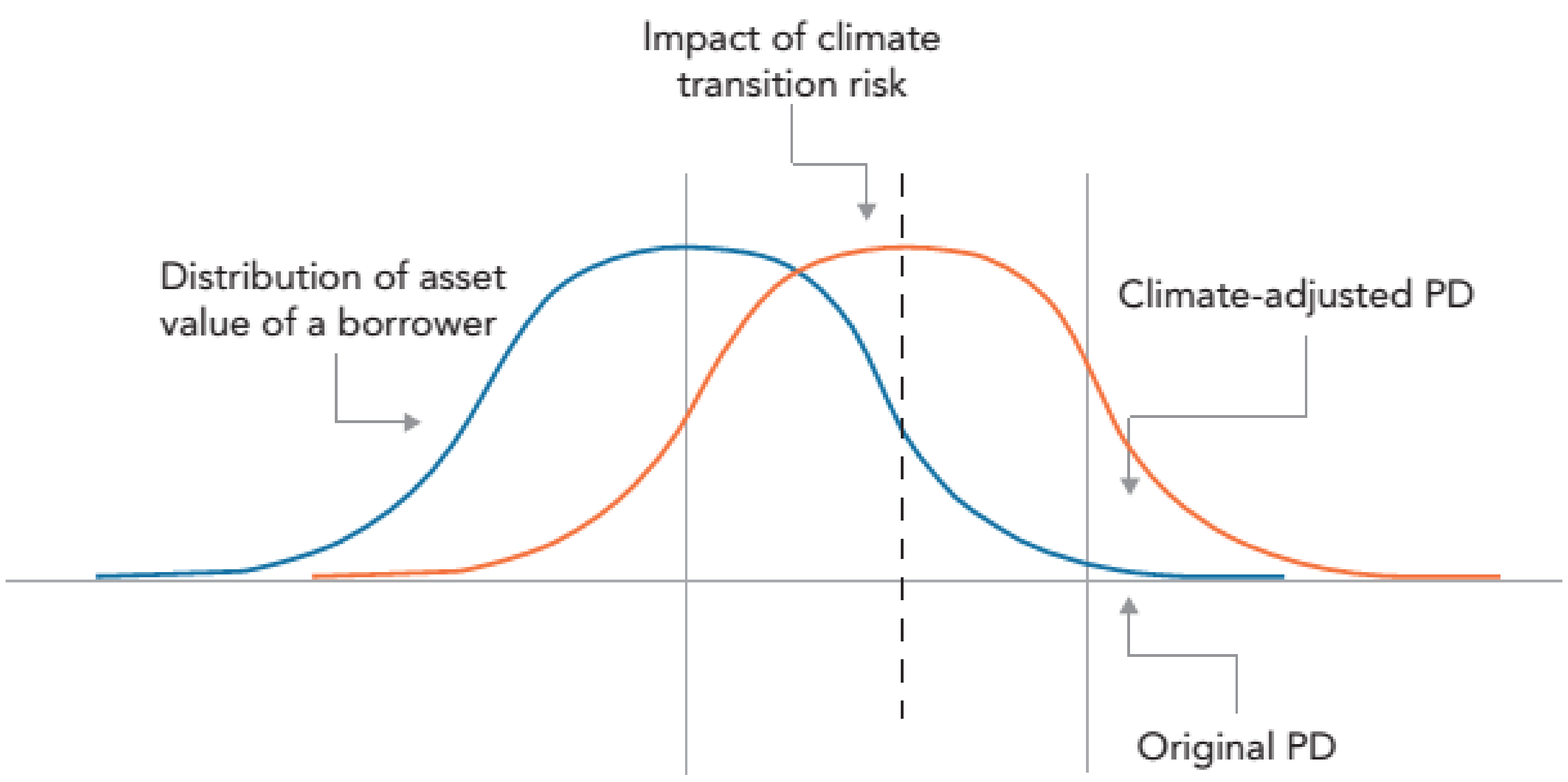

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Figure 4

bond markets). LGD is expected to be highly sector-specific and it requires high degrees of customization (UNEP Finance Initiative, 2018). In general, climate risk is expected to shift the entire PD risk distribution of a borrower (see graphic, labeled for transition risk but applicable for all types of climate risk).

One important transmission channel from climate to credit risk runs through operational risk. A company whose factories, warehouses, or supply chains are particularly vulnerable to extreme weather impacts (physical risk), or indeed to abrupt policy changes (abrupt transition risk), will have greater business interruption, resulting in a loss of revenues and profits. This weakens the company's ability to repay loans compared to a similar company that is not exposed, thus translating into increased PD and increased credit risk for a lender. Project finance tied to a specifically vulnerable asset, such as a warehouse at risk of flooding, would be subject to even higher PD and LGD than the exposure of an entire company owning a mix of vulnerable and non-vulnerable assets.

Another important channel operates through valuation effects, that is, asset stranding (as covered in Chapter 3). If a company's core assets fall in value or even become worthless, this significantly affects the financial health of the firm. With less valuable assets, a company's liabilities suddenly weigh a lot heavier on its balance sheets and make it more likely that the company will default on future debts and that losses given default will be greater—not to mention that the company also has less collateral to use to secure funding. The asset stranding can be due to physical risk, such as a warehouse in a floodprone area with a much lower resale value, or due to transition risk, if a company's high-emissions factory is hit with a regulatory shutdown mandate or a higher carbon tax.

The oil & gas sector is a good example of a sector that has been hit by the stranded asset transmission channel. Historically, much of the value of such firms has been in their reserves and the expectation of their consistent or growing revenues. The fact that many of these firms' assets may become stranded and that oil demand is expected to fall means that these firms may become less creditworthy than they would in the absence of climate change. (Of course, there are still differences within the sector—for instance, oil companies with very low extraction costs on their reserves will tend to have a smaller proportion of stranded assets than companies with assets that are more expensive to extract.)

A final, related channel is that of pricing effects—both through markets for inputs (raw materials) and outputs (products). If climate risk causes a company's raw materials to become more expensive, or makes its products less valuable, this, too, can increase its credit risk. Pricing effects can also work the other way and, in fact, reduce a company's credit risk. Companies in the mining sector that extract minerals important for mass electrification, such as copper for wiring or lithium for lithium-ion batteries, can benefit from the higher prices of these commodities, make greater revenues and profits, and be more creditworthy than they would have been without climate change.

Policy considerations regarding the rise of credit risk due to climate risk are being increasingly incorporated by major credit ratings agencies, which serve as important arbiters of credit risk for financial markets. In January 2021, S&P, one of the three major rating agencies, revised its entire outlook on the oil & gas industry due to "[s]ignificant challenges and uncertainties engendered by the energy transition, including market declines due to growth of renewables," and shortly afterward downgraded oil & gas firms ExxonMobil, Chevron, and ConocoPhillips by one step to "AA-" (S&P Global Ratings, 2021).

The rise of sustainability-linked bonds and loans, as discussed in Chapter 5, can also be seen as an example of the financial industry internalizing the linkage between credit risk and sustainability performance. Offering a lower rate on a loan or lowering the coupon on a bond that an issuer must pay in return for meeting sustainability targets, as these instruments do, implicitly recognizes the corollary, which is that that performing worse in this respect raises credit risk.

6.3.3 Firm-Specific Liquidity Risk

Liquidity risk is about losing access to liquidity—the ability to quickly and easily convert assets into cash. For banks, liquidity risk means something very specific, as banks' business models are based on liquidity transformation: Banks take on short-term deposits and underwrite long-term loans.

<u>Key metrics</u> for liquidity risk include **loan-to-deposit ratios** (specifically for banks) and **bid-ask spreads** (specifically for markets; also see Section 6.4.3).

Because liquidity is of such paramount importance to banks, banks are also particularly affected by climate risk impacts on liquidity. Climate risk drivers can prompt depositors to draw down deposits and debtors to draw down credit lines at the same time, dramatically increasing (worsening) loan-to-deposit ratios.

Some empirical evidence suggests that this does occur due to physical climate risks, specifically in the wake of natural disasters, as households and corporations withdraw deposits and draw on credit lines to finance cash-flow needs for recovery. This combination puts pressure on banks' liquidity and can lead to crystallized liquidity risks (Basel Committee on Banking Supervision, 2021). This phenomenon could potentially affect other types of financial firms as well. For instance, if abrupt climate-related drivers prompt end investors to want to liquidate their fund holdings at the same time as climate drivers are causing market dislocations, this could cause some asset managers to suffer liquidity risk. (Market dislocations are a more meaningful source of risk through their macro effects and their effects on financial stability and the potential for "Minsky moments," all of which are discussed in Section 6.4).

For an individual non-financial company, liquidity risk only manifests as a consequence of climate risk under specific circumstances. An acute climate-related event, such as a major hurricane devastating a firm's operations and underlining its lack of preparedness, or a fine imposed by authorities for non-compliance with carbon emissions regulations, leads investors and lenders to reassess their view of a firm's viability so suddenly and abruptly that the firm has trouble accessing liquidity. However, under most circumstances and given the gradual pace of climate change, it is more likely that climate risk filters through to companies more gradually through increased credit risk rather than abruptly through liquidity risk. Increased investor awareness of risks, and increasing manifestation of climate risk, leads to higher credit risk and thus higher cost of capital for a firm.

6.3.4 Underwriting Risk

Although underwriting risk only directly affects the insurance sector, it is still important to single out as a type of risk affected by climate risk, especially physical climate risk, as many other corporations and financial institutions rely on insurance coverage as a crucial part of their risk-mitigation strategies.

<u>Key metrics</u> to gauge underwriting risk from a corporation's perspective are **changes in insurance premiums** and the availability of insurance. The insurance industry itself uses a variety of metrics and models to arrive at estimates of the riskiness of the entities it insures, many of which are proprietary not the focus here.

Insurance works best when a large pool of participants (motorists, corporations, homeowners, etc.) all have a small, and close-to-equal, chance of being struck by misfortune, and when these accidents or other losses follow predictable patterns discernible from historical data. The problem with climate risk, especially some types of physical climate risk, is that the risks become so concentrated that the risk of underwriting affected facilities and properties in those areas can grow too high to be economical. Examples include buildings in low-lying coastal areas subject to sea level rise and coastal flooding or buildings in wooded areas that are becoming drier and hotter due to climate change and thus more prone to wildfire, such as in California and parts of Australia. In areas such as these, climate risk is very concentrated geographically, and it is intensified as climate change progresses, with events that were previously rare, such as 1-in-100 year events, becoming much more common. To provide just one example, the severe heatwave in France and the Netherlands in 2019 was estimated as a 1-in-50 year event in the current climate, but it would be a 1-in-1000 year event (or even less frequent) in the absence of climate change (Vautard, 2019). With further warming, the return period—the period during which such events are expected to recur (50 years in the above example)—for these sorts of events will continue to decrease.

For shorter return periods, for the insurer to break even would require very high premiums; for instance, a ten-year return period (i.e., a 10% chance of annual occurrence) of a total destruction event in a specific location would require an insurance premium of at least 10% of the value of the insured property. This level of occurrence is not outlandish for many physical risks. One study found that for an extreme rain event in Texas equivalent in size to Hurricane Harvey (which flooded Houston in 2017), the annual probability of occurrence was 1% from 1981 to 2000; 6% by 2017, when Harvey occurred; and 18% by 2081 to 2100 under a worst-case climate scenario (Emanuel, 2017). An 18% probability of annual occurrence is the same as a return period of just 5.5 years.

Of course, larger insurers with diversified exposures can and do cross-subsidize to an extent, but smaller, regional insurers without geographical diversity do not have that luxury. (Insurers can sometimes offload a portion of their risk to reinsurers, but these firms are also becoming warier of taking on climate risk.) There are already some anecdotal examples of smaller insurers, such as in California in areas hard-hit by climate-exacerbated wildfires, that have gauged the underwriting risk to be too high and have refused renewals to homeowners—most types of insurance available to individuals or corporations are on one-year renewal cycles, so insurers can pull coverage with relatively short notice.

Climate transition risk, too, can affect underwriting risk. The policy, operational, and technological changes required for a transition to a net-zero economy could cause litigation against fossil-fuel companies or other emissions-intensive industries, which could then transmit into insurance through general liability or "directors and officers" (D&O) policies through which insurance takes on (at least part of) the financial risks of a firm being sued.

Underwriting-risk increases can also affect other types of risk. For example, if a company can no longer obtain insurance coverage for physical damage, business interruption, or directors' liability, it cannot use insurance as one of its resilience and buffer mechanisms, which further increases operational risk. This, in turn, increases its credit risk from the perspective of a lender. Indeed, it is unsurprising that in many cases, such as home or commercial property mortgages, lending banks require insurance coverage as a condition of issuing a mortgage.

6.4 Macro Climate Risk: Systemic Risk and Financial Stability

Because climate change, both through its physical impacts and policy and societal effects to mitigate emissions and achieve a zero-carbon transition, is such a broad phenomenon, it can be a source of systemic risk and potentially pose a risk to financial stability. Generally, the risk types covered in Section 6.3 can have systemic effects if they occur widely enough, and affect entire sectors or swathes of the economy—each of these is covered briefly in turn (Sections 6.4.1–6.4.4). But there are also other categories of risk that operate primarily at the systemic and/or macroeconomic level, such as market risk and sovereign risk.

6.4.1 Operational Risk

If physical climate impacts cause operational risk to manifest across a range of companies, this can have ripple effects across supply chains and through to markets, customers, and financial counterparties. For operational risk to have this wide of an effect typically requires a particular set of circumstances, such as geographic concentration and pinch points in supply chains. The climate change-exacerbated Thai floods of 2011, which significantly affected global semiconductor production and had ripple effects across supply chains, are a good example of the macro effects of operational risk. But they only had a macro effect because so many intermediate components for the global semiconductor manufacturers specifically came from Thailand.

6.4.2 Credit Risk

Increased counterparty credit risk that results from climate change can directly transmit into the financial sector and pose a potential threat to financial stability if it occurs broadly enough. A lot of the climate risk drivers that can lead to increased credit risk at an individual firm can affect entire sectors. In sectors such as utilities (for those still reliant on fossil power plants) or oil & gas, sector-wide asset stranding is expected to occur or has already occurred, which increases credit risk. Changing demand and cost structures resulting from climate-related pressures can impact companies' revenues and profits, as can physical climate impacts leading to business interruption, both of which can lead to widespread increases in credit risk. For financial institutions heavily exposed to these sectors, this can pose a risk to the financial institution's soundness. If exposures run across the financial sector, increased credit risk at the company level can become a threat to financial stability.

6.4.3 Liquidity Risk

As examined above, banks are also particularly affected by climate risk impacts on liquidity. Given the wide reach and potential severity of climate impacts, it is possible for liquidity risk to be a source of systemic risk to the banking sector and to therefore threaten financial stability. If enough households, corporations, and financial firms sharply increase their demand for precautionary liquidity after a severe natural disaster, this can be at a systemic enough scale to necessitate intervention by the central bank. A good example of the potential for this kind of course of events comes from the aftermath of the large Japanese earthquake in March 2011—admittedly not a climate-related natural disaster, but comparable to one. After the shock, the Bank of Japan (BoJ) had to offer record amounts of liquidity to Japanese banks to ensure stability in the markets: On the first business day after the earthquake, the BoJ offered funds totaling 21.8 trillion yen, nearly three times the maximum daily liquidity during the 2007–2009 financial crisis (Basel Committee on Banking Supervision, 2021).

Another potential concerning source of systemic liquidity risk would be a "climate Minsky moment". A Minsky moment, in general, is a sudden, major collapse of asset values. In 2016, Mark Carney, then Governor of the Bank of England, warned of the potential for a climate Minsky moment in the case of a wholesale, abrupt and broad-based re-evaluation of climate risks by markets, causing massive repricing of assets and a pro-cyclical crystallization of losses (Carney, 2016). If severe enough, such a climate Minsky moment could provoke a market-wide liquidity crunch not unlike the shock of the global financial crisis of 2008, perhaps even greater.

However, it is worth noting that large-scale dislocations and repricings resulting from climate risk are expected to be a problem even if they do not occur suddenly enough to constitute a Minsky moment and a liquidity shock. These kinds of market changes are classified under market risk rather than liquidity risk (see Section 6.4.5).

6.4.4 Insurance Risk

Insurance risks, particularly the specter of uninsurability, in cases where the insurers deem climate risks to be too great to underwrite, can have systemic effects. Even if insurers are acting individually to reduce their exposure to climate-related risks, these actions, taken collectively, could have negative consequences for the financial system as a whole. If large numbers of insurers significantly increase premiums or completely withdraw their coverage of certain climate-related risks, this might leave households and firms without coverage, potentially amplifying the resulting risks to financial stability (FSB, 2020).

6.4.5 Market Risk

At the systemic level, climate risk translates into market risk through repricing and dislocation effects as well as through asset stranding. The repricing effect is an important channel through which physical or transition risks that are anticipated but not yet realized can more quickly and tangibly have an impact on asset prices, whether they are physical assets such as housing or financial assets such as shares and bonds. The research by Bernstein and co-authors cited in Chapter 3 shows how sea level rise and coastal flooding risk transmits into, and is reflected in, US coastal property prices today, with discounts ranging from 14.7% for properties exposed at 1 ft (0.3m) of sea level rise to 4% for properties exposed at 6 ft (1.8m) (Bernstein et al., 2019).

Of more concern to most market actors, however, are quicker, more abrupt pricing shocks and increased volatility. These are reflected in key metrics such as **Value at Risk (VaR),** or the climate version thereof, climate VaR (see box). Other metrics are useful for individual institutions to gauge their own exposure to climate-related market risk, such as the weighted average carbon intensity of a portfolio, which is a proxy for transition risk exposure, or portfolio-level physical risk scores (see also next section, Section 6.5).

CLIMATE VALUE AT RISK (CVaR)

Standard Value at Risk is a metric for quantifying the level of financial risk in a firm, a portfolio, or a given investment, and it is meant to give an estimate of a bad outcome. A standard way of calculating VaR is to take an estimated profit-and-loss probability density curve of an investment or portfolio and then look at the lowest 5% of the distribution to estimate tail risk. VaR is useful for its cross-comparability across different types of investments, although it is sensitive to the data used to construct it—for example, if constructed using data from a period of low volatility, the probability distribution can be unrealistically "optimistic" and even the 5% cutoff does not show a particularly significant loss. Because of its relation to market volatility, however, VaR is one of the best metrics of market risk and has therefore been adapted by at least one data provider to look specifically at climate risk.

MSCI, a data provider, sells a commercial tool called "Climate Value at Risk," which, like standard VaR, is meant to capture a rough estimate of climate-related financial losses. While the MSCI methodology is proprietary, the firm does disclose that it includes both transition and physical risk as well as economic data and company-level data. Climate risk, on both the transition and physical side, is calculated as a combination of hazards, vulnerability, and exposure that is converted into monetary amounts using a financial valuation model. Aggregated at the sector level, CVaR shows that construction, coal, and electrical utilities are the most exposed to a combination of physical and transition risks.

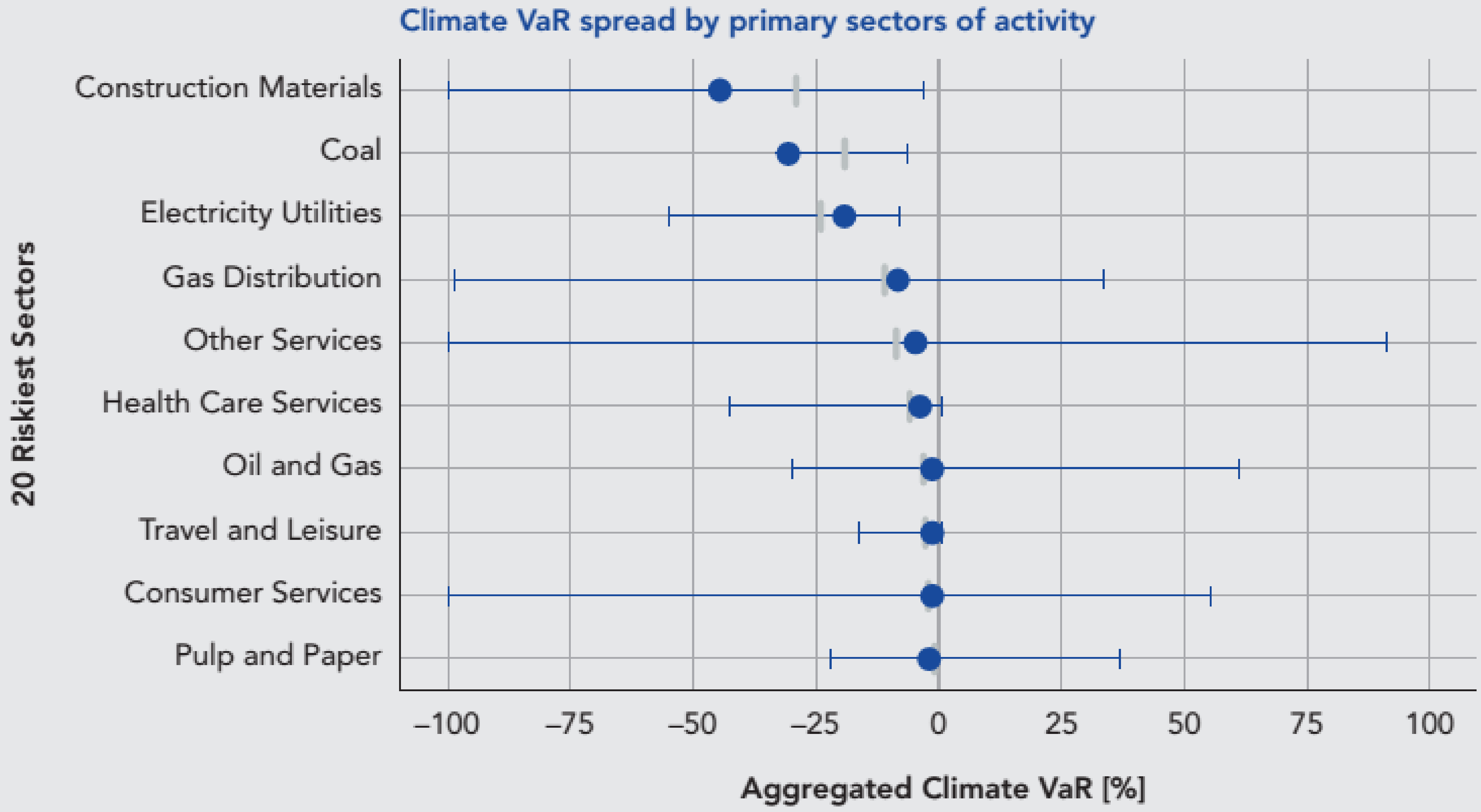

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Figure 5

Climate risk drivers, both physical and transition risk, can reveal new information about future conditions, precipitating downward price shocks and increases in market volatility in traded assets. It is also possible that climate risk could lead to a (partial) breakdown of typical correlation pattern between assets, reducing the effectiveness of hedges and challenging banks' abilities to actively manage their risks. The empirical evidence, while mixed, suggests that climate risk is not yet priced into many asset classes (Basel Committee on Banking Supervision, 2021).

As and when climate risk drivers become priced in, it is likely that there will be less potential for unexpected price movements or volatility. Climate risk incorporation into asset prices might also reduce risks to financial stability. That said, it may also end up serving to illustrate that risks are concentrated in certain parts of the financial system, which could in fact increase the threat to financial stability, particularly if it triggers amplifying behaviors among financial institutions (FSB, 2020).

It is also important to note that even if abrupt repricing has been relatively infrequent so far, this is partly due to the insufficiency of both governments' and companies' actions for reaching commitments such as the Paris 2°C target. Many experts expect much more severe repricing and market risk in the years ahead as climate policy tightens. For instance, the Principles for Responsible Investment has a project called the "Inevitable Policy Response," which assumes that as the realities of climate change become increasingly apparent and urgent, governments, firms, and others will be forced to act more decisively, potentially in quite a rapid, abrupt, and disorderly way. This, in turn, could have important implications for financial markets and trigger repricing on much larger scales. (Note that deeper analysis of different outcomes necessitates scenario-based analysis, which will be covered in Chapter 7.)

6.4.6 Sovereign Risk

The transmission of climate risk into sovereign risk is examined here separately due to the unique considerations involved. On physical risk, evaluating a country starts, as with a company, with geographical exposures, such as the presence or proportion of low-lying coastal areas vulnerable to sea level rise and coastal flooding. But understanding entire countries also means examining the size and sectoral composition of their economies; capacity to create adaptive policies and responses to climate change; debt accessibility and affordability; and specific policy decisions. Moody's, the credit ratings agency, came up with a physical risk methodology for sovereigns as early as 2016 and found that India, Pakistan, Vietnam, Cambodia, and much of Central America and sub-Saharan Africa was most vulnerable. Academic research from Buhr et al. (2018) has demonstrated empirically that countries with higher exposure to physical climate vulnerability do face a higher cost of capital, by up to 1.17 percentage points (Buhr, 2018).

As for transition risk effects on sovereigns, discussions are mostly still centered on countries' reliance on fossil fuel and other carbon-intensive exports. For instance, as tighter climate policies, new technologies and preference changes reduce the demand for fossil fuels, this may turn states heavily reliant on fossil fuel exports into "stranded nations" (by analogy to stranded assets). If this occurs, fossil-fuel reserves become commercially unattractive to extract and a substantial share of national wealth may permanently lose its value, leading to a massive drop in sovereign creditworthiness and a corresponding increase in sovereign risk (Manley, 2017). A scenario-based study using modeling to look at the medium-term impact of climate on countries' GDP per capita, GDP growth, and debt ratios, and thereby their sovereign credit ratings, predicted that 63 nations will experience a drop in credit rating by 2030 without emissions reductions (Klusak, 2021).

6.5 Climate Risk Measurement: Data and Analysis

Accurately gauging transition and physical risks requires multiple types of data as well as appropriate analytical tools to understand their application to the user's needs (see also Section 6.5 and Chapter 7). Transition risk requires, first and foremost, accurate asset-level and company-level data on greenhouse gas emissions but also data on policy landscapes, technological changes, and consumer preferences to capture the various drivers of transition risk as laid out in Chapter 3. Physical risk requires data on current and future physical hazards, derived from a combination of historical data and climate models; topographical data and locational data of assets; and information on vulnerability and adaptive capacity.

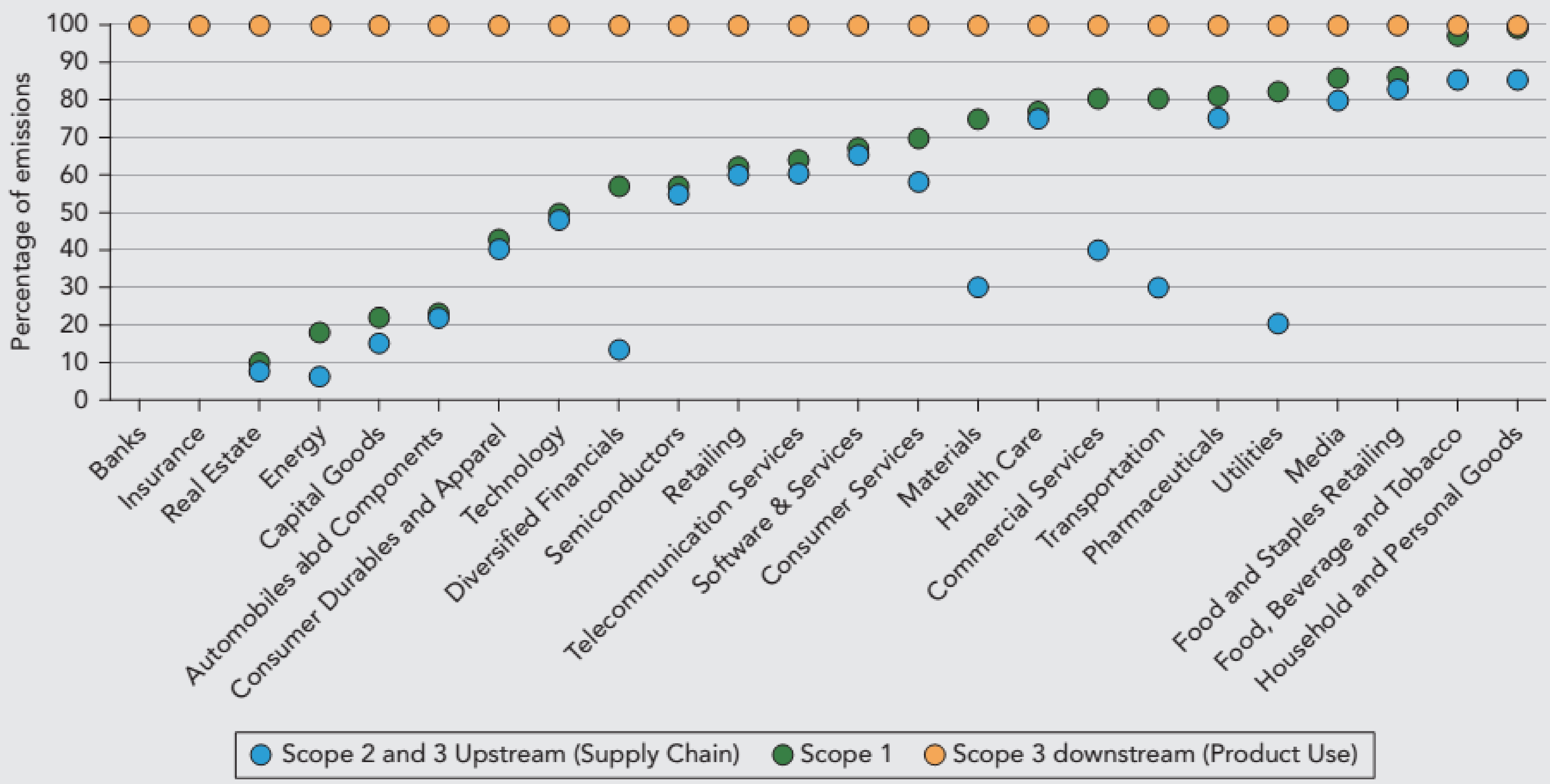
6.5.1 Company-Level Transition Risk Data

Measuring transition risk starts with measuring greenhouse-gas emissions, which need to be nearly eliminated to reach a net-zero economy. The Greenhouse Gas (GHG) Protocol provides a widely accepted way of categorizing emissions. It defines Scope 1 as those emissions resulting directly from a company's operations; Scope 2 includes upstream emissions from purchased electricity, heating and cooling; and Scope 3 includes all other upstream emissions from supply chains as well as downstream emissions resulting from the use, or disposal, of products and services sold by the company. Sectors vary widely in the proportion of these different kinds of emissions. For instance, almost all banks' emissions are categorized as downstream Scope 3, as are the majority of oil & gas firms' emissions (from the combustion of vehicles or in the power plants of the oil and gas they sell). Meanwhile, utilities have a lot of Scope 1 emissions (see graph below).

These carbon emissions data, or **corporate carbon footprints**, as they are also called, have some shortcomings. Most data currently come from self-reporting by companies themselves, through mechanisms such as an annual questionnaire by CDP, an NGO formerly known as the Carbon Disclosure Project. These voluntary disclosures are not only typically unaudited but also vary in their breadth and detail. Beyond the many companies that do not disclose at all, others disclose only Scope 1 and/or Scope 2 emissions. Few firms disclose all of the Scope 1, 2, and 3 emissions. To get around the limitations of data availability, some data providers model the predicted emissions of non- or partial-disclosing companies on sectoral data. At the portfolio level, issues of double-counting also need to be considered; for example, an industrial firm's Scope 2 emissions (from purchased electricity) would be counted as part of the electricity utility's Scope 1.

But transition risk is not only about current emissions but also about whether companies have solid and credible plans to reduce emissions in the future and to ultimately align their corporate emissions trajectories with national and international goals, such as alignment with the Paris Agreement 2°C target or the target of net-zero emissions by 2050. Various approaches seek to measure the degree

BREAKDOWN OF CARBON EMISSIONS WITHIN SECTORS:



Adapted from Chart 5 Scope 3 of the publication Investor Guide to Carbon Footprinting, published on the 23 of November 2015 (Kepler Cheuvreux).

Figure 6

of **corporate alignment**. At the corporate level, there are both opt-in initiatives, such as the Science-Based Targets that companies can sign up to as well as external parties, such as the Transition Pathway Initiative, that seek to gauge firms' plans. Various methodologies have been developed for **temperature scores** that give a shorthand way of understanding what level of warming a company's plans are aligned with. Most of these, however, examine which climate scenario a company's strategy is aligned with, and thus are covered in greater detail in Chapter 7.

Combined with new approaches to more accurately measure carbon footprints without relying on self-disclosure, the use of asset-level data on specific factories or power plants ultimately provides a lot more granular information on which to base investment or lending decisions (see schematic graphic below).

SCHEMATIC: DISCLOSURE VS ASSET-LEVEL DATA ON CARBON FOOTPRINTS

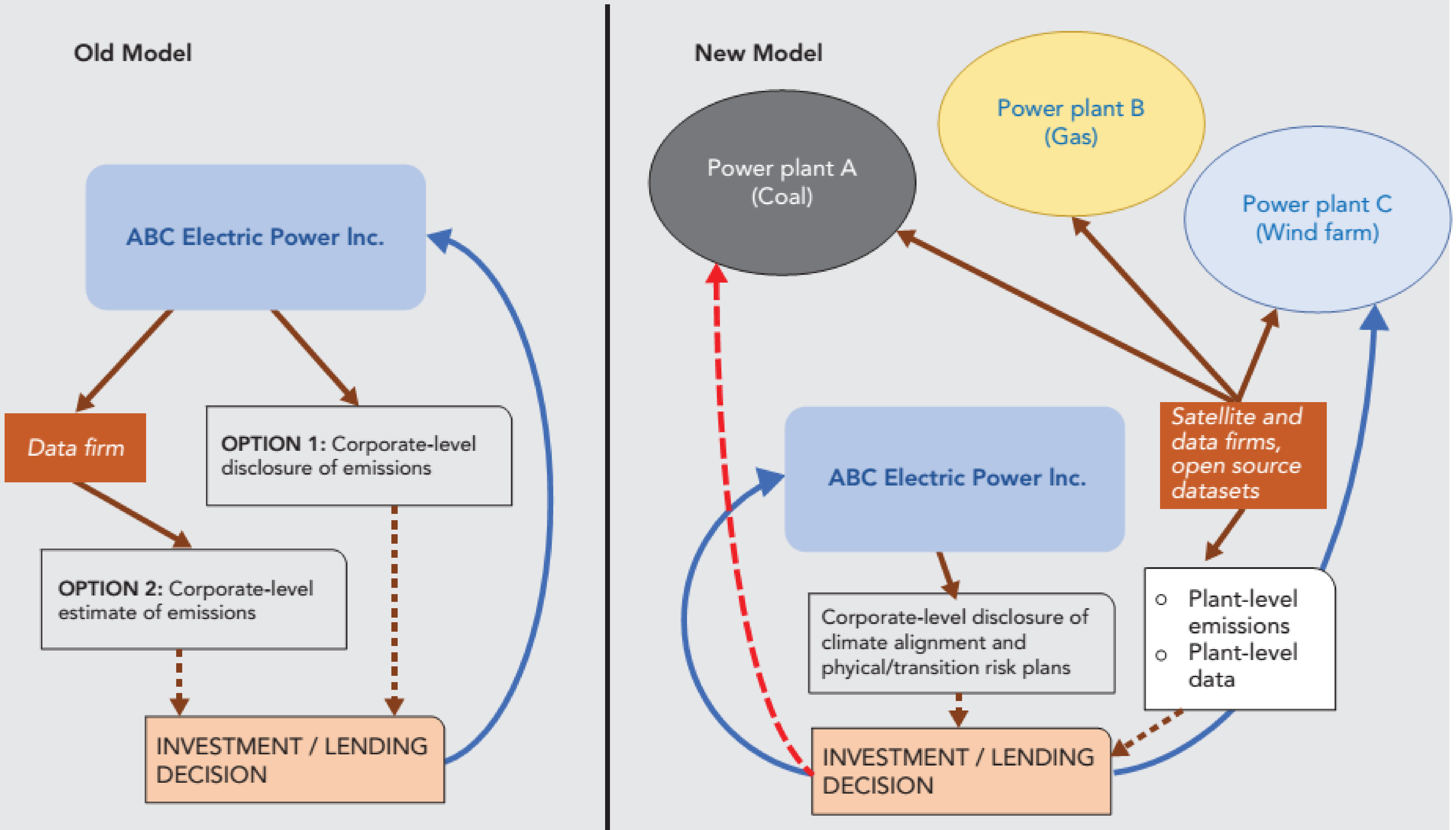


Figure 7

This schematic shows how much more granular the new model of data collection and decision-making is than the old one for an example firm, ABC Electric Power Inc. Historically, ABC's shareholders, bondholders, and bank lenders would have had to rely either on ABC's own disclosures of emissions or on estimates from data firms. Increasingly, however, asset-level data is becoming available at the facility level (in this case at the power plant level) through data firms, including through earth observation and satellite data as well as from open source datasets. Meanwhile, corporations are increasingly expected to disclose not just emissions but also on alignment and plans for addressing both transition and physical climate risk. Thus, investors and lenders can start to make more granular decisions, such as relating to project finance of specific plants or at the corporate level, based on much more sophisticated datasets.

Source: Author.

More sophisticated transition risk analysis typically requires the use of climate scenarios, covered in Chapter 7. But for the purpose of this chapter, the last important point to mention regarding transition risk is that even data on both emissions and emissions trajectories are not enough without an understanding of the drivers of transition risk such as policies, changing technologies, shifts in consumer preferences, and market sentiment (as discussed in Chapter 3). There are international agencies, such as the International Energy Agency (IEA) or International Renewable Energy Agency (IRENA); specialist consultancies, such as Bloomberg New Energy Finance or Rystad Energy; and large data firms, such as S&P Global, that offer quantitative and qualitative data on policies and new technologies, such as by providing data on the learning curves and pricing of solar modules or lithium-ion batteries. Some types of data are quite difficult to come by and valuable to market participants, which means purchasing access can be quite expensive.

6.5.2 Company-Level Physical Risk Data

The basic data for gauging physical hazards is provided by global climate models developed by climate scientists for the periodic reports of the IPCC; an example is the Coupled Model Intercomparison Project, versions 5 or 6 (CMIP5 and CMIP6), Only some corporations and financial counterparties have the ability and desire to bring the specialist knowledge in-house to make direct use of these models. Moreover, for them to be relevant and usable for firms or investors, the output of the different models must be reconciled, downscaled to give regional or local estimates, and then it needs to be combined with exposure and vulnerability data (see schematic below). The use of climate models to run different scenarios is covered in Chapter 7 as part of scenario analysis.

Some physical climate risk tools that are one notch above simple raw data—for example, combining climate hazard

SCHEMATIC: REACHING PHYSICAL RISK ESTIMATES

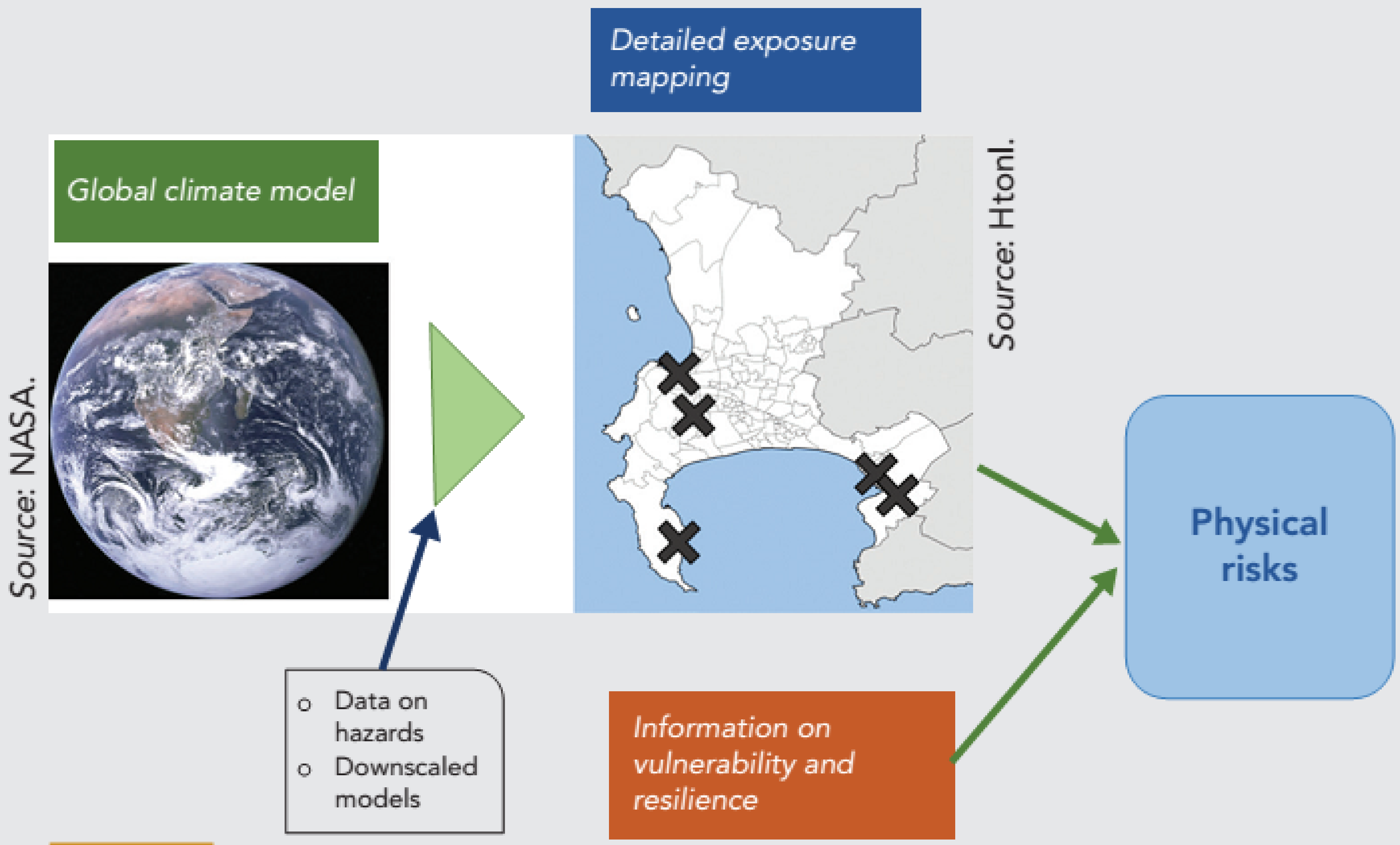


Figure 8

To reach an understanding of physical risks, global climate models must be downscaled, both in spatial and temporal resolution, as they are usually designed for global use on multi-decadal timescales; then, exposures must be mapped geographically and combined with information on vulnerability and resilience to arrive at an estimate of physical risks.

data with topographical or vegetation data—are available for free from governmental or non-profit organizations. Examples include the dataset from Climate Central on projected sea level rise, combining sea level estimates with local topography; the World Resources Institute's (WRI) data on water stress; and the Max Planck Institute's index on wildfire vulnerability, combining drought and precipitation estimates with vegetation cover.

That being said, many physical risk indicators have been developed by, and are sold by, specialist for-profit consultancies. One survey, recent at the time of publication, identified eight firms or organizations that provide investors with physical climate risk analysis tools of some kind: Acclimatise, Moody's, WRI, Four Twenty Seven (since acquired by Moody's, the credit rating agency), Carbone 4, Carbon Delta (since acquired by MSCI, a data firm), Mercer, and a collaboration between Ecolab, Trucost, and Microsoft (ClimINVEST, 2019). Since the survey, Trucost, a division of S&P Global, the ratings and data firm, has also started selling physical risk data on firms; and McKinsey & Co, the global management consultancy, acquired Vivid Economics and Planetrics, two other firms that have also worked with investors on physical risks. Other consultancies beyond these, such as XDI or South Pole Group, have been hired by investors on an ad hoc customized basis on issues of physical climate risk, but they do not provide scores or analysis for broad use.

Company or asset-level physical risk data and scores are arguably the most easily interpretable approach to physical risk analysis in a way that is accessible to lenders, investors, and other stakeholders. Although some of the free datasets offer a high level of geographic precision, the output is fairly "raw" (e.g., whether a given location is above or below the 2050 coastal flooding line). A real estate tool such as Four Twenty Seven's, by contrast, allows real estate investors to easily gain a sense of the exposure of their assets by overlaying the location of buildings with the tool, which uses normalized numerical scales to give a sense the relative severity of extreme precipitation, hurricane-force winds, sea level rise, water stress, and heat stress for a given geographical location or address.

Company-level scores, as sold by Four Twenty Seven, Carbone 4, and Trucost, take this approach a step further. The competing offerings all combine the proprietary methodologies of downscaling and normalizing climate model data with detailed facility-level location information of firms, mainly those that are publicly listed. By combining data on climate hazards with the location of companies' factories and warehouses and an estimate of vulnerability, the physical climate risk scores can tell investors about the relative physical risk of investing in, say, Volkswagen as compared to Ford or Microsoft without needing to, themselves, delve deeply into the climate models or into figuring out exactly where VW or Ford have their factories, or Microsoft its data centers. The scores are normalized on a 0–100 scale, and they are available both by hazard type, and as an overall score.

These "heavily digested" scores do have their downsides, however. The proprietary methods and datasets that they derive from remain a "black box" to the investors who purchase the scores, which is why some investors have opted to work with "raw" data themselves or construct in-house scores. Many of these scores also attempt to capture several hazards in one score, meaning that the weighting and averaging methodology can matter as much to the end result as the underlying raw climate data. Due to the inclusion of different hazards, different ways of measuring, and different methodologies, scores from competing providers, or compiled internally by different financial firms, are not necessarily comparable.

6.5.3 Portfolio-Level Analysis (Transition and Physical)

Portfolio-level analysis, as opposed to asset- or firm-level analysis, is the type of analysis of most relevance to a financial counterparty, such as a lender or an investor. Understanding both transition and physical risk at the portfolio level can be somewhat different than just understanding the impact of these risks on a particular firm.

On transition risks, many portfolio-level approaches start with numbers that are proportional to an amount, either of an invested amount or of corporate revenues, rather than simply total absolute emissions. Two common metrics are **carbon intensity,** or greenhouse gas emissions normalized by portfolio market value (for example, tons of CO2 equivalent/million USD invested), and **weighted average carbon intensity** (tCO2e/million USD of revenues). Other methodologies pin a temperature or "warming potential" on an entire portfolio. More risk-based approaches to transition risk include stress testing (for example, modeling how a portfolio reacts to a transition shock such as a sudden rise in carbon tax). However, most stress testing on climate risks, especially transition risks, is heavily scenario-based and thus will be covered more deeply in Chapter 7.

On physical risks, portfolios made up of individual physical assets such as buildings or factories can be evaluated as a whole fairly easily, looking at which assets are exposed to which hazards using free and commercial tools. But sensibly aggregating and evaluating portfolio-level physical risk is difficult for equity or bond portfolios, where exposure is to entire companies (and all their facilities as well as all of their supply chains). Some tools do give (rough) estimates of physical hazards in monetary terms: For example, a

EXAMPLE: A SIMPLE APPROACH TO PORTFOLIO-LEVEL PHYSICAL RISK ANALYSIS

One relatively simple way of examining physical risk at portfolio level is to look at the best- and worst- in class of an index, which the below figure from Moody's ESG Solutions demonstrates. It shows the physical climate risk, based on the physical risk exposure of the companies' underlying assets to floods,heat stress, hurricanes & typhoons, sea level rise, water stress and wildfires, as well as a view of market and supply chain risk based on a company's industry.

However, in a space that has changed and matured quickly, most physical climate risk analyses currently use and compare different climate outcomes and scenarios.

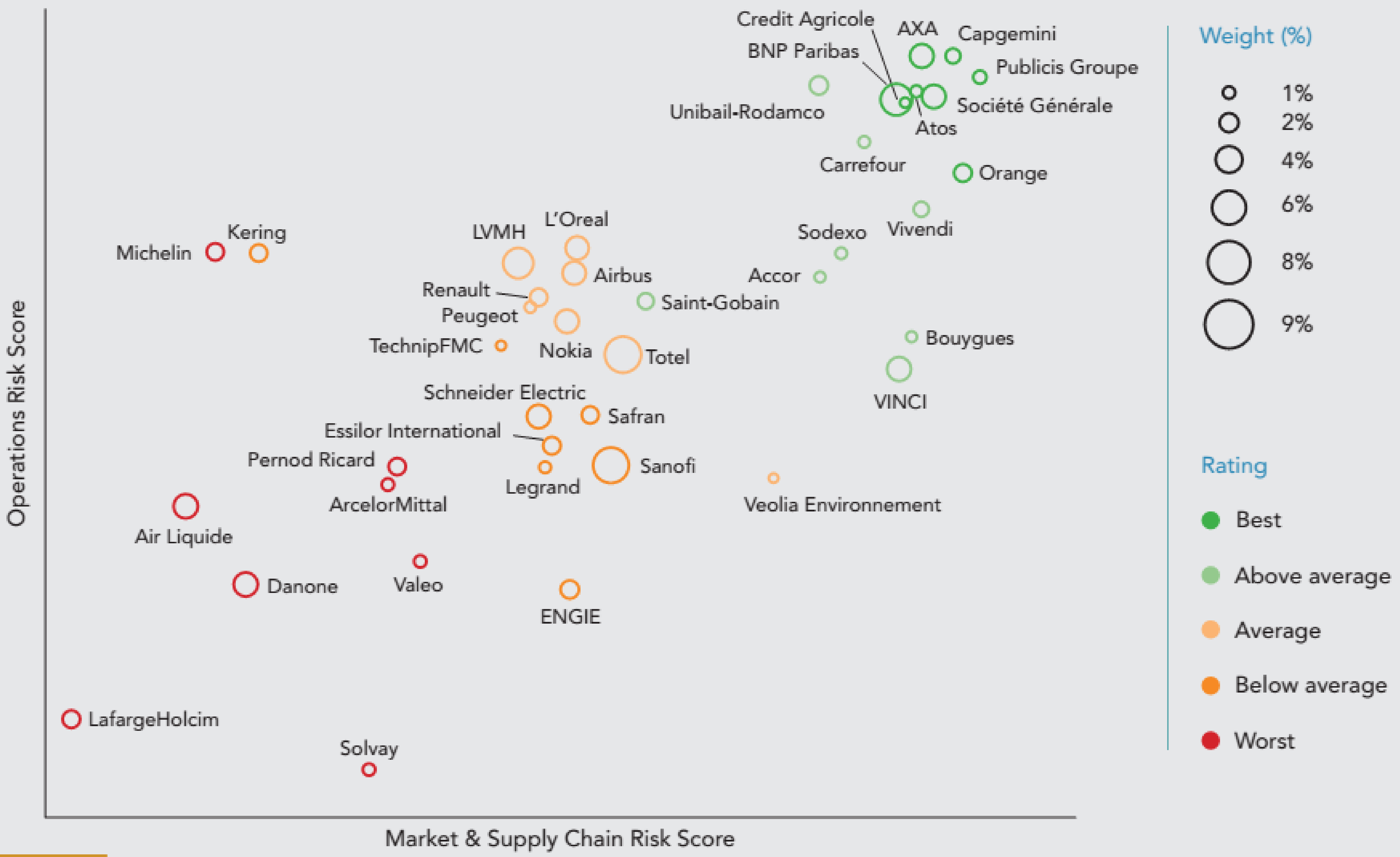


Figure 9 Best and worst-in class in France's CAC40

Source: Reprinted with permission of Moody's ESG Solutions.

framework called "climate Value at Risk (VAR)" from a company called Carbon Delta, now part of MSCI, gives a quantitative estimate of the expected financial losses or gains from climate risks and opportunities. In this way, it seeks to mimic traditional VAR, a measure used heavily by financial institutions (especially before the 2008 global financial crisis).

6.6 Climate Risk within Enterprise Risk Management

In recent years, the notion of climate risk as an analogous risk to other types of financial risk, and indeed one that affects most "traditional" categories of risk, has led to an interest in managing climate risks proactively.

This has notably been the case with regard to including climate risk drivers in **enterprise risk management (ERM),** that is, comprehensive approaches to managing risk across and within an organization, such as a large corporation. One of the most widely used frameworks for ERM was developed by the Committee of Sponsoring Organizations of the Treadway Commission (COSO), originally released in 2004 and periodically updated. The latest version, from 2017, includes actions and responsibilities across five broad areas, from governance and strategy to performance, review, and communication, with subcategories under each (see graphic). Importantly, ERM is not considered to simply be a function or a department, but it consists of "culture, capabilities and practices that organizations integrate with strategy-setting." Neither is ERM simply about compiling a list of risks, having internal controls, or using checklists, rather, COSO argues, it is a holistic modus operandi across an entire firm (COSO, 2017).

This section is generally structured in line with the COSO categories, as they are well suited to examining climate risk. However, other important frameworks are also

Figure 2: COSO's Enterprise Risk Management Framework

GOVERNANCE & CULTURE

1. Exercises Board Risk Oversight
2. Establishes Operating Structures
3. Defines Desired Culture
4. Demonstrates Commitment to Core Values
5. Attracts, Develops and Retains Capable Individuals

STRATEGY & OBJECTIVE-SETTING

6. Analyzes Business Context
7. Defines Risk Appetite
8. Evaluates Alternative Strategies
9. Formulates Business Objectives

PERFORMANCE

10. Identifies Risk
11. Assesses Severity of Risk
12. Prioritizes Risks
13. Implements Risk Responses
14. Develops Portfolio View

REVIEW & REVISION

15. Assesses Substantial Change
16. Reviews Risk and Performance
17. Pursues Improvement in Enterprise Risk Management

INFORMATION, COMMUNICATION & REPORTING

18. Leverages Information and Technology
19. Communicates Risk Information
20. Reports on Risk, Culture and Performance

Reprinted with permission of Committee of Sponsoring Organizations of the Treadway Commission (COSO).

Figure 10

incorporated, notably regulatory ones. The TCFD, in particular, has been a key initiator of framing climate change as a source of risk (as described in Chapter 3), of promoting disclosure to investors and other stakeholders, and of pushing scenario analysis as a methodological tool (see Chapter 7). Another prominent example of a regulatory initiative taking action is the Network for Greening the Financial System, a consortium of central banks and supervisors. At a country level, some countries have national-level bodies, such as the Climate Financial Risk Forum (CFRF) in the UK, where the country's two main financial regulators bring together industry representatives. The CFRF has helped categorize and frame the management of climate risk, and this section also partly draws on its CFRF categorizations.

6.6.1 Risk Governance and Culture

Managing climate risk properly within an institution, as with managing any other sort of risk, starts with having structures and staff in place to monitor these risks. Successful **risk governance** starts at the highest level, with the board and senior executives. Effective risk governance can ensure understanding and diffusion of knowledge as well as genuine accountability at all levels of an institution, and it can help increase the resilience of a firm.

Best practice governance arrangements tend to involve multiple layers of employees and internal processes. For instance, client-facing staff, responsible for new transactions, or portfolio managers, who make allocation decisions, can be tasked with making initial judgments on the environmental and climate risks of the transactions they are considering (see ING case study). Climate risk can also be built into legal and compliance processes. This kind of integration can supplement and complement formalized internal risk management procedures and oversight. The TCFD recommendations on governance have helped prompt many companies to institute climate risk-governance structures and to allocate responsibility to specified senior executives. Firms often disclose these arrangements and, indeed, promote them as differentiating factors of their respective firms.

Culture can seem more difficult to pin down; nevertheless, it is just as important to risk management and climate risk management, as are specific governance arrangements. A corporation's **culture** has been defined by COSO as the "attitudes, behaviors and understanding about risk [...] that influence the decisions of management and personnel and reflect the mission, vision and core values of the organization" (COSO and WBCSD, 2018). For climate change and sustainability to be reflected in a company's culture, its mission and core values should address climate risk drivers; the tone from senior leadership should convey expectations on climate; and employee behaviors and initiatives that are in line with strategic corporate priorities should be welcomed and encouraged (COSO and WBCSD, 2018).

6.6.2 Strategy and Setting Objectives, Goals, and Targets

Corporate strategy, that is, high-level decisions on an organization's priorities and mission, is an important component of a holistic ERM approach in general, as well as of any enterprise's response to climate risk drivers in particular. An important prerequisite for strategic decisions is strategic landscape evaluation; this is especially the case in regard to climate issues. Understanding the full business context on climate risk requires understanding the external environment and megatrends, such as the expected physical, societal. and macroeconomic impacts of climate change. But it also requires understanding how the inputs, business activities, and outputs of that particular company are affected by climate change.

COSO and the World Business Council for Sustainable Development (WBCSD) have recommended starting with megatrend analysis and then delving deeper through the use of tools such as SWOT analysis, impact mapping, and materiality assessment. A **SWOT analysis** *(strengths, weaknesses, opportunities, threats)* uses a two-by-two matrix to compare the (internal) strengths and weaknesses, (external) opportunities, and threats an organization is facing, and it is commonly used for strategic planning (see example). In **impact and dependency mapping,** impacts and dependencies are described in terms of stock and flow in relation to various types of capital, not only financial capital but also natural, human, and physical capital, among others. Because all organizations face a unique set of challenges based on their circumstances, **materiality assessment** allows companies to assess the relative importance of various climate risk and other sustainability risk drivers. A common tool is the SASB materiality assessment framework (covered in Chapter 2).

CASE STUDY: INTEGRATING CLIMATE RISK GOVERNANCE—ING

The large Dutch bank ING has been one of the forerunners in holistically and deeply integrating climate change risk into its risk-governance structures. The current level of integration is described in detail in its annual report and its Climate Risk Report. Like many continental European banks, the bank has a two-tiered board structure. At the supervisory board level, the risk committee is tasked with oversight of climate risks, whereas at management board level, the Chief Risk Officer has this responsibility.

From a credit risk angle, climate risk is within the remit of the bank's Global Credit & Trading Policy Committee (GCTP) and its Global Credit Committee—Transaction Approval (GCC-TA), both of which include the CRO, CFO, and Head of Wholesale Banking.

Seen horizontally, the bank describes its risk and control structure as a "three lines of defense" model. Here, front office staff, including relationship managers and deal principals who actually negotiate transactions, form the "first line of defense" and are tasked with identifying potential environmental risks. Local and regional risk committees at the bank, as well as regional risk managers, constitute the "second line of defense," and regular internal audits provide the "third line" (see graphic).

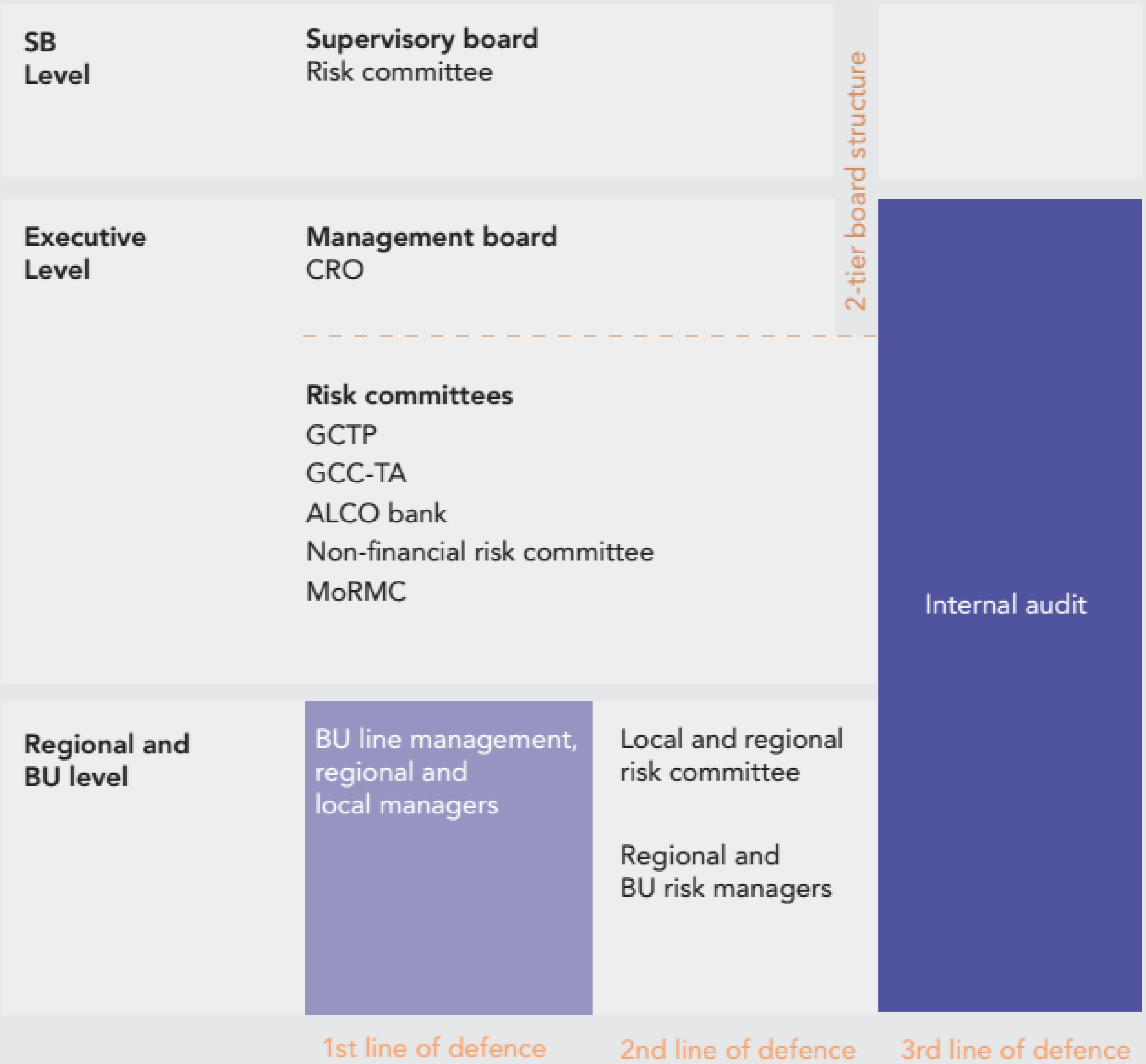


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Figure 11

Two other key components of strategy with regards to climate change, and emphasized by the TCFD, are **time horizons** and outcome variance by scenario, which can be addressed through **scenario analysis**. Climate-related risks and opportunities vary significantly over the short-, medium-, and long-term, and organizational strategy-setting and ERM processes to address climate change need to examine different time horizons separately. Climate

Table 2

EXAMPLE: SWOT analysis table for climate risk drivers

	Helpful	Harmful
Internal origin	**Strengths:** How can a company apply its existing strengths to the physical and transition challenges of climate change?	**Weaknesses:** Do any peers face similar weaknesses or risks from climate change?
External origin	**Opportunities:** Can the company create new solutions to climate-related challenges? Is there a gap that can be addressed?	**Threats:** Where are climate-related (physical or transition) challenges creating threats to future business value?

Source: Adapted from (COSO and WBCSD, 2018).

outcomes also significantly vary based on emissions trajectories, for which scenario analysis can help corporate preparedness (see Chapter 7).

Finally, strategy is also about setting goals and targets. On climate change, a lot of corporate goal setting revolves around climate change mitigation and emissions commitments, including alignment with net zero emissions (for example, as the members of the Net Zero Asset Owners Coalition have done), or even commitments to being carbon negative (e.g., Microsoft has pledged to remove all carbon dioxide attributable to its historical operations from the atmosphere by 2050). These goals may be driven by a range of motivations, and they seek various different risk objectives, such as corporate social responsibility and keeping up with peers and societal norms (avoidance of reputational risk) or protection from asset valuation through pre-emptive corporate transition (avoidance of stranded asset and market risk). But, once these targets are in place, they also then help to shape future decisions.

6.6.3 Performance: Tracking and Measuring Risks

According to the COSO ERM framework, tracking performance for ESG and climate risks consists of three sub-components: risk identification, risk assessment and prioritization, and the implementation of risk responses.

Risk identification starts with examining the transmission channels of climate risk drivers into financial risk (Sections 6.2–6.4) and then identifying which of these are the most relevant for a particular organization. Not all climate risks present an enterprise-level risk to all companies, and it is part of risk managers' remit to translate external trends into identifiable risks and assess the impact and severity on the organization in question. Beyond simply "listing" pertinent risks, risk identification involves articulating the potential impact on business operations and strategy.

Risk assessment involves gathering data on the actual scope of these risks. Investors and banks can use company-level data, including scores on physical and transition risk exposure, and they can also conduct portfolio-level analysis to determine whether they have excess overall risk at the portfolio level—or if they would have such a level in an unfavorable climate scenario (as described in Section 6.5, as well as in Chapter 3 and in Chapter 7 on scenario analysis). A financial institution will tend to do this sort of analysis at a counterparty level (see McKinsey case study on banking).

Non-financial companies looking inward at their own operations will be able to source some data from external providers or from publicly available sources, such as maps of projected sea level rise that can be compared against facility and asset locations. But internal risk assessment for a company will also require assessing the vulnerability and adaptive capacity of these facilities.

Risk prioritization is especially important in an ERM context, as any large enterprise will be exposed to a multitude of risks, and it is important to rank these in order of importance. Ranking methods include ranking by likelihood of occurrence, adaptability and complexity, or severity. One way of ranking by severity is to examine what outcomes the risks affect, where risks affecting the fundamentals of business—profits, revenues, and asset values—are ranked as more severe than risks that only affect more ancillary outcomes such as employee morale or land use. Another way of prioritizing risks is to filter by the risks that the company can

CASE STUDY: MCKINSEY & CO ON COUNTERPARTY CLIMATE RISK ASSESSMENT IN BANKING

McKinsey gives the example of a (real life, unnamed) international banking group that has embedded climate risk into its counterparty risk evaluation process. The process allows the bank to assess climate risk for 2,500 counterparties on an annual basis. For the sake of straightforwardness, the bank opted for a scorecard system that starts with the counterparty's industry and geographical footprint, with adjustments for the firm's emissions intensity and reliance on fossil fuels on the transition risk side and exposure to physical hazards on the physical risk side. The model was especially helpful for differentiating climate risk exposure between counterparties within the same sector. As an example, within the utilities portfolio, electricity providers and multi-utilities scored more poorly than did regulated networks.

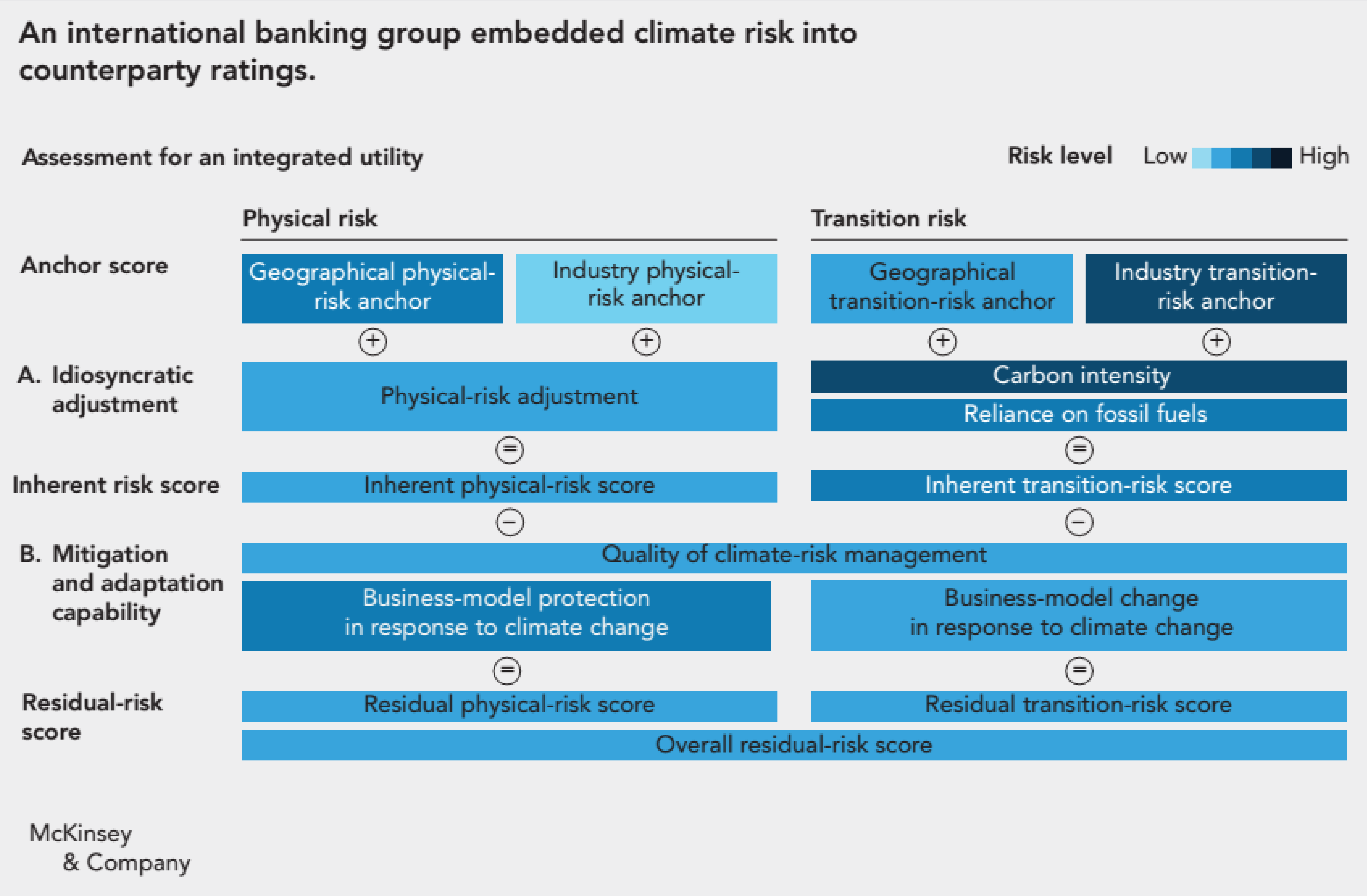

Exhibit from "Banking imperatives for managing climate risk", June 2020, McKinsey & Company, www.mckinsey.com. Copyright (c) 2021 McKinsey & Company. All rights reserved. Reprinted by permission.

Figure 12

actually control. As an example of such an approach, Solvay, a French chemicals firm, has, in the past, rated risks both on impact and on level of control, focusing on those risks with the severest impact but over which it has the most control to actually improve outcomes (COSO and WBCSD, 2018).

For all risks that are identified and assessed, firm management and risk managers can take a limited number of **risk responses.** The standard COSO ERM framework counts five possibilities: acceptance, avoidance, pursuit, reduction, and sharing. Accepting a risk means accepting it will have an impact, but not taking action. Avoidance refers to removing the risk completely, and anything related to it: A transition risk-related example is the refusal by some asset managers to invest in, and some insurers to insure, any businesses that derive above a certain percent of revenues from thermal coal, making thermal coal "too noxious to touch." Pursuit refers to converting risks into opportunities. Reduction of risk through improvements in processes, systems, or strategies. Sharing refers to collaboration as a risk-mitigation strategy, whether with suppliers, regulators, professional associations, or even competing firms (COSO and WBCSD, 2018).

6.6.4 Review and Revision

The **review and revision** portion of the COSO framework mainly refers to additional checks and balances on the ERM framework. This portion of ERM starts with re-assessing risks in light of any substantial changes to the business context of a firm. But more importantly, it is about being self-critical and responsive with regard to the effectiveness of ERM processes themselves. Any substantial changes in the external environment should ideally be flagged speedily and trigger modified ERM responses (see Infosys example). But even in the absence of large external changes, comprehensive ERM involves having processes in place to monitor the implementation of ERM and provide additional checks and balances. This kind of function can be performed, for example, through a periodic internal audit in addition to normal, continuous risk management (as at ING—see case study in Section 6.6.1).

6.6.5 Communication, Reporting, and Disclosure

Communication to stakeholders, internal and external, is considered an integral part of successful ERM. Obviously, the larger a company, the less straightforward even internal communication can be, which is why organizations need processes in place to ensure that the board and senior management get timely information about climate and sustainability risk exposure and the risk management operations undertaken.

Communicating to external stakeholders, including investors and lenders but also credit rating agencies, employees, suppliers, regulators, and the public at large, is likewise an important outcome of successful ERM. Of course, individual risk management decisions, particularly around sensitive issues like controversial transactions and avoidance of reputational risk, can be made in private. However, risk management that is practiced fully in private is not successful risk management. It is important for shareholders and lenders to know that a company has solid ERM in place to ensure continued value creation in the face of the crystallization of risks such as climate risk. But public disclosure of best practices in risk management can itself have a systemic effect, helping even competing firms, and thus entire sectors, to transition toward a more climate-ready and a zero-emissions future. This is why the entire TCFD framework is predicated on disclosure. (Many of the case studies highlighted in this book, especially in this chapter and in Chapters

EXAMPLE: INFOSYS—PROACTIVE MONITORING FOR CHANGES IN RISK EXPOSURE

Infosys is a large, India-based information technology company that does a lot of outsourcing work and employs close to 260,000 people (as of 2021), a large majority of whom are based in India. India is a country that periodically suffers water stress, and Infosys relies on water to ensure employees' well-being (cooking, cleaning, drinking, and bathrooms) and for landscaping and cooling at its office campuses. Infosys considers water scarcity a significant operational risk to its activities in India, due to the deleterious effects of water scarcity on employee's well-being and ability to work.

Although water is not always scarce and this risk is not always considered severe, Infosys has set up a monitoring system to proactively monitor water availability and allow it to quickly update its risk severity assessment. The monitoring tracks, in particular, the 1) water tables in each geographic area, 2) storage capacity of rainwater on each office campus, and 3) availability and cost of water for delivery via water tankers.

Each of these criteria have specific thresholds that, if crossed, alert management to allow for follow-up measures.

Source: WBCSD.

3 and 7, are drawn specifically from companies' TCFD reports, which would not exist without this push for disclosure, which helps to spread knowledge and expertise.)

6.7 Conclusions

This chapter shows that climate risk measurement and management is possible and can be integrated into standard enterprise risk management frameworks. However, importantly, climate is a transversal risk, which affects nearly all "traditional" categories of risk in some way at the company-specific level, and it also poses a potential threat to financial stability, constituting a source of systemic risk at the macro level. Thus, any holistic approach to risk management must consider climate risk at nearly every stage, from the different drivers of physical and transition risks to the transmission channels through various types of risks into financial risk. Ultimately, however, many of the best risk-assessment methods rely quite heavily on scenario analysis, which will be examined and explored in the next chapter (see Chapter 7).

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