Lesson 4.4

Carbon Metrics and Climate Value-at-Risk

Quantifying Portfolio Exposure

Module 4: Green Finance Risk Management

GREEN FINANCE micro-credential

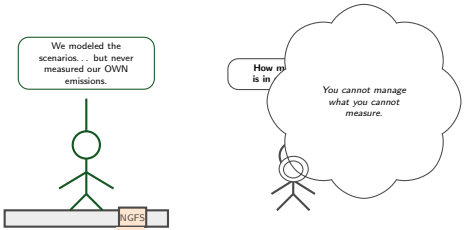
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Why Could a Bank Not Answer "How Much Carbon Exposure Do We Have?"

[FOUNDATION]

Situation: A risk manager has completed the scenario analysis (L4.3). NGFS pathways modeled. Fan charts produced. The board asks: "How much carbon is in our portfolio?"
Complication: The risk manager looks at a stack of scenario reports and says: "We modeled the scenarios... but we never measured our own emissions."

- Scenario analysis tells you **what MIGHT happen**
- Carbon metrics tell you **how much you are EXPOSED**
- Without measurement, risk management is guesswork



Scenario analysis tells you what MIGHT happen.
Carbon metrics tell you how much you are EXPOSED.

You cannot manage what you cannot measure. Carbon metrics turn scenario narratives into portfolio-level numbers.

From Modeled Scenarios to the Bank's Own Carbon

[FOUNDATION]

Scenarios Modeled (Lesson 4.3)

- NGFS pathways **established**: Orderly, Disorderly, Hot House World
- Monte Carlo uncertainty **quantified** via fan charts
- Sectoral PD/LGD shocks **calibrated** from scenario variables
- But the bank does not yet know its **own carbon footprint**

"We know what the world might do to us. But how much are we exposed?"

Now Measure the Exposure (Lesson 4.4)

- Calculate **financed emissions** for every borrower using PCAF
- Compute **portfolio WACI** to benchmark carbon intensity
- Estimate **Climate Value-at-Risk** under those same scenarios
- Build a **carbon dashboard** that quantifies the exposure

Key Insight

L4.3 told you what the **WORLD** might do. L4.4 measures what **YOUR PORTFOLIO** is exposed to.

Scenario analysis is the telescope. Carbon metrics are the ruler. You need both to navigate climate risk.

Road Map: From Emissions Accounting to Climate Value-at-Risk

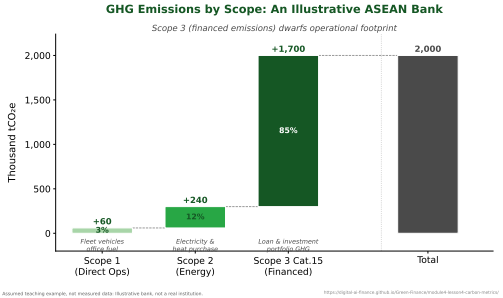
Section	Slides	Central Question
Introduction	1 to 4	Why can't scenario analysis alone quantify exposure?
Context	5 to 9	How do you measure a portfolio's carbon footprint?
Challenge	10 to 15	What are the data gaps in ASEAN carbon measurement?
Analysis	16 to 24	How do you translate carbon metrics into financial risk (CVaR)?
Resolution	25 to 30	What does the Vietnam banking sector reveal about CVaR?
Summary	31 to 33	What should you remember?

The lesson follows a **case-based** arc: we open with a risk manager who cannot answer "how much carbon?", build the measurement toolkit (GHG scopes, financed emissions, WACI, PCAF), surface the ASEAN data challenges, deepen to CVaR and carbon beta at PhD level, and resolve with the Vietnam case study, where the agriculture-coal CVaR inversion provides a counterintuitive punchline.

Lesson 4.4 of 6 in Module 4. Foundation level with Intermediate and PhD extensions.

What Are Scope 1, Scope 2, and Scope 3 Emissions?

[FOUNDATION]



Three GHG Protocol Scopes

- **Scope 1** (direct): company vehicles, on-site generators: ∼3% of a bank's total
- **Scope 2** (purchased energy): electricity, heating, ∼12% of total
- **Scope 3 Cat. 15** (financed emissions): the lending portfolio, ∼**85%** of total

For financial institutions, Scope 3 dwarfs Scope 1+2. This is why PCAF (Partnership for Carbon Accounting Financials) was created: to standardize the calculation of financed emissions.

Key Insight

Scope 3 has 15 categories. Category 15 ("investments") is the one relevant to banks and asset managers.

For banks, ∼85% of emissions are financed emissions (Scope 3 Category 15). This is why PCAF was created.

How Do You Calculate Financed Emissions?

[FOUNDATION]

The PCAF Financed Emissions Formula

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

where $Outstanding_i$ = bank's outstanding loan amount to borrower i, $EVIC_i$ = Enterprise Value Including Cash of borrower i (the **attribution factor**), and $Emissions_i$ = absolute GHG emissions of borrower i (Scope 1 + Scope 2, optionally Scope 3).

Portfolio total: $FE_{portfolio} = \sum_i FE_i$

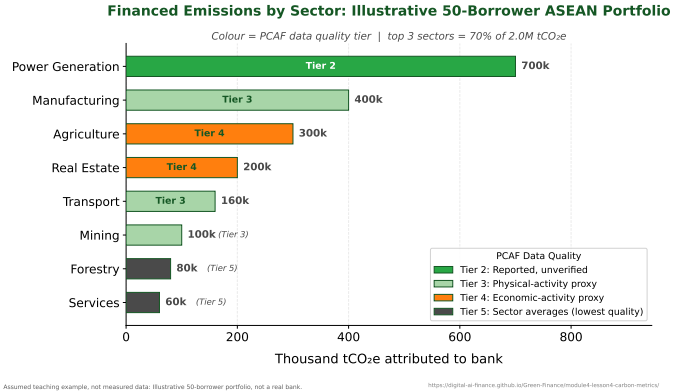
Worked Example: Vietnamese steel company.
Outstanding loan = **$**50M. EVIC = **$**500M. Borrower emissions = 200,000 tCO_2e.
$FE = \frac{50}{500} \times 200{,}000 =$ **20,000** tCO_2e attributed to the bank.

The attribution factor $Outstanding_i / TotalAssets_i$ ensures each bank is responsible only for its share of borrower emissions. If three banks each lend to the same steel company, the emissions are split proportionally.

The financed emissions formula is the foundation of carbon accounting for financial institutions. PCAF standardized this calculation globally.

What Does a Financed Emissions Portfolio Look Like?

[FOUNDATION]



- **Concentration risk:** 3 sectors account for ∼70% of financed emissions (power, manufacturing, agriculture)
- **Data quality deteriorates** for agriculture and forestry: these rely on PCAF Tier 4 to 5 estimates
- Portfolio-level financed emissions = **2.0 million tCO$_2$e** for this $2B synthetic ASEAN portfolio

Three sectors typically account for 70%+ of a bank's financed emissions. Focus measurement efforts where the carbon is concentrated.

What Is WACI and Why Is It the Industry Standard?

[FOUNDATION]

WACI Formula

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

where w_i = portfolio weight (% of total portfolio value), $Emissions_i / Revenue_i$ = carbon intensity (tCO_2e per \$M revenue) of company i.

WACI normalizes for company size: a \$10B utility and a \$100M manufacturer are compared on equal footing.

WACI is recommended by TCFD and used by >80% of signatories. It is the most widely reported portfolio carbon metric.

Worked Example

3-company portfolio:

(A) Power utility: $w = 40\%$, intensity = 800 tCO_2e/\$M
(B) Manufacturer: $w = 35\%$, intensity = 200 tCO_2e/\$M
(C) Tech firm: $w = 25\%$, intensity = 15 tCO_2e/\$M

$WACI = 0.40 \times 800 + 0.35 \times 200 + 0.25 \times 15$
$= 320 + 70 + 3.75 =$ **393.75** tCO_2e/\$M

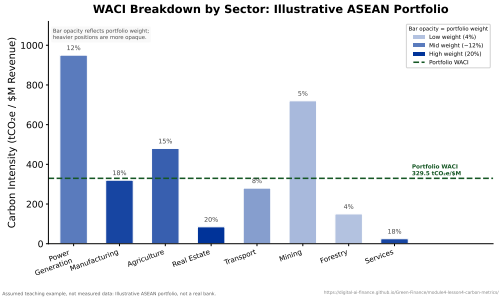
Key Insight

WACI reveals that the power utility contributes 81% of portfolio carbon intensity despite being only 40% of portfolio value.

WACI is the TCFD-recommended metric for portfolio carbon intensity. It normalizes for company size and is comparable across portfolios.

How Does WACI Vary Across Our ASEAN Portfolio?

[FOUNDATION]



ASEAN Portfolio vs Benchmarks

- **ASEAN portfolio WACI:** 329.5 $tCO_2e/\$M$ (derived from the sector bars)
- Benchmarking needs a *stated* reference: alignment is defined relative to a parent index, not against a fixed absolute threshold
- No body publishes a global average WACI, so compare against a named index

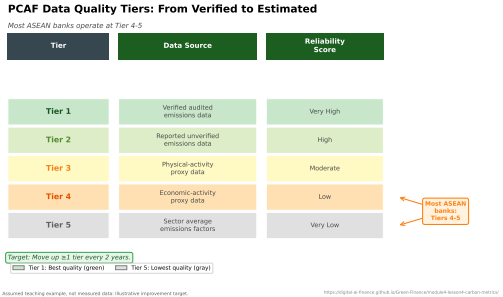
Why is ASEAN higher?

- Power generation drives WACI due to coal-heavy ASEAN energy mix
- ASEAN portfolios tend 40% higher than global average
- Reducing WACI requires **divesting** from high-carbon sectors or **engaging** borrowers to decarbonize

ASEAN portfolios typically have 30 to 50% higher WACI than global peers due to coal-intensive energy mix and agricultural dependence.

How Does PCAF Score Data Quality?

[INTERMEDIATE]



Five PCAF Data Quality Tiers

- **Tier 1:** Verified audited emissions, highest confidence
- **Tier 2:** Reported unverified data
- **Tier 3:** Physical-activity-based estimates
- **Tier 4:** Economic-activity-based estimates
- **Tier 5:** Sector average proxies, lowest confidence

ASEAN reality: Most banks rely on Tiers 4 to 5 due to limited borrower reporting. The tier is the honest width of the number: report it beside every metric.

Intermediate: Data quality is the Achilles heel of carbon metrics in ASEAN. Most banks operate at PCAF Tier 4 to 5, on sector-average estimates. PCAF's scale is ordinal, so a tier ranks confidence.

How Do PACTA, TPI, and SBTi Compare as Alignment Tools?

[FOUNDATION]

PACTA
Paris Agreement Capital Transition Assessment

- Sector decarbonization **pathways**
- Portfolio alignment with $2^{\circ}C$ or $1.5^{\circ}C$
- Developed by 2DII
- Covers 7 to 8 climate-relevant sectors globally

"Is my portfolio on a Paris-consistent pathway?"

TPI
Transition Pathway Initiative

- **Dual evaluation**: governance + emissions trajectory
- Management quality score (0 to 4)
- Carbon performance assessment
- 450+ companies assessed

"Are companies governing their transition seriously?"

SBTi
Science Based Targets initiative

- Company-level **target validation**
- Certifies consistency with climate science
- 7,000+ companies committed
- Near-term and net-zero targets

"Are their emissions targets science-based?"

Cross-Tool Observation

Use together: **PACTA** for portfolio-level pathway, **TPI** for company governance, **SBTi** for target validation. No single tool is sufficient.

No single alignment tool is sufficient. PACTA, TPI, and SBTi each answer a different question about portfolio alignment.

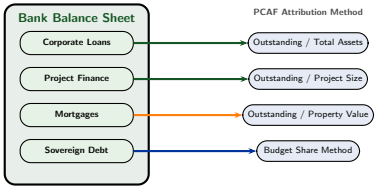
How Does PCAF Apply to Different Asset Classes?

[INTERMEDIATE]

PCAF Attribution by Asset Class

Asset Class	Attribution Factor
Corporate loans	Outstanding / (Total equity + Total debt)
Project finance	Outstanding / Total project size
Mortgages	Outstanding / Property value at origination
Sovereign debt	Outstanding / PPP-adjusted GDP

Key: Using the wrong formula overstates or understates exposure by up to 3x. Mortgage attribution uses property value, not borrower total assets.



Intermediate: PCAF provides asset-class-specific attribution formulas. Using corporate-loan methodology for mortgages can misstate exposure by 3x.

Can You Calculate WACI for a Sample ASEAN Portfolio?

[INTERMEDIATE]

10-Borrower ASEAN Portfolio

#	Country	Sector	w_i	CI	Tier
1	VN	Power	15%	920	2
2	TH	Power	12%	780	3
3	PH	Manufacturing	11%	310	3
4	VN	Agriculture	10%	450	5
5	TH	Real Estate	10%	85	4
6	VN	Manufacturing	9%	280	4
7	PH	Agriculture	8%	520	5
8	TH	Transport	10%	190	3
9	VN	Services	8%	25	4
10	PH	Services	7%	30	5

CI = $tCO_2e/\$M$ revenue.

Three Data Challenges

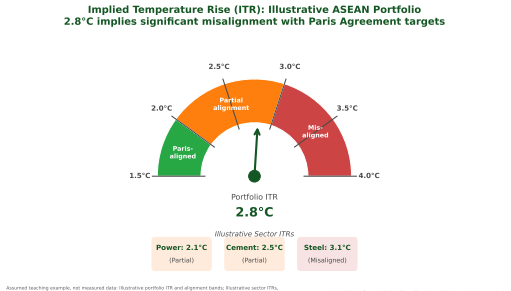
1. **Gap-filling:** 4 of 10 borrowers have no reported emissions: must use sector averages (Tier 5)
2. **Normalization:** Revenue in local currency must be converted to USD at consistent exchange rates
3. **Double counting:** A conglomerate with power and manufacturing divisions: how to avoid counting twice?

Result:
$WACI = \sum w_i \times CI_i = \mathbf{394}$ $tCO_2e/\$M$
Data-quality-weighted uncertainty: $\pm 28\%$

Intermediate: Calculating WACI for an ASEAN portfolio requires gap-filling for $\sim$40% of borrowers. Uncertainty ranges of $\pm$25 to 50% are common.

What Is the Implied Temperature Rise (ITR) of a Portfolio?

[INTERMEDIATE]



How ITR Works

ITR maps a portfolio's emissions trajectory to a temperature outcome: "If every company had the same trajectory, what temperature would we reach?"

Calculation outline:

1. Compute portfolio's current emissions trajectory (WACI trend)
2. Compare against IEA/PACTA sector decarbonization pathways
3. Convert overshoot/undershoot into temperature delta

ASEAN-specific: Typical ASEAN bank portfolio ITR: 2.5 to 3.2°C, primarily driven by coal power and agricultural exposure.

Illustrative sector ITRs (Module 4's example portfolio)

Power: 2.1°C | Cement: 2.5°C | Steel: 3.1°C

Intermediate: ITR translates carbon metrics into a single temperature number. Most ASEAN portfolios imply 2.5 to 3.2°C warming: well above Paris targets.

Why Is Carbon Measurement in ASEAN So Challenging?

[INTERMEDIATE]

Four ASEAN Data Challenges

1. **Low Scope 1/2 coverage:** Only ∼15% of ASEAN listed companies report verified emissions (vs ∼60% in EU)
2. **Scope 3 near-zero:** Almost no ASEAN firms report value chain emissions, forcing reliance on sector proxies
3. **Sector-proxy limitations:** Global sector averages do not reflect ASEAN intensity (e.g., Thai cement is 20% more carbon-intensive than EU cement)
4. **PCAF Tier 4 to 5 reliance:** >80% of ASEAN bank calculations use economic-activity estimates or sector averages

What Can Be Done?

1. **Mandatory reporting:** Vietnam's Green Finance Roadmap 2025, Thailand's SEC ESG disclosure requirements
2. **Capacity building:** Train borrowers on emissions measurement and verification
3. **Technology:** Satellite imagery, AI-based estimation models for agricultural emissions
4. **Regional collaboration:** ASEAN Taxonomy Board emissions data initiative

Key Insight

Acknowledge the uncertainty: do not hide it. PCAF Tier 4 to 5 data is better than no data, but report the uncertainty range alongside every metric.

Intermediate: Only ∼15% of ASEAN listed firms report verified emissions. Carbon metrics in ASEAN are inherently uncertain: acknowledge this, don't hide it.

What Is Climate Value-at-Risk (CVaR)?

[PhD]

The CVaR Formula

$$CVaR = Portfolio_{t_0} - \mathbb{E}[Portfolio_{t_T} \mid Scenario]$$

where $Portfolio_{t_0}$ = current portfolio value, $\mathbb{E}[Portfolio_{t_T} \mid Scenario]$ = expected portfolio value at horizon T conditional on a climate scenario.

Interpretation: CVaR is the expected loss of portfolio value due to climate change under a specified scenario. It is **NOT** the same as standard VaR.

Three key distinctions from standard VaR:

1. CVaR is **scenario-conditional**, not probabilistic (no confidence level)
2. CVaR has a **multi-decade horizon** (vs 1 to 10 day standard VaR)
3. CVaR decomposes into **Physical** and **Transition** components

Example: Portfolio value today = **$**2B. Expected value under Hot House 2050 = **$**1.62B.
$CVaR = \$2B - \$1.62B = \$380M$ (19% of portfolio value at risk).

PhD: CVaR is the central risk metric connecting carbon metrics to financial loss. It answers: how much value could my portfolio lose under this climate scenario?

How Does CVaR Connect Carbon Metrics to Financial Loss?

[PhD]

Five-Step CVaR Calculation Pipeline

1. **Step 1: Measure** financed emissions per borrower using the PCAF formula (slide 6)
2. **Step 2: Map** emissions to scenario exposure using NGFS pathways (from Lesson 4.3)
3. **Step 3: Estimate** climate-adjusted PD for each borrower
   - Physical channel: flood/drought frequency → PD increase
   - Transition channel: carbon tax → operating cost → PD increase
4. **Step 4: Estimate** climate-adjusted LGD for each borrower
   - Collateral damage under physical scenarios (e.g., uninsured crop destruction)
5. **Step 5: Aggregate** across portfolio: $CVaR = \sum_i Exposure_i \times \Delta PD_i \times LGD_i$

Key Insight

Carbon metrics (slides 5 to 14) provide the **INPUT**. CVaR is the **OUTPUT**. The pipeline chains four lessons: L4.1 (identify) → L4.2 (frameworks) → L4.3 (scenarios) → L4.4 (measure and quantify).

PhD: The CVaR pipeline chains four lessons together: L4.1 (identify risk), L4.2 (frameworks), L4.3 (scenarios), L4.4 (measure and quantify).

How Do You Calculate Physical CVaR?

[PhD]

Physical CVaR Formula

$$Physical\ CVaR = \sum_i Exposure_i \times PD_i^{climate} \times LGD_i$$

where $PD_i^{climate}$ = climate-adjusted probability of default, LGD_i = climate-adjusted loss given default.

Two components:

- **Acute:** extreme weather events (typhoons, floods, droughts)
- **Chronic:** gradual changes (sea level rise, temperature increase, water stress)

Worked Example

Vietnamese rice farming borrower:

Exposure = **$**10M
Baseline PD = 5%
Climate-adjusted PD (Hot House 2050) = 12%
(Mekong Delta flood frequency doubles)
Baseline LGD = 45%
Climate-adjusted LGD = 65%
(uninsured crop destruction)

Physical CVaR contribution:
$= \$10M \times (12\% - 5\%) \times 65\%$
$= \$10M \times 7\% \times 65\%$
$= \mathbf{\$455{,}000}$

PhD: Physical CVaR captures the financial loss from extreme weather and gradual environmental degradation. For ASEAN, this typically dominates total CVaR.

How Do You Calculate Transition CVaR?

[PhD]

Transition CVaR Formula

$$\textit{Transition CVaR} = \sum_i \textit{Exposure}_i \times \Delta PD_i^{carbontax} \times LGD_i$$

where $\Delta PD_i^{carbontax}$ = change in PD due to carbon pricing, stranded assets, or technology disruption.

Three transition channels:

- **Carbon pricing:** direct cost increase for emitters
- **Stranded assets:** fossil fuel reserves that cannot be burned
- **Technology shift:** competitive displacement by clean alternatives

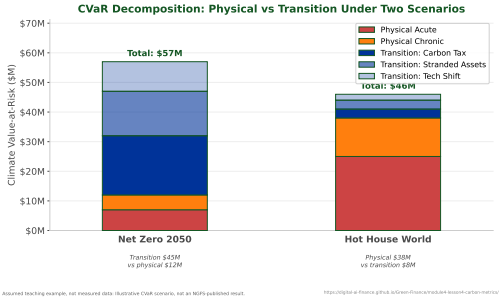
Worked Example

Vietnamese coal power company:
Exposure = \$20M
Baseline PD = 3%
Carbon tax at \$75/tCO_2 by 2035:
$\rightarrow$ operating costs increase by 40%
$\rightarrow$ new PD = 18%
ΔPD = 15%
LGD = 55% (partially recoverable plant assets)
Transition CVaR contribution:
= $\$20M \times 15\% \times 55\%$
= **\$1,650,000**

PhD: Transition CVaR captures losses from policy shifts, stranded assets, and technology disruption. For fossil-fuel-heavy exposures, it can exceed physical CVaR.

How Do Physical and Transition CVaR Compare Across Scenarios?

[PhD]



Two NGFS Scenarios Compared

Net Zero 2050:

- Transition CVaR = $45M (**dominates**)
- Physical CVaR = $12M

Hot House World:

- Physical CVaR = $38M (**dominates**)
- Transition CVaR = $8M

Key insights:

- The scenario **choice** determines which CVaR component dominates
- Net Zero = transition pain now, physical relief later
- Hot House = physical pain later, no transition cost
- Robust risk framework must estimate **both** under **multiple** scenarios

PhD: The scenario you choose determines which CVaR component dominates. A robust assessment requires both Physical and Transition CVaR under multiple pathways.

Can You Visualize the CVaR Framework as a Decision Tree?

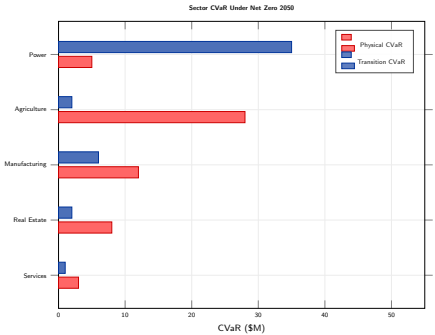
[PhD]

CVaR Summary Table

Component	Formula	Data Needed
Physical CVaR	$\sum Exp \times PD^{clim} \times LGD$	Flood/storm maps, PD models
Transition CVaR	$\sum Exp \times \Delta PD^{tax} \times LGD$	Carbon prices, sector costs
Total CVaR	Physical + Transition	Both channels

Typical ASEAN magnitudes:

- Physical CVaR: 5 to 20% of exposure
- Transition CVaR: 2 to 10% of exposure
- Total: 8 to 25% under worst-case scenario



PhD: CVaR composition is sector-dependent. Portfolio allocation determines whether physical or transition risk dominates your climate exposure.

What Is the Carbon Beta?

[PhD]

Carbon Beta Factor Model

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

where R_i = return on asset i, R_m = market return, $CarbonIntensity_i$ = carbon emissions per unit revenue of firm i, β_{carbon} = the carbon beta (cross-sectional pricing factor).

Interpretation: If $\beta_{carbon} > 0$, investors demand a **carbon premium**: higher returns for holding carbon-intensive assets, compensating for transition risk.

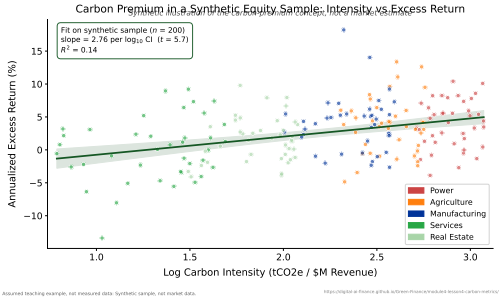
Bolton & Kacperczyk (2021) key findings:

- β_{carbon} is statistically significant and **positive** in US, EU, and global cross-sections
- Magnitude: $\sim$1.2 to 1.8% annual return premium per standard deviation of carbon intensity
- The premium is driven by **Scope 1** emissions (direct) more than Scope 2 or 3
- The premium has **increased** post-Paris Agreement (2015)

PhD: The carbon beta measures whether financial markets price carbon risk. Bolton & Kacperczyk (2021) found a significant carbon premium: high-carbon firms must offer higher returns.

Does the Carbon Premium Exist in ASEAN Markets?

[PhD]



ASEAN Carbon Premium Evidence

OLS regression on ∼200 synthetic ASEAN-listed firms:

$$R_i = \alpha + \beta_{carbon} \times \log(CI_i) + \varepsilon_i$$

The figure reports the slope, t and R^2 fitted from its own sample.

Key findings:

- The carbon premium **exists** in ASEAN, though weaker than US/EU
- Power and manufacturing **drive** the premium
- Services show **no significant** carbon pricing
- Implication: carbon-intensive ASEAN firms may face rising cost of capital

Reference: Bolton & Kacperczyk (2021) methodology replicated with synthetic ASEAN data.

PhD: Bolton & Kacperczyk (2021) found a carbon premium in the US cross-section; their 2023 Journal of Finance paper extends the result to global markets. Emerging evidence suggests it exists in ASEAN markets too, though with more noise and weaker signal.

How Do You Test Carbon Policy Impact Empirically?

[PhD]

Event Study Approach

Natural experiment: Vietnam's Green Finance Roadmap announcement (2023).

- Measure **abnormal returns** for high-carbon vs low-carbon firms in the 5-day window around announcement
- Expected finding: **negative** abnormal return for coal/cement firms
- Expected finding: **positive** for renewable energy firms

Event studies identify how markets re-price assets in response to discrete policy signals: causal inference at its most direct.

Difference-in-Differences (DiD)

Design:

- Treatment: firms above median carbon intensity
- Control: firms below median
- Pre/post: policy announcement date

DiD estimator:

$$\hat{\delta} = (\bar{Y}_{treat,post} - \bar{Y}_{treat,pre}) - (\bar{Y}_{ctrl,post} - \bar{Y}_{ctrl,pre})$$

Key applications:

- Carbon tax impact on borrower PDs
- ASEAN Taxonomy impact on green bond spreads

Reference: Sautner et al. (2023) firm-level climate exposure methodology.

PhD: Event studies and DiD designs are the gold standard for estimating carbon policy impact. These methods support the empirical foundation for CVaR calibration.

Case Study: What Do Vietnam's Financed Emissions Reveal?

[FOUNDATION]

The Vietnamese banking sector has ∼18% agricultural loan exposure and ∼3% coal/fossil fuel exposure. Total banking sector assets: ∼$840B (mid-2024). The State Bank of Vietnam (SBV) has begun requiring climate risk assessments but has no financed emissions mandate yet.

Question: If we calculate financed emissions for a representative Vietnamese bank, which sectors dominate? And what happens when we compute CVaR: does coal or agriculture pose the bigger financial risk?

Vietnam Banking Sector Profile	Value	Source
Agricultural lending share	∼18%	SBV statistics
Coal/fossil fuel lending share	∼3%	SBV statistics
Total banking sector assets	∼$840B	SBV (2024)
PCAF data availability	Tier 4 to 5 predominantly	PCAF SE Asia Report
SBV regulatory status	Climate risk assessment required; FE mandate pending	SBV Green Finance Roadmap

ASEAN Case Study: Vietnam has ∼18% agricultural loan exposure and ∼3% coal exposure. The carbon metrics tell a surprising story.

How Do You Calculate Financed Emissions for a Vietnamese Bank?

[FOUNDATION]

Step-by-Step Calculation

Representative Vietnamese bank: $30B assets.

Sector	Exposure	Share
Agriculture	$5.4B	18%
Manufacturing	$4.5B	15%
Real estate	$6.0B	20%
Services	$8.4B	28%
Coal/Power	$0.9B	3%
Other	$4.8B	16%

PCAF formula applied per sector with sector-specific emission factors (Tier 4 to 5 estimates for most sectors).

Results

Sector	FE ($ktCO_2e$)	% of Total
Agriculture	810	38%
Manufacturing	540	25%
Coal/Power	360	17%
Real estate	180	8%
Services	120	6%
Other	120	6%
Total	**2,130**	**100%**

Key insight: Coal is 3% of loans but **17% of financed emissions**. Agriculture is 18% of loans and **38% of financed emissions**.

Financed emissions reveal hidden concentration: coal is 3% of the Vietnamese bank's portfolio but 17% of its carbon footprint.

What Happens When You Compute Physical vs Transition CVaR?

[INTERMEDIATE]

Agriculture Sector CVaR

Physical CVaR:
Exposure = $5.4B
Climate-adjusted $\Delta PD = +8\%$
(Mekong Delta flood frequency doubles under Hot House)
LGD = 65% (uninsured crop + livestock)

Physical CVaR = $5.4B $\times$ 8% $\times$ 65% = **$281M**

Transition CVaR:
Limited carbon tax exposure (subsistence agriculture exempt in most ASEAN proposals)

Transition CVaR = $5.4B $\times$ 1% $\times$ 45% = **$24M**

Coal/Power Sector CVaR

Physical CVaR:
Minimal: power plants are structurally resilient

Physical CVaR = $0.9B $\times$ 2% $\times$ 40% = **$7.2M**

Transition CVaR:
Exposure = $0.9B
Carbon tax at $\$75/tCO_2 \rightarrow \Delta PD = +15\%$
LGD = 55% (partially recoverable plant assets)

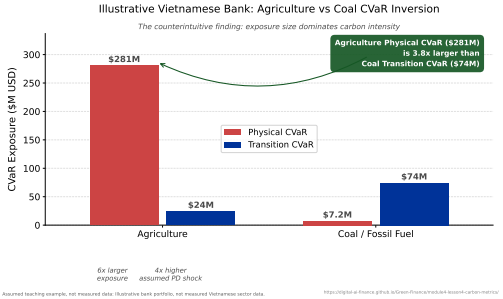
Transition CVaR = $0.9B $\times$ 15% $\times$ 55% = **$74M**

Agriculture Physical CVaR ($281M)
$\gg$ Coal Transition CVaR ($74M)

Intermediate: The counterintuitive finding: agriculture Physical CVaR of $281M far exceeds coal Transition CVaR of $74M. Flood risk dwarfs carbon tax risk.

Why Does Agriculture CVaR Exceed Coal CVaR?

[INTERMEDIATE]



Three Drivers of the Inversion

1. **Exposure size:** Agriculture is **6x larger** in the loan book (**$**5.4B vs **$**0.9B). Absolute loss scales with exposure.
2. **Physical vulnerability:** Mekong Delta rice farming is acutely exposed to flooding, drought, and salinity intrusion. Climate change approximately **doubles** severe event frequency.
3. **Insurance gap:** Agricultural output is far more thinly insured than power infrastructure, so uninsured losses flow directly to bank LGD.

Policy exemption: Most carbon pricing proposals exempt subsistence agriculture, further limiting transition risk.

Central Lesson

Exposure size and physical vulnerability can dominate carbon intensity in determining financial risk.

Intermediate: The agriculture-coal CVaR inversion is the central lesson. Exposure size and physical vulnerability can dominate carbon intensity in determining financial risk.

What Does the Full Carbon Dashboard Look Like?

[INTERMEDIATE]

Portfolio Carbon Dashboard: Representative Vietnamese Bank ($30B assets)

Financed Emissions

- Total: 2.13M tCO_2e
- Top 3: Agriculture (38%), Manufacturing (25%), Coal/Power (17%)

WACI

- Portfolio: 440 tCO_2e/$M revenue
- Benchmark against a named parent index; alignment is a relative cut, not an absolute ceiling

Implied Temperature Rise

- Portfolio ITR: 2.9°C (misaligned with Paris)

CVaR Summary

Scenario	Physical	Transition
Net Zero 2050	$80M	$180M
Hot House World	$420M	$35M

Agriculture is the largest single contributor under Hot House. Coal dominates under Net Zero.

Lab Deliverable

The carbon dashboard is the output students produce in the Quantitative Lab. Its figures are for the representative $30B Vietnamese bank of slides 26 to 27; the $2B synthetic 50-borrower portfolio used earlier is a separate example.

Intermediate: This carbon dashboard is the deliverable of the Quantitative Lab. Students build it for the representative Vietnamese bank; the $2B synthetic portfolio of slides 7 to 20 is a separate, smaller worked example.

What Are the Key Gaps in ASEAN Carbon Measurement?

[FOUNDATION] [INTERMEDIATE]

Five Gaps and How to Close Them

1. **Data coverage:** Only ∼15% of ASEAN firms report Scope 1/2; Scope 3 near-zero.
   → *Close with: mandatory reporting requirements, ASEAN Taxonomy Board emissions initiative.*
2. **Sector-proxy bias:** Global emission factors overestimate services and underestimate ASEAN agriculture (paddy rice methane is 3x the global average proxy).
   → *Close with: ASEAN-specific emission factor databases calibrated to local fuel mix and farming practices.*
3. **Double counting:** Conglomerate borrowers with multiple business lines risk counting emissions twice.
   → *Close with: PCAF segment-level attribution methodology and borrower-provided divisional breakdowns.*
4. **Temporal mismatch:** Emissions data is 18 to 24 months lagged vs real-time lending decisions.
   → *Close with: satellite-based near-real-time estimation and AI-driven nowcasting models.*
5. **Alignment tool coverage:** PACTA covers 6 sectors globally but only 3 have ASEAN-specific calibration.
   → *Close with: ASEAN-calibrated PACTA extensions for agriculture, real estate, and transport.*

These five gaps define the frontier for ASEAN carbon measurement, and the capacity building agenda for this Erasmus+ project.

Seven Things You Now Know About Carbon Metrics and CVaR

[FOUNDATION]

Seven Key Concepts

1. For banks, ∼85% of emissions are **financed emissions** (Scope 3 Category 15)
2. The PCAF formula **attributes** borrower emissions to the lending institution proportionally
3. WACI normalizes carbon intensity for **portfolio comparison**
4. PCAF data quality ranges from Tier 1 (verified) to Tier 5 (proxy): most ASEAN banks use **Tier 4 to 5**
5. CVaR decomposes into **Physical** and **Transition** components
6. Exposure size and physical vulnerability can **dominate** carbon intensity (the agriculture-coal inversion)
7. The carbon beta suggests markets are beginning to **price carbon risk**

Where This Leads

Lesson	Builds On
4.5	*Stress testing*: applying carbon metrics to bank balance sheets
4.6	*Data & tech*: operationalizing carbon measurement at scale
M5	*Reporting*: disclosing carbon metrics to regulators and investors

Five questions to assess carbon measurement maturity:

1. Does the institution calculate financed emissions?
2. What PCAF data quality tier is achieved?
3. Is WACI tracked against benchmarks?
4. Is CVaR estimated under multiple scenarios?
5. Is the carbon dashboard integrated into ERM?

Lesson 4.4 complete. Next: Lesson 4.5, Climate Stress Testing (applying these carbon metrics to stress test institutional resilience).

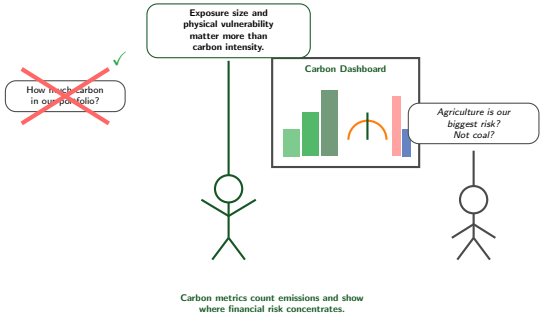
The Risk Manager Who Learned to Count Carbon

The Pedagogical Arc

- We began with a risk manager who could not answer "how much carbon?": **scenarios without measurement**
- We end with the same risk manager presenting a complete carbon dashboard: financed emissions, WACI, CVaR decomposition

The surprise: Agriculture, not coal, is the bank's biggest climate risk. Exposure size and physical vulnerability dominate carbon intensity.

Remember: Carbon metrics count emissions and show where financial risk **concentrates**.



Original illustration. The pedagogical arc of Lesson 4.4: from "We don't know our carbon exposure" to "We know exactly where the risk concentrates."

Key References

Institutional References

- PCAF (2022). *The Global GHG Accounting and Reporting Standard for the Financial Industry, Part A: Financed Emissions* (2nd edition). Partnership for Carbon Accounting Financials.
- 2DII (2024). *PACTA Methodology Documentation*. 2 Degrees Investing Initiative.

Supplementary

- PCAF Southeast Asia Implementation Guide.
- State Bank of Vietnam (2023). *Green Finance Roadmap*.
- ASEAN Taxonomy Board (2023). *ASEAN Taxonomy for Sustainable Finance, Version 2*.

Academic References

- Bolton, P. & Kacperczyk, M. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2), 517 to 549.
- Battiston, S., et al. (2017). A climate stress-test of the financial system. *Nature Climate Change*, 7, 283 to 288.
- Sautner, Z., van Lent, L., Vilkov, G., & Zhang, R. (2023). Firm-level climate change exposure. *Journal of Finance*, 78(3), 1449 to 1498.

All references are open-access or available through university libraries.

Acknowledgments

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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 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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