# Scenario Analysis and Climate Modeling: NGFS Pathways to IAMs

## Module 4: Green Finance Risk Management, Lesson 3

GREEN FINANCE Consortium

Erasmus+ CBHE Project 101237817

2026

# Lesson 4.3

## Scenario Analysis and Climate Modeling

### NGFS Pathways to Integrated Assessment Models

Module 4: Green Finance Risk Management

GREEN FINANCE micro-credential

Erasmus+ CBHE 101237817

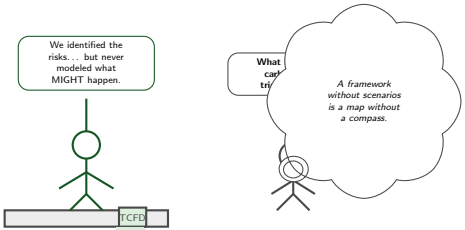
# Why Did the Board Reject the Risk Report?

## [FOUNDATION]

**Situation:** A risk manager presents the climate risk taxonomy (L4.1) and TCFD framework (L4.2) to the board. The board asks: "What happens to our portfolio if carbon prices triple by 2035?"

**Complication:** The risk manager replies: "We identified the risks and have a disclosure framework... but we never modeled the scenarios."

- Risk taxonomy tells you **WHAT** risks exist
- TCFD tells you **HOW** to disclose
- Scenario analysis tells you **WHAT IF**: under different futures




**Risk taxonomy tells you WHAT. TCFD tells you HOW. Scenario analysis tells you WHAT IF.**

**Scenarios are NOT predictions. They are structured explorations of plausible futures under deep uncertainty.**

# From Frameworks to Modeled Scenarios

## [FOUNDATION]

**Frameworks Established (Lesson 4.2)**

- TCFD four pillars **understood**: governance, strategy, risk management, metrics
- TNFD nature-related risks **mapped** via LEAP approach
- Disclosure requirements **documented**
- But the bank has not yet **modeled a single scenario**

*"We know what to disclose. But what futures should we test against?"*

**Now Model the Future (Lesson 4.3)**

- Select **NGFS scenarios** appropriate for ASEAN portfolios
- Trace the **transmission chain** from climate pathway to portfolio losses
- Calibrate **sectoral PD/LGD shocks** from scenario variables
- Generate **Monte Carlo fan charts** quantifying uncertainty

### Key Insight

L4.2 told you **WHAT TO DISCLOSE**. L4.3 gives you **THE SCENARIOS TO DISCLOSE AGAINST**.

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**The TCFD Strategy pillar asks firms to "describe the resilience of the organization's strategy, taking into consideration different climate-related scenarios". Lesson 4.3 provides the scenarios.**

# Road Map: From Climate Scenarios to Financial Impact

| Section | Slides | Central Question |
|---|---|---|
| **Introduction** | 1 to 4 | Why can't frameworks alone quantify future risk? |
| **Foundation** | 5 to 12 | What are NGFS scenarios and how do they transmit to portfolios? |
| **Intermediate** | 13 to 19 | How do you calibrate sectoral shocks and model uncertainty? |
| **PhD Extension** | 20 to 26 | What are IAMs and why do damage functions matter? |
| **Case Study** | 27 to 29 | What does the Philippines reveal about ASEAN vulnerability? |
| **Summary** | 30 to 31 | What should you remember? |

The lesson follows a **problem-first** arc: we open with a board that demands scenario analysis, build the NGFS toolkit, deepen to IAM mechanics at PhD level, and resolve with the Philippines typhoon case, where the cubic wind-damage relationship provides a counterintuitive punchline about physical risk amplification.

**Lesson 4.3 of 6 in Module 4. Foundation level with Intermediate and PhD extensions.**

# Scenarios under deep uncertainty

**[FOUNDATION]**

**Three Reasons Predictions Fail**

- **Non-linear dynamics:** Climate systems involve tipping points, feedback loops, and cascading failures that defy linear extrapolation
- **Policy dependence:** Outcomes depend on carbon pricing, phase-out timelines, and regulatory choices **not yet made**
- **Deep uncertainty:** We cannot assign meaningful probabilities to 30-year climate-economy outcomes

*Deep uncertainty* $\neq$ risk. Risk has known probabilities. Deep uncertainty means the probability distribution itself is unknown.

**What Scenarios Provide**

- Structured exploration of **plausible futures**
- Stress testing of portfolios against **multiple pathways**
- Identification of **vulnerabilities** that persist across scenarios
- Decision-making under uncertainty: **robust strategies** that work across scenarios

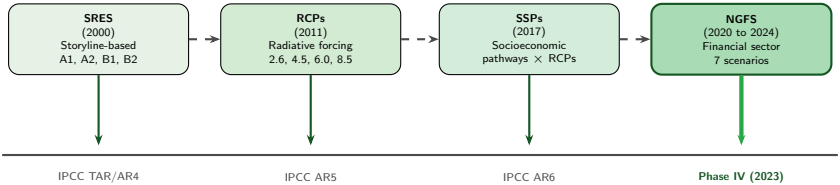
**Key Principle**

Scenarios are not predictions. They are "what if" stories with internally consistent assumptions about climate, policy, and technology.

**In the Philippines, about 20 tropical cyclones form in the region each year and 8 or 9 cross the country. No single prediction captures the range of intensification trajectories; scenarios explore all of them.**

# How Did Climate Scenarios Evolve?

**[FOUNDATION]**




*Each generation builds on its predecessor. NGFS adapts climate science for financial supervision.*

**Key evolution:** From purely scientific scenarios (SRES/RCPs) to socioeconomic integration (SSPs) to financial-sector operationalization (NGFS). The NGFS framework was designed specifically so that banks and supervisors can stress-test portfolios.

**Source: van Vuuren et al. (2011); Riahi et al. (2017); NGFS (2024) Phase IV.**

# What Is the NGFS?

## [FOUNDATION]

**Network for Greening the Financial System**

- Coalition of **130+ central banks and supervisors**
- Founded 2017 at the Paris One Planet Summit
- Purpose: develop **climate scenarios for financial supervision**
- Free, open-access scenario database

**ASEAN members include:** Bangko Sentral ng Pilipinas (BSP), Bank of Thailand (BOT), State Bank of Vietnam (SBV), Bank Negara Malaysia (BNM).

### Why NGFS Matters

NGFS scenarios are the **de facto standard** for climate stress testing globally. ECB, BoE, MAS, and BSP all mandate NGFS-based exercises.

**What NGFS Provides**

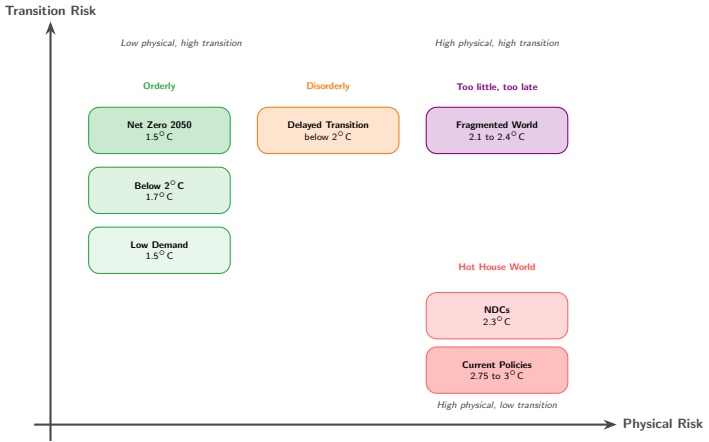
- **7 reference scenarios** in four categories: Orderly, Disorderly, Hot House World, and Too little too late
- **Macro-financial variables:** GDP, carbon price, temperature, energy mix
- **Sectoral detail:** 40+ economic sectors
- **Regional granularity:** including Southeast Asia
- **Multiple IAM backends:** REMIND-MAgPIE, GCAM, MESSAGEix-GLOBIOM

Phase IV (2023) enhanced acute physical risk modeling (droughts, heatwaves) with finer geographic granularity. Phase IV also retired Divergent Net Zero and added Fragmented World and Low Demand.

**Source: NGFS Scenarios, results version 5.0, released November 2024 (Phase V).**

# The NGFS Seven Scenarios: Transition Risk vs Physical Risk

**[FOUNDATION]**




**Key tradeoff:** Orderly scenarios accept high transition costs to limit physical damage. Hot House World avoids transition costs but faces catastrophic physical risk. Disorderly scenarios get the worst of both in the short term. Too little, too late is the fourth category: delayed and regionally divergent action, so high physical *and* high transition risk together.

**Source: NGFS Scenarios, results version 5.0, November 2024. Seven scenarios in four categories.**

# NGFS Scenarios: Key Variables Compared

**[FOUNDATION]**

| Scenario | Category | Temp (2100) | ASEAN Risk |
|---|---|---|---|
| Net Zero 2050 | Orderly | 1.5°C | Transition |
| Below 2°C | Orderly | 1.7°C | Moderate |
| Low Demand | Orderly | 1.5°C | Transition |
| Delayed Transition | Disorderly | below 2°C | Carbon shock |
| Fragmented World | Too little, too late | 2.1 to 2.4°C | **Physical + transition** |
| NDCs | Hot House World | 2.3°C | **Physical** |
| Current Policies | Hot House World | 2.75 to 3°C | **Catastrophic** |

- **Delayed Transition** features a sudden carbon price jump around 2030: most financially disruptive scenario
- **For ASEAN:** Hot House World is worst on physical damage; **Fragmented World** is the case that is high on both, and it is the more plausible adverse path
- **Carbon prices and GDP impacts are deliberately absent.** They are model outputs, not scenario definitions: Net Zero 2050 alone spans 500 to 1,250 US$2010 per tonne in 2050 across models. Quote a range and its model, or pull the pathway live from the NGFS Scenario Explorer

**Source: NGFS Scenarios results version 5.0, November 2024. All values are from that release.**

# The Fundamental Tradeoff: Transition vs Physical Risk

**[FOUNDATION]**

**The Core Insight**

- **Orderly transition:** High transition costs NOW, low physical damages LATER
- **Hot House World:** Low transition costs NOW, catastrophic physical damages LATER
- **Disorderly:** Worst of both, delayed action then sudden transition
- There is **no zero-cost scenario**

**The "Green Swan" concept:** Bolton et al. (2020) introduced this term for climate-related tail risks that are highly likely to materialize but whose timing, form, and magnitude are deeply uncertain: unlike Black Swans, Green Swans are **expected** but still unpreparable in their specifics.

**Why ASEAN Is Different**

| | Developed Markets | ASEAN Markets |
|---|---|---|
| Worst scenario | Disorderly | Hot House World |
| Primary risk | Transition | Physical |
| Key exposure | Fossil assets | Agriculture, coast |
| Time horizon | Medium-term | Near & long-term |
| Insurance | High penetration | $\sim$5% |

**ASEAN Insight**

For ASEAN portfolios, Hot House World typically produces 2 to 3$\times$ larger losses than Disorderly: the **inverse** of developed markets.

**Source: Bolton, P. et al. (2020). The Green Swan. BIS/Banque de France. Physical risk dominates for tropical emerging markets.**

# IEA Energy Scenarios: NZE, APS, and STEPS

**[FOUNDATION]**

### Three IEA Scenarios

- **Net Zero Emissions (NZE):** All pledges met plus additional action to reach net zero by 2050. Fossil fuels drop to ∼20% of primary energy.
- **Announced Pledges (APS):** Only existing government commitments honored. Fossil share ∼45%.
- **Stated Policies (STEPS):** Only policies currently in force. Fossil share remains ∼60%.

The difference between NZE and STEPS is $130+ trillion in cumulative energy investment (IEA, 2024).

### How IEA Complements NGFS

| | NGFS | IEA |
|---|---|---|
| Scope | Macro-financial | Energy sector |
| Variables | GDP, carbon price | Fuel mix, tech, capex |
| Users | Central banks | Energy companies |
| Granularity | 40+ sectors | Fuel-by-fuel detail |

Together they give both the "big picture" (NGFS: GDP, carbon price, temperature) and the "sector detail" (IEA: which fuels, which technologies, how much investment).

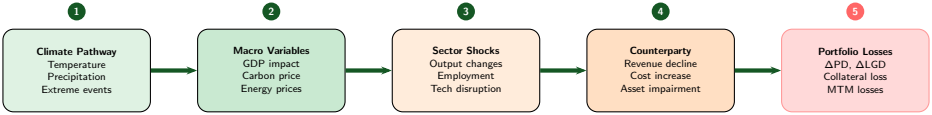
**Best Practice**

Use NGFS for portfolio-level stress testing; use IEA for energy-sector deep dives. Map NGFS Orderly ↔ IEA NZE, NGFS Hot House ↔ IEA STEPS.

**Source: IEA (2024). World Energy Outlook 2024. NGFS and IEA scenarios are complementary, not competing.**

# The Scenario-to-Financial-Impact Transmission Chain

**[FOUNDATION]**




**ASEAN Example, Philippine Agriculture Under Hot House World:**
$+2.5^{\circ}$C by 2050 $\rightarrow$ GDP deviation $-8\%$ $\rightarrow$ Rice yield decline 15% $\rightarrow$ Agricultural revenue drops $\rightarrow$ NPL rate rises from 8% to $\sim$16%.

- Every climate scenario analysis follows this five-stage chain
- Each stage introduces additional model uncertainty: propagation from stage 1 to 5 can amplify errors
- The chain is what connects an abstract temperature number to a concrete portfolio loss number

**The transmission chain is the core analytical structure of scenario-based climate risk assessment. Master it and you can apply any scenario.**

# Six Variables You Need for Any Climate Scenario Analysis

**[FOUNDATION]**

| Variable | Financial Channel | Example Impact | Data Source |
|---|---|---|---|
| Carbon price | Cost of emissions → margin compression | \$250/t$CO_2$ by 2050 (NZE) | NGFS Explorer |
| GDP growth | Aggregate demand → credit quality | Philippines: −8% under Hot House | NGFS Explorer |
| Temperature pathway | Physical damage frequency/severity | Typhoon intensity +25% | IPCC AR6 |
| Energy mix | Stranded assets vs green investment | Fossil share: 60% → 20% | IEA WEO |
| Technology cost | Competitive advantage shifts | Solar 90% cheaper since 2010 | IRENA |
| Policy stringency | Regulatory compliance costs | Carbon border adjustments | NGFS/national |

- These six variables form the **minimum inputs** for any credible scenario exercise
- NGFS Scenario Explorer provides all except technology cost (use IEA/IRENA)
- For ASEAN, **temperature pathway** and **GDP growth** are the two most important: they drive physical risk

**Foundation: The six-variable framework ensures scenario exercises are comprehensive. Missing even one variable creates blind spots.**

# Using the NGFS Scenario Explorer

**[INTERMEDIATE]**

### Step-by-Step Guide

1. Navigate to `data.ece.iiasa.ac.at/ngfs`
2. Select scenario family (Phase IV, 2024 vintage)
3. Choose IAM model (REMIND-MAgPIE recommended for ASEAN)
4. Select region (Southeast Asia or individual countries)
5. Choose variables (GDP, carbon price, temperature, energy mix)
6. Download CSV for analysis in Python or Excel

The NGFS Scenario Explorer is **free and open-access**. All data used in the Quantitative Lab comes from this tool.

### Available Variable Categories

| Category | Key Variables |
|---|---|
| Macro | GDP, population, investment |
| Energy | Primary energy by fuel |
| Emissions | $CO_2$, $CH_4$, $N_2O$ |
| Prices | Carbon price, fuel prices |
| Land use | Agricultural area, forest cover |
| Climate | Temperature anomaly |

**Tip for ASEAN**

REMIND-MAgPIE has the best Southeast Asia regional granularity. GCAM offers finer 32-region detail but less financial-sector calibration.

**Intermediate: The NGFS Scenario Explorer is your primary data source. All exercises in Module 4 use Phase IV (2023) data.**

# Which Scenarios Matter Most for ASEAN?

**[INTERMEDIATE]**

**GDP Impact by 2050 Under Three Scenarios**

| Country | Hot House World | Disorderly | Orderly | Dominant Risk |
|---|---|---|---|---|
| Philippines | **−8.0%** | −4.0% | −1.0% | Physical (typhoons) |
| Vietnam | **−6.0%** | −3.5% | −1.0% | Physical (flooding) |
| Thailand | **−5.0%** | −3.0% | −0.5% | Mixed |

**Developed markets:** High transition risk (fossil assets, heavy industry). **Disorderly** scenario is worst.

**ASEAN markets:** HIGH physical risk (tropical exposure, typhoons, agriculture-dependent). **Hot House World** is worst.

**Regulatory context:**

- BSP (Philippines): mandates NGFS-aligned stress testing from 2024
- BOT (Thailand): TCFD-aligned climate risk assessment from 2024
- SBV (Vietnam): developing climate risk guidelines

**Intermediate: For ASEAN, always include Hot House World. It produces 2 to 3× larger losses than Disorderly: the inverse of developed markets.**

# Calibrating Sectoral PD Shocks from Scenario Variables

**[INTERMEDIATE]**

**Probability of Default Adjustment**

$$\Delta PD_{sector} = -\beta_{sector} \times \Delta GDP_{scenario} \quad \text{(percentage points)}$$

where $\beta_{sector}$ is the sector sensitivity coefficient: how much the sector's default rate moves per unit of GDP change.

**Worked Example:** Philippine agriculture under Hot House World.
$\Delta GDP = -8\%$, $\beta_{agriculture} = 1.5$ (agriculture is more GDP-sensitive than services)
$\Delta PD = -1.5 \times (-8\%) = +\mathbf{12}$ percentage points on the agricultural default probability.

**LGD Adjustment for Physical Risk**

$$LGD_{climate} = LGD_{base} + (1 - Insurance_Coverage) \times Physical_Damage_Rate$$

**Example:** Agricultural loan in Philippine typhoon corridor.
$LGD_{base} = 45\%$, insurance $= 30\%$, damage rate $= 25\%$.
$LGD_{climate} = 45\% + 0.70 \times 25\% = \mathbf{62.5}\%$.

**Intermediate: LGD adjustment for physical risk is often the largest single impact for ASEAN portfolios: larger than PD shifts.**

# Worked Example: Philippine Bank Sector Exposures

**[INTERMEDIATE]**

**Portfolio Composition:** Agriculture 25%, Manufacturing 20%, Real Estate 15%, Energy 10%, Services 30%.

**Disorderly Scenario PD Adjustments**

| Sector | PD Increase | Driver | Portfolio Weight |
|---|---|---|---|
| Energy | **+15%** | Transition dominated (carbon price shock) | 10% |
| Agriculture | **+8%** | Physical + transition | 25% |
| Manufacturing | +5% | Energy cost pass-through | 20% |
| Real Estate | +3% | Physical: flood risk, collateral devaluation | 15% |
| Services | +2% | GDP elasticity only | 30% |

**Portfolio-weighted PD increase:**

$$\Delta PD_{portfolio} = 0.10 \times 15 + 0.25 \times 8 + 0.20 \times 5 + 0.15 \times 3 + 0.30 \times 2 = \mathbf{5.55} \text{ points}$$

On a **$**2B loan portfolio at the 62.5% climate-adjusted LGD from the previous slide, this implies an additional ∼**$**69M in expected credit losses under the Disorderly scenario. The LGD is not optional: $\Delta PD\times$ exposure gives what enters default, and only $EL = PD \times LGD \times EAD$ turns that into a loss.

**Intermediate: The portfolio-weighted PD increase summarizes a complex sectoral analysis into a single number for the board.**

# Monte Carlo Fan Charts: Visualizing Scenario Uncertainty

**[INTERMEDIATE]**

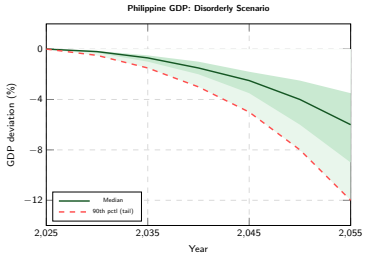
### What Is a Fan Chart?

Fan charts visualize the full range of scenario uncertainty. The central path is the **median** of 10,000 simulated paths, not a prediction.

**Key Percentile Bands**

- **25th to 75th percentile:** "likely" range (darker shading)
- **10th to 90th percentile:** "plausible" range (lighter shading)
- Risk management should focus on the **tails**, not the center

The fan **widens over time** as uncertainty compounds. The **width of the fan is the message**, not the central path.




**Intermediate: Under NGFS Disorderly the median reaches −4% by 2050, but the 90th-percentile tail shows GDP loss could reach −8% or worse.**

# Scenario Design: Time Horizons and Sectoral Granularity

**[INTERMEDIATE]**

### Three Time Horizons

| Horizon | Years | Focus |
|---|---|---|
| Short-term | 1 to 5 | Policy shocks, regulation |
| Medium-term | 5 to 15 | Technology transition, stranded assets |
| Long-term | 15 to 50 | Physical risk, temperature pathway |

**Matching horizon to risk type:**

- Transition risk peaks in **short/medium** term (policy + carbon price)
- Physical risk grows **monotonically** over all horizons
- For ASEAN: physical risk is already material in the **short term** (annual typhoons)

### Sectoral Granularity

Not all sectors respond equally. Minimum granularity for ASEAN:

- **Energy:** Coal power (highest transition risk)
- **Agriculture:** Rice, palm oil, fisheries (physical + transition)
- **Real estate:** Coastal vs inland (flood exposure)
- **Transport:** ICE vehicles vs EVs (technology disruption)
- **Manufacturing:** Cement, steel (carbon-intensive)
- **Tourism:** Climate-dependent revenue

**Geographic Specificity**

NGFS provides regional aggregates. For individual country analysis, supplement with national data (BSP, BOT, SBV publications).

**Intermediate: Match the time horizon to the risk type. Transition risk = short/medium term. Physical risk = all horizons (already material in ASEAN).**

# What Is an Integrated Assessment Model?

**[PhD]**

**The Concept: Economy-Energy-Climate Coupling**

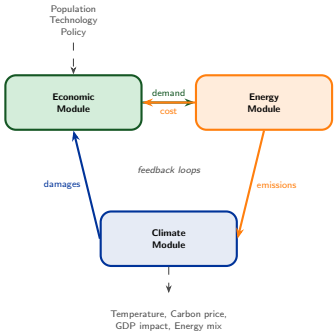
An Integrated Assessment Model (IAM) couples three modules:

- **Economic module:** GDP, investment, consumption, trade
- **Energy module:** Fuel mix, technology cost, emissions
- **Climate module:** Carbon cycle, radiative forcing, temperature

**Inputs:** Population growth, technology assumptions, policy constraints (carbon budgets, carbon prices).

**Outputs:** Emissions pathways, temperature trajectories, carbon prices, energy mix, GDP impacts.

IAMs are the **computational engines** behind every NGFS scenario.




**PhD: IAMs are optimization or simulation models that couple economy, energy, and climate. They generate the numbers behind NGFS scenarios.**

# Four Major IAMs Behind NGFS Scenarios

**[PhD]**

| Model | Institution | Scope | Key Strength | ASEAN Relevance |
|---|---|---|---|---|
| **DICE** (Nordhaus) | Yale | Global, aggregate | Pedagogy, intuition | Low (no regional detail) |
| **REMIND-MAgPIE** | PIK | 12 regions, energy+land | **Best ASEAN granularity** | High |
| **GCAM** | PNNL | 32 regions, energy+water+land | Technology richness | High |
| **MESSAGEix-GLOBIOM** | IIASA | Global/regional, energy | SDG integration | Medium |

**Optimization vs Simulation**

- DICE, REMIND: **optimization**, find cost-minimizing emission pathway subject to a temperature constraint
- GCAM: **partial equilibrium**: iterate energy markets to equilibrium
- MESSAGE: **linear programming**, minimize energy system costs

**Why Models Disagree**

- Different structural assumptions (top-down vs bottom-up)
- Different technology cost trajectories
- Different land-use modeling
- Different discount rates and welfare functions
- Same scenario name $\neq$ same numbers

**PhD: REMIND-MAgPIE is recommended for ASEAN financial analysis. DICE is useful for teaching but too aggregated for portfolio applications.**

# The Carbon Budget Constraint: The Central Equation

**[PhD]**

**Remaining Carbon Budget for 1.5°C**

The total cumulative emissions must not exceed the remaining carbon budget:

$$\sum_{t=0}^{T} E_t \leq B_{1.5}$$

where $E_t$ = global emissions in year $t$, and $B_{1.5} \approx 400$ $GtCO_2$ remaining (IPCC AR6, from 2023).

**Temperature Response (Simplified)**

$$\Delta T \approx \lambda \cdot \Delta F$$

where $\Delta T$ = temperature change (°C), $\lambda$ = climate sensitivity parameter ($\approx 0.8$ °C per W/m$^2$), and $\Delta F$ = change in radiative forcing (W/m$^2$).

**Implication for Finance:** At current emission rates ($\sim$40 $GtCO_2$/yr), the 1.5°C budget is exhausted in $\sim$10 years. Every year of delay tightens the constraint, increasing the required pace of transition and the associated financial disruption.

**PhD: The carbon budget constraint is the fundamental equation linking emissions to temperature. It determines how aggressive transition pathways must be.**

# Damage Functions: How Temperature Becomes GDP Loss

**[PhD]**

**Standard Damage Function**

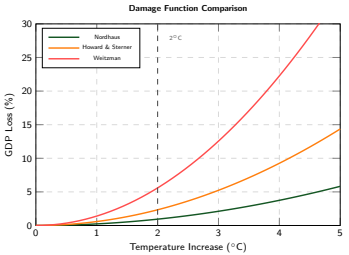
$$D(T) = \frac{\alpha\, T^2}{1 + \beta\, T^2}$$

where $D$ = damage as fraction of GDP, $T$ = temperature increase above pre-industrial, $\alpha$ and $\beta$ are calibration parameters.

**Divergence Above 3°C**

- **Nordhaus (conservative):** ∼8% GDP loss at 4°C
- **Weitzman (catastrophic):** ∼25% GDP loss at 4°C
- **Howard & Sterner (meta):** ∼15% GDP loss at 4°C

The choice of damage function changes estimated financial impact by **3× or more** at the same temperature.




**PhD: Damage function choice is the single most consequential assumption in IAMs. Sensitivity: $\alpha$ sets the curvature, $\beta$ caps the asymptote.**

# The Stern-Nordhaus Discount Rate Debate

**[PhD]**

**The Central Question:** How much should we value future damages relative to present costs?

| Parameter | Stern (2006) | Nordhaus (2017) |
|---|---|---|
| Discount rate ($\delta$) | 1.4% | 4.5% |
| Social Cost of Carbon | $\sim$\$200+/tCO$_2$ | $\sim$\$35/tCO$_2$ |
| Policy implication | Urgent, aggressive action | Gradual, cost-optimized |
| Ethical basis | Future generations = present | Market-observed rates |
| Optimal carbon tax (2025) | $>$\$100/tCO$_2$ | $\sim$\$40/tCO$_2$ |

The discount rate choice alone accounts for a **2 to 5$\times$ difference** in the social cost of carbon.

The Ramsey equation: $r = \delta + \eta \cdot g$
where $\delta$ = pure time preference, $\eta$ = elasticity of marginal utility, $g$ = growth rate.

**ASEAN Relevance**

For ASEAN, the discount rate debate is **less relevant** because physical damages arrive in the **near term** (annual typhoons, flooding), not in 2100. Near-term damages are barely discounted regardless of the rate chosen.

**PhD: The Ramsey equation $r = \delta + \eta g$ connects ethics ($\delta$, $\eta$) to economics ($g$). The debate is fundamentally about intergenerational justice.**

# Critiques of Integrated Assessment Models

**[PhD]**

### Weitzman (2009): Fat-Tailed Catastrophic Risk

- IAMs assume **thin-tailed** damage distributions
- But climate tipping points create **fat tails**
- Even a small probability of $6^{\circ}$C+ warming should **dominate** cost-benefit analysis
- The "dismal theorem": under fat tails, expected damages are **infinite**

### Pindyck (2013): "Climate Change Policy: What Do the Models Tell Us?"

- IAMs create an **illusion of precision** with deeply uncertain parameters
- Damage functions are essentially **calibrated guesses**
- Results are sensitive to **arbitrary assumptions**
- IAMs tell us nothing useful about **optimal policy**

### Uncertainty and Model Limitations

- **Model disagreement:** REMIND and GCAM can produce $2\times$ different carbon prices for the same scenario
- **Tipping points:** Ice sheet collapse, Amazon dieback, permafrost thaw, not in standard IAMs
- **Non-linearities:** Compound events, cascading failures
- **Deep uncertainty vs risk:** IAMs treat deep uncertainty as if it were quantifiable risk

**The Pragmatic View**

Despite these critiques, IAMs remain the **best available tool** for structured scenario analysis. The alternative is no quantitative framework at all. Use IAMs **with awareness of limitations**, not as truth.

**PhD: Weitzman (2009) "On Modeling and Interpreting the Economics of Catastrophic Climate Change." Pindyck (2013) "Climate Change Policy: What Do the Models Tell Us?"**

# Sensitivity Analysis: Which Parameters Matter Most?

**[PhD]**

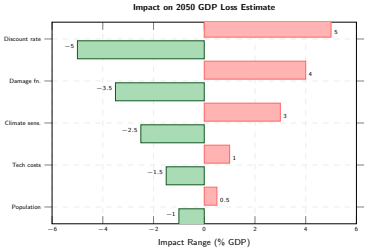
### Key Sensitivity Parameters

- **Discount rate:** 2 to 5× impact on SCC (Stern vs Nordhaus)
- **Climate sensitivity:** 1.5 to 4.5°C per doubling of $CO_2$ (IPCC range)
- **Damage function curvature:** $\alpha$ parameter in $D(T) = \alpha T^2/(1 + \beta T^2)$
- **Technology cost trajectory:** Solar/wind learning rates
- **Population growth:** SSP1 (low) vs SSP3 (high)

### Narrative vs Quantitative Scenarios

- **Quantitative:** IAM-generated numbers (carbon price, GDP impact)
- **Narrative:** Qualitative storylines ("what if China bans coal by 2030?")
- Best practice: **combine both**, narratives for plausibility, quantitative for portfolio impact

### Tornado Diagram: Parameter Sensitivity




**PhD: Discount rate and damage function dominate. Climate sensitivity is third. Technology and population are secondary. Always report sensitivity ranges.**

# Philippines: Typhoon Exposure Under Climate Scenarios

**[FOUNDATION]**

### Climate Context

- About **20 tropical cyclones** form in the region yearly; **8 or 9** cross the country
- Climate models project intensity increases of **10 to 30% by 2050**
- Super Typhoon Haiyan (2013): **$12.9 billion** in damages, 14.1 million affected
- Agricultural lending = 15 to 20% of bank portfolios
- Insurance penetration $\approx$ **5%** (vs 60 to 80% in developed markets)

### BSP Climate Requirements

Bangko Sentral ng Pilipinas (BSP) mandated NGFS-aligned climate stress testing from 2024 for all universal and commercial banks.

### The Task

Model agricultural loan default rates under NGFS Hot House and Disorderly scenarios, incorporating:

- Projected typhoon **intensity increases**
- **Cropping pattern** shifts (rice, corn, coconut)
- **Insurance gap** amplification
- **Collateral devaluation** in coastal zones

### Key Variable: Agricultural Exposure

Philippine agriculture GDP share: $\sim$10%. But agricultural **employment** share: $\sim$25%. Rural loan books are concentrated in agriculture, making banks disproportionately exposed to physical climate risk.

**Source: ADB (2023). Climate Risk and Adaptation in the Philippines Financial Sector. Super Typhoon Haiyan remains the benchmark event.**

# The Cubic Wind-Damage Relationship: Small Changes, Large Losses

## [FOUNDATION]

### The Physics of Wind Damage

$$Damage \propto WindSpeed^3$$

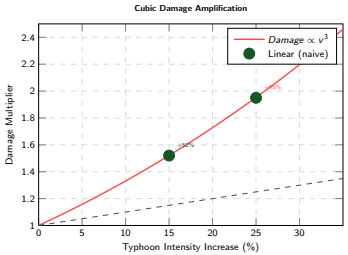
A 25% increase in typhoon wind speed implies approximately **95% more damage**:

$$1.25^3 \approx 1.95$$

This cubic relationship is the key reason why "moderate" climate projections translate into **extreme** financial impacts for the Philippines.

### Default Rate Projections

| Metric | Current | Hot House | Disorderly |
|---|---|---|---|
| Agri NPL rate | 8% | ∼**15.6%** | ∼12.2% |
| Heat stress | n/a | +2 to 3% | +1 to 2% |




**The cubic wind-damage law means a "moderate" 25% intensity increase nearly DOUBLES financial losses. This is the ASEAN physical risk amplifier.**

# Philippines Case: Discussion and Policy Implications

**[INTERMEDIATE]**

**Discussion Questions**

1. How does the cubic wind-damage relationship amplify small changes in typhoon intensity into large financial losses for Philippine agricultural banks?
2. Why does insurance penetration of $\sim$5% make the Philippines uniquely vulnerable compared to developed markets with 60 to 80% coverage?
3. What portfolio adjustments would you recommend to BSP based on these scenario results?

**Policy Implications for BSP**

- **Capital buffers:** Climate-adjusted capital requirements for agricultural and coastal exposures
- **Insurance mandates:** Require crop insurance as loan condition to reduce LGD
- **Stress testing frequency:** Annual NGFS-based exercises
- **Sectoral limits:** Concentration caps on typhoon-corridor agricultural lending
- **Data infrastructure:** National climate risk data platform for banks
- **Transition support:** Green lending incentives for climate-resilient agriculture

**The Philippines case illustrates why ASEAN regulators must prioritize physical risk scenarios alongside transition risk.**

# Summary: Key Takeaways

### Foundation

1. Scenarios $\neq$ predictions. They explore **plausible futures** under deep uncertainty.
2. NGFS Phase V (November 2024) provides **seven reference scenarios** in four categories: Orderly, Disorderly, Hot House World, and Too little too late (Fragmented World).
3. The **transmission chain** links climate pathway $\rightarrow$ macro $\rightarrow$ sector $\rightarrow$ counterparty $\rightarrow$ portfolio losses.
4. For ASEAN, **Hot House World** is worst (physical risk dominance): the inverse of developed markets.

### Intermediate

5. Calibrate sectoral shocks via $\Delta PD = -\beta \times \Delta GDP$, in percentage points.
6. Monte Carlo fan charts quantify **the width of uncertainty**: the fan width is the message.

### PhD Extension

7. IAMs (REMIND, GCAM, MESSAGE) are the computational engines behind NGFS scenarios.
8. The **carbon budget constraint** $\sum E_t \leq B_{1.5}$ determines transition urgency.
9. Damage functions diverge **3**$\times$**+** above 3°C (Nordhaus vs Weitzman).
10. The Stern-Nordhaus discount rate debate drives a **2 to 5**$\times$ difference in the social cost of carbon.

**Next Lesson**

**Lesson 4.4: Carbon Metrics and Climate Value-at-Risk.** Now that we can model the future (scenarios), we need to **measure our exposure** (carbon metrics) and translate scenarios into financial loss numbers (CVaR).

**With risk identified (L4.1), frameworks established (L4.2), and scenarios modeled (L4.3), Lesson 4.4 measures the exposure.**

# References


NGFS (2024). *NGFS Climate Scenarios for Central Banks and Supervisors: Phase IV Technical Documentation*. Network for Greening the Financial System.

Riahi, K., et al. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications. *Global Environmental Change*, 42, 153 to 168.

van Vuuren, D.P., et al. (2011). The representative concentration pathways: an overview. *Climatic Change*, 109, 5 to 31.

Bolton, P., et al. (2020). *The Green Swan: Central banking and financial stability in the age of climate change*. BIS/Banque de France.

IPCC (2023). *AR6 Synthesis Report: Climate Change 2023*.

Bertram, C., Hilaire, J., Kriegler, E., et al. (2021). NGFS Climate Scenarios Database: Technical Documentation (V2.2). Prepared for NGFS by the academic consortium (PIK, IIASA, UMD, Climate Analytics, ETH Zurich).


**All NGFS data available at data.ece.iiasa.ac.at/ngfs (free, open access).**

# References (Supplementary)


Nordhaus, W. (2017). Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, 114(7), 1518 to 1523.

Weitzman, M. (2009). On modeling and interpreting the economics of catastrophic climate change. *Review of Economics and Statistics*, 91(1), 1 to 19.

Pindyck, R.S. (2013). Climate change policy: What do the models tell us? *Journal of Economic Literature*, 51(3), 860 to 872.

Howard, P. & Sterner, T. (2017). Few and not so far between: A meta-analysis of climate damage estimates. *Environmental and Resource Economics*, 68(1), 197 to 225.

IEA (2024). *World Energy Outlook 2024*. International Energy Agency.

ADB (2023). *Climate Risk and Adaptation in the Philippines Financial Sector*. Asian Development Bank.

# Acknowledgments

Developed by the University of Twente as Module 4 of the GREEN FINANCE curriculum, under Work Package 3 of the Erasmus+ Capacity Building in Higher Education project GREEN FINANCE (Grant 101237817).

### 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 and Opus 5, used from July 2026 to the submission of this module on 11 September 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;
- 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 values from derived values and from illustrative teaching assumptions. The authors remain fully responsible for the originality, accuracy, integrity, references, and conclusions of the material.

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