Climate risk in a loan book, from hazard to capital

Joerg Osterrieder

University of Twente

Three loans of USD 100 million

Coal power plant
merchant sales, Vietnam
Scope 1: 3.0 Mt CO_2
PD today 1.0%

Solar farm
Chao Phraya flood plain, Thailand
Scope 1: 0
PD today 1.5%

Garment maker
coal-fired boilers, Vietnam
Scope 1: 0.04 Mt CO_2
PD today 2.0%

A bank lends USD 100 million to each of three borrowers, and its rating model puts the coal plant's PD lowest of the three.

Which loan loses most in a 2030 stress test with a carbon price of 100 US dollars of 2010 per tonne and a 1-in-100-year flood?

Stylised values.

Six objectives

1. Classify a hazard as a physical or transition driver and name the bank risk it becomes
2. Explain why a PD estimated on past defaults misses a carbon price set for 2030
3. Compute a borrower's PD under a carbon price from Scope 1, EBITDA, interest and the grid
4. Compute LGD and expected loss of a collateralised loan after a flood
5. Describe the three NGFS families and say which of the three loans each one hits
6. Compute the IRB capital a scenario PD implies and evaluate one lever

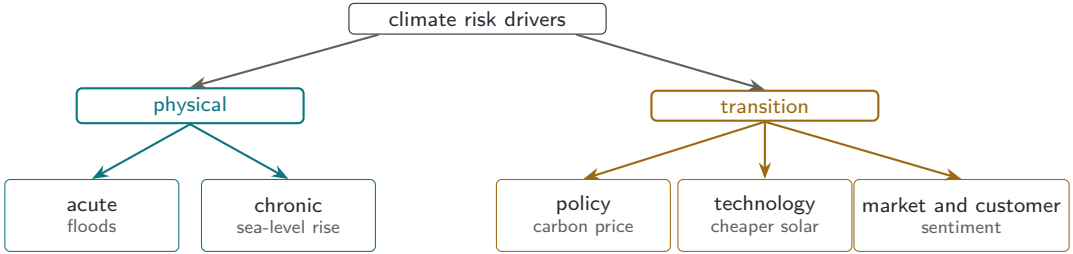
Four questions

1. Which climate risks reach a bank's loans?
2. How does a hazard change a borrower's PD and LGD?
3. How does a bank measure the loss across scenarios?
4. What does a bank do about the loss it measures?

A hazard reaches a borrower as a cost or a loss of income and assets. The borrower's PD and LGD move, a scenario sets the hazard for every loan of the book, and the bank provisions and holds capital for what it measures.

Climate risk reaches a bank through five drivers in two families

1 2 3 4 **Which climate risks reach a bank's loans?**

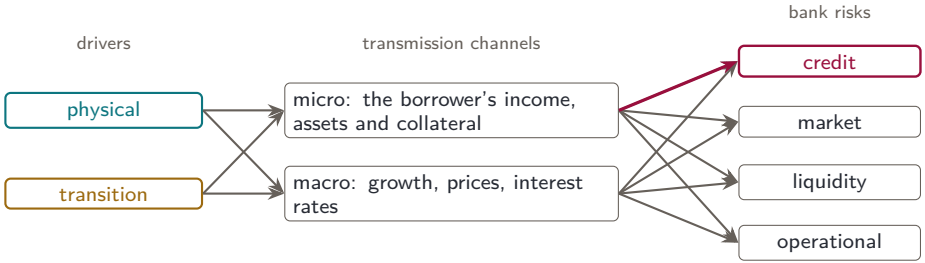


Five drivers: the physical ones are the weather, acute events such as floods and chronic shifts such as sea-level rise. Transition drivers are the economy's move to low carbon: policy, technology, and market and customer sentiment.

BCBS (2021), Climate-related risk drivers and their transmission channels: physical, section 2.2, p. 6; transition, Glossary, p. vi.

A government stops approving new coal power plants. Which family of drivers is that, and which driver?

Drivers reach a lender as credit, market, liquidity and operational risk



Micro channels act on one borrower: a flood stops its sales, a carbon price raises its costs, a damaged plant secures less of the loan. Macro channels act on the economy around it. A lender meets most of both as credit risk.

BCBS (2021): micro and macro channels, Executive summary, p. 1; the four bank risks, p. 3.

Depositors withdraw their savings after a typhoon hits the bank's home province. Which of the four bank risks is that?

Two of the three loans face a carbon price, and one faces a flood

Coal power plant
merchant sales, Vietnam
Scope 1: 3.0 Mt CO_2
transition: carbon price

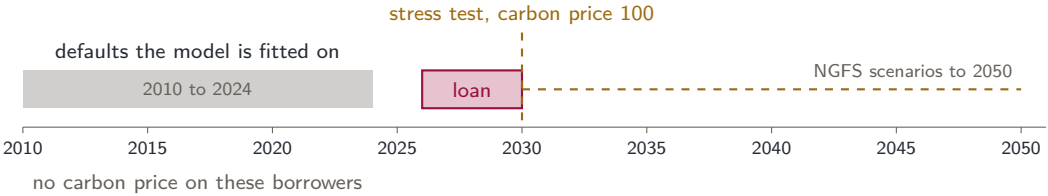
Solar farm
Chao Phraya flood plain, Thailand
collateral 60 of 100
physical: flood

Garment maker
coal-fired boilers, Vietnam
Scope 1: 0.04 Mt CO_2
transition: carbon price

The coal plant and the garment maker burn coal and pay for every tonne under a carbon price. The solar farm emits nothing; a flood on its plain stops its output and damages the panels that secure the loan. Stylised values.

The garment maker's export market charges for the carbon in imported clothing. Which loan does the charge hit, and through which driver?

A rating model fitted on past defaults has never priced carbon



The rating model maps coverage to PD from the defaults of 2010 to 2024. None of those borrowers paid a carbon price, so the coal plant's coverage of 7.0 earns it 1.0 per cent.

> *"very little reliance can be placed upon historical experience to assess their magnitude or to identify patterns"*
>
> BCBS (2021), section 2.4, p. 9.

Stylised values.

Which input of the rating model must change before it rates the coal plant above 1.0 per cent?

The 2011 Thai floods cost USD 46.5 billion, most of it in manufacturing

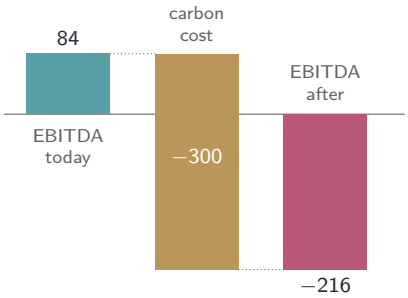


Six industrial estates in Ayutthaya and Pathum Thani flooded from mid-October to November 2011. Damage and losses came to THB 1.43 trillion, USD 46.5 billion; manufacturing took 71 per cent of it.
World Bank (2012), Thai Flood 2011, Overview: p. 2; Table 1, p. 4.

Losses, the income the floods took, were 56 per cent of the total and damage to assets 44. Which of the two reaches a lender through EBITDA, and which through collateral?

A carbon price turns tonnes of CO_2 into a cost against EBITDA

1 2 3 4 **How does a hazard change a borrower's PD and LGD?**



Carbon cost = Scope 1 emissions in tonnes of CO_2 × the carbon price per tonne. For the coal plant:

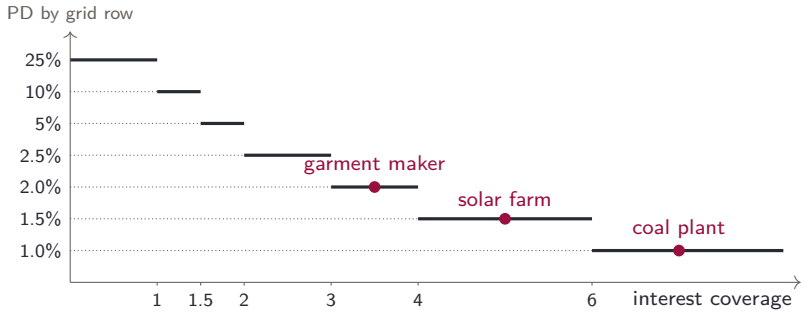
$$3.0 \text{ Mt} \times 100 = \text{USD } 300 \text{ m}.$$

Its EBITDA of 84 becomes −216, and its interest of 12 is unchanged. The plant passes none of the cost to its customers and receives no free allowances.

Stylised values.

At what carbon price does the coal plant's EBITDA fall to its interest of 12?

The coverage grid maps interest coverage to a probability of default



The grid stands for a rating model's probability of default (PD). Each row holds from its lower bound up to the next: coverage of 6 or more gives 1.0 per cent, 4 to 6 gives 1.5. Today the coal plant covers its interest 7.0 times, the solar farm 5.0, the garment maker 3.5. Stylised values.

A borrower earns EBITDA of 45 and pays interest of 10. What is its coverage, and what PD does the grid give?

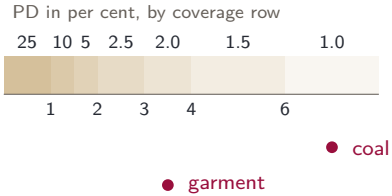
The coal plant and the garment maker at 100 dollars of 2010 per tonne

Coal power plant

$$\text{carbon cost} = 3.0 \times 100 = 300$$
$$\text{EBITDA} = 84 - 300 = -216$$
$$\text{coverage} = -216/12 = -18.0$$
$$\text{PD} =$$

Garment maker

$$\text{carbon cost} = 0.04 \times 100 = 4$$
$$\text{EBITDA} = 35 - 4 = 31$$
$$\text{coverage} = 31/10 = 3.1$$
$$\text{PD} =$$



At 100 US dollars of 2010 per tonne.

Stylised values.

The coal plant passes 85 per cent of its carbon cost to its customers. What coverage and what PD does it reach?

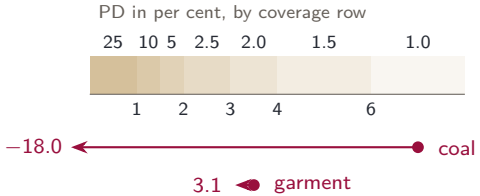
The coal plant and the garment maker at 100 dollars of 2010 per tonne

Coal power plant

$$\text{carbon cost} = 3.0 \times 100 = 300$$
$$\text{EBITDA} = 84 - 300 = -216$$
$$\text{coverage} = -216/12 = -18.0$$
$$\text{PD} = 1.0\% \;\rightarrow\; 25\%$$

Garment maker

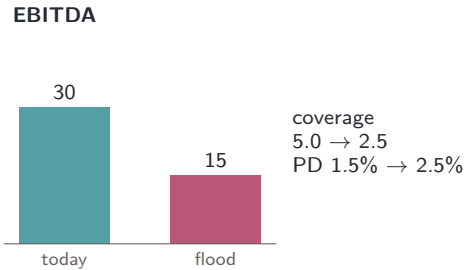
$$\text{carbon cost} = 0.04 \times 100 = 4$$
$$\text{EBITDA} = 35 - 4 = 31$$
$$\text{coverage} = 31/10 = 3.1$$
$$\text{PD} = 2.0\% \;\rightarrow\; 2.0\%$$

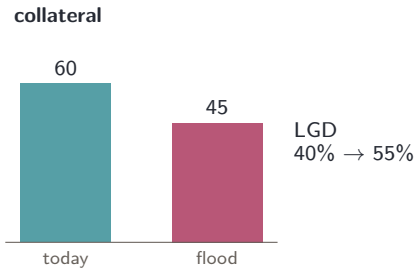


At 100 US dollars of 2010 per tonne. The coal plant falls six rows to the last; the garment maker stays in its row. Stylised values.

The coal plant passes 85 per cent of its carbon cost to its customers. What coverage and what PD does it reach?

A flood cuts the solar farm's EBITDA and the value of its collateral

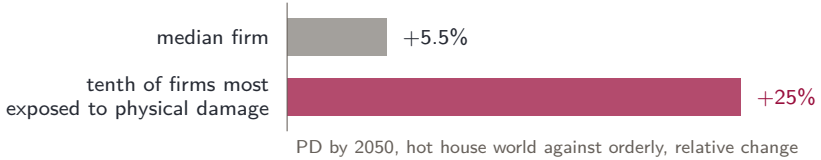




The stress-test flood, a 1-in-100-year event, removes 15 of the solar farm's EBITDA for the year and 25 per cent of the value of its collateral. With LGD $= 1 -$ collateral/exposure, the farm's EL rises from $1.5\% \times 40\% \times 100 = 0.60$ to $2.5\% \times 55\% \times 100 = 1.375$. Stylised values.

A flood removes 9 of the farm's EBITDA and 20 per cent of its collateral. What PD, LGD and expected loss follow?

Firm-level models raise hot-house PDs most where physical risk is high



The ECB's economy-wide stress test is a firm-level model of PDs under NGFS scenarios. By 2050 the hot-house scenario raises the median firm's PD by 5.5% and the PD of the firms with the highest physical risk by almost 25%, both relative to the orderly transition.

Alogoskoufis et al. (2021), ECB Occasional Paper 281: section 5.3, p. 44; section 5.5, p. 49.

A borrower's PD of 2.0 per cent rises by 25% in relative terms. What PD does the bank use?

A cement plant at 100 dollars of 2010 per tonne

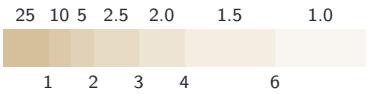
EBITDA	interest	Scope 1	carbon price	LGD
52	10	0.4	100	45
USD m	USD m	Mt CO_2	USD per t	per cent

A cement plant borrows USD 100 m; carbon costs 100 US dollars of 2010 per tonne. In pairs, eight minutes:

1. its coverage and PD today, from the grid;
2. its carbon cost, EBITDA and coverage at the carbon price;
3. its PD and expected loss under the stress test.

Stylised values.

PD in per cent, by coverage row

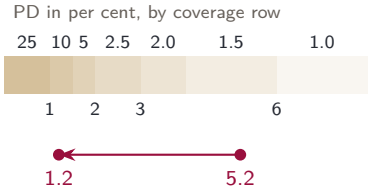


cement plant: which row?

The cement plant's PD rises from 1.5 to 10 per cent

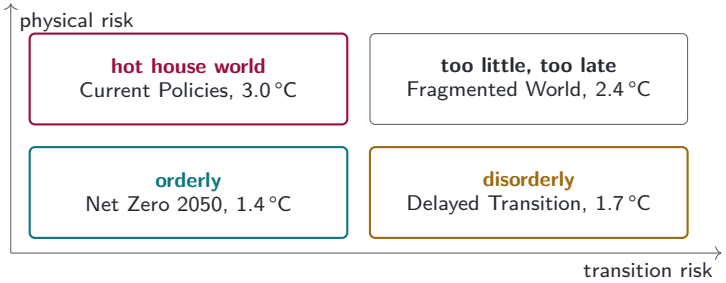
$$\text{coverage today} = 52/10 = 5.2 \qquad \text{PD } 1.5\%$$
$$\text{carbon cost} = 0.4 \times 100 = 40$$
$$\text{EBITDA} = 52 - 40 = 12$$
$$\text{coverage} = 12/10 = 1.2 \qquad \text{PD } 10\%$$
$$\text{EL} = 1.5\% \times 45\% \times 100 = 0.675$$
$$\rightarrow 10\% \times 45\% \times 100 = 4.5$$

A carbon cost of 40 takes the cement plant from the second row of the grid to the sixth, and its expected loss rises from 0.675 to 4.5. Stylised values.



NGFS scenarios differ in transition risk and in physical risk

1 2 **3** 4 **How does a bank measure the loss across scenarios?**

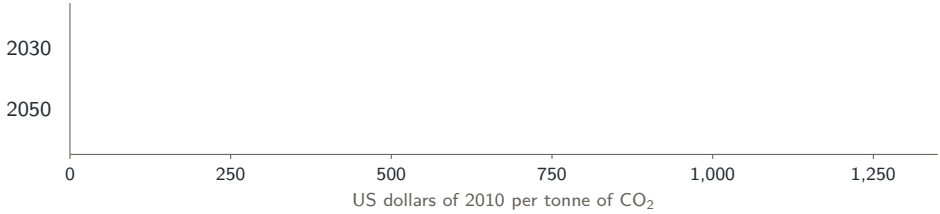


Warming by 2100, NGFS model averages. Orderly acts early, disorderly late and abruptly; hot house world keeps current policies. On the three loans orderly applies the carbon price, hot house world the flood, and disorderly both. Stylised values.

NGFS (2024), long-term scenarios for central banks and supervisors, Phase V, p. 10.

A late, sharp policy turn holds warming near 1.7 °C. Which module of the stress test does it apply?

Net Zero 2050 carbon price in 2030

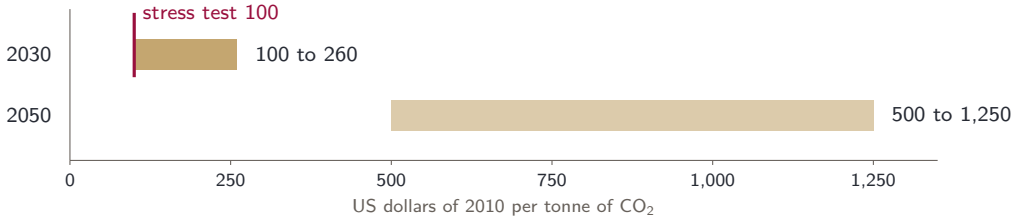


How high does the Net Zero 2050 carbon price reach in 2030, across the NGFS models?

NGFS (2025), long-term scenarios, narratives and key findings, Net Zero 2050, p. 10.

At the top of the 2030 range, 260 dollars a tonne, what coverage and PD does the garment maker reach?

Net Zero 2050 carbon price in 2030



How high does the Net Zero 2050 carbon price reach in 2030, across the NGFS models? The models span 100 to 260, and the stress test's 100 sits at the foot of that range.

NGFS (2025), long-term scenarios, narratives and key findings, Net Zero 2050, p. 10.

At the top of the 2030 range, 260 dollars a tonne, what coverage and PD does the garment maker reach?

The three loans under three NGFS families

	today	orderly	hot house world	disorderly
coal plant	0.45			
solar farm	0.60			
garment maker	0.90			
book	**1.95**			

Expected loss of the three loans in USD m, by NGFS family. Stylised values.

A port in the Mekong delta emits nothing and floods often. Under which of the three families does its expected loss rise?

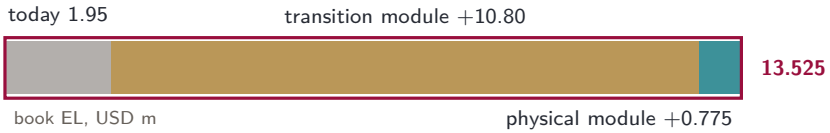
The three loans under three NGFS families

	today	orderly	hot house world	disorderly
coal plant	0.45	11.25	0.45	11.25
solar farm	0.60	0.60	1.375	1.375
garment maker	0.90	0.90	0.90	0.90
book	**1.95**	**12.75**	**2.725**	**13.525**

Expected loss of the three loans in USD m, by NGFS family. Stylised values.
In the disorderly column the coal plant loses 11.25, the solar farm 1.375 and the garment maker 0.90: the reverse of today's PD ranking. Orderly falls on the emitters, hot house world on the asset in the flood plain.

A port in the Mekong delta emits nothing and floods often. Under which of the three families does its expected loss rise?

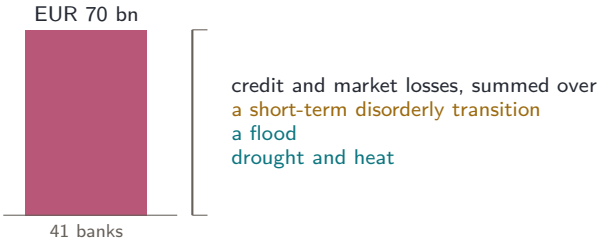
A stress test sums a transition module and a physical module



In the stress test the transition module applies the carbon price alone and adds 10.80 to the book's expected loss, all of it on the coal plant. The physical module applies the flood alone and adds 0.775 on the solar farm. No loan takes both shocks, so the disorderly loss is today's 1.95 plus the two additions, 13.525. The ECB's 2022 test summed its modules the same way. Stylised values.

The coal plant passes 85 per cent of its carbon cost on. What does the transition module add, and what is the book's disorderly expected loss?

The ECB's 2022 test put losses near EUR 70 billion for 41 banks



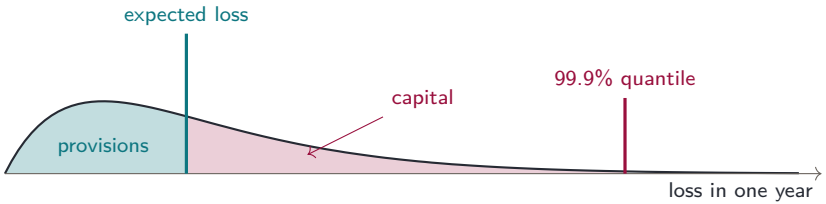
The total covers three modules run one at a time, credit and market losses only, for the 41 banks that projected them. The ECB's own verdict: "this estimate significantly understates the actual risk".

ECB Banking Supervision (2022), 2022 climate risk stress test, Executive summary, p. 5.

Which two of the four bank risks does the EUR 70 billion leave out?

Provisions cover expected loss, and capital covers loss to the 99.9% quantile

1 2 3 **4** **What does a bank do about the loss it measures?**

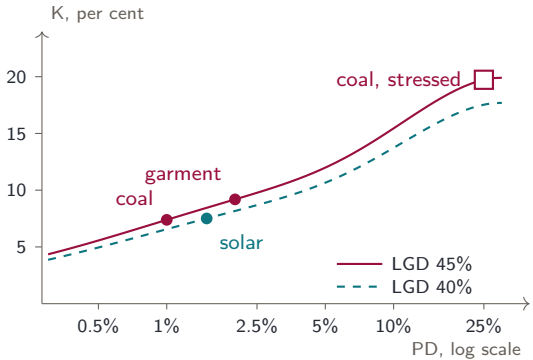


A bank provisions the loss it expects, PD $\times$ LGD $\times$ exposure, and charges it to profit. It holds capital for the unexpected loss, up to the 99.9% quantile of the loss distribution: one year in a thousand the loss exceeds the two together. Stylised positions.

BCBS (2006), International Convergence of Capital Measurement and Capital Standards, paragraph 272.

A loss distribution has a mean of 2 and a 99.9% quantile of 12. What does the bank provision, and what capital does it hold?

The IRB formula sets capital per unit of exposure from PD and LGD



The IRB formula gives capital per unit of exposure:

$$K = \text{LGD} \times \Big[q(\text{PD}) - \text{PD}\Big] \times \text{MA}(M),$$

with q the default rate at the 99.9% quantile and MA a maturity adjustment, at $M = 2.5$ years. K rises steeply at low PDs and flattens above 10 per cent. With LGD set from the bank's own collateral, the approach is advanced IRB.

BCBS, Basel Framework, CRE31.5; BCBS (2006), Annex 5.

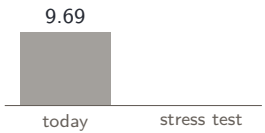
Read K at a PD of 10 per cent and an LGD of 45 per cent off the curve.

Capital for the coal loan, today and under the stress test

	today	stress test
PD, LGD	1.0%, 45%	25%, 45%
K	7.385%	
RWA $= 12.5 \times K \times 100$	92.31	
capital $=$ 10.5% of RWA	9.69	

Capital is 10.5% of risk-weighted assets: the 8.0% minimum plus the 2.5% conservation buffer. USD m on the coal loan of 100, today and under the stress test.

BCBS (2011), Basel III, Annex 1, p. 64.



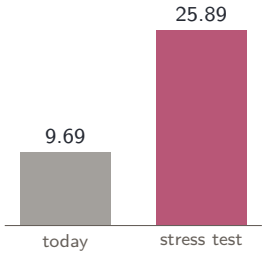
Stylised values.

What capital does the garment maker's loan need, at a PD of 2.0 per cent and an LGD of 45 per cent?

Capital for the coal loan, today and under the stress test

	today	stress test
PD, LGD	1.0%, 45%	25%, 45%
K	7.385%	19.728%
RWA $= 12.5 \times K \times 100$	92.31	246.60
capital $=$ 10.5% of RWA	9.69	**25.89**

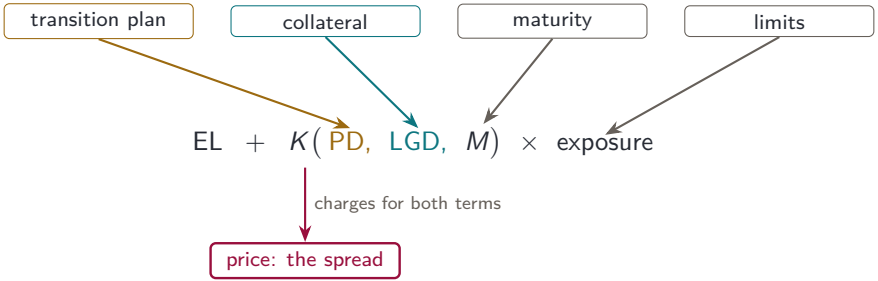
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BCBS (2011), Basel III, Annex 1, p. 64.



Stylised values.

What capital does the garment maker's loan need, at a PD of 2.0 per cent and an LGD of 45 per cent?

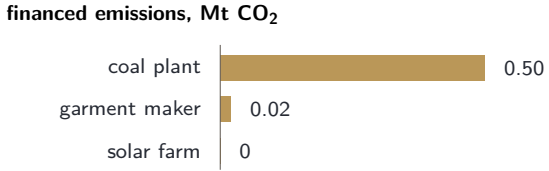
Five levers act on expected loss, capital and the spread

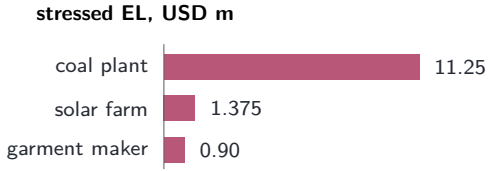


Five levers: a transition plan that cuts Scope 1 lowers the carbon cost and the PD; collateral lowers LGD; shorter tenor lowers M; sector limits lower the exposure. The spread charges for the expected loss and the cost of capital.
BCBS (2022), Principles for the effective management and supervision of climate-related financial risks, Principle 8, paragraph 37, p. 6: client engagement, shorter tenor, lower loan-to-value limits, loan limits.

Collateral cuts the coal loan's stressed LGD to 30 per cent. What K and what capital follow?

Financed emissions rank the three loans unlike expected loss





PCAF attributes a borrower's emissions to the lender by its share of the borrower's financing, the outstanding amount over EVIC: 100 of 600 for the coal plant, 100 of 200 for the garment maker. Emissions reporting and credit risk read one book in two orders. Stylised values.

PCAF (2025), Global GHG Accounting and Reporting Standard, Part A, section 5.2, p. 58.

The bank sells half of the coal loan. What are the book's financed emissions and its stressed expected loss?

Four answers

1	Which climate risks reach a bank's loans?	Physical drivers (acute, chronic) and transition drivers (policy, technology, and market and customer sentiment) reach borrowers and the economy. They arrive as credit, market, liquidity and operational risk, credit first for a lender.
2	How does a hazard change a borrower's PD and LGD?	A carbon price is a cost against EBITDA, and a flood cuts EBITDA and collateral. Lower coverage raises PD through the grid, and lower collateral raises LGD.
3	How does a bank measure the loss across scenarios?	It applies a scenario's carbon price and hazards to every borrower and sums PD $\times$ LGD $\times$ exposure: orderly falls on emitters, hot house world on exposed assets, disorderly on both.
4	What does a bank do about the loss it measures?	It provisions expected loss and holds IRB capital against loss to the 99.9% quantile. Collateral, limits, maturity and the transition plan move the terms of EL $+$ $K\times$ exposure, and the price charges for both in the spread.

Sources

- Alogoskoufis, S., et al. (2021). ECB economy-wide climate stress test. ECB Occasional Paper 281, sections 5.3 and 5.5.
- BCBS (2006). International Convergence of Capital Measurement and Capital Standards, comprehensive version: paragraph 272; Annex 5. Basel Framework, CRE31.5.
- BCBS (2011). Basel III: A global regulatory framework for more resilient banks and banking systems, revised June 2011: Annex 1, p. 64.
- BCBS (2021). Climate-related risk drivers and their transmission channels: pp. 1, 3, 6, 9 and vi.
- BCBS (2022). Principles for the effective management and supervision of climate-related financial risks: Principle 8, paragraph 37.
- ECB Banking Supervision (2022). 2022 climate risk stress test: Executive summary, p. 5.
- NGFS (2024). NGFS long-term scenarios for central banks and supervisors, Phase V: warming by 2100, p. 10.
- NGFS (2025). NGFS long-term scenarios, narratives and key findings: Net Zero 2050 carbon price, p. 10.
- PCAF (2025). Global GHG Accounting and Reporting Standard, Part A, December 2025: section 5.2, p. 58.
- World Bank (2012). Thai Flood 2011: Rapid Assessment for Resilient Recovery and Reconstruction Planning, Overview: p. 2; Table 1, p. 4.

Read between 26 September and 2 October 2026.

Use of generative AI

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).

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 2 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 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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Six checkpoint questions

1. Sea-level rise salts the paddy fields that supply a Mekong rice processor. Which family and driver is that, and which bank risk does it create for the processor's lender?
2. Why does a rating model fitted on the defaults of 2010 to 2024 rate the coal plant at 1.0 per cent?
3. A steel mill earns EBITDA of 96, pays interest of 15 and emits 0.5 Mt. What are its coverage and PD today, and at 100 dollars a tonne?
4. Collateral of 80 secures a loan of 100, and a flood cuts its value by 30 per cent. At a PD of 2 per cent, what are LGD and expected loss before and after?
5. Which NGFS family raises the solar farm's PD and leaves the coal plant at 1.0 per cent?
6. A loan of 100 has a PD of 5 per cent and an LGD of 45 per cent, with $K = 11.988$ per cent. What capital does it need at 10.5% of RWA, and what if collateral cuts LGD to 30 per cent, with $K = 7.992$?

Stylised values.



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Climate risk in a loan book, from hazard to capital - Module 4 Green Finance Risk Management, lecture

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The project site is https://digital-ai-finance.github.io/Green-Finance. A question about this file goes to joerg.osterrieder@utwente.nl.

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