Discovery Challenge: The $557 Trillion Stranded Asset Time Bomb

The Puzzle

- Study warns: $557 trillion stranded assets by 2050
- US$1+ trillion in upstream oil/gas alone
- Most losses borne by OECD pension funds
- Industry capital spending down 30-40% from 2014 peak
- Banks started pricing climate policy risk after 2015
- Only 50% of cashflows return to traditional supply (vs 80% decade ago)

Questions This Raises

- Why weren't these assets already written down?
- How do you measure stranded asset risk?
- What are the financial system implications?
- Can this happen faster than expected?
- Which sectors are most exposed?
- How do you model transition risk in portfolios?

[Discovery 1] This puzzle will be resolved by Goal 1—climate risk assessment frameworks

Learning Goal 1

Understand Physical and Transition Climate Risks

Theoretical — Foundation - Establishes climate risk taxonomy

Why Climate Risk Matters for Finance

The Climate-Finance Nexus
Climate change creates financial risks through:

- Asset value impairment
- Credit quality deterioration
- Insurance loss increases
- Regulatory compliance costs
- Stranded asset risk

Mark Carney's Warning (2015)
"Breaking the Tragedy of the Horizon" speech identified climate as a systemic financial risk.

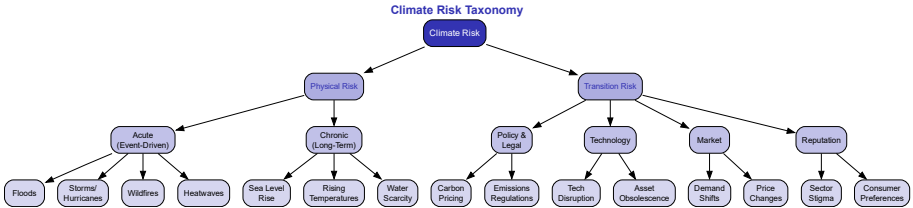
Key Statistics

- $1.4 trillion in stranded oil & gas assets (present value)
- 4% GDP loss by 2050 in hot house scenario
- 82% of companies now report climate risks
- $45.7 billion: Thailand floods 2011 losses

Regulatory Response
Central banks and regulators now require climate risk assessment through stress testing and disclosure mandates.

[Goal 1] Climate risk has moved from environmental concern to core financial risk management

Climate Risk Taxonomy



[Goal 1] Climate risks divide into physical (event-driven and chronic) and transition (policy, technology, market, reputation)

Physical Risk: Acute Events

Definition
Acute physical risks are event-driven hazards that are becoming more frequent or intense due to climate change.

Key Hazard Types

- **Floods**: River, coastal, and flash flooding
- **Storms**: Hurricanes, cyclones, typhoons
- **Wildfires**: Forest and brush fires
- **Heatwaves**: Extreme temperature events
- **Extreme precipitation**: Heavy rainfall

Financial Impacts

- Direct asset damage
- Business interruption
- Supply chain disruption
- Insurance claims surge
- Infrastructure damage

Case Example: Thailand 2011
Floods disrupted hard disk and automotive manufacturing globally. World Bank estimated $45.7 billion in financial losses.

[Goal 1] Acute risks cause immediate, visible damage but are increasingly predictable with climate modeling

Physical Risk: Chronic Changes

Definition
Chronic physical risks are driven by longer-term shifts in climate patterns that progressively alter the environment.

Key Chronic Hazards

- **Sea level rise**: Coastal asset exposure
- **Rising temperatures**: Productivity impacts
- **Water scarcity**: Resource availability
- **Changing precipitation**: Agricultural yields
- **Ocean acidification**: Marine ecosystems

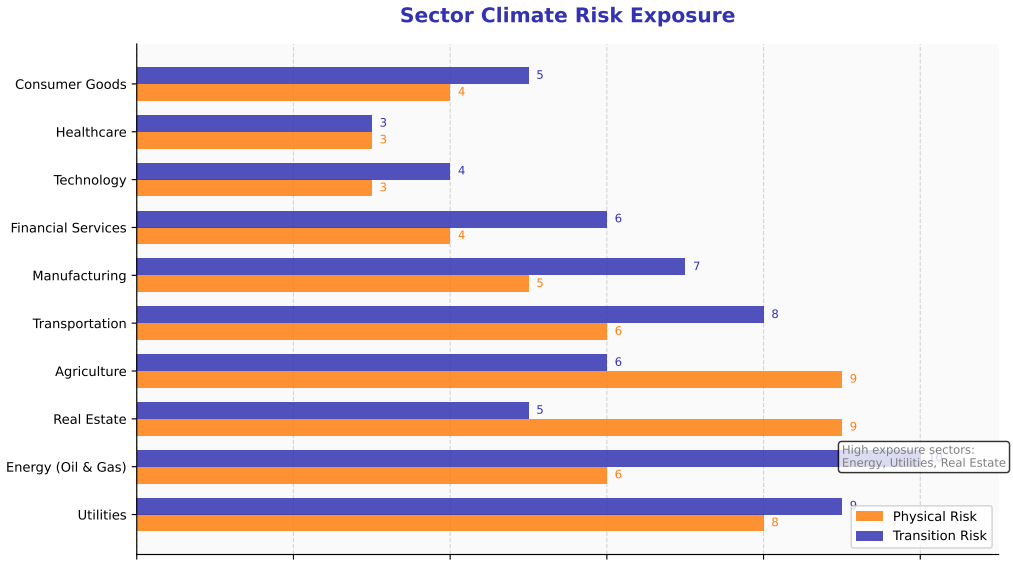
Financial Implications

- Long-term asset devaluation
- Changed operating conditions
- Resource availability constraints
- Migration and demographic shifts
- Agricultural productivity changes

Interconnection
Chronic increases in average temperatures can exacerbate the severity and frequency of acute events like heatwaves and droughts.

[Goal 1] Chronic risks unfold gradually but can fundamentally alter asset values and business viability

Sector Climate Risk Exposure



Transition Risk: Four Categories

Policy & Legal Risk

- Carbon pricing and taxes
- Emissions trading systems
- Stricter emissions regulations
- Climate disclosure requirements
- Climate litigation claims

Technology Risk

- Renewable energy disruption
- Electric vehicle adoption
- Energy storage advances
- Carbon capture technology
- Obsolescence of fossil assets

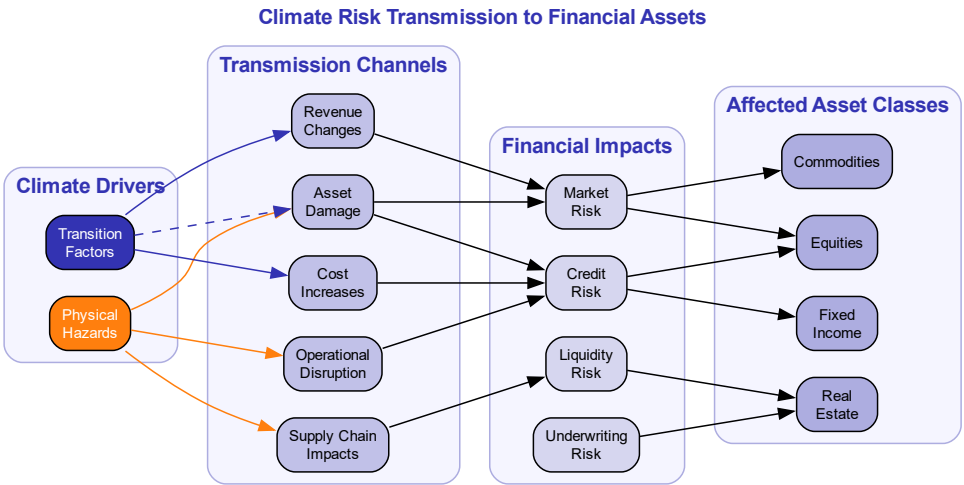
Market Risk

- Consumer preference shifts
- Commodity price changes
- Supply chain restructuring
- New market opportunities
- Asset repricing

Reputation Risk

- Sector stigmatization
- ESG investor screening
- Consumer boycotts
- Talent attraction challenges
- Brand damage

[Goal 1] Transition risks arise from the policy, technological, and market shifts in moving to a low-carbon economy


Climate Risk Transmission to Financial Assets
Climate Drivers
Transition Factors
Physical Hazards
Transmission Channels
Revenue Changes
Asset Damage
Cost Increases
Operational Disruption
Supply Chain Impacts
Financial Impacts
Market Risk
Credit Risk
Liquidity Risk
Underwriting Risk
Affected Asset Classes
Commodities
Equities
Fixed Income
Real Estate

Stranded Assets: Theory and Estimates

Definition
Stranded assets are resources that become obsolete or worthless before the end of their expected useful life due to the transition to a low-carbon economy.

Key Drivers

- Climate policy (carbon pricing)
- Technology disruption
- Changing market preferences
- Regulatory restrictions
- Physical damage from climate

Current Estimates

- Upstream oil & gas: $1.4 trillion PV
- Coal power generation: $1.3-2.3 trillion
- Fossil fuel reserve devaluation: 37-50%
- 50% of assets could strand by 2034

IEA Projections

- $90 billion by 2030
- $400 billion by 2040

Three-quarters of stranded assets belong to governments.

[Goal 1] Stranded asset risk is material for energy sector investments and sovereign debt of resource-dependent nations

Learning Goal 1: Summary

What We Achieved

- ✓ Defined physical vs. transition risk
- ✓ Identified acute and chronic hazards
- ✓ Mapped four transition risk categories
- ✓ Analyzed sector exposure levels
- ✓ Understood stranded asset theory
- ✓ Traced risk transmission channels

Can You Now...

- Classify climate risks by type?
- Identify which sectors face highest exposure?
- Explain how climate risks transmit to financial assets?
- Estimate stranded asset implications?
- Distinguish policy from technology risk?

Next: Goal 2
Apply TCFD framework and quantification methods to measure these risks.

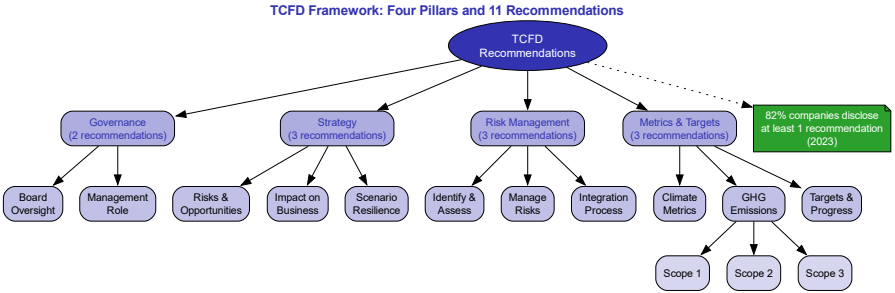
[Goal 1] Achieved - You can now identify and classify climate-related financial risks

Learning Goal 2

Apply TCFD Framework and Quantification Methods

Quantitative — Build - Develops risk measurement skills

TCFD Framework: Four Pillars



[Goal 2] TCFD provides standardized disclosure framework now integrated into ISSB standards (effective January 2024)

TCFD Adoption and Transition to ISSB

Global Adoption (2023)

- 82% of companies disclose at least one TCFD recommendation (up from 73% in 2022)
- 44% disclose five or more (up from 38%)
- Only 2-3% report all 11 recommendations
- Average: 5.2 disclosures per company

Regional Variations

- Europe leads: 6.4 average disclosures
- Insurance sector: 5.5 disclosures
- Energy sector: 5.4 disclosures

U.S. Progress

- Russell 1000: 65% aligned (2024)
- Up from 60% in 2023
- Up from 4% in 2019

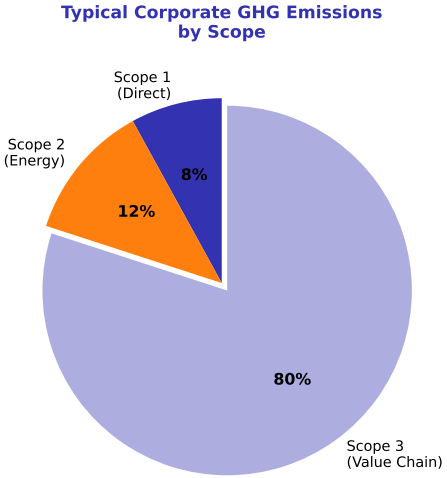
Transition to ISSB

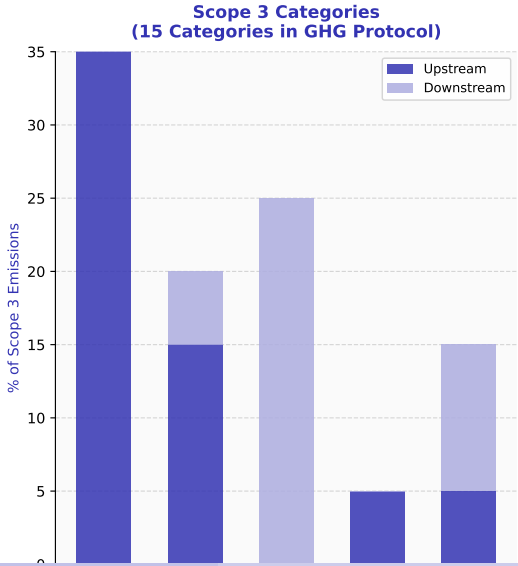
TCFD disbanded October 2023. Legacy continues through:

- IFRS S1 (general sustainability)
- IFRS S2 (climate-specific)
- Effective January 1, 2024
- 1,000+ companies referenced ISSB by March 2024

[Goal 2] TCFD has achieved significant adoption and its framework is now embedded in mandatory ISSB standards

Carbon Footprinting: Scope 1, 2, and 3 Emissions





GHG Protocol Scope Definitions

Scope 1: Direct
Emissions from owned or controlled sources:

- Fuel combustion (boilers, furnaces)
- Company vehicles
- Refrigerants
- On-site energy

Fully within company control

Scope 2: Energy
Indirect emissions from purchased energy:

- Electricity
- Steam
- Heating
- Cooling

At least 1/3 of global GHG emissions

Scope 3: Value Chain
All other indirect emissions:

- Purchased goods
- Transportation
- Use of products
- Employee commute
- End-of-life

15 categories in GHG Protocol

Key Insight: Scope 3 often represents 70-90% of total emissions but is hardest to measure and control.

[Goal 2] Understanding scope boundaries is essential for accurate carbon footprinting and target-setting

Climate Value-at-Risk (Climate VaR)

Definition
Climate VaR forecasts climate change-driven costs and profits for corporate issuers under different climate scenarios.

Framework Components

- **Physical VaR**: Asset damage and business interruption from climate hazards
- **Transition VaR**: Policy costs, technology shifts, market changes
- **Opportunity VaR**: Green revenue opportunities

Methodology Steps

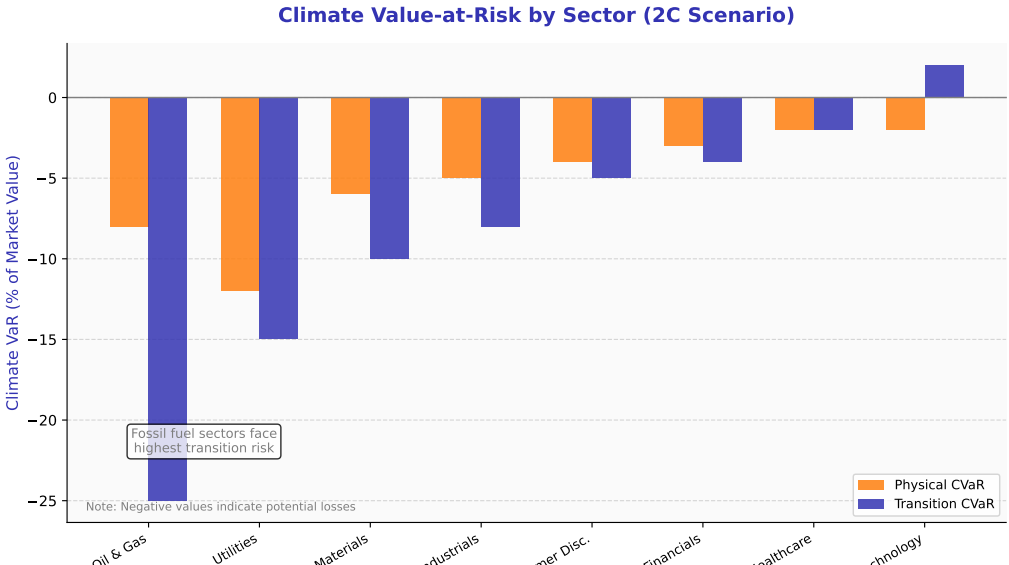
1. Estimate time series of forecasted climate costs
2. Overlay asset locations with hazard exposure
3. Apply damage functions
4. Model policy and technology impacts
5. Aggregate to portfolio level

Data Sources

- CDP disclosures
- Government databases
- MSCI ESG Research estimates

[Goal 2] Climate VaR extends traditional risk metrics to capture climate-specific financial exposures

Climate VaR by Sector



Implied Temperature Rise (ITR)

Concept
ITR translates a portfolio's emissions pathway into an implied global temperature outcome.

How It Works

- Map company emissions to carbon budgets
- Calculate overshoot/undershoot
- Translate to temperature equivalent
- Aggregate at portfolio level

Interpretation

- 1.5C = Paris-aligned
- 2.0C = Upper limit of Paris
- 2.5C+ = Significant transition risk
- 3.0C+ = Extreme risk

Typical Measurements

- Current benchmarks: 2.5-3.5C
- Paris-aligned funds: Below 2C
- Best-in-class: 1.5-2C

Providers

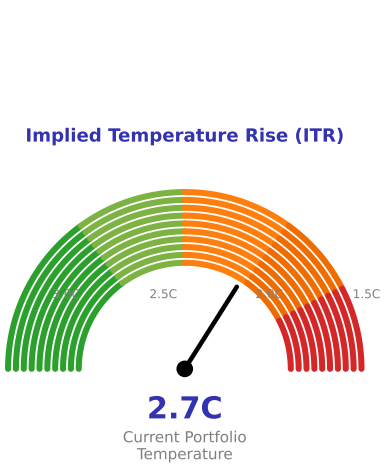
- MSCI Implied Temperature Rise
- CDP-WWF Temperature Rating
- Science Based Targets initiative
- ISS Climate Solutions

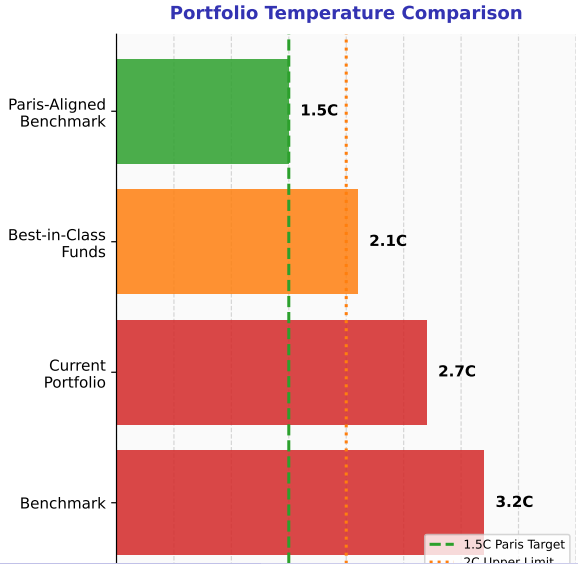
Use Cases

- Portfolio alignment tracking
- Investment screening
- Engagement prioritization

[Goal 2] ITR provides an intuitive metric linking portfolio holdings to climate outcomes

Portfolio Temperature Comparison





Learning Goal 2: Summary

What We Achieved

- ✓ Mastered TCFD four pillars
- ✓ Understood Scope 1/2/3 emissions
- ✓ Applied Climate VaR methodology
- ✓ Interpreted temperature alignment
- ✓ Analyzed sector CVaR exposure
- ✓ Tracked TCFD to ISSB transition

Can You Now...

- Explain TCFD's 11 recommendations?
- Calculate portfolio carbon intensity?
- Interpret Climate VaR outputs?
- Assess temperature alignment?
- Distinguish Scope 1/2/3 boundaries?

Next: Goal 3
Conduct climate scenario analysis using NGFS frameworks.

[Goal 2] Achieved - You can now apply TCFD and quantify climate risk using industry-standard metrics

Learning Goal 3

Conduct Climate Scenario Analysis

Applied — Apply - Hands-on scenario modeling

NGFS Scenario Framework

Network for Greening the Financial System
NGFS provides standardized climate scenarios for financial institutions and supervisors.

Phase V (November 2024)

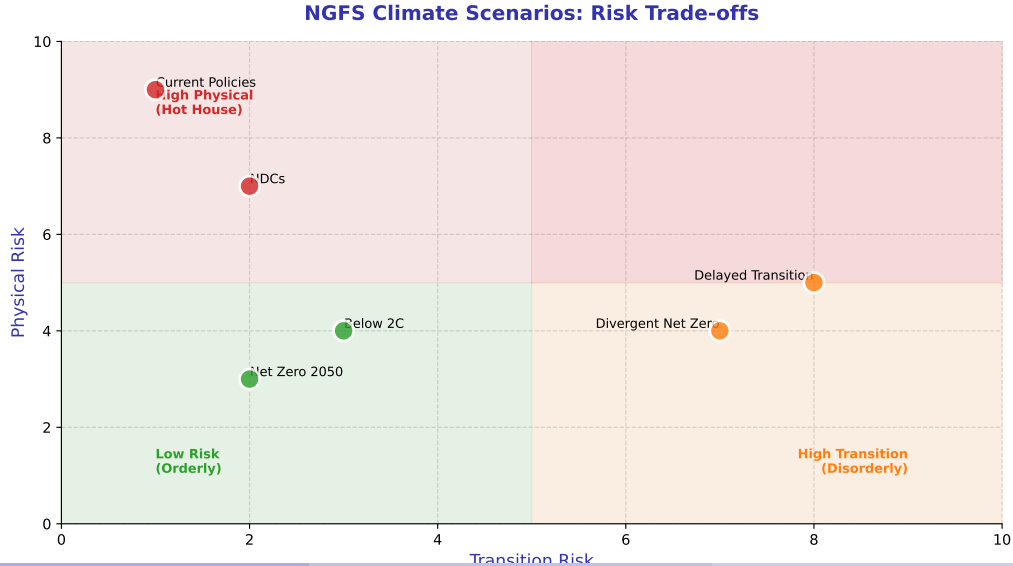
- Six reference scenarios
- Three categories (orderly, disorderly, hot house)
- Updated damage functions (Kotz et al. 2024)
- Country-level net-zero commitments
- Latest renewable technology trends

Three Categories

1. **Orderly**
   - Early, gradual policy action
   - Low transition and physical risk
2. **Disorderly**
   - Delayed or divergent policies
   - High transition risk
3. **Hot House World**
   - Insufficient climate action
   - Low transition, high physical risk
   - Temperature exceeds 2.5C

[Goal 3] NGFS scenarios are the global standard for financial sector climate stress testing

NGFS Scenario Risk Trade-offs



The Six NGFS Reference Scenarios

Orderly
Net Zero 2050

- Immediate, smooth action
- 1.5C pathway
- Lowest combined risk

Below 2C

- Gradual strengthening
- 67% probability below 2C
- Moderate adjustments

Disorderly
Delayed Transition

- Action starts after 2030
- Sharp policy changes
- High transition costs

Divergent Net Zero

- Uneven global action
- Sector inconsistencies
- Carbon leakage risks

Hot House World
Nationally Determined Contributions

- Current pledges only
- 2.5C+ outcome
- Severe physical impacts

Current Policies

- No new policies
- 3C+ outcome
- Catastrophic impacts

[Goal 3] Financial institutions should test portfolios against multiple scenarios to understand risk range

Scenario Analysis Methodology

Step 1: Select Scenarios

- Choose 2-4 NGFS scenarios
- Include orderly and disorderly
- Cover different time horizons

Step 2: Map Exposures

- Identify climate-sensitive assets
- Assess sector concentrations
- Locate physical asset positions

Step 3: Apply Shocks

- Carbon price trajectories
- Physical hazard probabilities
- Technology adoption curves

Step 4: Model Impacts

- Revenue and cost changes
- Asset value adjustments
- Credit quality migrations

Step 5: Aggregate Results

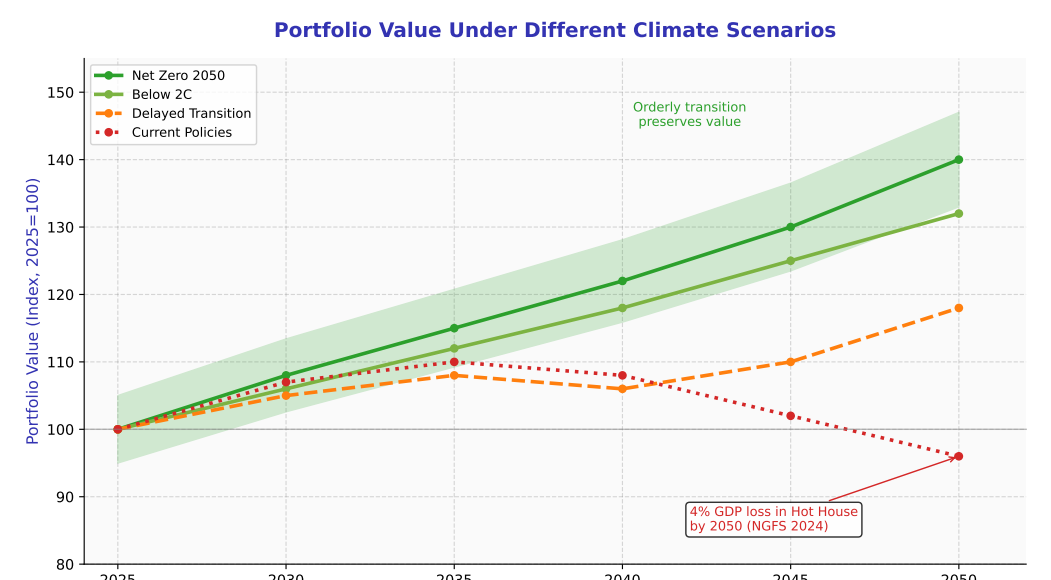
- Portfolio-level losses
- Sector contributions
- Uncertainty ranges

Step 6: Interpret & Act

- Risk appetite comparison
- Strategy implications
- Engagement priorities

[Goal 3] Scenario analysis is forward-looking and complements historical risk measures

Portfolio Value Under Climate Scenarios



Climate Stress Testing for Financial Institutions

Regulatory Requirements

- Bank of England: Biennial Exploratory Scenario
- ECB: Climate stress test (2022)
- Fed: Pilot climate scenario analysis
- APRA: Climate Vulnerability Assessment

Key Differences from Traditional Stress Tests

- Longer time horizons (30+ years)
- Forward-looking scenarios
- Novel risk transmission channels
- Greater uncertainty

Implementation Challenges

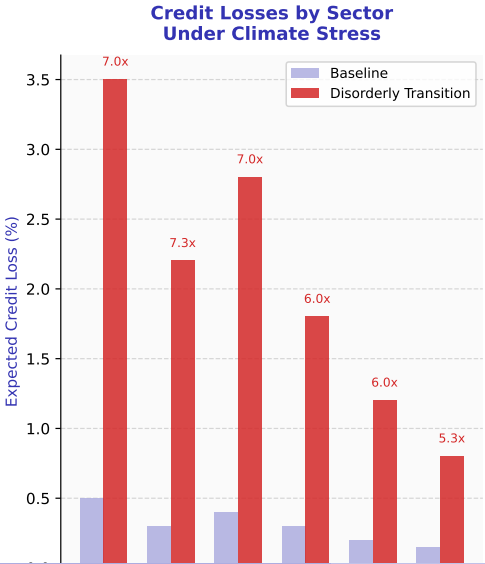
- Data availability gaps
- Long-term modeling uncertainty
- Cross-sector dependencies
- Climate science evolution

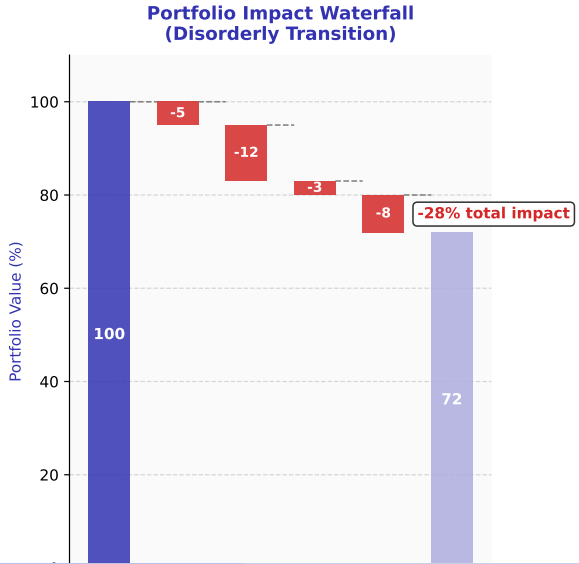
Bank of England Findings (2022)

- Banks could absorb losses
- But £225 billion additional provisions needed under severe scenario
- Early action reduces total costs
- No first-mover advantage in inaction

[Goal 3] Climate stress testing is becoming mandatory for systemically important financial institutions

Climate Stress Test Results Visualization





Interpreting and Communicating Scenario Results

Key Metrics to Report

- Portfolio Climate VaR (% of value)
- Sector contribution breakdown
- Time horizon sensitivity
- Scenario range (best to worst)
- Temperature alignment path

Audience Considerations

- **Board**: Strategic implications
- **Risk committees**: Quantified exposures
- **Investors**: Comparable metrics
- **Regulators**: Methodology compliance

Best Practices

- Present range, not point estimates
- Explain key assumptions
- Show sensitivity to parameters
- Link to strategy response

Common Pitfalls

- Over-precision in long-term forecasts
- Ignoring scenario interdependencies
- Treating scenarios as predictions
- Neglecting second-order effects

Action Framework

Results should inform: engagement priorities, divestment decisions, product development, and capital allocation.

[Goal 3] Scenario analysis is a decision-support tool, not a prediction of the future

Discovery Challenge: When Banks Underestimate Losses by 70%

The Puzzle

- ECB 2023: Median EU bank faces 0.6-1% portfolio losses
- But VaR underestimation up to 70% using proxy data
- Ignoring tail risks: 82% underestimation of losses
- Banking NPLs increase 0.5-0.6% post-disaster
- Climate losses: $600B (2002-2022), growing 6.5% annually
- Global income could fall 19% by 2050 ($38T annually)

Questions This Raises

- Why such massive estimation errors?
- Are stress tests fit for purpose?
- What data do you need for accurate risk assessment?
- How do you model tail risk events?
- Can TCFD frameworks fix this?
- What's missing from current risk models?

[Discovery 2] This puzzle will be resolved by Goal 2—TCFD and stress testing methods

Discovery Challenge: The NGFS Scenario Reality Gap

The Puzzle

- NGFS 2030 GDP range: Only 2.5% variation
- IMF one-year forecast error: 2.7% (larger than 9-year scenario range!)
- Missing: tipping points, migration, nature loss
- Physical and transition risks treated separately
- Damage estimates unreconcilable with 3C as catastrophic"
- One expert: Like assessing Titanic hitting iceberg but excluding ship sinking"

Questions This Raises

- Are NGFS scenarios too optimistic?
- How do you incorporate non-linear risks?
- What about physical-transition risk interaction?
- Can equilibrium models capture transition benefits?
- Should banks use alternative scenarios?
- How do you validate scenario realism?

[Discovery 3] This puzzle will be resolved by Goal 3—scenario analysis best practices

Learning Goal 3: Summary and Week Integration

What We Achieved

- ✓ Mastered NGFS scenario framework
- ✓ Applied scenario analysis methodology
- ✓ Interpreted stress test results
- ✓ Understood regulatory expectations
- ✓ Communicated scenario outcomes

Week 4 Integration
Goal 1 (taxonomy) → Goal 2 (quantification) → Goal 3 (scenario analysis) forms a complete climate risk assessment toolkit.

Can You Now...

- Apply NGFS scenarios to portfolios?
- Conduct climate stress testing?
- Interpret and communicate results?
- Link scenarios to strategy?

Key Takeaways

- Early action reduces total costs
- Scenario analysis is exploratory
- Uncertainty is a feature, not a bug
- Climate risk is financially material

Next Week: Portfolio Construction and Green Investment Strategies

[Goal 3] Achieved - You can now conduct comprehensive climate risk assessments using industry-standard frameworks