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Module 4: Green Finance Risk Management

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Use of generative AI

Generative AI was used as a writing and research assistant in preparing this module. The tool was Claude (Anthropic), versions Opus 4.8, Opus 5 and Opus 5.5, used from July 2026 to 8 October 2026.

Its use was confined to the following purposes:

- idea generation and brainstorming on module structure and worked examples;
- language editing of author-specified content;
- literature classification and organisation of the reading list;
- coding assistance for the chart, data-processing, and document-build scripts;
- checking recorded numbers and quotations against their published sources;
- interactive literature searching using AI-enhanced search tools.

The authors specified and reviewed the content of this module. Every cited source was checked against the original publication, and every figure states its provenance on its own face, distinguishing sourced from derived values and from illustrative teaching assumptions; figures whose data could not be sourced were withdrawn. The authors remain fully responsible for the originality, accuracy, integrity, references, and conclusions of the material.

Chapter 1

Climate-Related Financial Risks and Taxonomy

Climate risk comes in three categories, physical, transition and liability, and each reaches a bank through credit, market, operational or liquidity risk.

1.1 Climate risk is a financial risk

In 2015 the then Governor of the Bank of England, Mark Carney, told an audience of insurers at Lloyd's of London that the catastrophic impacts of climate change will be felt beyond the traditional horizons of most actors[1]. He called this the *tragedy of the horizon*: a cost on future generations that the current generation has no direct incentive to fix. He set those impacts against the horizons of central banks, two to three years for monetary policy and the outer boundaries of the credit cycle, about a decade, for financial stability[2].

Natural disasters caused losses of roughly $250 billion worldwide in 2023, about $95 billion of them insured (Munich Re)[3]. The 2011 Thailand floods caused $46.5 billion of damage and losses[4], and the manufacturing sector bore roughly 70 percent of the total after six industrial estates in Ayutthaya and Pathum Thani flooded[5]. Studies of how natural disasters disrupt global supply chains often take Thailand as a case, and global supply chains increase the potential for physical risk to reach banks' counterparties[6]. Typhoon Rai hit the Philippines in December 2021 and affected close to 2 million people, with extensive damage to public infrastructure and the farming sector[7]. These are realised losses from today's climate, before the additional warming projected for mid-century.

Four properties make climate risk systemic

Climate risk is **correlated** (a single typhoon hits thousands of borrowers at once), **non-diversifiable** (every sector and geography is exposed), **non-linear** (tipping points create sudden, irreversible losses), and **forward-looking** (historical data understates future exposure). These properties make it a systemic risk that affects the whole financial system simultaneously.

1.2 The taxonomy: physical, transition, liability

Climate risk divides into three categories. **Physical risk** is the loss when a climate hazard damages assets, cuts output or stops operations. Its hazards split into *acute* events (typhoons and cyclones, flooding, wildfires, heatwaves) and *chronic* trends (sea-level rise, sustained temperature change, altered precipitation). Acute risks are insurable in principle, but climate change may itself affect the future availability and affordability

[1] Carney, M. (2015). Breaking the tragedy of the horizon: climate change and financial stability. Speech at Lloyd's of London, 29 September 2015. Bank of England. Full text: BIS Review r151009a.

[2] Carney, M. (2015). Breaking the tragedy of the horizon: climate change and financial stability. Speech at Lloyd's of London, 29 September 2015. Bank of England, page 4.

[3] Munich Re (2024). Natural disaster figures 2023. Media information, 9 January 2024.

[4] World Bank (2012). Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning.

[5] World Bank (2012). Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning, Overview, page 2.

[6] BCBS (2021). Climate-related risk drivers and their transmission channels. Basel Committee on Banking Supervision, April 2021, page 12.

[7] World Bank (2021). World Bank Support for the Impacts of Typhoon Rai in the Philippines (Odette). Brief, 28 December 2021.

of insurance, and in the medium to long term more risks may become uninsurable or unaffordable[8]. Chronic risks are gradual trends, and a bank manages them by adjusting its portfolio. Dietz et al. (2016) estimate the impact of climate change itself on the present market value of global financial assets: along a business-as-usual emissions path the expected climate value at risk is $2.5 trillion[9], rising to $24.2 trillion at the 99th percentile[9].

Transition risks arise from the adjustment towards a lower-carbon economy. The Task Force on Climate-related Financial Disclosures (TCFD) sorts them into four types, policy and legal, technology, market and reputation[10], and lists "changing customer behavior" as a market risk[11]. Policy and legal risk covers carbon pricing, emission mandates and the European Union (EU) Carbon Border Adjustment Mechanism, in its definitive regime from 2026[12]; technology risk covers renewables and electric vehicles that make fossil assets obsolete; market risk covers shifting demand, customer behaviour and commodity volatility; and reputation risk covers divestment and boycotts. Physical risk rises with *warming*, and transition risk rises with *policy ambition*. An orderly transition has low transition risk; a hot house world has low transition risk and extreme physical risk. Stranded assets are assets that have suffered unanticipated or premature write-downs, devaluations or conversion to liabilities, and the transition risks of policy and technology can create them[13]: fossil reserves that cannot be burned, coal plants retired early, carbon-intensive real estate below efficiency standards.

Liability risks are the third category. Carney (2015) defines them as the impacts that could arise if parties who have suffered loss or damage from the effects of climate change seek compensation from those they hold responsible[14]. Setzer and Higham (2023) count 2,341 cases in the Sabin Center's climate change litigation databases[15].

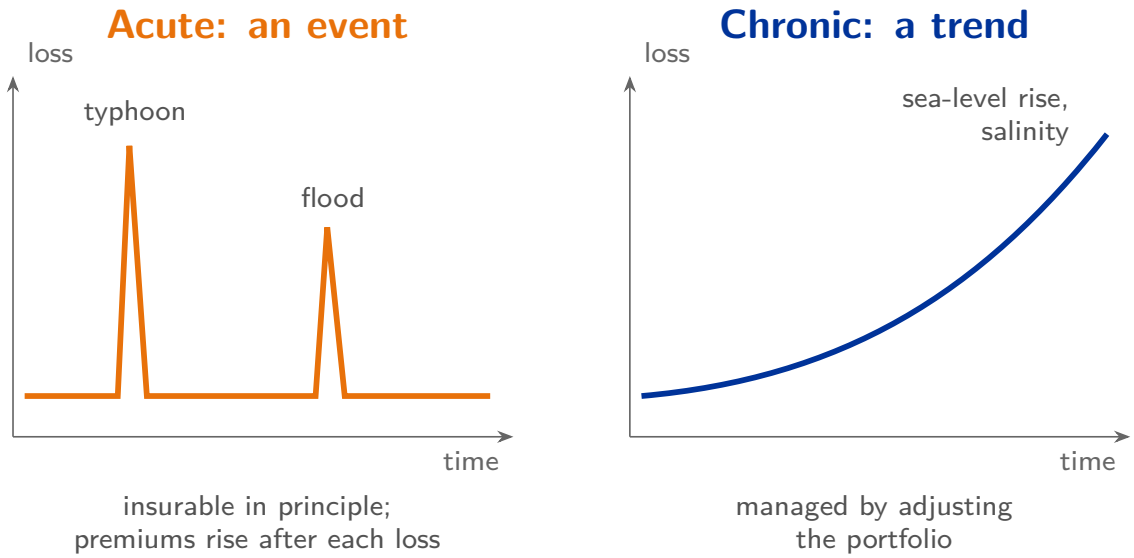


Figure 1.1: An acute hazard is an event, insurable in principle, with premiums that rise after each loss. A chronic hazard is a trend, and a bank manages it by adjusting its portfolio.

1.3 Transmission channels

A climate event becomes a financial loss through one or more transmission channels, and these channels interact. The four core channels are **credit risk**, where drought lifts the probability of default (PD), floods lift loss given default (LGD) through damaged collateral, and borrowers under stress draw their credit lines, which

[8] BCBS (2021). Climate-related risk drivers and their transmission channels. Basel Committee on Banking Supervision, April 2021, page 26.

[9] Dietz, S., Bowen, A., Dixon, C., and Gradwell, P. (2016). Climate value at risk of global financial assets. Nature Climate Change, 6, 676 to 679.

[10] TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures, Final Report, Figure 1.

[11] TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures, Final Report, Table 1.

[12] European Commission, Taxation and Customs Union. Carbon Border Adjustment Mechanism.

[13] Caldecott, B., Kruitwagen, L., Dericks, G., Tulloch, D. J., Kok, I., and Mitchell, J. (2016). Stranded Assets and Thermal Coal: An analysis of environment-related risk exposure. Smith School of Enterprise and the Environment, University of Oxford, January 2016, page 9.

[14] Carney, M. (2015). Breaking the tragedy of the horizon: climate change and financial stability. Speech at Lloyd's of London, 29 September 2015. Bank of England. Full text: BIS Review r151009a.

[15] Setzer, J. and Higham, C. (2023). Global trends in climate change litigation: 2023 snapshot. Grantham Research Institute, LSE.

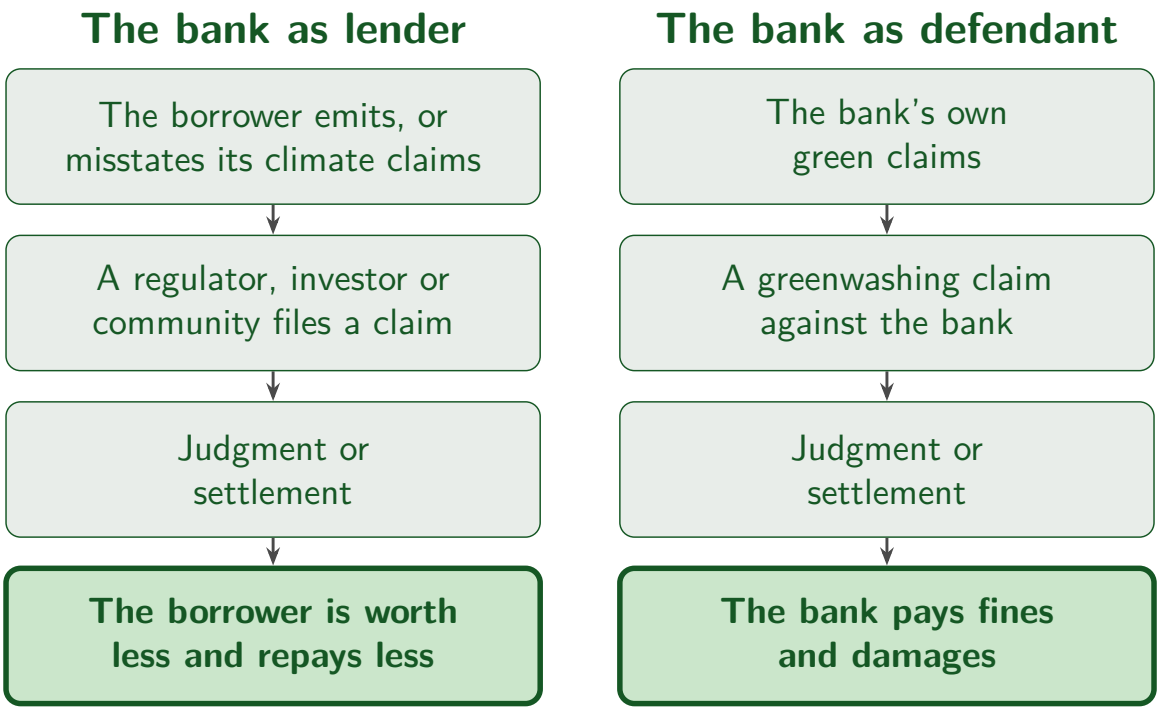


Figure 1.2: Liability risk reaches the lender through the courts, and the bank is hit twice: as lender to a defendant whose value falls, and as a defendant over its own green claims.

Table 1.1: Climate risk taxonomy: categories, channels, and horizons

Category	Sub-type	Financial channel	Horizon
Physical	Acute	Insurance claims, collateral damage	Short
	Chronic	Asset devaluation, yield decline	Medium to long
Transition	Policy and legal	Compliance costs, stranded assets	Short to medium
	Technology	Stranded assets, capex needs	Medium
	Market	Revenue decline, cost of capital	Short to medium
	Reputation	Revenue decline, cost of capital	Short to medium
Liability	Litigation	Contingent liabilities, settlements	Medium to long
	Adaptation failure	Damages, regulatory fines	Medium
	Greenwashing	Fines, reputational loss	Short

lifts exposure at default (EAD); **market risk** (asset repricing and mark-to-market losses); **operational risk** (business disruption); and **liquidity risk** (fire sales and deposit withdrawals). Two further channels matter at system level: the **insurance** channel, which absorbs part of the loss where cover exists, and the **asset management** channel, through which portfolio repricing and coordinated divestment propagate losses. In emerging and less developed countries the protection gap is wider, and insured losses are less than 10 percent of total damages[16].

Credit risk is the channel studied most: existing literature largely focuses on the impacts of climate risk drivers on banks' credit risk, and to a lesser extent on market risk[17].

[16] BCBS (2021). Climate-related risk drivers and their transmission channels. Basel Committee on Banking Supervision, April 2021, page 30, citing Munich Re (2020).

[17] BCBS (2021). Climate-related risk drivers and their transmission channels. Basel Committee on Banking Supervision, April 2021, Executive summary, page 1.

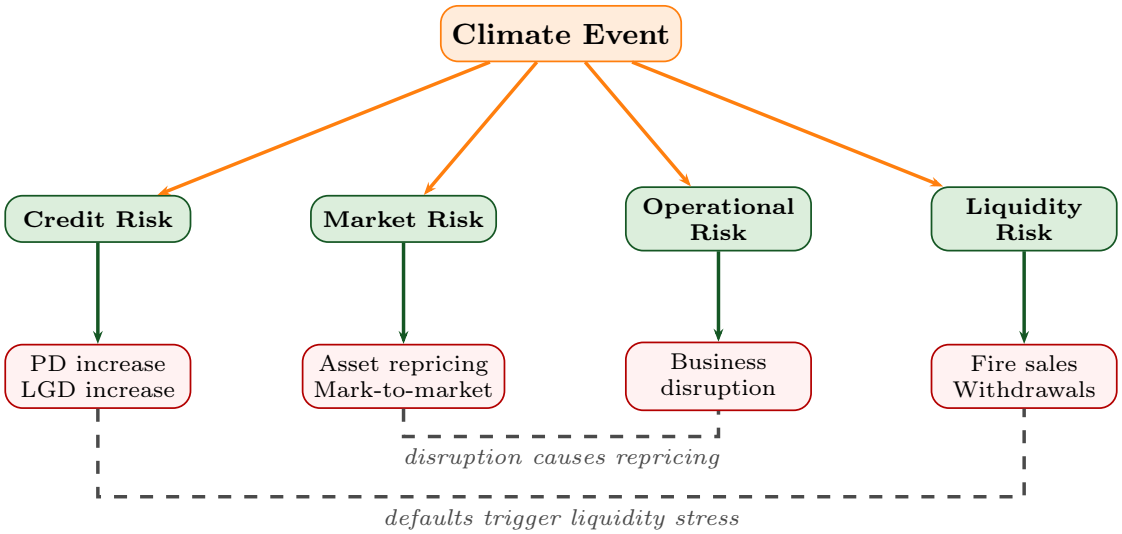


Figure 1.3: A single climate event reaches the balance sheet through four channels at the same time. The interaction between them makes the resulting loss non-linear.

1.4 Time horizons

Climate risks operate across three timescales that mismatch traditional planning. Short-term risk (zero to three years) covers acute physical events, policy shocks, and regulatory enforcement, relevant to trading books and annual budgets. Medium-term risk (three to ten years) covers transition acceleration and the onset of chronic physical change, relevant to corporate loan books and infrastructure investment. Long-term risk (ten to thirty years and beyond) covers systemic transformation and tipping points, relevant to sovereign bonds, pension funds, and real-estate solvency. Long-term risk lies beyond the horizons Carney gives for monetary policy and financial stability, and this mismatch is his tragedy of the horizon.

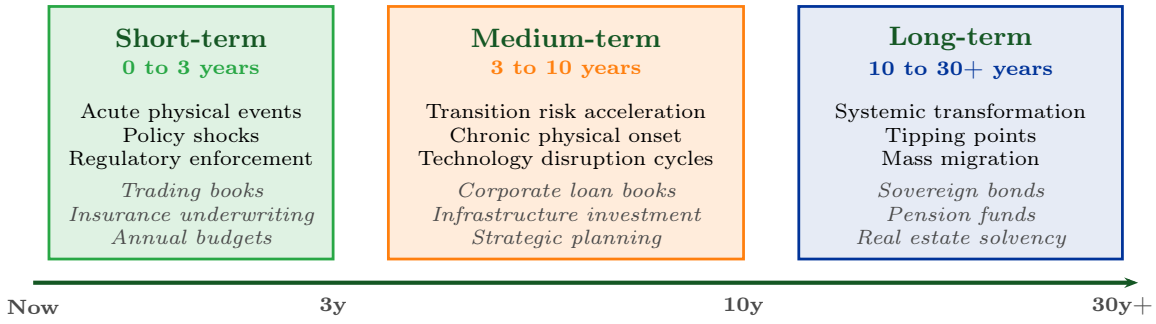


Figure 1.4: The tragedy of the horizon: the planning windows that govern trading books, loan books and pension funds, set against the timescale over which the risk arrives.

1.5 Single and double materiality

Materiality decides which climate risks matter enough to require action, and three frameworks define it differently. *Financial materiality* is an outside-in view: IFRS S1, an International Financial Reporting Standard (IFRS) of the International Sustainability Standards Board (ISSB), requires disclosure of the sustainability-related risks and opportunities that could reasonably be expected to affect an entity's cash flows, its access to finance or cost of capital[18]. *Impact materiality* is an inside-out view: in the standards of the Global Reporting

[18]IFRS Foundation (2023). IFRS S1 General Requirements for Disclosure of Sustainability-related Financial Information, paragraph 3. International Sustainability Standards Board (ISSB), June 2023.

Initiative (GRI), material topics are those that represent an organisation's most significant impacts on the economy, environment and people[19]. The EU Corporate Sustainability Reporting Directive (CSRD) asks for both, information on the undertaking's impacts on sustainability matters and on how sustainability matters affect its development, performance and position[20]. The directive calls this the *double materiality* perspective, in which the risks to the undertaking and the impacts of the undertaking each represent one materiality perspective[21].

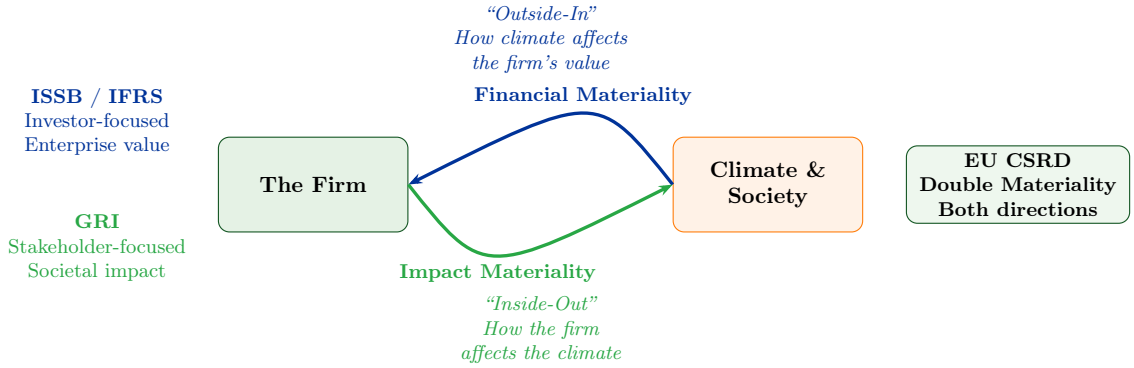


Figure 1.5: Financial materiality looks inward from the climate to the firm; impact materiality looks outward from the firm to the climate. The EU CSRD requires both directions at once.

Double materiality in an ASEAN loan book

Consider a coal-fired power plant in Vietnam that sells its output under a long-term purchase agreement. Its financial materiality may be low in the short term, but its impact materiality is high. Under double materiality both dimensions require disclosure and management. In the Association of Southeast Asian Nations (ASEAN), Singapore Exchange Regulation (SGX RegCo) has amended its listing rules to phase in the climate requirements in the ISSB Standards for listed issuers from 1 January 2025[22]; the ISSB Standards apply financial materiality.

1.6 Climate-adjusted expected loss

The standard credit expected-loss (EL) identity extends to incorporate climate effects:

$$EL_{climate} = \underbrace{PD_{base}\,(1 + \Delta T \cdot \beta_{climate})}_{PD_{climate}} \times \underbrace{(LGD_{base} + \Delta LGD_{physical})}_{LGD_{climate}} \times EAD$$

where ΔT is the warming beyond today's climate in °C and $\beta_{climate}$ is a sector-specific climate sensitivity of PD per degree (illustrative values: near 0.35 for agriculture, 0.25 for energy, 0.05 for technology). $\Delta LGD_{physical}$ is the collateral lost to physical damage, and EAD is held at today's value. PD_{base} comes from historical default rates; ΔT and $\beta_{climate}$ come from a scenario, so $PD_{climate}$ is a projection.

Table 1.2: Worked example: the Mekong Delta rice portfolio at plus 2.0 °C

Metric	Baseline	Plus 2.0 °C
Probability of default (PD, %)	5.0	8.5
Loss given default (LGD, %)	60	65
Exposure at default (EAD)	$300 million	$300 million
Expected loss	$9.0 million	$16.6 million
Added expected loss	n/a	**plus $7.6 million (plus 84 percent)**

[19] GRI (2021). GRI 3: Material Topics 2021, Introduction, page 4. Global Reporting Initiative, effective 1 January 2023.

[20] Directive (EU) 2022/2464 of 14 December 2022 (Corporate Sustainability Reporting Directive, CSRD), Article 1(4), replacing Article 19a(1) of Directive 2013/34/EU. Text as signed: PE-CONS 35/22, Council of the European Union, 16 November 2022.

[21] Directive (EU) 2022/2464 of 14 December 2022 (Corporate Sustainability Reporting Directive, CSRD), recital 29. Text as signed: PE-CONS 35/22, Council of the European Union, 16 November 2022.

[22] IFRS Foundation (2025). Jurisdictional snapshot: Singapore. Updated 12 June 2025.

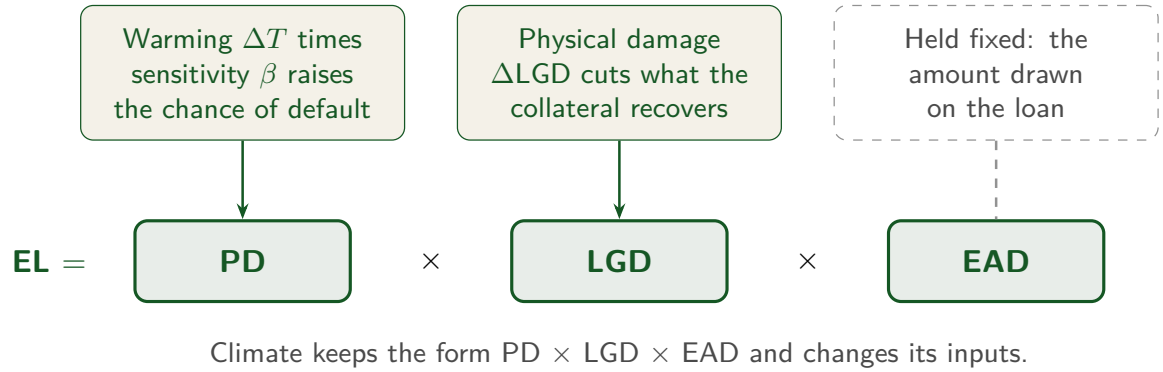


Figure 1.6: Climate keeps the form $PD \times LGD \times EAD$ and changes its inputs. Warming times sensitivity raises PD, physical damage cuts what the collateral recovers, and EAD is held at today's value.

With $PD_{climate} = 0.05 \times (1 + 2.0 \times 0.35) = 0.085$ and $LGD_{climate} = 0.60 + 0.05 = 0.65$, the expected loss rises from \$9.0 million to \$16.6 million, an 84 percent increase for the agriculture sector alone. A bank that holds provisions of \$9.0 million against this book for the baseline needs \$7.6 million more under the scenario. Every input in the example is an illustrative teaching value, chosen to make the mechanism visible.

1.7 Sectoral exposure

Sectors differ in which leg of the taxonomy reaches them. Agriculture and fisheries face mainly physical risk, power generation mainly transition risk, and real estate and transport both. A heatmap scoring each sector from 1 to 5 on acute physical, chronic physical, policy, technology, market and litigation risk, weighted by portfolio share, gives a portfolio risk score. A bank concentrated in agriculture and power generation is exposed to both physical and transition risk.

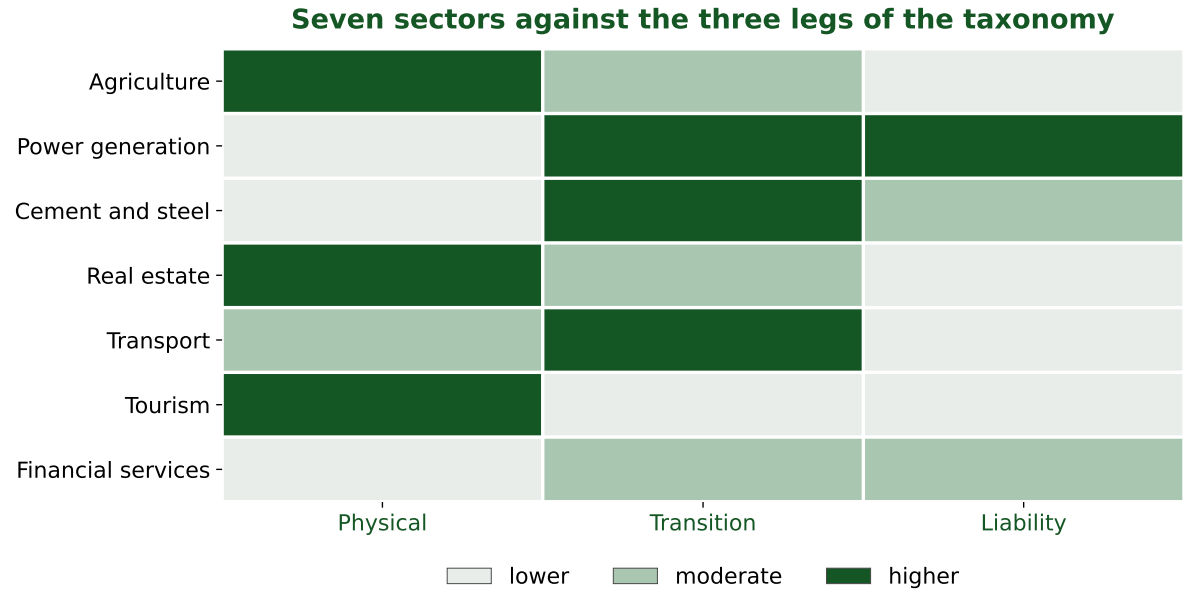


Figure 1.7: Seven sectors against the three legs of the taxonomy, in three named bands. Which leg reaches a sector is well established; a portfolio-specific assessment sets how strongly.

Chapter 2

TCFD and TNFD Risk Assessment

The Task Force on Climate-related Financial Disclosures published its recommendations in June 2017, in four areas: governance, strategy, risk management, and metrics and targets.

Two global frameworks give climate and nature risk a common structure: the Task Force on Climate-related Financial Disclosures (TCFD) for climate, and the Taskforce on Nature-related Financial Disclosures (TNFD) for nature.

The Module 4 / Module 5 boundary

TCFD and TNFD serve here as **risk assessment** tools: their Risk Management pillar and the processes for identifying and assessing risk. Their disclosure and reporting dimensions, together with IFRS S1 and IFRS S2, two International Financial Reporting Standards (IFRS) of the International Sustainability Standards Board (ISSB), belong to Module 5.

2.1 Standardised climate disclosure

Users of climate-related disclosures cited inconsistencies in disclosure practices and non-comparable reporting as major obstacles to using climate-related information in investment, lending and insurance underwriting decisions[1]. The Financial Stability Board (FSB) established the Task Force on Climate-related Financial Disclosures (TCFD) in December 2015[1], and the recommendations followed in June 2017[2], presented by Michael Bloomberg on behalf of the Task Force to Mark Carney as Chairman of the FSB[3]. In June 2021 the Group of Seven (G7) finance ministers and central bank governors supported moving towards mandatory climate-related financial disclosures based on the TCFD framework[4]. The TCFD disbanded in October 2023, and the FSB asked the IFRS Foundation to take over monitoring companies' climate-related disclosures[5]; IFRS S2 is effective for annual reporting periods beginning on or after 1 January 2024[6].

2.2 The TCFD four pillars

The TCFD organises its recommendations in four pillars. **Governance** assigns board and management responsibility. **Strategy** identifies risks and opportunities over the short, medium, and long term, their impact on the business and its financial planning, and the resilience of the strategy under different climate scenarios, including a 2 °C or lower scenario[7]. **Risk Management** has three recommended disclosures: the processes for identifying and assessing climate risk, the processes for managing it, and how both are integrated into overall risk management[7]. **Metrics and Targets** disclose the metrics in use; Scope 1, Scope 2 and, if appropriate, Scope 3 emissions, where a bank's Scope 3 includes its financed emissions; and targets with performance against

[1]TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. Final Report, June 2017. Financial Stability Board. Section A, Introduction.

[2]TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. Final Report, June 2017. Financial Stability Board.

[3]TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures. Final Report, June 2017. Financial Stability Board. Letter from Michael R. Bloomberg, 15 June 2017.

[4]G7 Finance Ministers and Central Bank Governors (2021). Communique, London, 5 June 2021, paragraph 4. GOV.UK.

[5]TCFD. Task Force on Climate-related Financial Disclosures website, notice of October 2023. fsb-tcfd.org.

[6]IFRS Foundation. IFRS S2 Climate-related Disclosures, standard page, ifrs.org.

[7]TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures, the recommendations and recommended disclosures of Figure 4 of the Final Report, as set out on the TCFD recommendations page, fsb-tcfd.org.

them[8]. Carbon intensity and Climate Value-at-Risk (Climate VaR) are two of the metrics a bank discloses under this pillar.

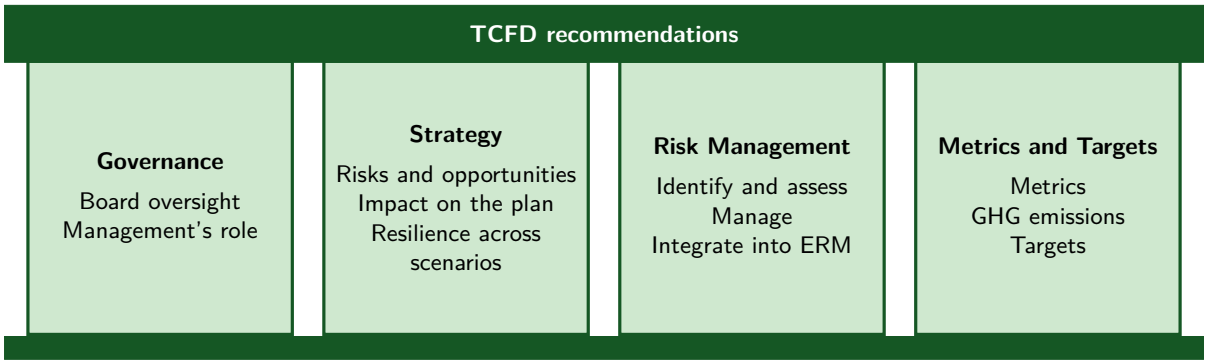


Figure 2.1: The four pillars of the TCFD recommendations: governance, strategy, risk management, and metrics and targets.

Table 2.1: The TCFD four pillars

Pillar	Scope	Key outputs
Governance	Responsibility for climate risk	Board mandate, committee structure, management roles
Strategy	Effect of climate on the business, strategy and financial planning	Scenario analysis, resilience assessment, horizon mapping
Risk Management	Processes to identify, assess and manage climate risk	Risk register, stress tests, risk-appetite thresholds, credit integration
Metrics and Targets	Measures of exposure and progress against targets	Greenhouse gas (GHG) emissions, Weighted Average Carbon Intensity (WACI), Climate VaR, net-zero targets

2.3 The three disclosures of the Risk Management pillar

The Risk Management pillar holds a bank's day-to-day climate risk processes. It has three recommended disclosures: how the bank identifies and assesses climate risk, how it manages it, and how both processes are integrated into its overall risk management. **Identify and assess**: map physical and transition exposures across business lines and geographies, run scenario screening, keep a climate risk register inside the enterprise risk register, quantify likelihood and impact, prioritise against other risks with consistent scoring, and stress test under multiple scenarios of the Network for Greening the Financial System (NGFS), producing heatmaps and scenario-adjusted estimates of the probability of default (PD) and loss given default (LGD). **Manage**: set risk-appetite thresholds, embed climate into credit approval, investment, and underwriting decisions, and monitor effectiveness. **Integrate**: run the climate processes inside the enterprise risk framework the bank already has.

2.4 Integrating climate into Enterprise Risk Management

Climate risk belongs inside the existing Enterprise Risk Management (ERM). The principle is to use the same machinery: the same risk-appetite framework, the same risk register, the same committee structure, and the same escalation processes. In practice a bank adds, say, "physical flood risk to the mortgage portfolio" as a line item in its credit risk register, scored on the same likelihood-impact matrix, reviewed by the same committee, and bounded by the same appetite limits. Only the climate line item is new.

The Basel Committee's 2022 principles for climate-related financial risks run 1 to 12 on how banks should manage those risks and 13 to 18 on how prudential supervisors should review them[9]. Principle 4 asks banks

[8]TCFD (2017). Recommendations of the Task Force on Climate-related Financial Disclosures, the recommendations and recommended disclosures of Figure 4 of the Final Report, as set out on the TCFD recommendations page, fsb-tcfd.org.

[9]BCBS (2022). Principles for the effective management and supervision of climate-related financial risks. Basel Committee on Banking Supervision, June 2022.

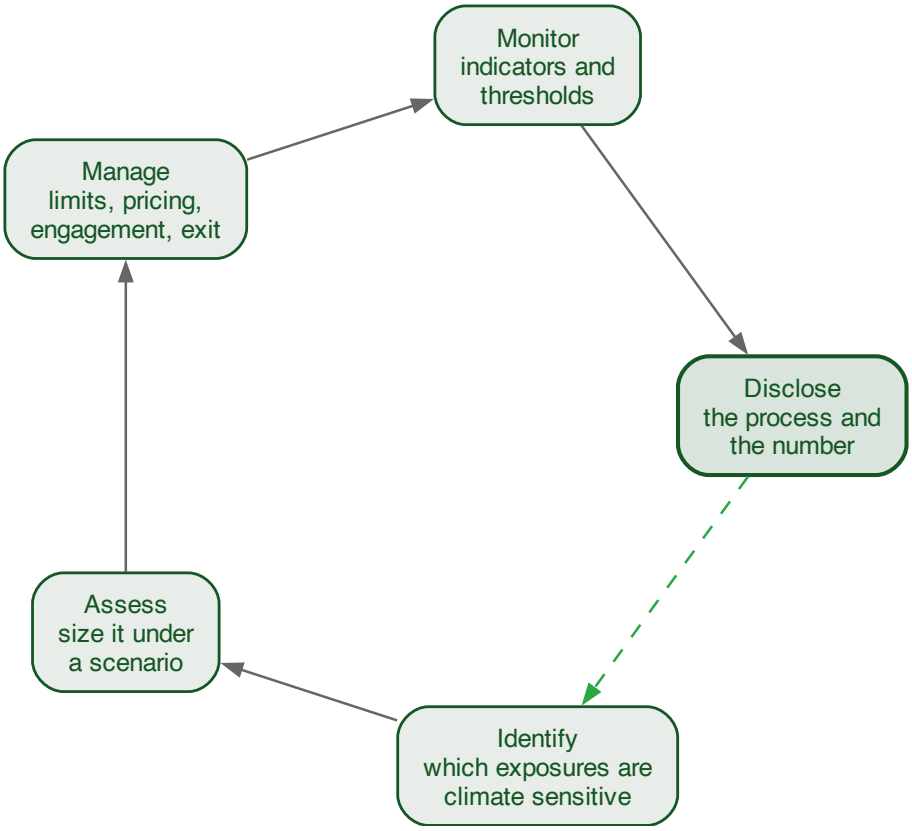


Figure 2.2: Identify, assess, manage and monitor form the risk cycle; the dashed edge runs from disclosure back to identification.

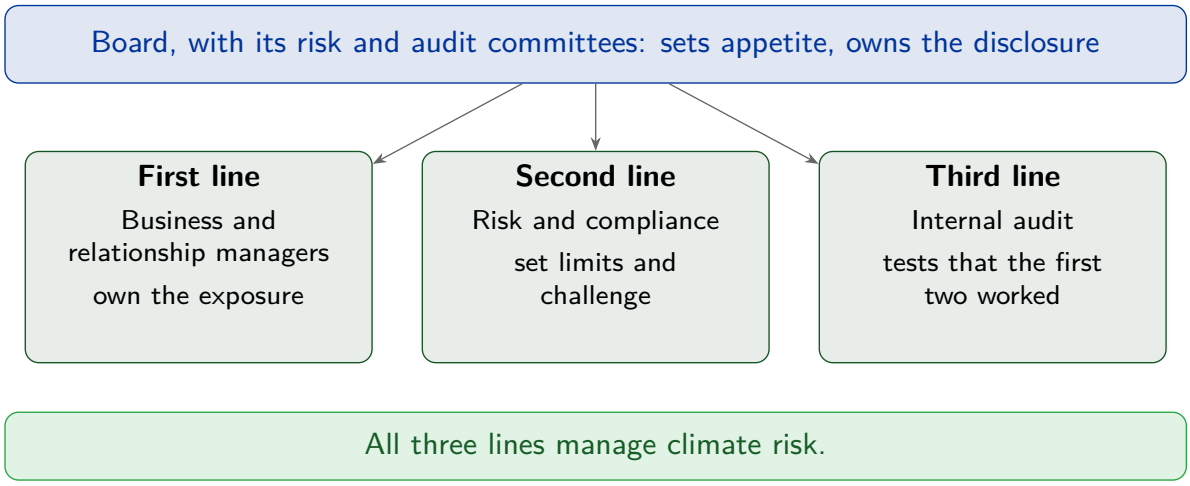


Figure 2.3: The three lines of defence under the board. All three manage climate risk.

to incorporate climate-related financial risks into their internal control frameworks across the three lines of defence. In the first line of defence, climate-related risk assessments may be undertaken at client onboarding, credit application and credit review; the second line, the risk function, assesses and monitors climate-related risk independently and challenges the first line's assessment; the third line, the internal audit function, gives

independent review and objective assurance of the first two lines[10].

2.5 From climate to nature: TNFD and LEAP

Climate is only one dimension of environmental risk. The World Economic Forum (2020) estimates that $44 trillion of economic value generation, more than half of the world's total gross domestic product (GDP), is moderately or highly dependent on nature and its services[11]. The Sundaland biodiversity hotspot lies in Southeast Asia[12]. The Taskforce on Nature-related Financial Disclosures (TNFD) published its recommendations in September 2023 with four pillars, risk and impact management among them[13]. Its **LEAP** approach has four phases: Locate the interfaces with nature, Evaluate dependencies and impacts on nature, Assess nature-related risks and opportunities, and Prepare to respond to them[13]. The TNFD defines nature-related risks as potential threats to an organisation that arise from its and wider society's dependencies and impacts on nature, and classes them as physical, transition or systemic risks[13]. Nature-related dependencies and impacts are location specific and need local, context-specific assessment[13]; the Integrated Biodiversity Assessment Tool (IBAT) helps locate an organisation's interfaces with nature[14], and the Exploring Natural Capital Opportunities, Risks and Exposure (ENCORE) tool helps identify which activities and assets warrant assessment[13]. The TNFD specifies no single metric for the state of nature, because none captures all its dimensions[13].

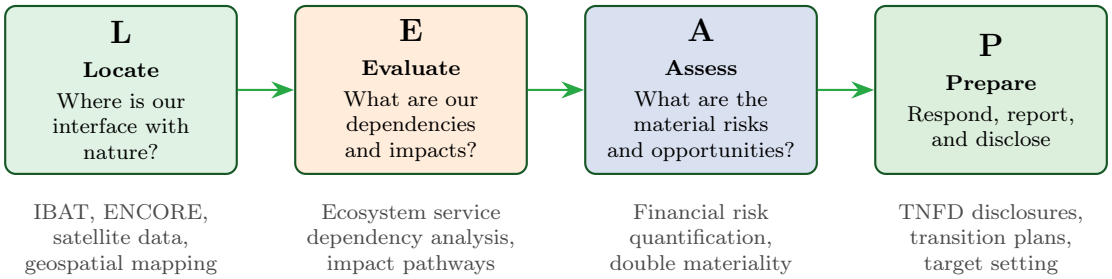


Figure 2.4: The four LEAP phases of the TNFD, from locating an organisation's interfaces with nature to preparing its response, with the tools used in each phase.

Table 2.2: TCFD and TNFD compared

Dimension	TCFD (climate)	TNFD (nature)
Established	December 2015 (FSB); recommendations 2017	2021; recommendations 2023
Risk assessment	Scenario-based (NGFS)	Spatial, location-based (LEAP)
Key metric	Tonnes of CO2 equivalent, tCO2e (globally fungible)	No single metric
Regulatory status	IFRS S2 effective from 1 January 2024	Voluntary adoption

The TNFD was launched in 2021[15], and it encourages and supports voluntary adoption of its recommendations[13]. Deforestation accelerates climate change and climate change accelerates biodiversity loss, so a bank assesses climate and nature risk together.

2.6 Quantifying maturity

The module's teaching rubric scores risk-management maturity on four dimensions (identify, assess, manage, integrate), each from 0 to 3, for a total from 0 to 12: 0 to 3 absent, 4 to 6 basic, 7 to 9 developing, 10 to 12

[10]BCBS (2022). Principles for the effective management and supervision of climate-related financial risks. Basel Committee on Banking Supervision, June 2022, Principle 4, paragraphs 20 to 22, page 4.
[11]World Economic Forum (2020). Nature Risk Rising: Why the Crisis Engulfing Nature Matters for Business and the Economy. New Nature Economy Report, January 2020.
[12]Critical Ecosystem Partnership Fund. Hotspots defined, cepf.net.
[13]TNFD (2023). Recommendations of the Taskforce on Nature-related Financial Disclosures. September 2023.
[14]TNFD (2023). Guidance on the identification and assessment of nature-related issues: the LEAP approach, version 1.1, October 2023.
[15]TNFD (2023). Recommendations of the Taskforce on Nature-related Financial Disclosures. September 2023. Section 1.2.

advanced. Applying it to a hypothetical Thai commercial bank gives identification 2, assessment 1 (qualitative only, limited scenario work), management 2 (sector policies but no portfolio steering), and integration 1 (reported separately from the main ERM), a total of 6 out of 12, that is *basic*. The bank's two lowest dimensions are assessment and integration: NGFS scenario analysis raises assessment, and a board risk-appetite statement that names climate risk raises integration.

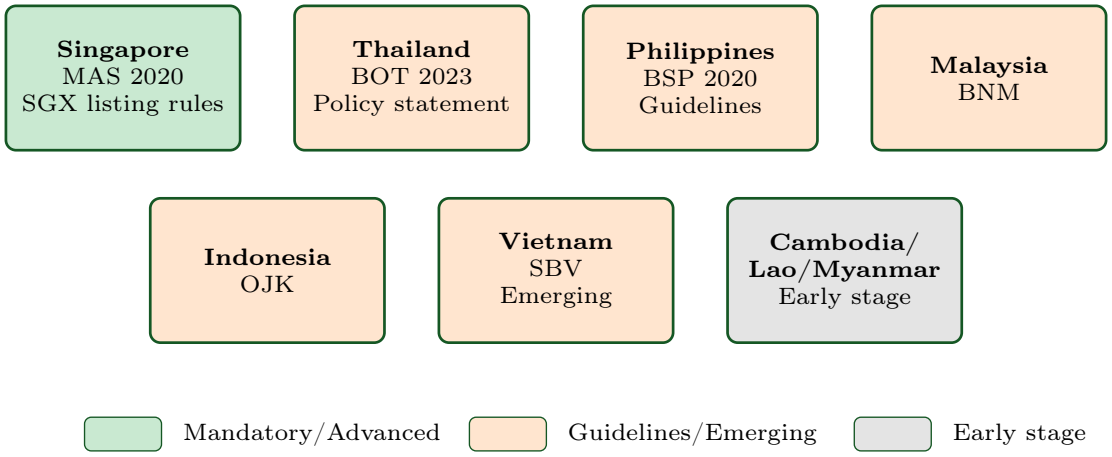


Figure 2.5: TCFD adoption across nine economies of the Association of Southeast Asian Nations (ASEAN) in three supervisory stages: mandatory or advanced, guidelines or emerging, and early stage. SGX is the Singapore Exchange, BNM is Bank Negara Malaysia, and OJK is Otoritas Jasa Keuangan of Indonesia.

Chapter 3

Scenario Analysis and Climate Modeling

The Network for Greening the Financial System (NGFS) publishes seven reference scenarios, and their end-of-century warming runs from 1.1 °C in Low Demand to 3.0 °C in Current Policies.

Scenario analysis turns a climate pathway, such as a tripling of carbon prices by 2035 or warming of 3 °C, into a portfolio loss. The Strategy pillar of the Task Force on Climate-related Financial Disclosures (TCFD) asks a bank to describe the resilience of its strategy under such scenarios.

3.1 Scenarios under deep uncertainty

Climate outcomes resist prediction: the system has non-linear dynamics and tipping points, outcomes depend on policy choices not yet made, and the uncertainty is deep, with no probability attached to any path. Risk has known probabilities; deep uncertainty means the probability distribution itself is unknown. Scenarios respond to this by offering structured explorations of plausible futures: internally consistent "what if" stories about climate, policy, and technology that let an institution stress test against several pathways and look for vulnerabilities that persist across all of them. The goal is a strategy that survives every pathway in the set.

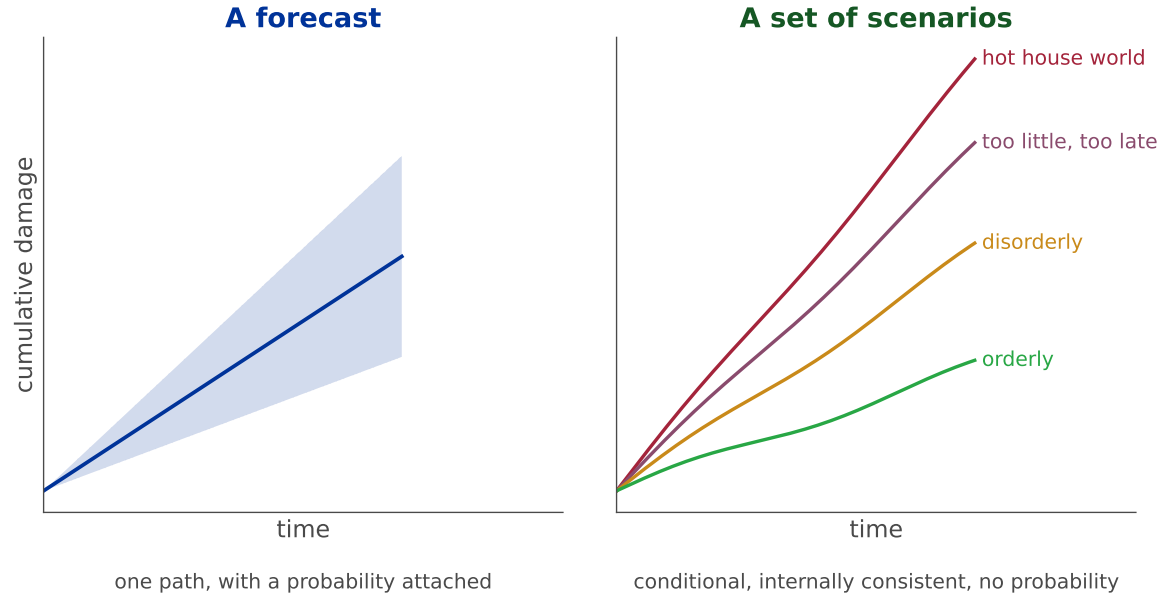


Figure 3.1: A forecast is one path with a probability attached; a scenario set is a family of conditional paths with none.

3.2 The NGFS scenarios

The Network of Central Banks and Supervisors for Greening the Financial System (NGFS), founded in 2017 at the Paris One Planet Summit[1], counts Bank Indonesia, the Bank of Thailand, Bank Negara Malaysia and the Bangko Sentral ng Pilipinas (BSP) among its members[2], and publishes climate scenarios for financial supervision. The current release, results version 5.0 of November 2024, provides seven reference scenarios in four categories: orderly transition, disorderly transition, hot world (Hot House World in the scenario narratives of the same release), and too little, too late[3].

Table 3.1: The seven NGFS scenarios of results version 5.0, November 2024, with end-of-century warming averaged across the three NGFS models.

Scenario	Category	End-of-century warming
Low Demand	Orderly	1.1 °C
Net Zero 2050	Orderly	1.4 °C
Below 2 °C	Orderly	1.8 °C
Delayed Transition	Disorderly	1.7 °C
Nationally Determined Contributions (NDCs)	Hot house world	2.3 °C
Current Policies	Hot house world	3.0 °C
Fragmented World	Too little, too late	2.4 °C

The same source gives each scenario's peak: Net Zero 2050 peaks at 1.7 °C and ends the century at 1.4 °C[4]. Carbon prices and impacts on gross domestic product (GDP) are model outputs: the same scenario run through a different integrated assessment model gives a different number, and the spread is wide enough that a single tabulated value misleads. For Net Zero 2050 the modelled global carbon price reaches $500 to $1,250 per tonne by 2050, in 2010 dollars, a two-and-a-half-fold spread across models for one scenario in one year[5]. Quote a range and its model, or pull the pathway live from the NGFS Scenario Explorer; do not quote a slide.

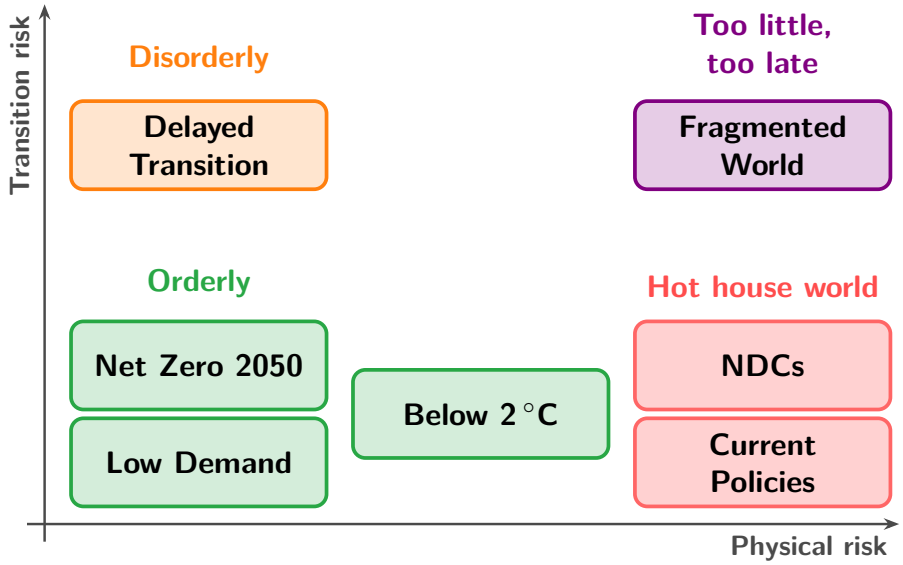


Figure 3.2: The seven NGFS scenarios placed by physical and transition risk. The orderly scenarios sit low on both, Delayed Transition high on transition risk, NDCs and Current Policies high on physical risk, and Fragmented World high on both.

[1] NGFS. Origin and Purpose. Network of Central Banks and Supervisors for Greening the Financial System.
[2] NGFS. Membership, list of members, Asia-Oceania. ngfs.net.
[3] NGFS (2025). NGFS Scenarios: narratives and key findings, November 2025, on results version 5.0 of November 2024 (Phase V). Box 1, NGFS Scenario framework, page 9.
[4] NGFS (2024). NGFS long-term scenarios for central banks and supervisors, November 2024 (Phase V), Scenarios at a glance (1/2), page 10.
[5] NGFS (2025). NGFS Scenarios: narratives and key findings, November 2025, on results version 5.0 of November 2024 (Phase V). Net Zero 2050 scenario narrative.

ASEAN and physical risk

Orderly scenarios assume that ambitious climate policies are introduced early and become gradually more stringent, so physical and transition risks both stay relatively subdued[6]. Disorderly scenarios assume that climate policies are delayed or divergent across countries and sectors, so physical risk stays subdued and transition risk is high, as carbon prices rise sharply and abruptly[7]. Hot house world scenarios assume that some jurisdictions implement some policies but that global efforts are insufficient to halt significant global warming, so they hold the least transition cost and the most physical damage[8]. Chronic physical risk is the main source of risk in the NGFS scenarios of November 2024[9], and the NGFS counts Asia among the regions most vulnerable to physical risks[10]. The Swiss Re Institute (2021) finds the economies of the Association of Southeast Asian Nations (ASEAN) hardest hit: with 3.2 °C of warming by mid-century, ASEAN GDP is 37.4 percent below a world without climate change, against 4.2 percent under the Paris target[11]. *Fragmented World*, the too little, too late case, assumes a late and uncoordinated transition, with uneven climate action across countries, so it holds high physical and high transition risk at once[12]. For a region that is physically exposed and also trade-exposed to other countries' carbon policy, Fragmented World belongs in an ASEAN stress test alongside the hot house world. Bolton et al. (2020) call climate tail risks "green swans": potentially extremely financially disruptive events that could be behind the next systemic financial crisis[13].

The International Energy Agency (IEA) publishes energy-sector scenarios in its World Energy Outlook: the Current Policies and Stated Policies scenarios are exploratory and the Net Zero Emissions by 2050 scenario is normative[14], and the 2025 edition leaves out the Announced Pledges scenario of earlier editions[15]. Use the NGFS set for portfolio-level stress testing and the IEA scenarios for energy-sector analysis.

3.3 The transmission chain

Every scenario analysis follows the same five-stage chain, and each stage adds model uncertainty:

1. **Climate pathway**: temperature, precipitation, extreme-event frequency.
2. **Macro variables**: GDP impact, carbon price, energy prices.
3. **Sector shocks**: output, employment, technology disruption.
4. **Counterparty**: revenue decline, cost increase, asset impairment.
5. **Portfolio losses**: changes in probability of default (PD) and loss given default (LGD), collateral loss, mark-to-market losses.

As an ASEAN illustration, Philippine agriculture under a hot house world pathway runs from +2.5 °C, through a GDP deviation of about minus 8 percent, to a roughly 15 percent decline in rice yield.

3.4 Calibrating sectoral shocks

Two calibrations turn scenario variables into credit parameters. The PD shock scales GDP by a sector sensitivity:

$$\Delta PD_{sector} = -\gamma_{sector} \times \Delta GDP_{scenario},$$

in percentage points, where γ_{sector} is the sector's default sensitivity to output and the minus sign turns a fall in output into a rise in defaults. For Philippine agriculture under a hot house world pathway, with $\Delta GDP = -8$

[6]NGFS (2024). NGFS Climate Scenarios Technical Documentation, version 5.0, November 2024, page 16.
[7]NGFS (2024). NGFS Climate Scenarios Technical Documentation, version 5.0, November 2024, page 17.
[8]NGFS (2025). NGFS Scenarios: narratives and key findings, November 2025, on results version 5.0 of November 2024, page 35.
[9]NGFS (2024). NGFS long-term scenarios for central banks and supervisors, November 2024 (Phase V), Main results, Gross Domestic Product.
[10]NGFS (2025). NGFS Scenarios: narratives and key findings, November 2025, on results version 5.0 of November 2024 (Phase V). Section 4, Fragmented World, GDP impact across jurisdictions.
[11]Swiss Re Institute (2021). The economics of climate change: no action not an option. April 2021, Key takeaways.
[12]NGFS (2025). NGFS Scenarios: narratives and key findings, November 2025, on results version 5.0 of November 2024, page 49.
[13]Bolton, P., Despres, M., Pereira da Silva, L. A., Samama, F., and Svartzman, R. (2020). The green swan: central banking and financial stability in the age of climate change. Bank for International Settlements.
[14]IEA (2025). Global Energy and Climate Model: Understanding GEC Model scenarios. International Energy Agency.
[15]IEA (2025). Global Energy and Climate Model: Announced Pledges Scenario (APS). International Energy Agency.

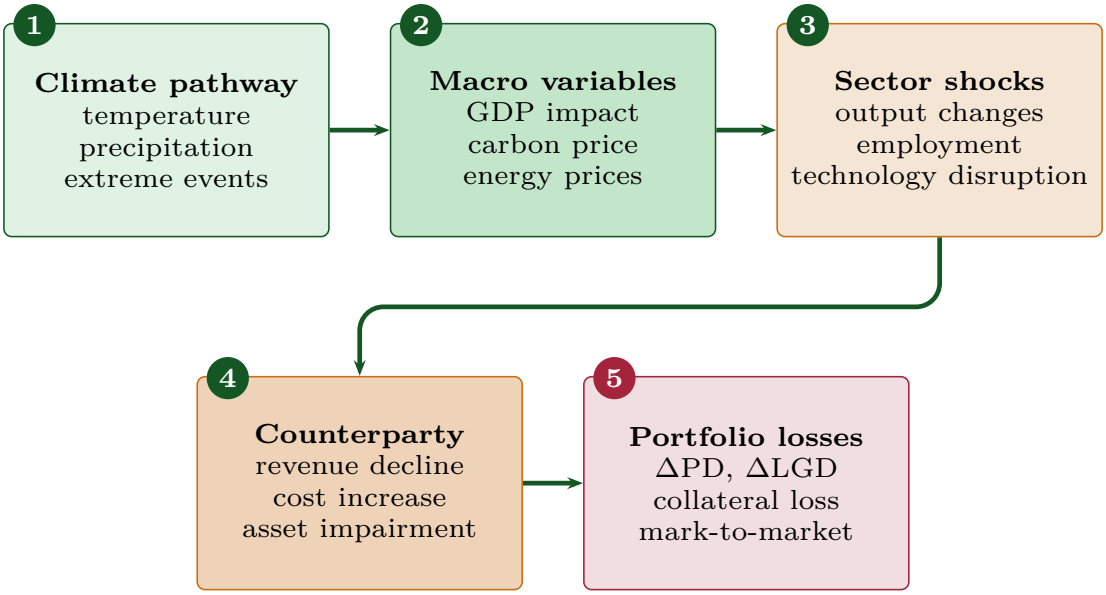


Figure 3.3: The five stages of the transmission chain, from climate pathway to portfolio losses. Each stage is a model, so each adds its own uncertainty to every stage after it.

percent and $\gamma_{agriculture} = 1.5$, this gives a rise of 12 percentage points in the default probability. The LGD adjustment captures the uninsured share of physical damage:

$$LGD_{climate} = LGD_{base} + (1 - \text{insurance coverage}) \times \text{physical damage rate},$$

where insurance coverage is the insured share of physical damage and the physical damage rate applies to the collateral, so an agricultural loan with a base LGD of 45 percent, 30 percent insurance coverage and a 25 percent damage rate has $LGD_{climate} = 45 + 0.70 \times 25 = 62.5$ percent. The LGD adjustment raises LGD by 17.5 percentage points, from 45 to 62.5 percent, and the PD shock raises PD by 12 percentage points. Per unit of exposure, the PD rise at the base LGD adds $0.12 \times 0.45 = 0.054$ to expected loss, the LGD rise at the base PD adds $0.175 \times PD_{base}$, and the two rises together add a further $0.12 \times 0.175 = 0.021$. The LGD rise adds more than the PD rise only where the base PD exceeds 31 percent. Take a sample Philippine bank under a disorderly scenario, with sector weights in percent and PD shocks in percentage points of energy 10 and 15, agriculture 25 and 8, manufacturing 20 and 5, real estate 15 and 3, and services 30 and 2. Its portfolio-weighted PD increase is 5.55 percentage points, which on a $2 billion book at the 62.5 percent climate-adjusted LGD implies about $69.4 million in additional expected credit losses from the PD rise; the LGD rise adds a further 17.5 percent of the base PD times the book. The LGD belongs in that step: a PD rise multiplied by exposure alone gives the amount entering default, and only the loss identity of Chapter 1 turns it into a loss.

3.5 Quantifying uncertainty

Within one scenario, a Monte Carlo simulation over uncertain model parameters gives a fan chart: the central line is the median of the simulated paths, and the shaded bands, the 25th to 75th and the 10th to 90th percentiles, widen with the horizon as uncertainty compounds. The percentiles are conditional on the scenario, and a bank reads its losses from the lower tail of the fan.

3.6 Integrated assessment models, carbon budgets and damage functions

The numbers behind every NGFS scenario come from a chain of models. The NGFS runs three integrated assessment models (IAMs), REMIND-MAgPIE (the Regional Model of Investments and Development coupled with the Model of Agricultural Production and its Impact on the Environment), GCAM (the Global Change Analysis Model) and MESSAGEix-GLOBIOM (the Model for Energy Supply Strategy Alternatives and their General Environmental Impact coupled with the Global Biosphere Management Model), and one macroeconomic model, NiGEM (the National Institute Global Econometric Model)[16]. Each IAM couples an economic, an

[16]NGFS (2024). NGFS Climate Scenarios Technical Documentation, version 5.0, November 2024, page 11.

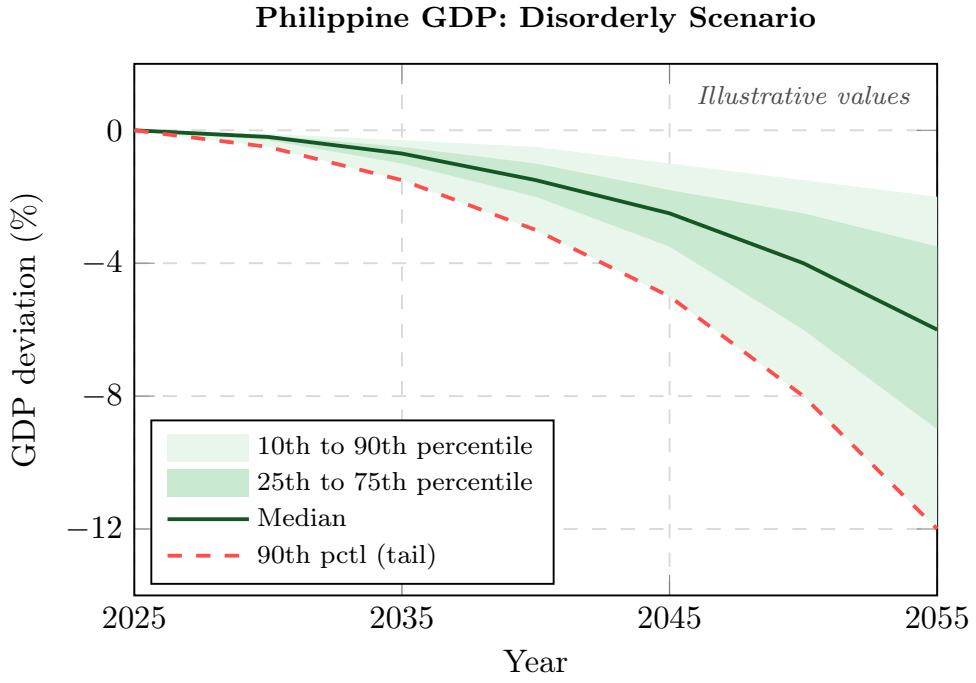


Figure 3.4: Philippine GDP deviation from baseline under a disorderly scenario, 2025 to 2055: the median of the simulated paths and two percentile bands that widen with the horizon. Illustrative values.

energy and a climate module and turns a policy path into energy use, emissions and land use. NiGEM turns the transition and the physical shocks into GDP, interest rates and prices. Physical damages feed back into the transition pathways only in REMIND-MAgPIE's runs with integrated damages[17].

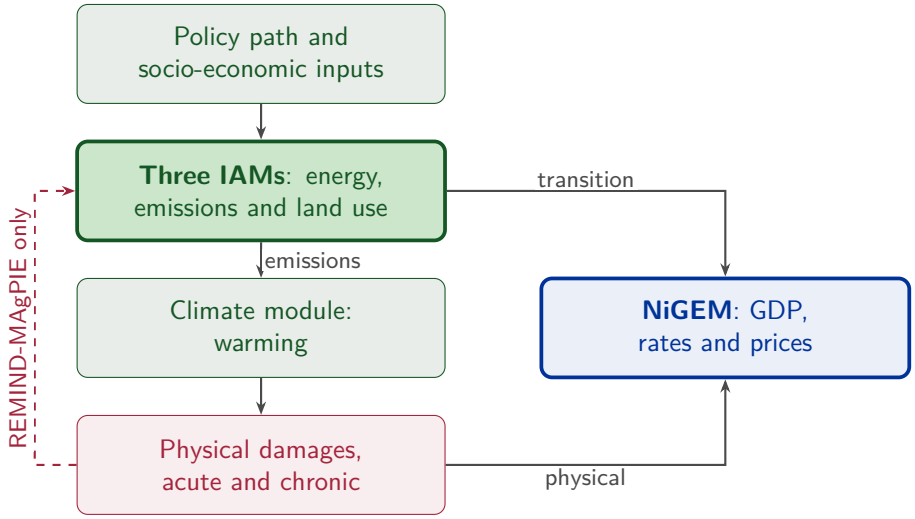


Figure 3.5: The NGFS model chain. Three IAMs turn a policy path into energy use, emissions and land use, a climate module turns emissions into warming, and NiGEM turns the transition and the physical shocks into GDP, interest rates and prices. The dashed return from damages to the IAMs exists only in REMIND-MAgPIE's runs.

DICE (the Dynamic Integrated Climate-Economy model) is a single-region teaching model. The three NGFS models make different structural assumptions, so the same scenario name can yield different numbers. The carbon budget constraint, $\sum_t E_t \leq B_{1.5}$, holds cumulative emissions below the budget consistent with a

[17]NGFS (2024). NGFS Climate Scenarios Technical Documentation, version 5.0, November 2024, page 22.

temperature limit; if annual CO2 emissions from 2020 to 2030 stayed at the 2019 level, the resulting cumulative emissions would almost exhaust the remaining carbon budget for 1.5 °C at a 50 percent likelihood[18], so every year of delay raises the rate at which emissions must fall afterwards. The damage function, often written $D(T) = aT^2/(1 + bT^2)$ with warming T and calibrated parameters a and b, translates temperature into GDP loss: at the same level of warming, published estimates of the GDP loss differ several-fold depending on whose damage function is used.

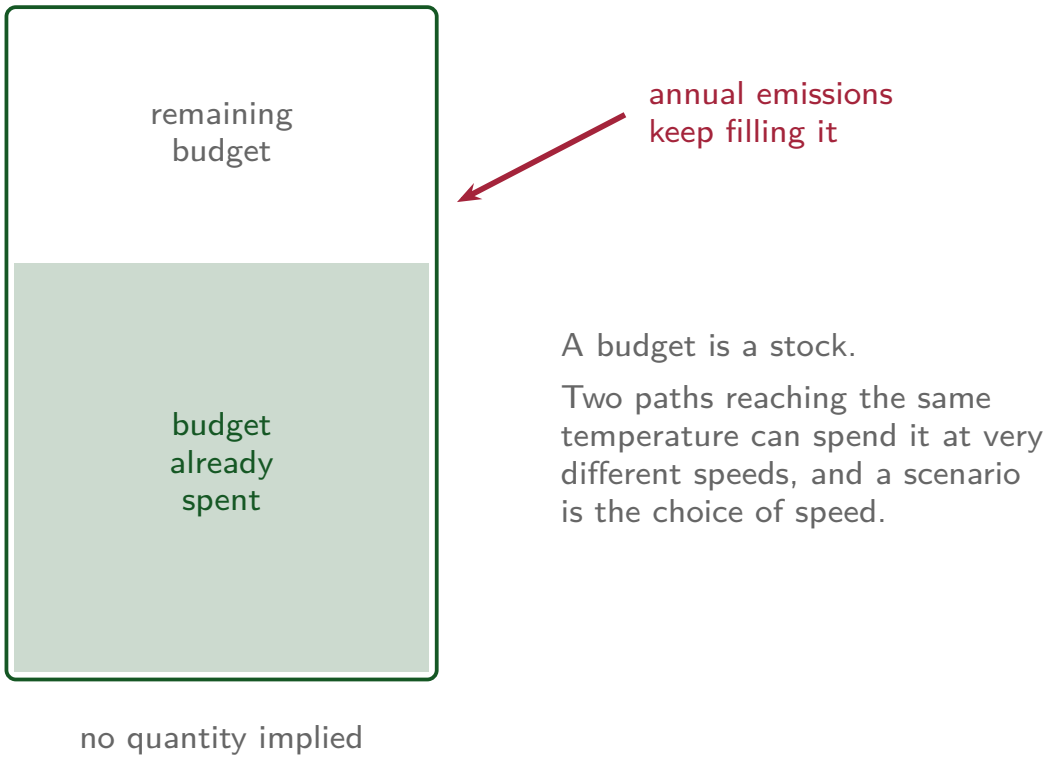


Figure 3.6: A carbon budget is a stock: two pathways reaching the same temperature spend the same fixed quantity at different speeds, and a scenario is a choice of speed. The size of the remaining budget is contested, so the stock is drawn without a scale.

[18]IPCC (2023). Climate Change 2023: Synthesis Report, Summary for Policymakers, B.5.3.

Chapter 4

Carbon Metrics and Climate Value-at-Risk

CDP, formerly the Carbon Disclosure Project, finds that the emissions associated with financial institutions' investing, lending and underwriting are on average more than 700 times their direct emissions[1].

Carbon metrics measure the emissions a portfolio finances: Greenhouse Gas (GHG) scopes, financed emissions, the Weighted Average Carbon Intensity (WACI), data quality scores and alignment metrics. Climate Value-at-Risk (Climate VaR) converts a climate scenario into a loss of portfolio value. In an illustrative Vietnamese bank, coal has the highest carbon intensity and agriculture the larger Climate VaR, about $281 million against about $74 million.

4.1 Financed emissions

Financed emissions are the Scope 1 and Scope 2 emissions of investees and borrowers attributed to the lender, which the Greenhouse Gas Protocol files under Scope 3, category 15, Investments[2]. The Partnership for Carbon Accounting Financials (PCAF) standardises how financed emissions are computed. Its attribution formula is

$$FE_i = \frac{Outstanding_i}{EVIC_i} \times Emissions_i,$$

where $Outstanding_i$ is the bank's loan to borrower i, $EVIC_i$ is the borrower's Enterprise Value Including Cash, the ratio $Outstanding_i/EVIC_i$ is the attribution factor, and $Emissions_i$ is the borrower's absolute emissions[3]. For a Vietnamese steel company with a $50 million loan, $500 million EVIC and 200,000 tonnes of carbon dioxide equivalent (tCO2e) of emissions, the bank is attributed $\frac{50}{500} \times 200{,}000 = 20{,}000$ tCO2e. The attribution factor ensures each lender is responsible only for its share.

4.2 Weighted Average Carbon Intensity

WACI measures a portfolio's exposure to carbon-intensive companies, in tCO2e per $ million of revenue[4], and the Task Force on Climate-related Financial Disclosures (TCFD) asks asset owners to disclose it for each fund or investment strategy[5]:

$$WACI = \sum_i w_i \times \frac{Emissions_i}{Revenue_i},$$

where w_i is the portfolio weight and the ratio is carbon intensity in tCO2e per $ million of revenue, so doubling every holding leaves WACI unchanged. An illustrative three-company portfolio of a power utility (40 percent weight, intensity 800), a manufacturer (35 percent, 200), and a tech firm (25 percent, 15) has $WACI = 0.40 \times 800 + 0.35 \times 200 + 0.25 \times 15 \approx 394$ tCO2e per $ million of revenue, and the utility alone contributes about

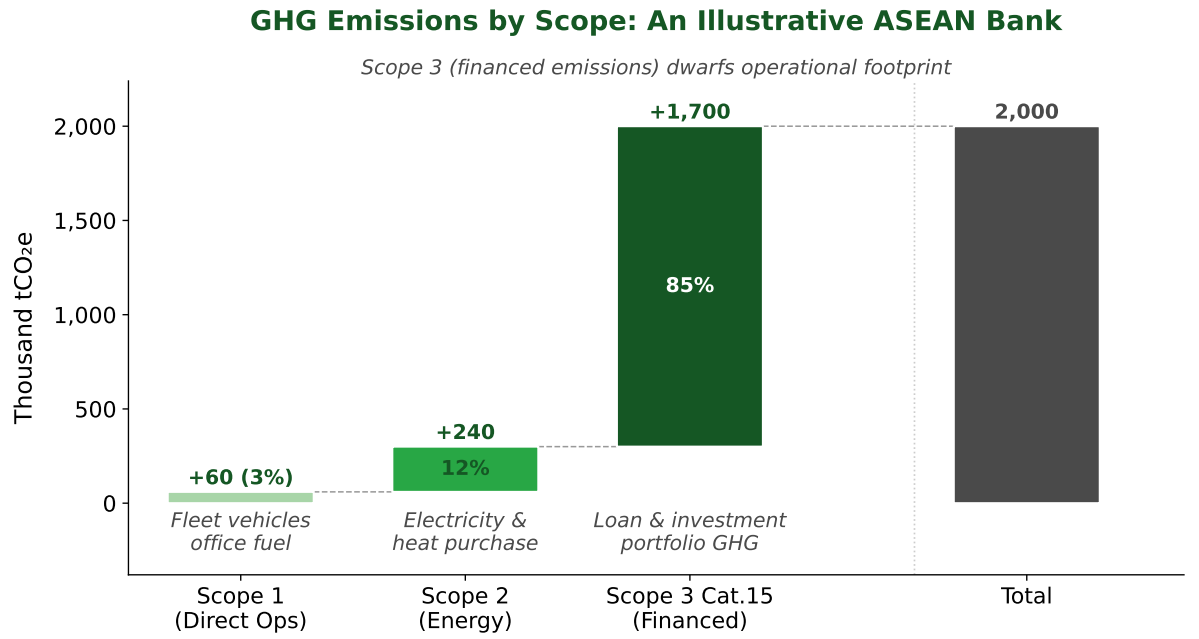
[1] CDP (2021). Finance sector's funded emissions over 700 times greater than its own. Press release, 28 April 2021.

[2] GHG Protocol (2011). Corporate Value Chain (Scope 3) Accounting and Reporting Standard. WRI and WBCSD, September 2011. Table 5.4, page 37; page 51; glossary, page 140.

[3] PCAF (2022). The Global GHG Accounting and Reporting Standard, Part A: Financed Emissions. Second Edition, December 2022. Section 5.2, Business loans and unlisted equity, page 70.

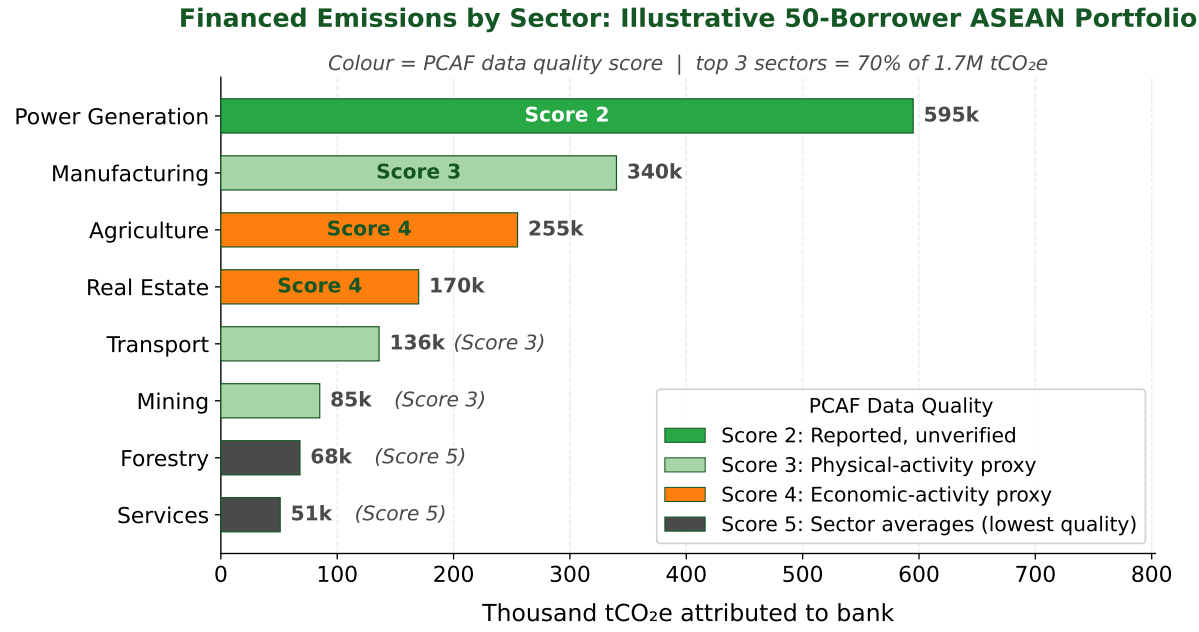
[4] TCFD (2021). Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures, October 2021. Table 3, Common Carbon Footprinting and Exposure Metrics, page 52.

[5] TCFD (2021). Implementing the Recommendations of the Task Force on Climate-related Financial Disclosures, October 2021. Supplemental Guidance for Asset Owners, page 42.



Assumed teaching example, not measured data: Illustrative bank, not a real institution.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.1: Scope 1, Scope 2 and financed emissions (Scope 3, category 15) of an illustrative bank in the Association of Southeast Asian Nations (ASEAN). Financed emissions are 85 percent of the total; at CDP's average ratio the Scope 1 and Scope 2 bars would be too small to see.

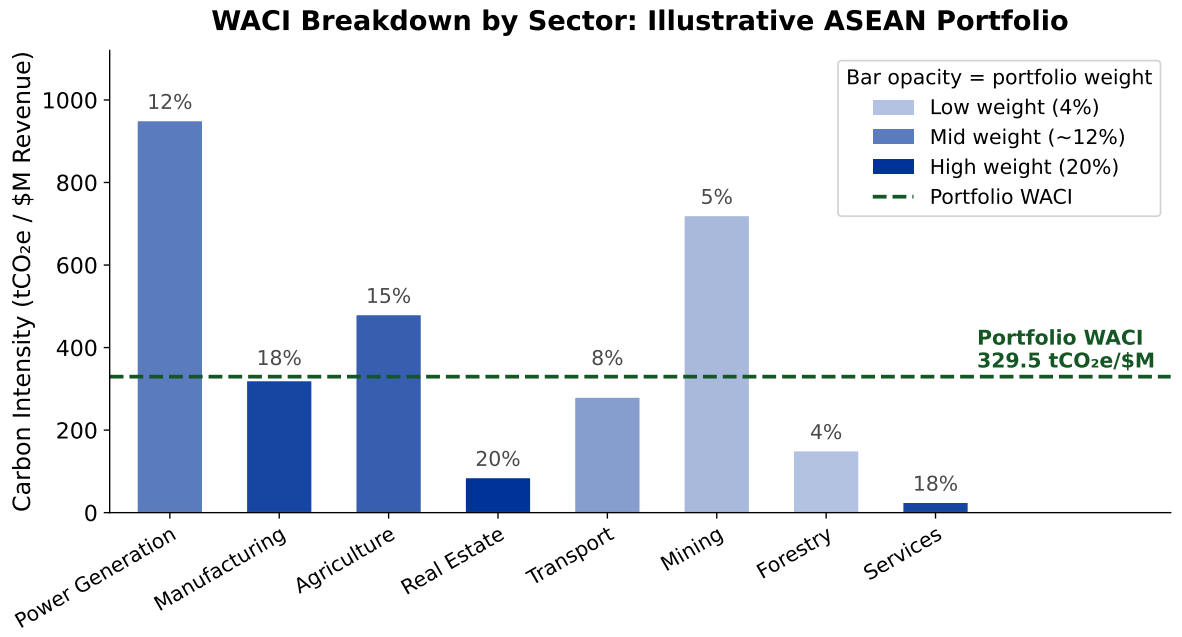


Assumed teaching example, not measured data: Illustrative 50-borrower portfolio, not a real bank.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.2: Financed emissions by sector of the same illustrative ASEAN bank, whose 50 borrowers account for 1,700 thousand tCO2e. Power generation, manufacturing and agriculture make up 70 percent. Colour gives the PCAF data quality score.

81 percent of that despite being 40 percent of value. Coal provided 44 percent of ASEAN electricity generation in 2023 and fossil fuels 74 percent[6]. The benchmark to compare against is the reporting institution's own book.

[6]Ember (2024). ASEAN's clean power pathways: 2024 insights. Power sector in 2023.



Assumed teaching example, not measured data: Illustrative ASEAN portfolio, not a real bank.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.3: WACI of an illustrative eight-sector ASEAN portfolio, 329.5 tCO2e per $ million of revenue. Power generation, 12 percent of the portfolio weight, contributes the largest share.

4.3 Data quality and alignment

PCAF grades each figure with a data quality score from 1, the highest, to 5, the lowest: score 1 means verified emissions reported by the company[7] and score 5 means emission factors for the borrower's sector per unit of revenue or of assets[8]. Report the data quality score and the uncertainty range alongside every metric. Three alignment tools answer different questions. The Paris Agreement Capital Transition Assessment (PACTA) measures the alignment of financial portfolios with climate scenarios[9]. The Transition Pathway Initiative (TPI) assesses companies on Management Quality and Carbon Performance, two complementary metrics[10]. Companies and financial institutions can have their targets validated by SBTi Services, a subsidiary of the Science Based Targets initiative (SBTi)[11]. An illustrative ASEAN bank portfolio with an Implied Temperature Rise of 2.8 °C lies in the partial-alignment band, 2.0 to 3.0 °C.

4.4 Climate Value-at-Risk

Climate VaR measures the impact of climate-related risks and opportunities on the market value of an asset or a portfolio under a specified climate scenario[12], as the expected loss of portfolio value,

$$\text{Climate VaR} = Portfolio_{t_0} - \mathbb{E}[Portfolio_{t_T} \mid Scenario]\,,$$

so an illustrative portfolio of $2 billion expected to be worth $1.62 billion under a hot house world pathway to 2050 has a Climate VaR of $380 million, or 19 percent. Value-at-Risk is a quantile of a loss distribution at a stated confidence level, over days. Climate VaR is a loss conditional on one named scenario, over years to decades, with no probability attached to the scenario, and it splits into physical and transition components. Operationally,

$$\text{Climate VaR} = \sum_i Exposure_i \times \Delta PD_i \times LGD_i,$$

[7]PCAF (2022). The Global GHG Accounting and Reporting Standard, Part A: Financed Emissions. Second Edition, December 2022. Pages 19, 52 and 53; Table 5-3, page 57.
[8]PCAF (2022). The Global GHG Accounting and Reporting Standard, Part A: Financed Emissions. Second Edition, December 2022. Table 5-3, options 3b and 3c, page 57.
[9]RMI. PACTA: Measure the alignment of financial portfolios with climate scenarios. Paris Agreement Capital Transition Assessment, RMI.
[10]Transition Pathway Initiative Centre, London School of Economics. Corporate assessments, TPI online tool.
[11]Science Based Targets initiative. How it works: setting science-based targets.
[12]UNEP FI (2019). Changing Course: A comprehensive investor guide to scenario-based methods for climate risk assessment, in response to the TCFD, page 38.

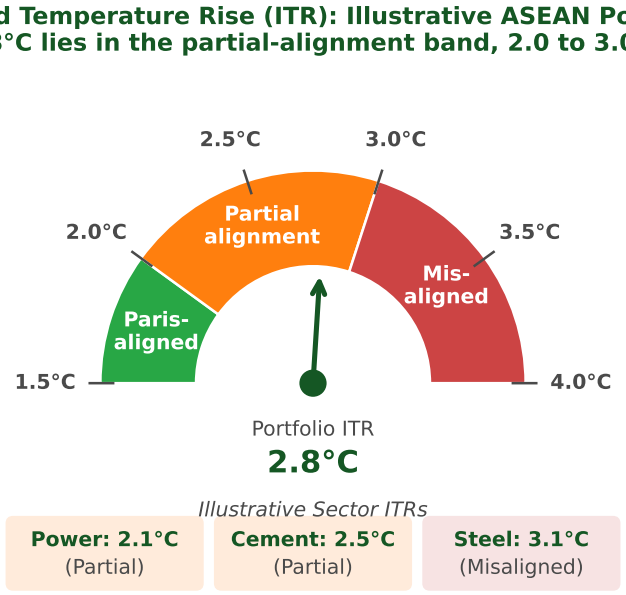
PCAF Data Quality Scores: From Verified to Estimated

Score	Data Source	Reliability
Score 1	Verified audited emissions data	Very High
Score 2	Reported unverified emissions data	High
Score 3	Physical-activity proxy data	Moderate
Score 4	Economic-activity proxy data	Low
Score 5	Sector average emissions factors	Very Low

Target: lower the score by at least 1 every 2 years.

Assumed teaching example, not measured data: Illustrative improvement target.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.4: The PCAF data quality scores, from verified emissions reported by the company to emission factors for the borrower's sector.

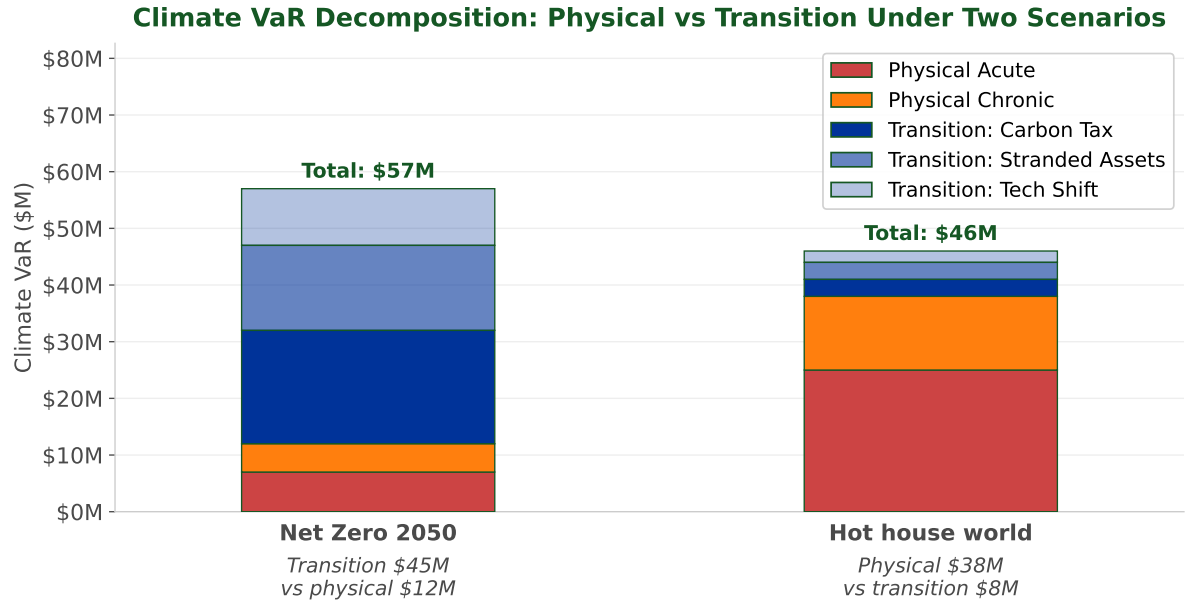


Assumed teaching example, not measured data: Illustrative portfolio ITR and alignment bands; Illustrative sector ITRs, not PACTA benchmarks.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.5: Implied Temperature Rise of an illustrative ASEAN portfolio, 2.8 °C, on a scale from 1.5 to 4.0 °C, with three illustrative sector values.

evaluated separately for the physical channel (climate-adjusted default and uninsured collateral loss) and the transition channel (carbon pricing, stranded assets, technology displacement), where ΔPD_i is the scenario's rise in the probability of default (PD) and LGD_i the loss given default (LGD) in the scenario. For the Mekong Delta rice portfolio of Chapter 1 the sum gives \$6.8 million against the \$7.6 million rise in expected loss; the difference is the higher LGD on the defaults the bank expected anyway. A Vietnamese rice borrower with \$10 million exposure, default probability rising by 8 percentage points from 5 to 13 percent, and LGD of 65 percent contributes $\$10\text{M} \times 0.08 \times 0.65 = \$520{,}000$ of physical Climate VaR. A coal borrower with \$20 million exposure,

default probability rising from 3 to 18 percent under a $75 carbon price, and LGD of 55 percent contributes $\$20\text{M} \times 0.15 \times 0.55 = \$1.65\text{M}$ of transition Climate VaR.



Assumed teaching example, not measured data: Illustrative Climate VaR scenario, not an NGFS-published result.

https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.6: Which Climate VaR component dominates depends on the scenario: transition under Net Zero 2050, physical under the hot house world.

Under Net Zero 2050 the transition channel leads, $45 million against $12 million; under a hot house world pathway the physical channel leads, $38 million against $8 million. A single Climate VaR figure hides the scenario that produced it, so an assessment reports both channels under several scenarios.

4.5 The carbon premium

The carbon beta β_{carbon} of a factor model measures whether markets price transition risk:

$$R_i = \alpha + \beta_{mkt} R_m + \beta_{carbon}\, CarbonIntensity_i + \varepsilon_i.$$

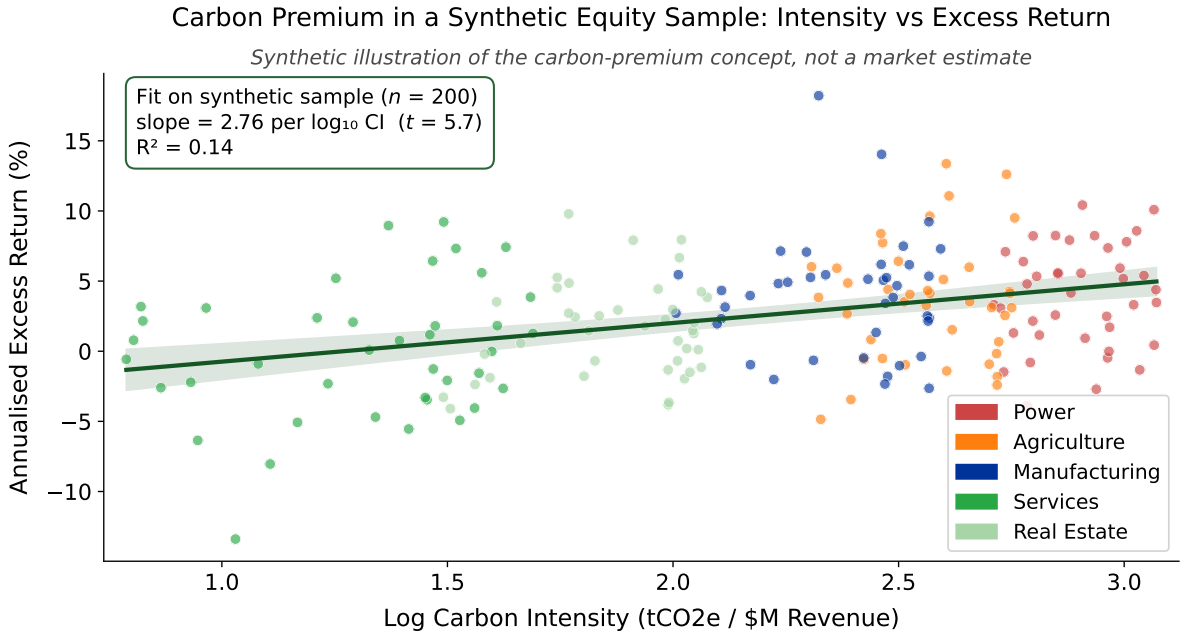
A positive β_{carbon} means investors demand a carbon premium, a higher return for holding carbon-intensive assets. Bolton and Kacperczyk (2021, *Journal of Financial Economics*) find such a premium in the *United States* cross-section: a one-standard-deviation increase in the level of Scope 1 emissions is associated with about 1.8 percent higher annualised returns, and in the change of emissions with about 3.1 percent[13]. Their post-Paris comparison is a caution: the premium does look larger after 2015, but the rise is mostly due to new firms entering the sample, and excluding those new firms leaves it insignificant[13]. The same authors later extend the result to a cross-section of over 14,400 firms in 77 countries, published in 2023[14].

Carbon intensity and Climate VaR rank coal and agriculture in opposite order

For an illustrative Vietnamese bank, coal has the highest carbon intensity and agriculture the larger Climate VaR, because agriculture's exposure is 6 times coal's. Financed emissions per dollar lent and Climate VaR rank agriculture and coal in opposite order.

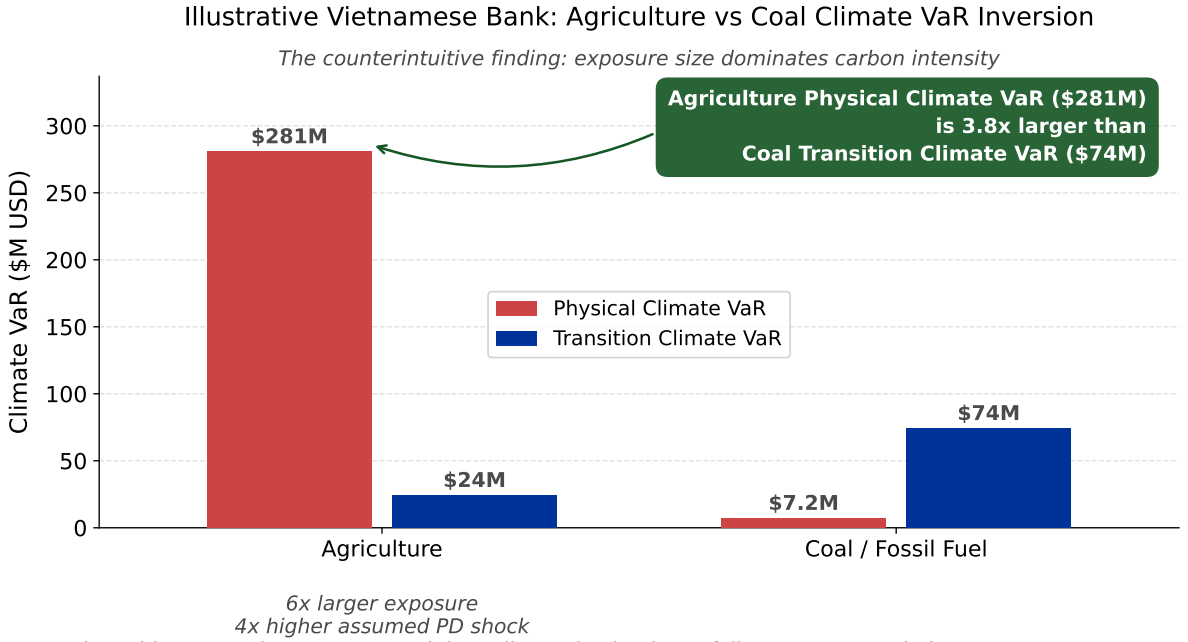
[13] Bolton, P. and Kacperczyk, M. (2021). Do Investors Care about Carbon Risk? Journal of Financial Economics 142(2), 517-549. NBER Working Paper 26968.

[14] Bolton, P. and Kacperczyk, M. (2023). Global Pricing of Carbon-Transition Risk. The Journal of Finance 78(6), 3677-3754. NBER Working Paper 28510.



Assumed teaching example, not measured data: Synthetic sample, not market data.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.7: A synthetic cross-section of 200 firms in five sectors, with a carbon premium built into the data. The scatter around the fitted line shows a tendency across many firms, and the line belongs to this sample.



Assumed teaching example, not measured data: Illustrative bank portfolio, not measured Vietnamese sector data.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson4-carbon-metrics/

Figure 4.8: Agriculture physical Climate VaR far exceeds coal transition Climate VaR for the illustrative Vietnamese bank.

Chapter 5

Climate Stress Testing

The 2022 climate stress test of the European Central Bank (ECB) covered 104 significant banks[1].

Climate stress testing applies the Climate Value-at-Risk (Climate VaR) of Chapter 4 to the whole balance sheet and tests whether the bank can absorb climate losses and still meet its capital requirements.

5.1 Five design elements of a climate stress test

A climate stress test differs from a traditional exercise on every axis: the horizon is multi-decadal, the uncertainty is deep, the data is novel and proxy-based, and the scope is economy-wide. It has five design elements in sequence. **Scenario selection** picks pathways of the Network for Greening the Financial System (NGFS) or bespoke physical events. **Exposure mapping** assigns each loan, bond and holding to the sectors and places the scenario strikes. **Transmission to the risk parameters** raises the probability of default (PD) and loss given default (LGD) and can move exposure at default (EAD). **Loss estimation** separates expected loss, met by provisions, from unexpected loss, met by capital. **Capital impact** deducts losses from capital, raises risk-weighted assets (RWA) through downgrades, and compares the capital ratio with the minimum and the buffer.

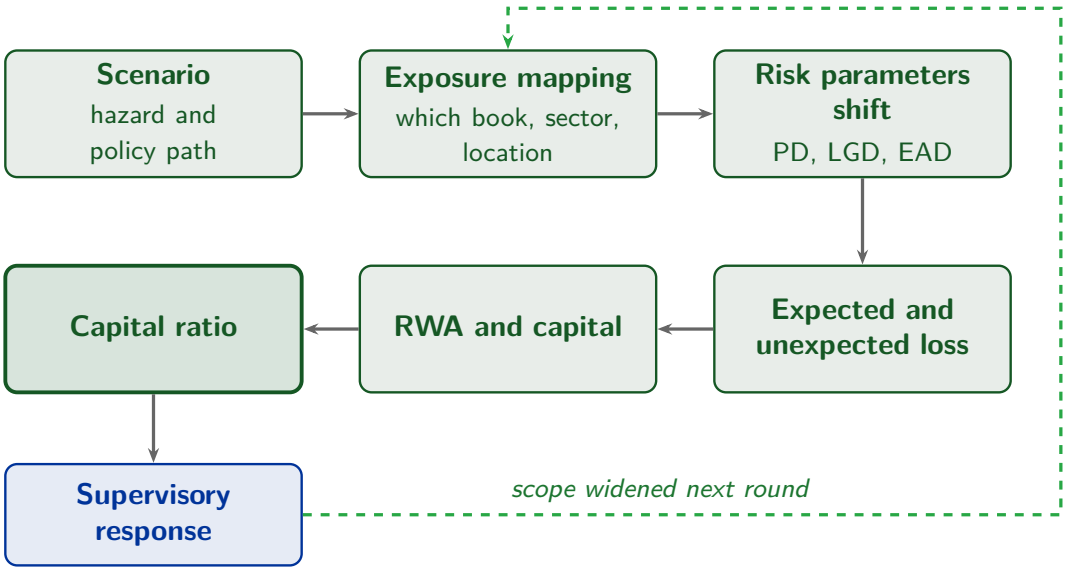
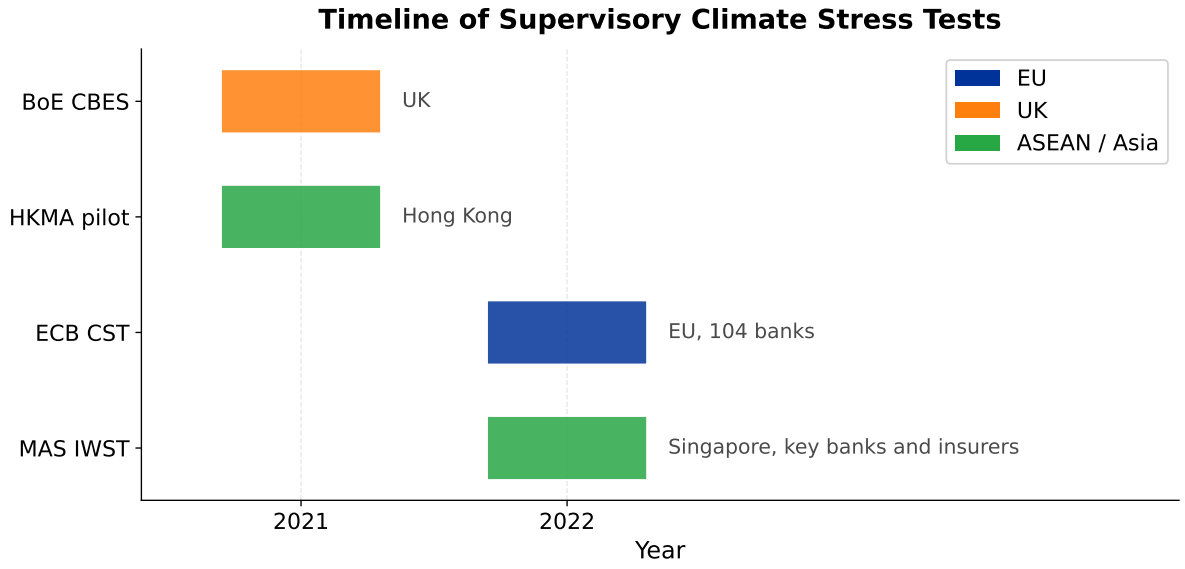


Figure 5.1: The five design elements drawn as six stages, from the scenario to the capital ratio, and the supervisory response, which widens the scope of the next round.

[1] European Central Bank (2022). Banks must sharpen their focus on climate risk, ECB supervisory stress test shows. Press release, 8 July 2022.

5.2 Supervisory climate stress tests

In a 2022 survey by the Financial Stability Board (FSB) and the NGFS, financial authorities reported 67 climate scenario analysis exercises, 35 of them completed[2]. The 2021 Climate Biennial Exploratory Scenario (CBES) of the Bank of England, the central bank of the United Kingdom (UK), explored the financial risks posed by climate change for the largest UK banks and insurers[3]. The pilot climate risk stress test of the Hong Kong Monetary Authority (HKMA), launched in January 2021, covered 20 major retail banks and 7 branches of international banking groups, 80 percent of the sector's lending, and the participating banks assessed their climate risk exposures under its scenarios[4]. The Monetary Authority of Singapore (MAS) conducted a climate scenario analysis for selected key banks and insurers as part of its 2022 Industry-Wide Stress Test[5]. The World Bank and the Bank of Thailand studied how floods affect the economy and banks with a flood scenario for Bangkok and neighbouring provinces, informed by past events like the 2011 floods[6]. Their analysis of bank-level data puts 41 percent of banks' corporate lending in districts with high riverine flood risk, with the Chao Phraya River among the most significant sources of that risk[6], and the Bank of Thailand requested banks to use the scenarios provided by the World Bank to evaluate their own climate risk assessment systems[6].



Each exercise is placed at the year its source states: Bank of England 2021 CBES, HKMA pilot launched January 2021, ECB 2022 climate risk stress test, MAS 2022 Industry-Wide Stress Test. Source: ECB Banking Supervision, press release, 8 July 2022: Banks must sharpen their focus on climate risk, ECB supervisory stress test shows.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson5-climate-stress-testing/

Figure 5.2: Supervisory climate stress tests by year: the Bank of England, the HKMA, the ECB and the MAS.

For a single bank the result reduces to one number, the post-stress capital adequacy ratio (CAR), judged against the Basel III floor: a minimum total capital ratio of 8.0 percent plus a capital conservation buffer of 2.5 percent, that is 10.5 percent[7]. A bank below 10.5 percent is inside the capital conservation buffer, and capital distribution constraints, on dividends and bonuses among others[8], apply to it until it rebuilds capital[9]. A bank that falls below the minimum itself is in breach. The ECB's 2022 climate risk stress test had no direct capital implications for the supervised banks[10], and the Bank of England stated that the CBES would not be used

[2]FSB and NGFS (2022). Climate Scenario Analysis by Jurisdictions: Initial findings and lessons. Financial Stability Board and Network for Greening the Financial System, 15 November 2022.
[3]Bank of England (2022). Results of the 2021 Climate Biennial Exploratory Scenario (CBES). 24 May 2022.
[4]Hong Kong Monetary Authority (2021). HKMA publishes the results of the pilot climate risk stress test. Press release, 30 December 2021.
[5]Monetary Authority of Singapore (2022). Financial Stability Review, November 2022. Special Feature 1.
[6]Dolk, M., Dunz, N., Lesage, F., Nie, O. and Pollitt, H. (2025). Assessing and managing natural disaster risks for the financial sector in Thailand. World Bank blog, All About Finance, 2 June 2025.
[7]BCBS (2011). Basel III: A global regulatory framework for more resilient banks and banking systems, revised June 2011. Basel Committee on Banking Supervision, Annex 1: Calibration of the capital framework.
[8]BCBS (2011). Basel III: A global regulatory framework for more resilient banks and banking systems, revised June 2011. Paragraph 132(a).
[9]BCBS (2011). Basel III: A global regulatory framework for more resilient banks and banking systems, revised June 2011. Paragraph 129.
[10]European Central Bank (2022). 2022 climate risk stress test. ECB Banking Supervision, July 2022.

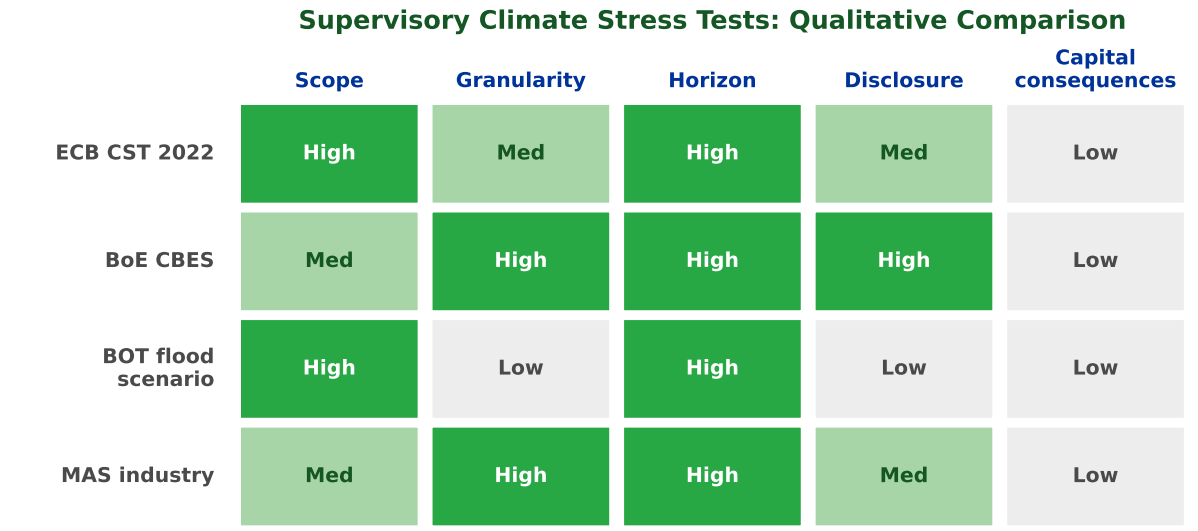


Figure 5.3: Four supervisory exercises rated High, Medium or Low on five design dimensions. The ratings are illustrative, and all four exercises rate Low on capital consequences.

to set capital requirements related to climate risk[11]. A bank can use a stress-test result in four ways: to size capital buffers, update sector limits, add a climate risk premium to loan rates and choose between divesting and engaging (Figure 5.4).

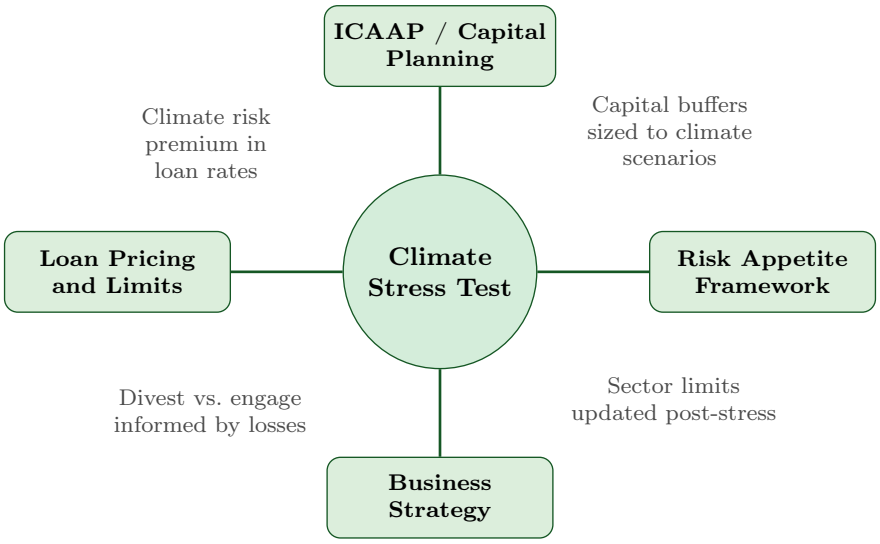
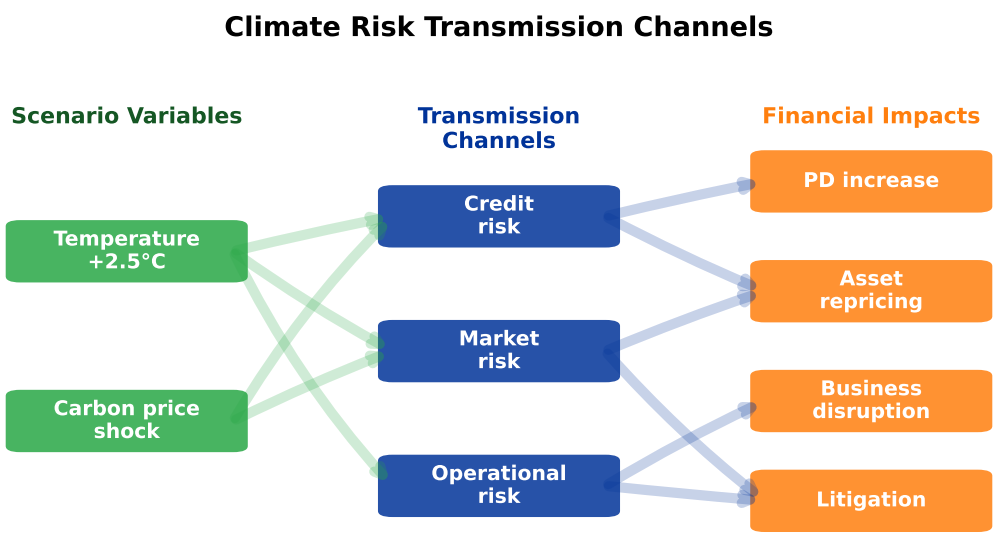


Figure 5.4: Four uses of a stress-test result: the internal capital adequacy assessment process (ICAAP) and capital planning, the risk appetite framework, loan pricing and limits, and business strategy.

5.3 Transmission, loss, and capital

Scenario variables enter the credit model as multipliers. A simple specification scales the baseline default rate, $PD_{climate} = PD_{base}\,(1 + \text{stress multiplier})$, so Thai agriculture with a 5.0 percent baseline and a flood-driven multiplier of 0.80 reaches 9.0 percent; loss given default adds a physical-damage uplift, $LGD_{climate} = LGD_{base} + \Delta_{physical}$, taking 45 percent to 65 percent. Expected loss is then $EL = PD \times LGD \times EAD$ summed across sectors. For a five-sector Thai bank with 500 billion Thai baht (THB) of exposure under Delayed

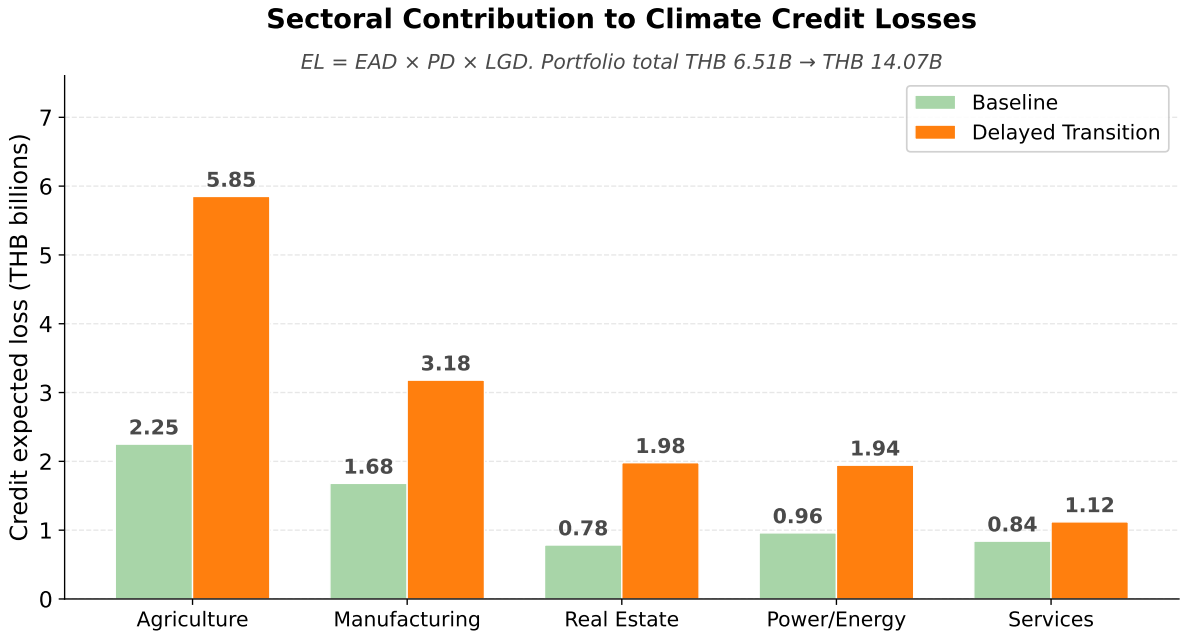
[11] Bank of England (2022). Results of the 2021 Climate Biennial Exploratory Scenario (CBES). 24 May 2022.



Concept schematic: arrows show connections, not magnitudes. Assumed teaching example, not measured data: Teaching scenario anchor, not a projection.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson5-climate-stress-testing/

Figure 5.5: How two scenario variables reach three risk channels and four financial impacts. The arrows all have one width, and the diagram gives no sizes.

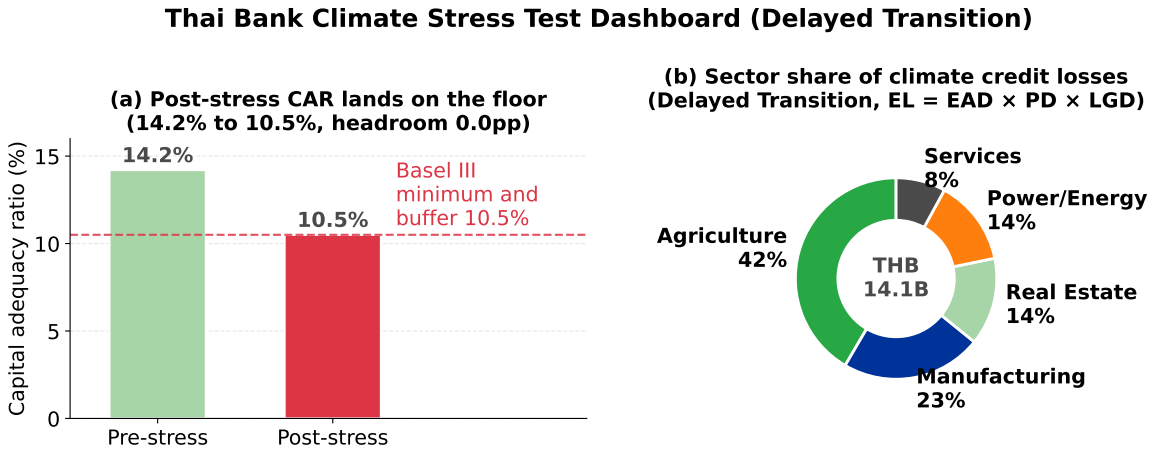
Transition, climate stress roughly doubles expected loss from about THB 6.5 billion to THB 14.1 billion, with agriculture contributing THB 3.6 billion of the THB 7.6 billion increase, 48 percent of it, and 42 percent of the stressed loss, from 20 percent of the exposure.



Assumed teaching example, not measured data: Illustrative bank, not a real institution.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson5-climate-stress-testing/

Figure 5.6: Credit expected loss by sector, baseline against Delayed Transition. The book's total rises from THB 6.5 billion to THB 14.1 billion; agriculture, a fifth of the book, rises from THB 2.25 billion to THB 5.85 billion, the largest share of the rise.

Battiston et al. (2017) take a network approach to trace how climate policy risk can propagate through the



Assumed teaching example, not measured data: Illustrative bank, not a real institution. Source: BCBS, Basel III: A global regulatory framework for more resilient banks and banking systems (rev. June 2011), para 64.

https://digital-ai-finance.github.io/Green-Finance/module4-lesson5-climate-stress-testing/

Figure 5.7: The illustrative Thai bank under Delayed Transition: its capital ratio falls from 14.2 to 10.5 percent, and agriculture holds 42 percent of the stressed credit loss, the largest sector share.

financial system[12]; in their model, second-round losses arise through interbank exposures and can be comparable in magnitude to first-round losses[13].

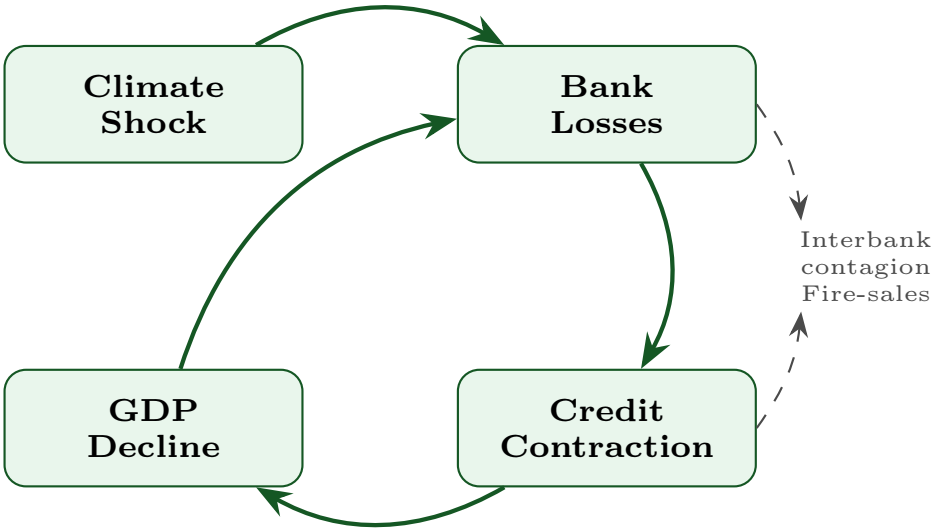


Figure 5.8: Second-round effects: climate losses cut bank capital, tighter capital cuts credit supply, the credit contraction lowers gross domestic product (GDP), and weaker borrowers raise bank losses again.

Post-stress capital adequacy is

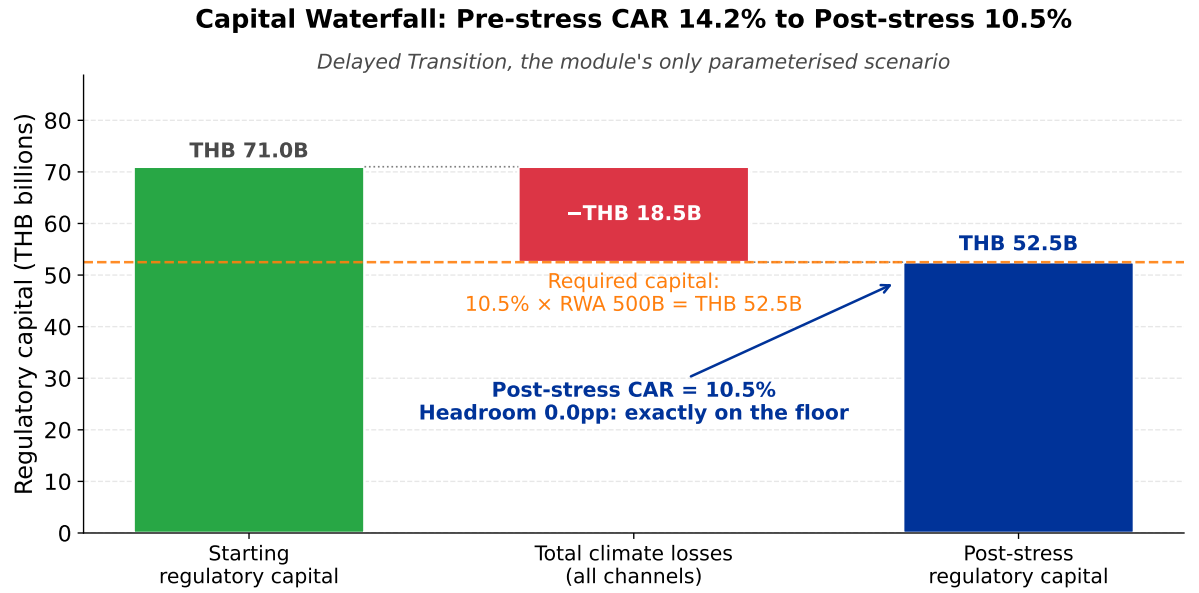
$$CAR_{post} = \frac{RegCapital - ClimateLosses}{RWA}.$$

Here *ClimateLosses* are the scenario's losses across all channels, an assumed THB 18.5 billion for the worked bank. The loan book's credit expected loss of THB 14.1 billion is one part of that total, and the remaining THB 4.4 billion is the assumed loss through the market and operational risk channels, taken as one sum. The formula

[12]Battiston, S., Mandel, A., Monasterolo, I., Schuetze, F., and Visentin, G. (2017). A climate stress-test of the financial system. Nature Climate Change, 7, 283 to 288.

[13]Battiston, S., Mandel, A., Monasterolo, I., Schuetze, F., and Visentin, G. (2017). A climate stress-test of the financial system. Nature Climate Change, 7, 283 to 288. Published article as hosted by the Stanford Energy Modeling Forum; the nature.com page is paywalled.

holds risk-weighted assets fixed; a full test also raises the risk weights of the borrowers the scenario downgrades, and the ratio falls further. A bank with THB 71 billion of capital and THB 500 billion of risk-weighted assets has a pre-stress CAR of 14.2 percent. The Basel III floor requires 10.5 percent of THB 500 billion, THB 52.5 billion, so the bank absorbs THB 18.5 billion of climate losses before it reaches the floor. The Bank of Thailand sets a minimum of 8.5 percent and the same 2.5 percent buffer, 11 percent in all, which requires THB 55 billion of capital and leaves THB 16 billion of headroom. After the loss of THB 18.5 billion the bank stands at 10.5 percent, 0.5 percentage points below the Bank of Thailand's 11 percent and above its 8.5 percent minimum, inside the Bank of Thailand's 2.5 percent buffer.



Assumed teaching example, not measured data: Illustrative bank, not a real institution. Source: BCBS, Basel III: A global regulatory framework for more resilient banks and banking systems (rev. June 2011), para 64.

https://digital-ai-finance.github.io/Green-Finance/module4-lesson5-climate-stress-testing/

Figure 5.9: Capital falls from THB 71 billion to THB 52.5 billion, the capital the Basel III floor of 10.5 percent requires; the Bank of Thailand's 11 percent requires THB 55 billion.

5.4 Top-down, bottom-up, static and dynamic designs

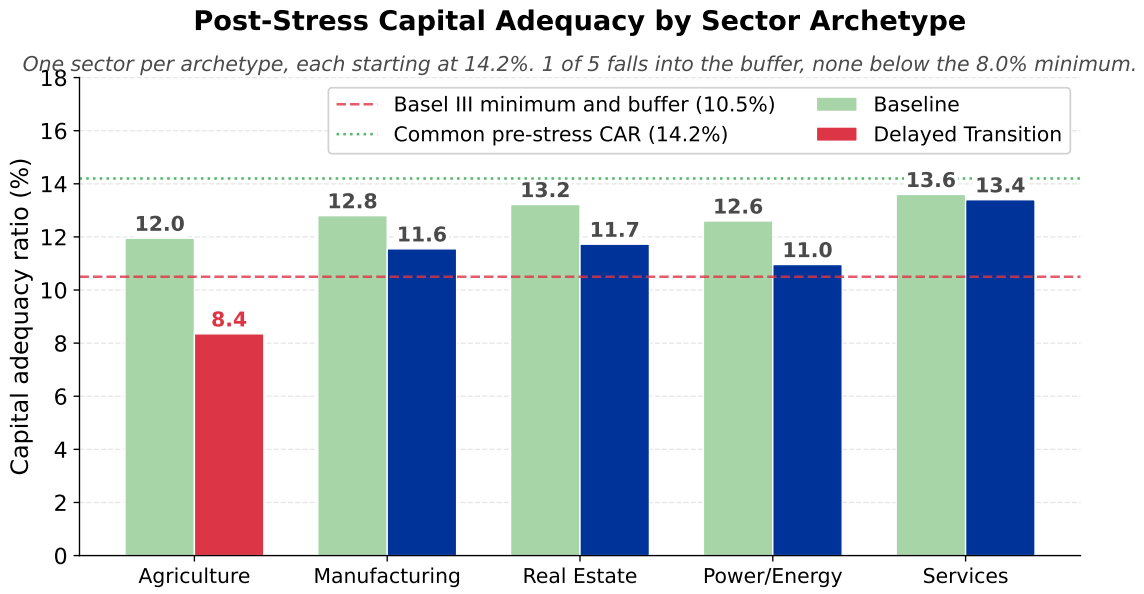
Three modelling choices change results. Around half of the climate scenario exercises the FSB and the NGFS surveyed in 2022 were *top-down*, run by the authority, an approach that increases the consistency and comparability of the results[14]. *Bottom-up* exercises, in which the institutions submit their own projections, were often used to understand how individual institutions would respond to the scenarios[14], and some exercises adopted a hybrid approach that combines the two[14]. Approximately 80 percent of the surveyed exercises adopted a *static balance sheet*[14]. In the worked bank, a *dynamic* balance sheet that lets the bank rebalance cuts losses by an assumed 15 to 30 percent. Finally, authorities surveyed by the FSB judge their measures of exposure likely understated, in many cases because the metrics do not capture *second-round effects* or climate non-linearities[14]. The ECB's 2022 exercise had three modules, and in the third, a bottom-up stress test, the 41 banks that provided projections put combined credit and market risk losses at around 70 billion euros[15]. The ECB wrote in the same report that "for a number of reasons this estimate significantly understates the actual risk"[15].

5.5 The ASEAN capacity-building agenda

Supervisors in the Association of Southeast Asian Nations (ASEAN) share five gaps in stress-testing practice. Data infrastructure is thin, and borrower-level emissions registries linked to loan books are missing. Methodology is unharmonised: different proxies give different PD shocks for the same portfolio, and an ASEAN-wide protocol would align them. Physical-risk models, such as platforms built on a geographic information system (GIS), are

[14]FSB and NGFS (2022). Climate Scenario Analysis by Jurisdictions: Initial findings and lessons. Financial Stability Board and Network for Greening the Financial System, 15 November 2022.

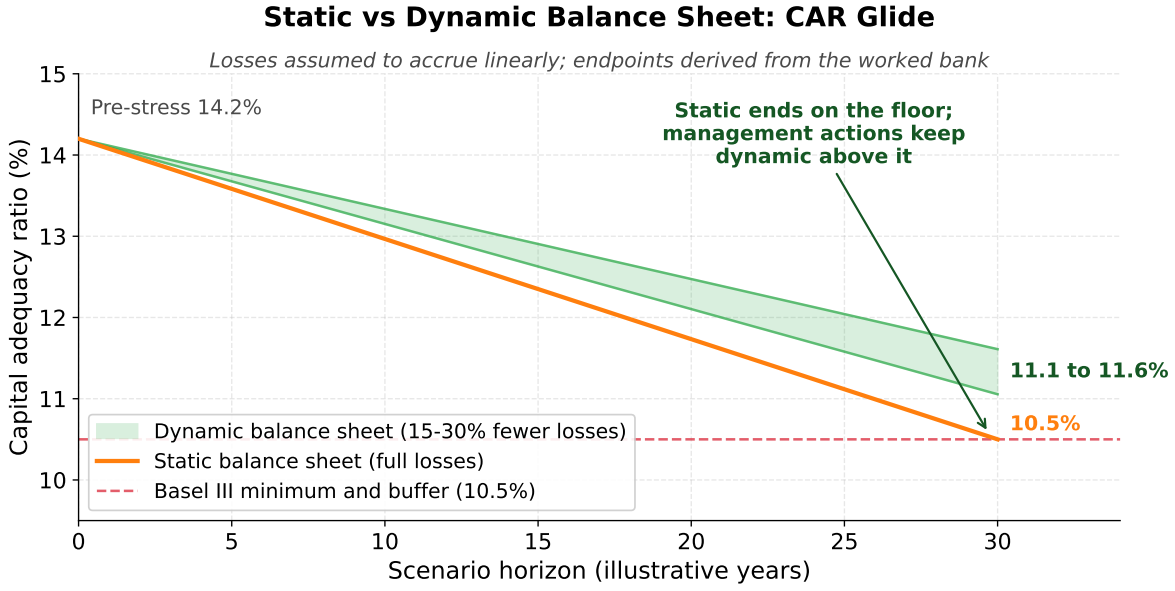
[15]European Central Bank (2022). 2022 climate risk stress test. ECB Banking Supervision, July 2022.



Assumed teaching example, not measured data: Illustrative bank, not a real institution. Source: BCBS, Basel III: A global regulatory framework for more resilient banks and banking systems (rev. June 2011), para 64.

https://digital-ai-finance.github.io/Green-Finance/module4-lesson5-climate-stress-testing/

Figure 5.10: Capital ratio of five single-sector archetypes of the worked Thai bank, each starting at 14.2 percent, at baseline and under Delayed Transition. The agriculture archetype falls below 10.5 percent, into the buffer, and stays above the 8.0 percent minimum. The archetypes hold no provisions, so all expected loss falls on capital.



Assumed teaching example, not measured data: Illustrative management actions, not a modelled or supervisory result; Illustrative bank, not a real institution. Source: BCBS, Basel III: A global regulatory framework for more resilient banks and banking systems (rev. June 2011), para 64.

https://digital-ai-finance.github.io/Green-Finance/module4-lesson5-climate-stress-testing/

Figure 5.11: The worked bank under a static balance sheet ends at 10.5 percent; with 15 to 30 percent fewer losses, a dynamic balance sheet ends between 11.1 and 11.6 percent.

outside bank systems. Balance sheets are static, and dynamic modules can be phased in. Second-round effects are omitted, and agent-based network models can add them.

Chapter 6

ASEAN Climate Vulnerability

About 20 tropical cyclones a year occur in the Philippine region, and 8 or 9 of them cross the country[1].

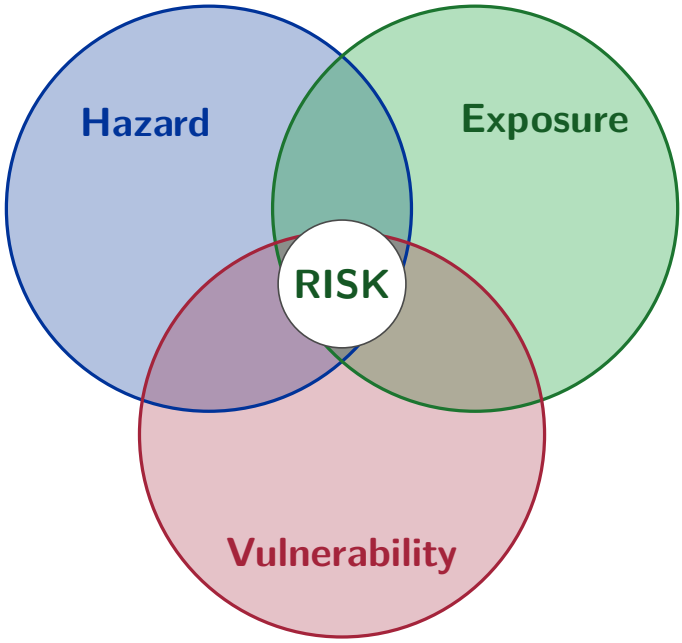


Figure 6.1: Risk results from the interaction of hazard, exposure and vulnerability. A typhoon over open ocean is a hazard and a risk to no bank, and a bank chooses its exposure through where it lends. Adaptation finance buys down vulnerability.

In the three decades before 2020, disasters in Southeast Asia affected more than 400 million people and caused losses of more than $136 billion[2]. The region faces rising seas, intensifying typhoons, prolonged droughts and coral bleaching at the same time. In 2023 the ten member states of the Association of Southeast Asian Nations (ASEAN) had 676.6 million people[3], and the Network of Central Banks and Supervisors for Greening the Financial System (NGFS) counts Asia among the regions most vulnerable to physical risks[4]. In the definition of the Intergovernmental Panel on Climate Change (IPCC), risk results from dynamic interactions between climate-related hazards and the exposure and vulnerability of the affected human or ecological system[5]. The risk identity multiplies the three terms,

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability},$$

[1] PAGASA. Tropical Cyclone Information. Philippine Atmospheric, Geophysical and Astronomical Services Administration, DOST.

[2] World Bank (2026). Southeast Asia Disaster Risk Insurance Facility (SEADRIF): Strengthening Financial Resilience in Southeast Asia (P170913). Implementation Completion and Results Report ICR00681, corrigendum of 30 January 2026.

[3] ASEAN Secretariat (2024). ASEAN Key Figures 2024, Vol. 7, December 2024.

[4] NGFS (2025). NGFS Scenarios: narratives and key findings, November 2025, on results version 5.0 of November 2024 (Phase V). Section 4, Fragmented World, GDP impact across jurisdictions.

[5] IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Working Group II contribution to the Sixth Assessment Report, Annex II: Glossary, entry Risk, page 2921.

so risk is zero when any one term is zero, and ASEAN scores high on all three terms.

6.1 Hazard, exposure and vulnerability in ASEAN

The three terms of the risk identity reinforce each other in Southeast Asia, where all three are high at once. The *hazard* is tropical: typhoons, monsoon flooding, sea-level rise, and coral bleaching arrive together. The *exposure* is large: long coastlines and much of the population living in coastal and delta zones. The *vulnerability* is high: most ASEAN countries have paid for disaster response from government budgets and donor aid after the event, and the larger economies have limited catastrophe insurance penetration[6], so a shock that a wealthier and better-insured economy absorbs is one this region borrows against.

6.2 Three country profiles

Table 6.1 compares the three countries on five dimensions, including their standing in the index of the Notre Dame Global Adaptation Initiative (ND-GAIN). **Vietnam** faces compound physical risk: two forecasting models in the World Bank's 2022 country report put its economic losses from climate change at 12 to 14.5 percent of gross domestic product (GDP) a year by 2050[7]. Almost half of the Mekong Delta would be inundated by a sea-level rise of 75 to 100 centimetres above the 1980 to 1999 average, which would raise salinity and end the production of some crops[7]. Agribank's agricultural and rural loans make up over 70 percent of its total loans, by its own account[8]. Circular No. 17/2022/TT-NHNN of the State Bank of Vietnam (SBV), on environmental risk management in credit extension, took effect on 1 June 2023[9]. **Thailand** spans urban subsidence and flood (the 2011 floods caused about $46.5 billion in damage and losses[10]) and drought. The Bank for Agriculture and Agricultural Cooperatives (BAAC) holds an excess loan-loss allowance against farm borrowers whose repayment is uncertain because of drought, falling farm prices and economic slowdown[11]. The World Bank and the Bank of Thailand built a flood scenario for Bangkok and neighbouring provinces, informed by the 2011 floods[12], and the Bank of Thailand requested banks to use the scenarios provided by the World Bank to evaluate their own climate risk assessment systems[12]. **The Philippines** lies in a region with an average of about 20 tropical cyclones a year, 8 or 9 of which cross the country[13]. Its central bank, the Bangko Sentral ng Pilipinas (BSP), issued the Sustainable Finance Framework as Circular No. 1085 on 29 April 2020[14], and the framework asks banks to convey their sustainability objectives and policies to investors, clients and other stakeholders through disclosures in the Annual Report[14].

Table 6.1: Three ASEAN countries compared on five dimensions, ranked without scores.

Dimension	Vietnam	Thailand	Philippines
Primary hazard	Sea-level rise, delta flooding	Subsidence-flood, drought	Typhoons, recurrent
Annual losses	Moderate and rising	Episodic but severe	Highest of the three
Insurance penetration	Thin	Deepest of the three	Thin
ND-GAIN standing	Vulnerable, low readiness	Least vulnerable, highest readiness	Vulnerable, low readiness
Regulatory stage	SBV circular 2023	Bank of Thailand and World Bank flood scenario	BSP framework 2020

The ND-GAIN index separates *vulnerability* (exposure, sensitivity, and adaptive capacity across life-

[6]World Bank (2026). Southeast Asia Disaster Risk Insurance Facility (SEADRIF): Strengthening Financial Resilience in Southeast Asia (P170913). Implementation Completion and Results Report ICR00681, corrigendum of 30 January 2026.

[7]World Bank Group (2022). Vietnam Country Climate and Development Report, July 2022.

[8]Agribank (Vietnam Bank for Agriculture and Rural Development). About Agribank, corporate page, figures as of 30 September 2019.

[9]State Bank of Vietnam (2022). Circular No. 17/2022/TT-NHNN of 23 December 2022 guiding environmental risk management in credit extension by credit institutions and foreign bank branches. English translation: LuatVietnam.

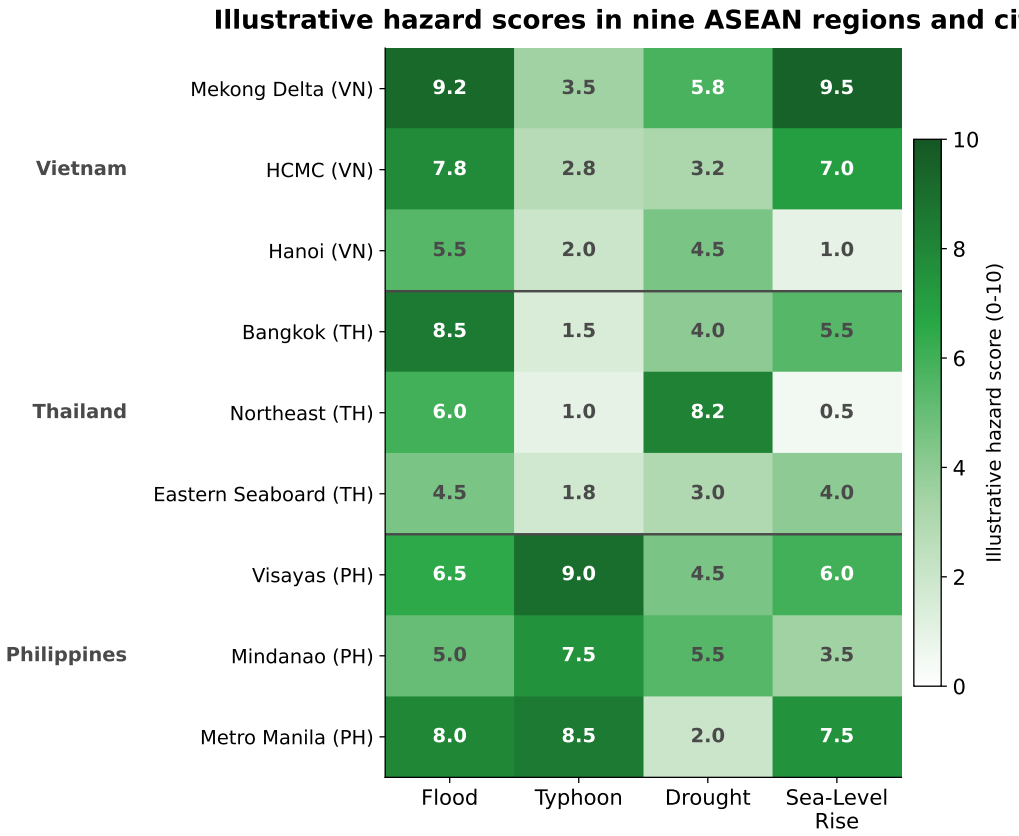
[10]World Bank (2012). Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning.

[11]Bank for Agriculture and Agricultural Cooperatives (2025). Annual Report 2024 (fiscal year to 31 March 2025).

[12]Dolk, M., Dunz, N., Lesage, F., Nie, O. and Pollitt, H. (2025). Assessing and managing natural disaster risks for the financial sector in Thailand. World Bank blog, All About Finance, 2 June 2025.

[13]PAGASA. Tropical Cyclone Information. Philippine Atmospheric, Geophysical and Astronomical Services Administration, DOST.

[14]Diokno, B. E. (2020). Integrating sustainability in corporate strategy: BSP sustainable finance framework. Speech by the Governor of the Bangko Sentral ng Pilipinas, 28 October 2020. BIS Central bankers' speeches, 10 December 2020.



Assumed teaching example, not measured data: Scores the module chose; no hazard model produced them.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson6-asean-climate-vulnerability/

Figure 6.2: Illustrative hazard scores for flood, typhoon, drought and sea-level rise in nine regions and cities of Vietnam, Thailand and the Philippines. A national score averages regions that face different hazards.

supporting sectors) from *readiness* (economic, governance, and social capacity to act)[15]. ND-GAIN's vulnerability score includes exposure, so it spans two terms of the risk identity. In the identity, vulnerability is the propensity or predisposition to be adversely affected, including sensitivity to harm and lack of capacity to cope and adapt[16]. Vietnam and the Philippines both score as vulnerable with low readiness. Thailand is the least vulnerable of the three and leads on governance and economic readiness. The distance between a country's vulnerability and its readiness sets its adaptation priorities.

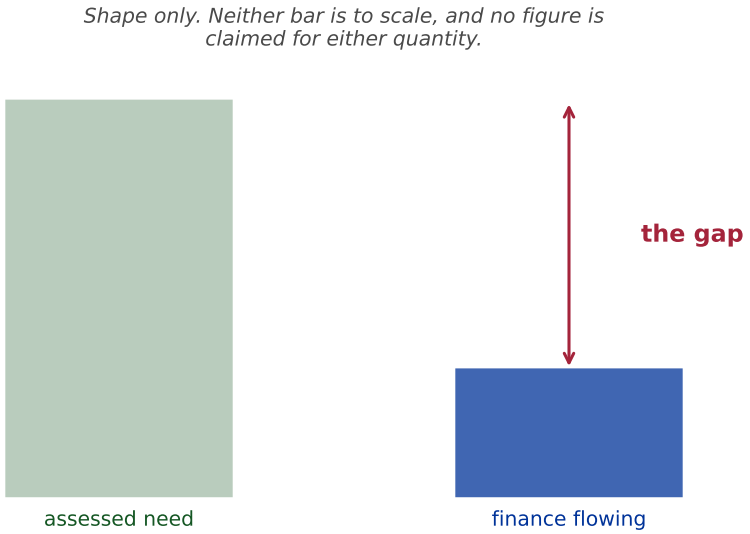
6.3 The adaptation finance gap

Mitigation alone cannot protect ASEAN, because substantial warming and sea-level rise are already locked in, so adaptation is necessary whatever the mitigation path. Global climate finance averaged almost $1.3 trillion a year in 2021/2022[17], of which adaptation drew $63 billion, about 5 percent of the total, against estimated needs of $212 billion a year by 2030 for developing countries alone[17].

Published estimates of the ASEAN adaptation gap differ by close to an order of magnitude, depending on whether they cover Asia or Southeast Asia, adaptation alone or climate finance combined, an annual gap or a total need, and which baseline year is used. One widely repeated pairing of need against mobilised finance quotes an Asia-wide need estimate as an ASEAN one. A regional gap figure is usable only with its scope, its source and its year.

The instruments to close the gap fall into market-based tools (catastrophe bonds with parametric or indemnity triggers, resilience bonds and parametric insurance) and public or multilateral capital (the Green Climate Fund, whose Board is to balance the allocation of resources between adaptation and mitigation activities[18], and the Adaptation Fund). In November 2019 the World Bank issued two tranches of catastrophe bonds that

[15] University of Notre Dame Global Adaptation Initiative. ND-GAIN Country Index: Methodology.
[16] IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Working Group II contribution to the Sixth Assessment Report, Annex II: Glossary, page 2927.
[17] Climate Policy Initiative (2023). Global Landscape of Climate Finance 2023. Press release, November 2023.
[18] Green Climate Fund. Governing Instrument for the Green Climate Fund, paragraph 50.



Assumed teaching example, not measured data: Shape only: neither bar is to scale and no quantity is claimed for either.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson6-asean-climate-vulnerability/

Figure 6.3: The relationship the cited figures describe, drawn without asserting its size. The gap's direction is documented; its size would need a need and a flow measured at one scope by one source.

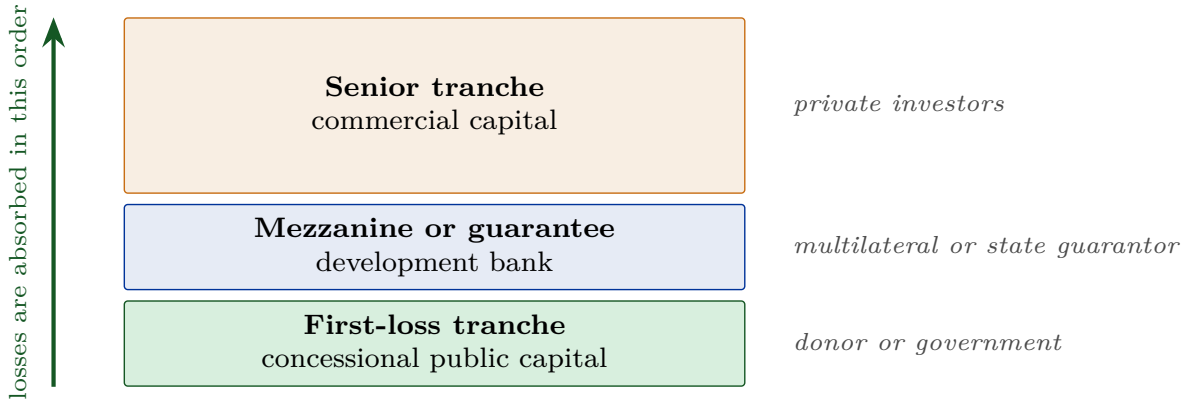


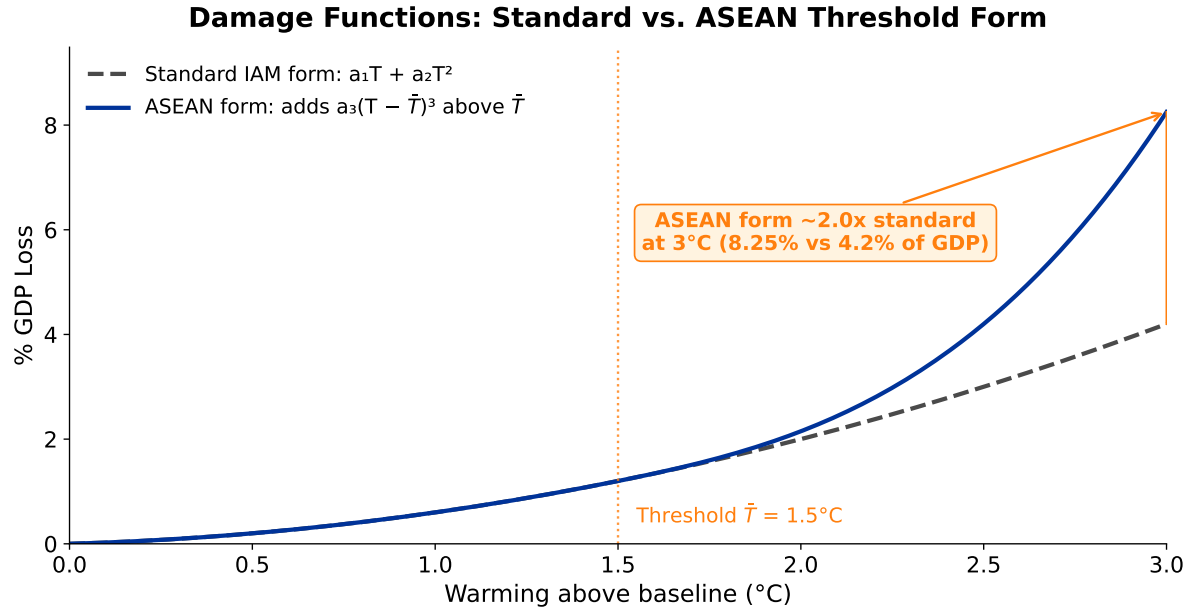
Figure 6.4: The blended-finance stack, drawn as an order of loss. Tranche sizes vary by deal; first-loss capital absorbs losses before the mezzanine layer, and the mezzanine layer before the senior tranche.

insured the Philippines against earthquakes and tropical cyclones for three years, for up to $225 million[19]. The Southeast Asia Disaster Risk Insurance Facility (SEADRIF), established in 2018 and launched in 2020, offers ASEAN countries market-based risk transfer products[20]. Parametric instruments pay on a measured trigger such as wind speed, so the money arrives in days. Blended finance links the two families. It places a thin layer of concessional first-loss capital below a guarantee or mezzanine layer and a majority senior commercial tranche, so public money absorbs the first losses and private capital prices the rest. Blended finance is judged by the private capital each public dollar mobilises. National pledges depend on international finance: the Philippines' first nationally determined contribution (NDC), of April 2021, commits to a 75 percent reduction and avoidance of projected emissions for 2020 to 2030, of which 2.71 percent is unconditional[21], and Vietnam's 2022 update targets 15.8 percent below business as usual when domestically supported and 43.5 percent when internation-

[19] World Bank Treasury (2022). Case study: The Philippines: Transferring the Cost of Severe Natural Disasters to Capital Markets.
[20] World Bank (2026). Southeast Asia Disaster Risk Insurance Facility (SEADRIF): Strengthening Financial Resilience in Southeast Asia (P170913). Implementation Completion and Results Report ICR00681, corrigendum of 30 January 2026.
[21] UNDP Climate Promise. Philippines: key highlights from the NDC (first NDC, April 2021).

ally supported[22]. The just-transition principle requires that adaptation reach coastal communities, smallholder farmers and informal workers as well as large corporates.

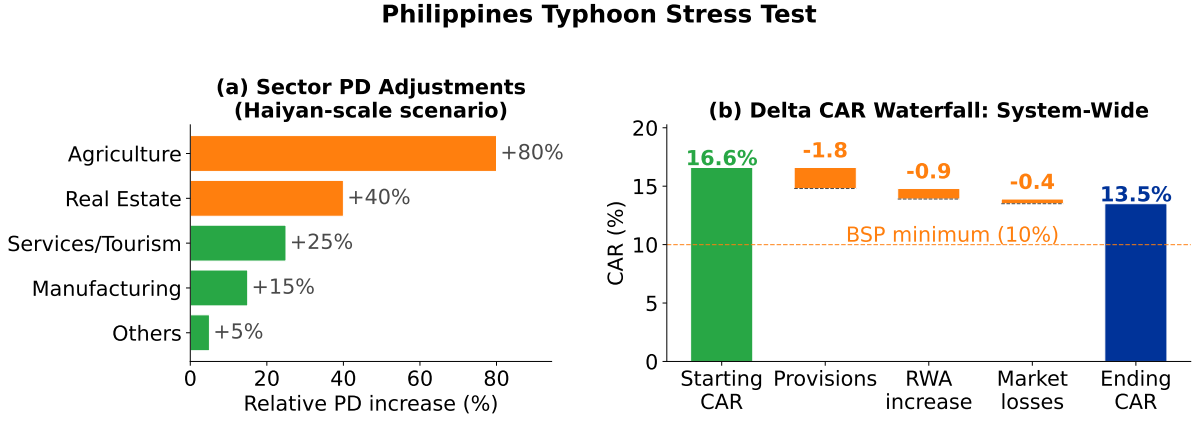
An illustrative ASEAN damage function adds a cubic term to the standard quadratic form above a threshold temperature, so its loss in percent of GDP grows faster beyond that point (Figure 6.5).



Assumed teaching example, not measured data: Illustrative damage function, not a calibration: the deck states these parameters are unestimated.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson6-asean-climate-vulnerability/

Figure 6.5: A standard quadratic damage function against one with an illustrative ASEAN threshold term at 1.5 °C. At 3.0 °C of warming the standard form gives 4.2 percent of GDP and the threshold form 8.25 percent.

An illustrative typhoon raises each sector's default probability by an assumed share, most for agriculture; provisions, higher risk-weighted assets and market losses lower the Philippine system's capital ratio (Figure 6.6).



Assumed teaching example, not measured data: Illustrative stress scenario, not a BSP exercise.
Source: Bangko Sentral ng Pilipinas, Report on Recent Trends in the Philippine Financial System, Issue No. 2024-03.
https://digital-ai-finance.github.io/Green-Finance/module4-lesson6-asean-climate-vulnerability/

Figure 6.6: The Philippine system's capital ratio falls from 16.6 to 13.5 percent, 3.5 percentage points above the BSP minimum of 10 percent and 1 percentage point above 12.5 percent with the buffer.

[22]UNDP Climate Promise. Viet Nam: key highlights from the NDC (updated NDC, November 2022).

6.4 Three regional gaps

Chapter 5 named the gaps in stress-testing practice; three more are regional: finance, capacity and coordination. Adaptation finance falls short of need (**finance**). Climate stress tests and adaptation programmes need specialist staff in supervisors and banks (**capacity**). No ASEAN-wide stress-test protocol exists despite cross-border transmission (**coordination**). Module 5 covers reporting climate risk through IFRS S1 and IFRS S2, two International Financial Reporting Standards (IFRS) of the International Sustainability Standards Board (ISSB); the European Union (EU) Corporate Sustainability Reporting Directive (CSRD); and the EU Sustainable Finance Disclosure Regulation (SFDR).