EUROPEAN CENTRAL BANK

EUROSYSTEM

The Road to Paris: stress testing the transition towards a net-zero economy

"Embedding Sustainability in Credit Risk Assessment" conference

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Today's presentation

ECB top-down economy-wide climate stress test v2.0

1. Overview of the exercise
2. Scenarios
3. Models
4. Results
5. Conclusion

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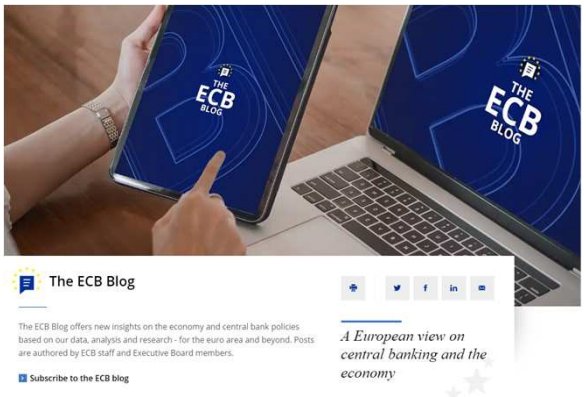


ECB top-down economy-wide climate stress test v2.0

Overview

CST v1.0: cost-benefit analysis

Main features:

1. **Climate scenarios** built to account for **transition** and **physical risk** over the next **30 years**
2. **Granular climate and financial information** for millions of corporates to which EA banks are exposed via loans & securities
3. **New models** to capture climate risk transmission channels to firms and banks

Main results:

1. **Short-term costs** of the transition are **more than compensated by long-term benefits**
2. **Potentially severe impact** for corporates and banks most at risk

New question → **CST v2.0:** impact assessment of net-zero transition

New context → **New scenarios**

1. **Short-term scenarios** focusing on **transition risk** and **energy developments** over the next 8 years
2. Scenarios developed in-house to reflect the **current macroeconomic and energy context** by combining BMPE projections, NGFS scenarios and updated starting points

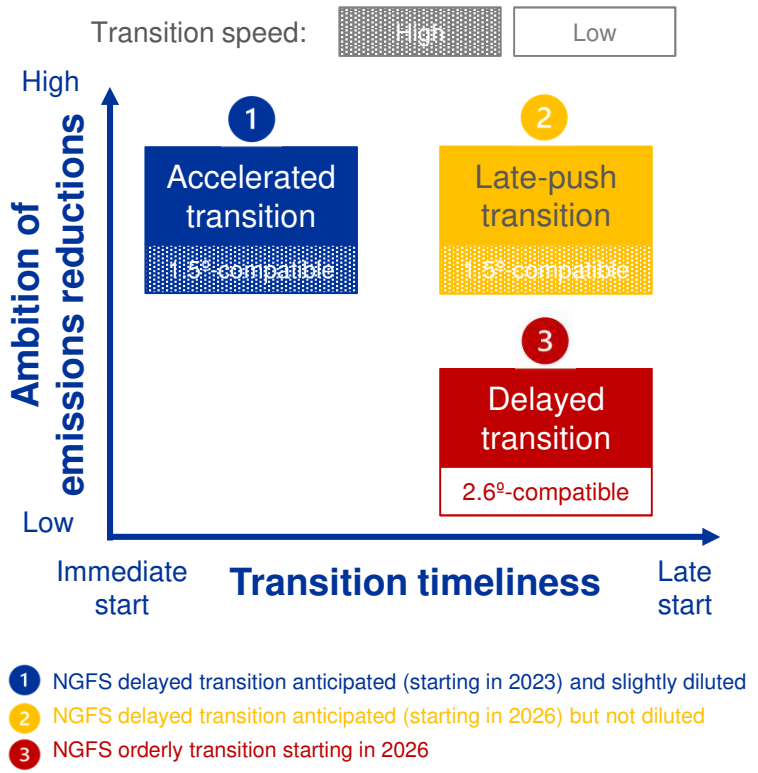
Model refinements → **Enhanced models**

1. **Energy-based modelling** and incorporation of **new transmission channels**, i.e. stranded assets & green investments
2. **Amplification mechanisms** in form of **downstream and upstream GVA shocks**
3. New modules: **households and non-banks**

NGFS-based scenarios: three potential transition paths

Scenarios

S1: Accelerated transition	*The energy crises triggers a quick and intense green transition starting immediately. Investments in renewables in the short term reduce energy expenses. Emission reductions by 2030 are compatible with "net-zero by 2050" and +1.5º targets.*
S2: Late-push transition	*Recent adverse macroeconomic developments lead to a stagnation of the carbon intensity over the next 3 years. The transition starts later, but it is intense enough to reach emission reductions by 2030 similar to S1, thanks to strong and decisive action.*
S3: Delayed transition	*The transition starts with a delay of around 3 years, when macroeconomic projections show an economy recovered from the 2022 shock. Contrarily to S2, the transition is orderly, but too weak to generate similar emission reductions.*



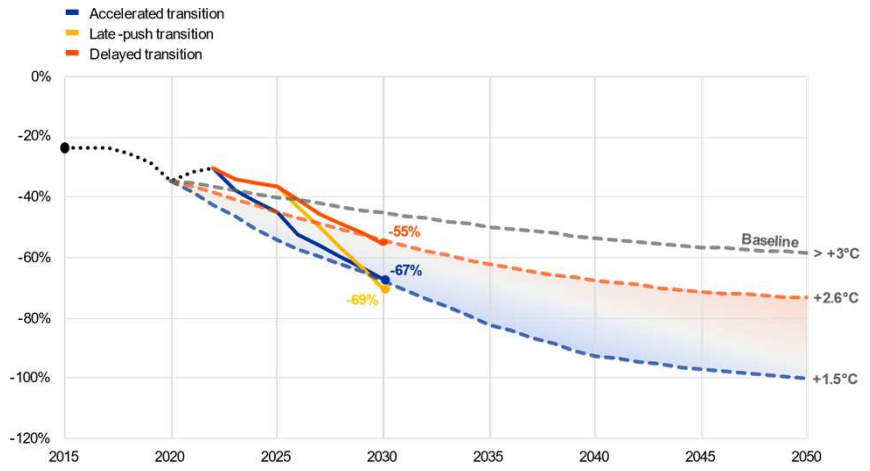
Two key transition variables: GHG emissions and energy prices

Scenarios

- In 2030, only S1 and S2 are compatible with the max +1.5°C target by the end of the century, achieving an overall **emission reduction** of around -68% with respect to 1990; while S3 is not
- **Energy prices** reflect the latest market developments and increase further during the transition

GHG emissions' pathways were calibrated to assess the impact of transition policies on the real economy

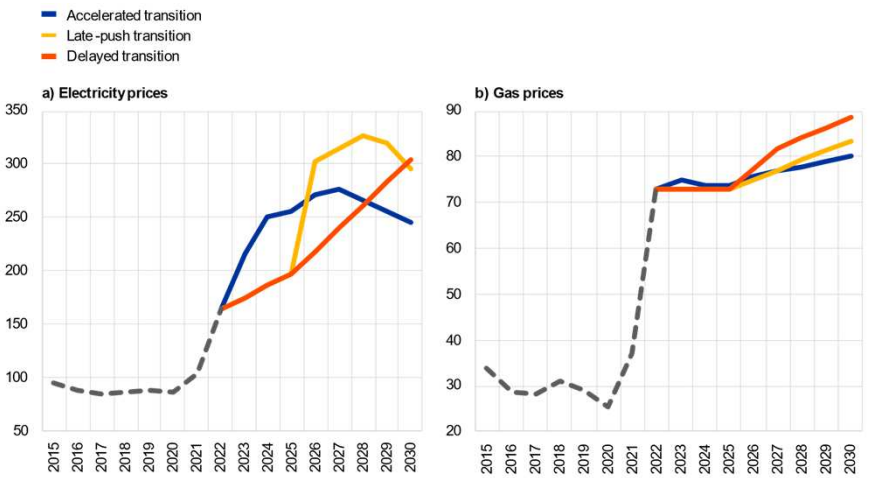
(percentage change compared to 1990 level; EA aggregate)



Source: ECB calculations based on European Environmental Agency (EEA), Eurostat and NGFS climate scenarios data.
Notes: The temperature increase refers to the year 2100. The emissions pathways until 2050 correspond to the NGFS net zero 2050 (+1.5°C), nationally determined contributions (+2.6°C) and current policies (>+3°C) scenarios.

Electricity and gas prices were affected by the energy crisis, with further rises expected due to the transition

(EUR/MWh)



Source ECB calculations based on Eurostat and NGFS climate scenarios data.
Notes: The black dotted line represents historical data. For each country, Eurostat reports electricity and gas prices separately for different consumption buckets. An average for the euro area has been calculated.

Recorded price increase (w.r.t. pre-Covid)

Electricity +89% Gas +150%

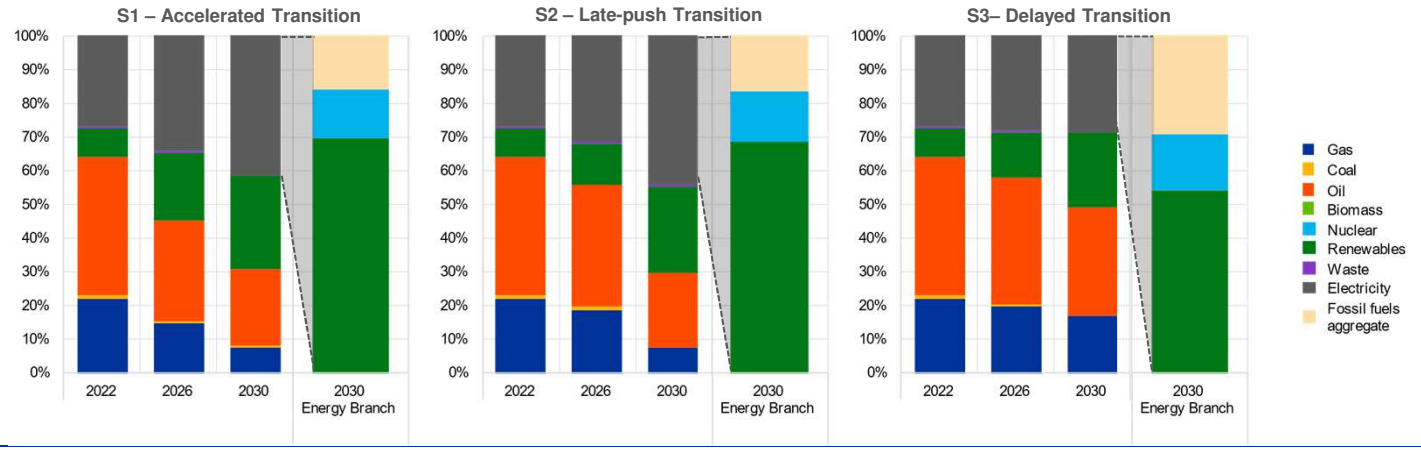
Increasingly green energy mix for the real economy

Scenarios

- The main transition efforts of the real economy focus on (1) **reducing the use of fossil fuels in favour of renewables** and (2) **electrifying the production processes**
- In 2030, in S1 and S2, **electricity** represents around **42%** of the final energy mix, of which **70%** is generated from **renewables**; in S3 electricity accounts for **28%**, of which **54%** from renewables
- The growing consumption of electricity must be backed up by a rapid switch from fossil fuels to renewable inputs in the electricity generation process

Energy mix for final consumers and for electricity generation in 2030 (EA aggregate)

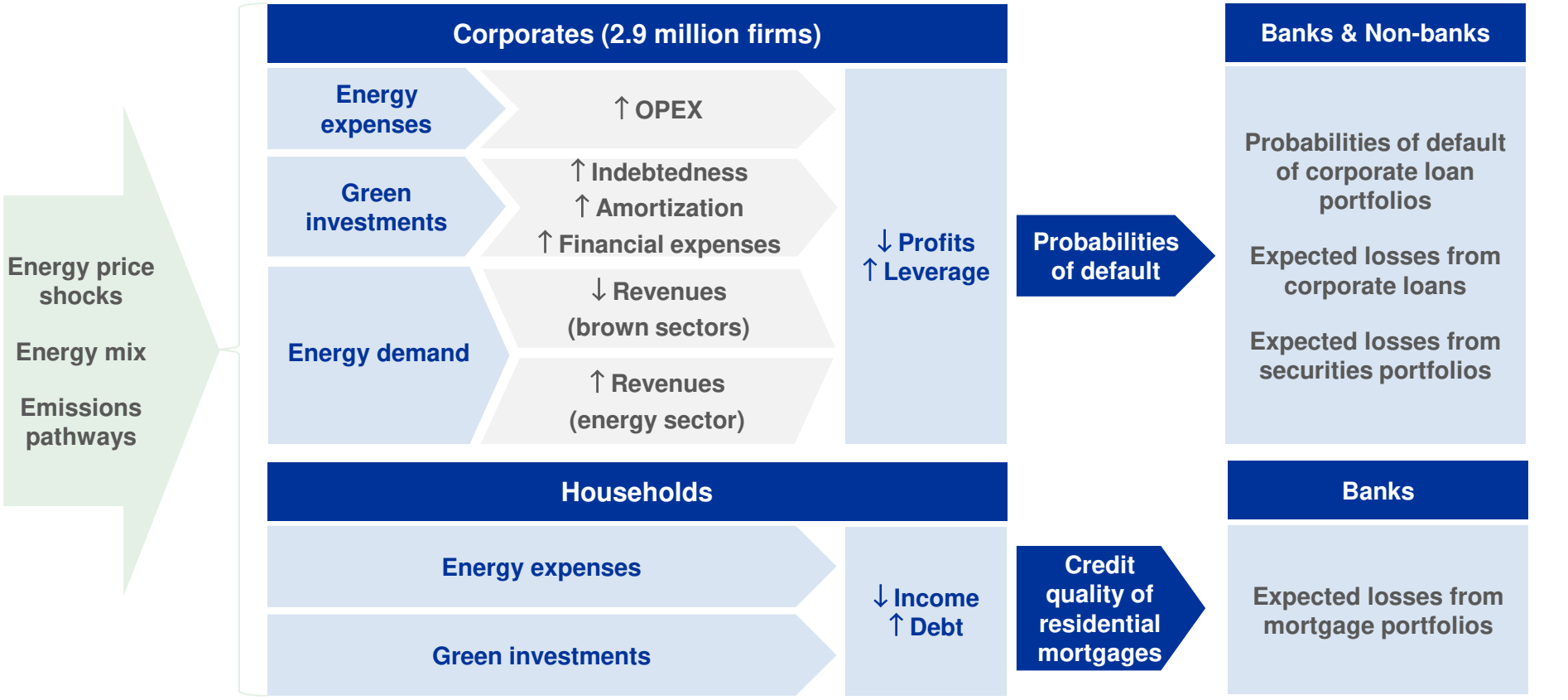
(share of total energy consumption represented by each energy input)



Source: ECB calculations based on Eurostat and NGFS climate scenarios data.

New and granular models: risk transmission channels

Models



Modelling of green investments

Models

All sectors: investment into carbon mitigation activities

- Based on IPCC estimates
- Carbon sequestration, energy efficient buildings and machinery, carbon capture utilization and storage

Mainly electricity sector: investment into renewable energy capacity

- Based on the modelling of experience curves
- Solar and offshore/onshore wind energy systems

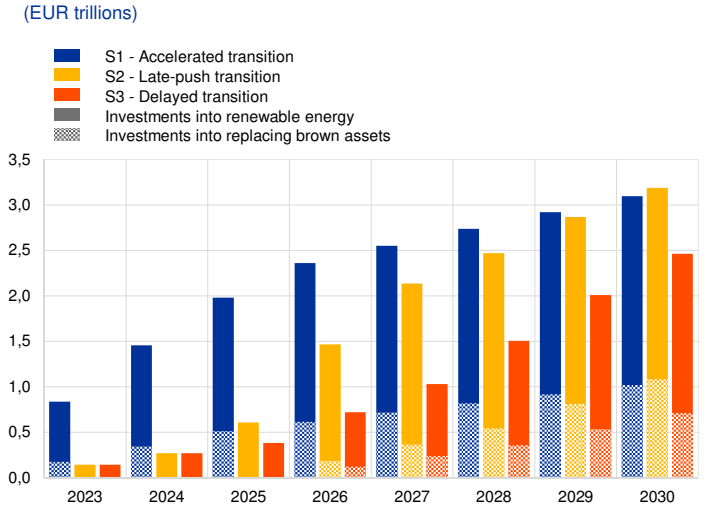
Amortization

Indebtedness

Profitability

Leverage

Cumulative green investments are the highest in the accelerated and late-push transition due to more ambitious emission reduction targets



Source: ECB calculations based on Orbis, Urgentem, Eurostat, NGFS, BMPE macroeconomic projections, IRENA (2021), and IPCC (2022) data.

Total green investments over the 8 years amount to 2.5-3.2 EUR trillion and are largest in S2

Results for **corporates**

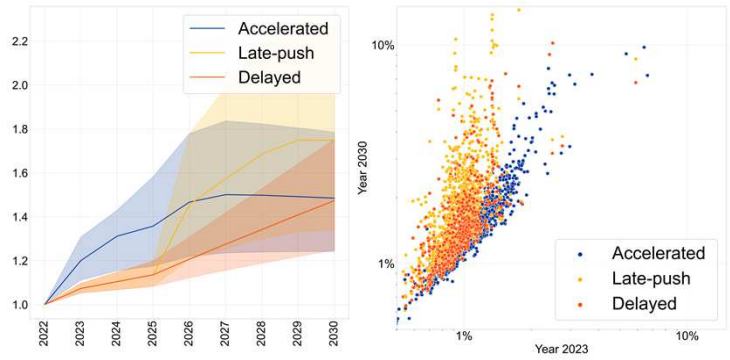
Result 1: *credit risk increases during the transition and is highest in a late-push scenario*

Result 2: *accelerated and delayed transition lead to similar risk levels by 2030, but only in the first scenario corporate PDs decrease by 2030, while being on track with the "net-zero by 2050" optimal pathway*

Result 3*: the transition impact is heterogenous across sectors; mining, manufacturing and electricity sectors are the most impacted; increasing reliance on electricity must be backed up by a rapid transition of this sector*

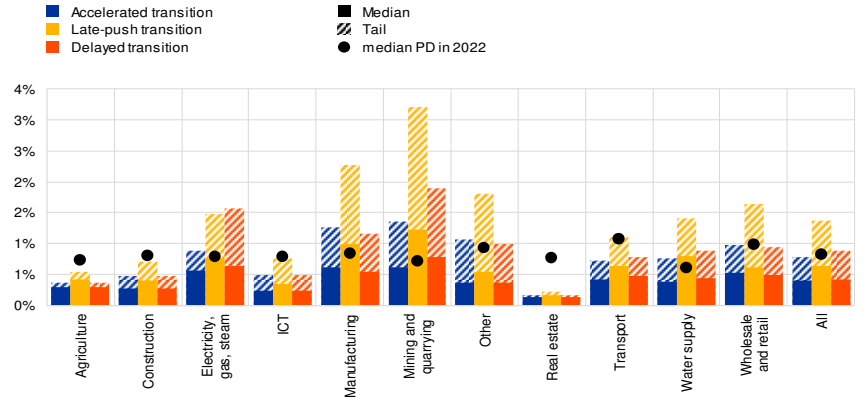
Credit risk would increase due to transition risk until 2030, especially under a late-push transition scenario

(left: change in median PD relative to 2022; index, 2022=1; right: median PD by country-sector NACE level 4; index, 2022=1, log-scale)



By 2030 the strongest rise in probability of default would be in energy-intensive sectors

(absolute difference in median PD between 2022 and 2030; percentage points)



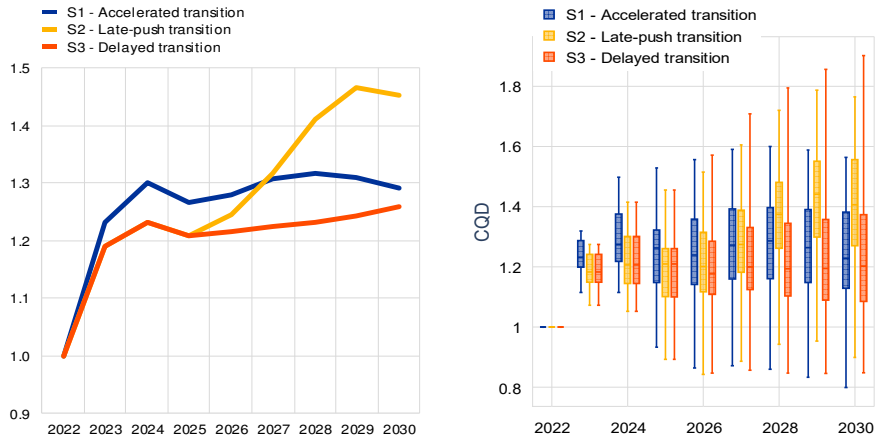
Source: ECB calculations based on Orbis, Urgentem, Eurostat, NGFS, BMPE macroeconomic projections, IRENA (2021) and IPCC (2022) data.
Notes: Tails were defined as the 75th percentile of firms in terms of PD changes between 2022 and 2030 in each sector and scenario.

Results for **households**

***Result 1**: credit risk increases during the transition and is highest in a late-push scenario*
***Result 2**: accelerated and delayed transition lead to similar risk levels by 2030, but in the accelerated transition risk levels start decreasing by 2030*

Household portfolio credit quality deterioration would be almost double under a late-push transition than under the other scenarios

(left: EA average; index; 2022=1; right: distribution across countries; index; 2022=1)



Source: ECB calculations based on ECB, Eurostat, NGFS, BMPE macroeconomic projections, Greenhouse Gas Protocol and IPCC (2022) data.

Credit quality deterioration

$$CQD = \frac{new\ defaulted\ exposures}{total\ exposures}$$

Results for **banks**: credit portfolio losses

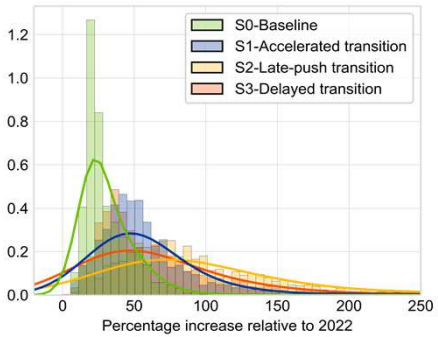
Result 1: *in 2030, annual expected losses for the median bank are 48% higher in S1, 78% in S2 and 48% in S3 compared to 2022; banks would be required to increase provisions at least as much*

Result 2: *25% increase in annual expected losses from 2022 to 2030 is driven by macro developments and current climate policies; the remaining impact is attributed to the additional transition efforts*

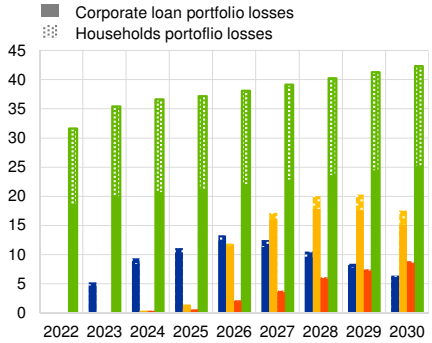
Macroeconomic and transition-related developments are expected to increase banks' annual expected losses…

(left: bank-level distribution; right: EUR billions)

Percentage increase in total annual expected losses

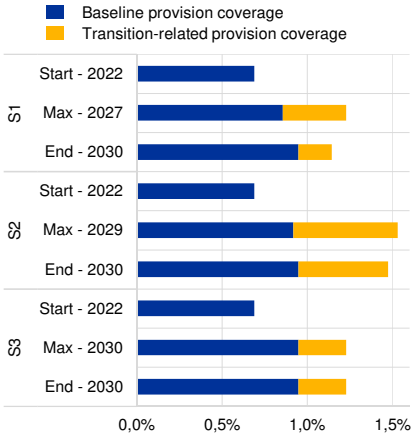


Baseline (green) and transition-related (others) increase in annual expected losses



…and their respective provisions needs

(coverage ratio; **stage 1 loans** only)



Source: ECB calculation based on ECB, AnaCredit, Orbis, Urgentem, Eurostat, NGFS, BMPE macroeconomic projections and IRENA (2021) data.

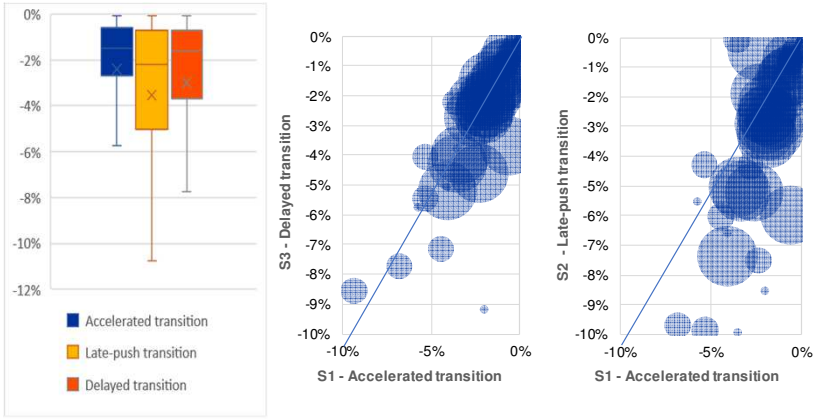
Results for **banks and non-banks**: corporate bond portfolio losses

Result 1: *for banks, absolute losses from market risk are limited; however, losses relative to the portfolio fair value are significant in the tail of the distribution*

Result 2: *for non-banks, market risk impact is substantial and follows similar dynamics over the scenario horizon, with different magnitude in individual sectors*

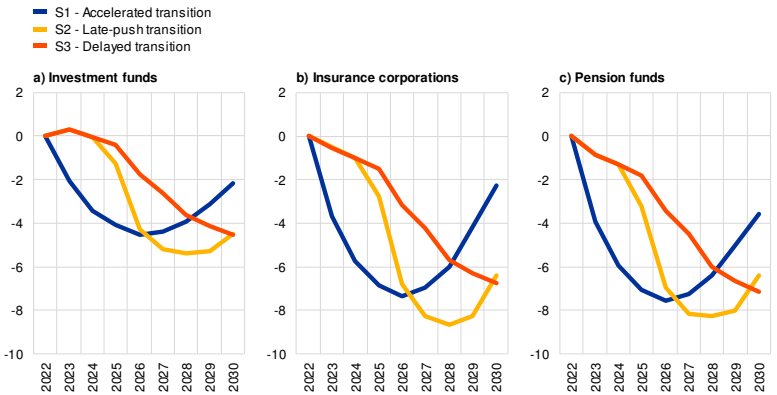
Banks' corporate bond portfolio losses until 2030 remain comprised in absolute terms

(losses relative to portfolio fair value)



Absolute losses until 2030 are the highest for investment funds and insurance companies

(percentage change relative to 2022)



Conclusions

This exercise constitutes an important step forward in the field of climate stress testing with:

- Newly designed **short-term transition scenarios**
- Granular modelling of **energy-related developments**
- Emphasis on **sector-level dynamics**
- **Unprecedented coverage** of entities and exposures

Exploring three potential transition pathways, we find that:

- **Credit risk increases significantly during the transition**, with heterogeneous impacts across sectors, and is **highest in a late-push scenario**
- **Accelerated and delayed transition lead to similar risk levels by 2030,** with relevant differences
  - Corporate PDs start decreasing around 2027 in the accelerated transition, while they keep increasing until 2030 (and potentially further) in the delayed transition
  - Emission reductions by 2030 are compatible with NGFS “net-zero by 2050” and max +1.5º only in the accelerated transition, meaning that financial risk could become much higher after 2030 in a delayed transition due to the physical risk effects

Thank you

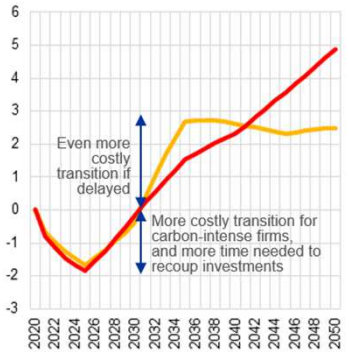
Annex

New question: what's the impact of different transition paths?

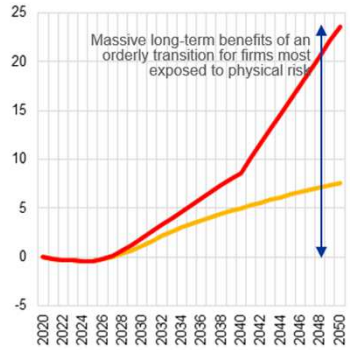
- First results (Sept. 2021) have shown that the short-term costs of the transition are more than compensated by long-term benefits, therefore proving the importance of a timely transition

PDs: carbon intensive firms

% differences in adverse scenarios compared to orderly transition scenario

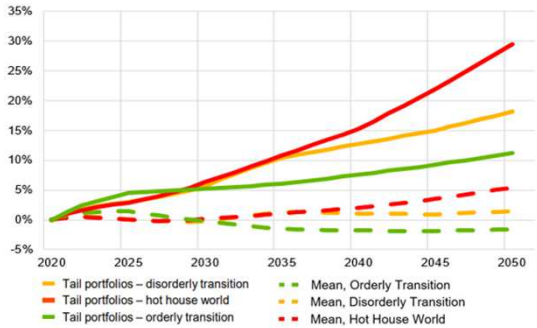


PDs: high physical risk firms



Evolution of banks' credit portfolio PDs (2020 to 2050)

% differences from 2020 for the tail of banks (upper 10th percentile)



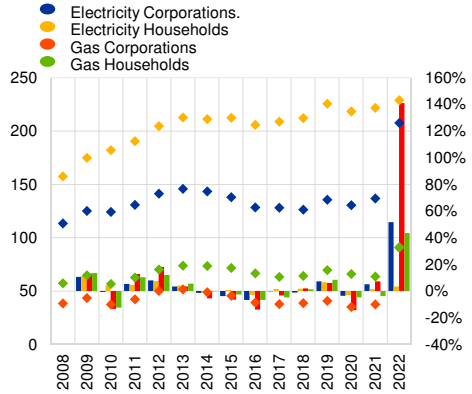
- Following most recent developments, an orderly transition is not only unlikely, but most likely also not feasible anymore: "1.5 is Dead!" - Global Media on The First Week of COP27
- Next questions: **what's the impact of different (still feasible) transition paths on the real economy and the financial system?**

➡ New scenario narrative with a focus on **transition risk** over the **time horizon 2022-2030**

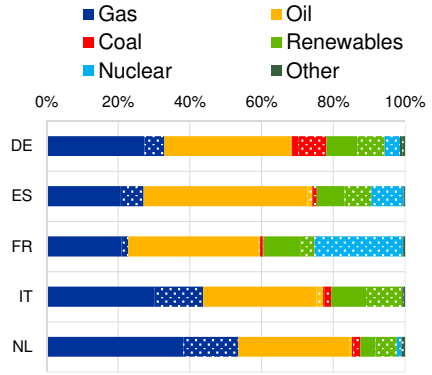
New context: energy crisis, high inflation, slowing economic growth

- The Russian war in Ukraine significantly reduced the availability of gas in Europe and was followed by a sudden increase in gas, oil and electricity prices, which constitute most of the EU energy input
- From a climate perspective, the current **energy crisis** presents **challenges and opportunities**
- *"The ongoing global spike in energy prices represents a **crossroads** in the world's journey towards net zero. We have a choice between two paths that have significantly different implications."*[*NGFS, Sept. 2022*]

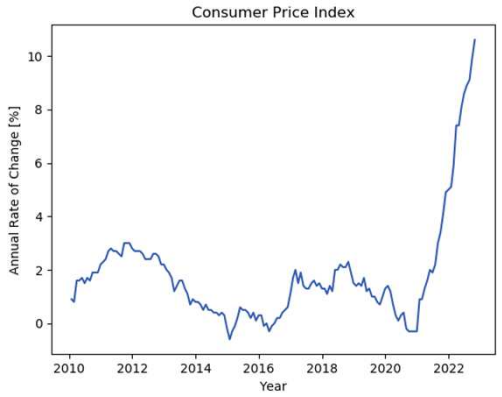
Energy price developments over time



Energy mix of biggest EA countries

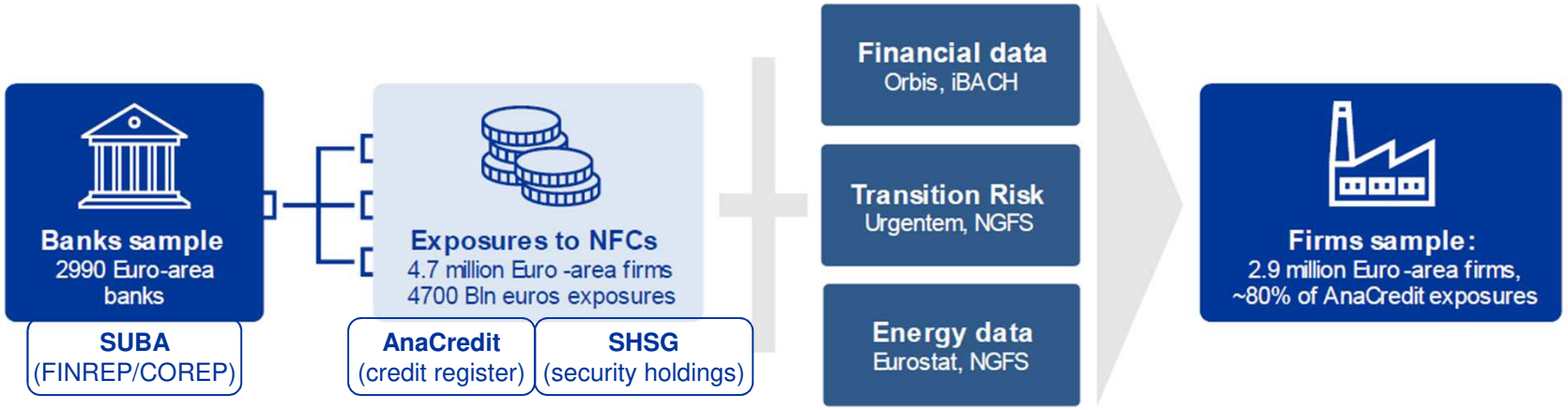


Euro Area inflation development



➡ Scenario calibration based on NGFS, Dec. 2022 BMPE projections and latest data on energy

Granular and integrated data infrastructure @ ECB

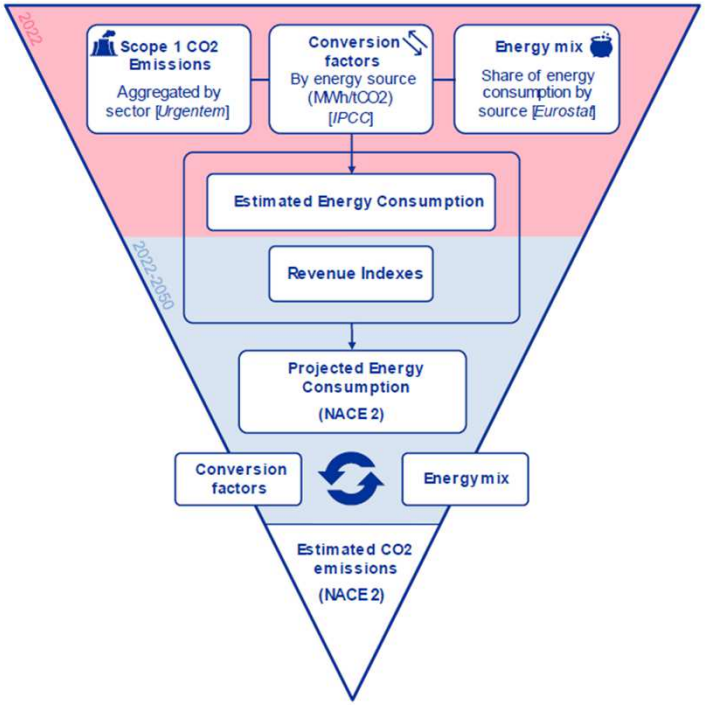


Source: ECB.
Notes: The final sample of companies is drawn from the sample of AnaCredit debtors and depends on the availability of financial, transition risk and energy data. When reasonable, proxies are calculated to fill data gaps.

Emissions downscaling methodology

Data

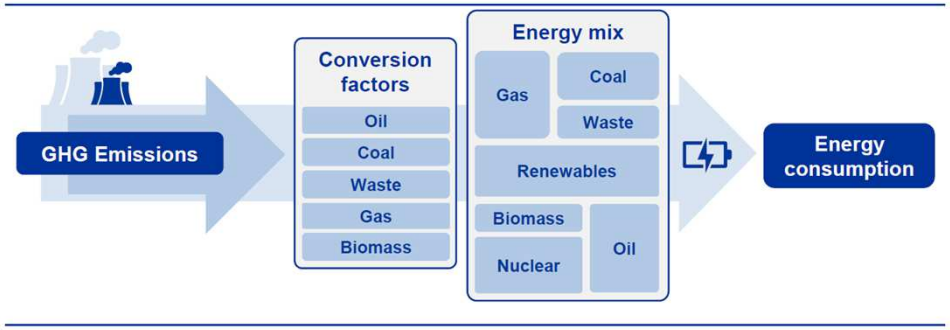
Emissions are distributed proportionally to projected energy consumption of sectors, also taking into account changes in their energy mix.



Technical steps:

1. For each scenario, **project** firms' '***baseline*' revenues until 2050**: **sourced but separate model from climate stress test**, does **not include firm-specific** climate shocks but **only "macro" shock** from GDP and inflation (NGFS)
2. Create a **country-sector-level index of average projected revenues** for each scenario
3. Use **sectors' energy consumption in 2020** (Eurostat) and **project** with the index created in step 2
4. Use the **formula for deriving firms' energy consumption** (from our climate stress test model) to **backward-engineer sector-level emissions for each scenario** (see details in next slide)
5. **Rescale** granular emissions based on aggregate NGFS emission levels

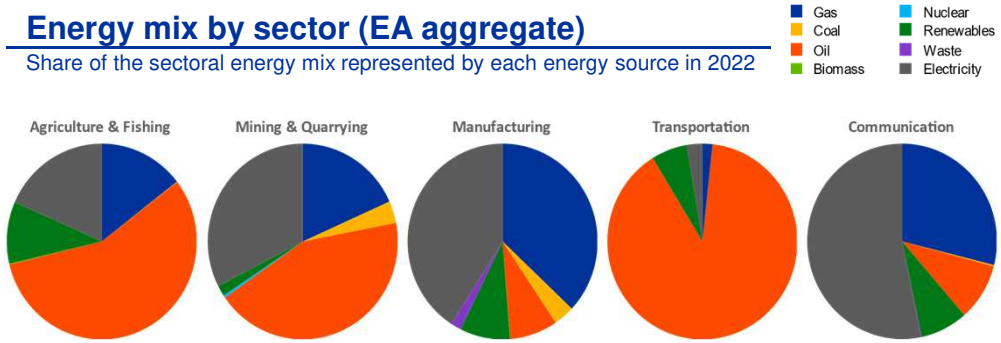
From emissions-based to energy-based modelling of the transition



Source: ECB methodology.
Notes: Conversion factors are expressed as tCO2e/MWh, and are available only for energy sources that produce GHG emissions. Energy consumption is adjusted proportionally to account for the share of non-emitting sources (i.e., renewables and nuclear). The relationship between emissions and energy consumption holds also in the opposite direction.

Energy mix by sector (EA aggregate)

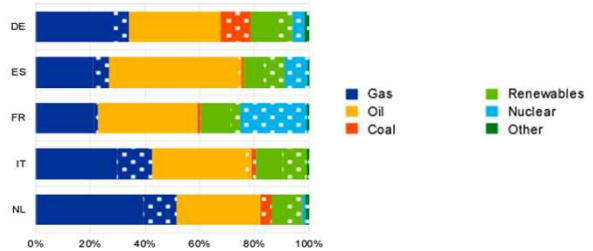
Share of the sectoral energy mix represented by each energy source in 2022



Sources: ECB calculations based on Eurostat Energy Balances.
Notes: Some subsectors of Manufacturing involved in electricity generation are excluded.

Energy mix by country

2021; percentages

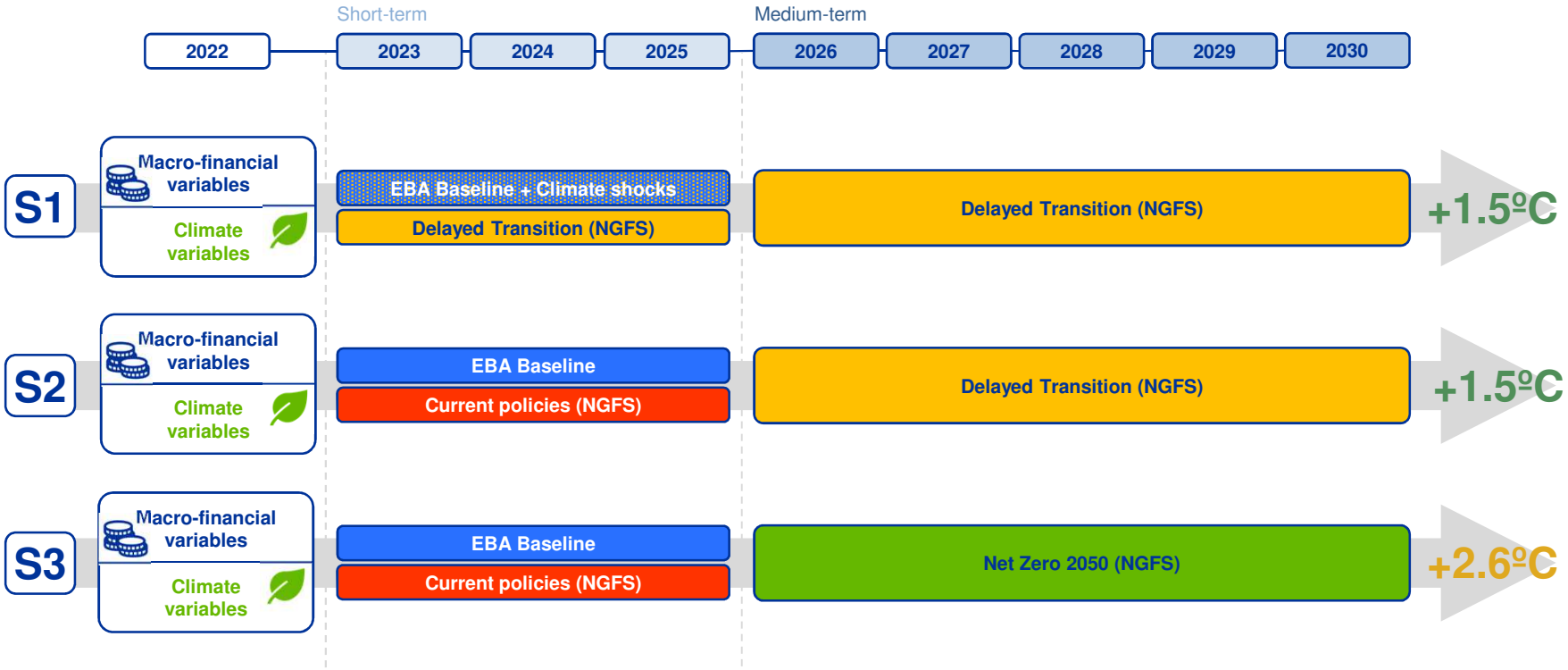


Source: ECB calculation based on Eurostat data. Notes: Primary energy is represented by the filled areas. Secondary energy is represented by dotted areas and refers to the transformation of primary sources into heat or electricity.

New scenarios: three potential transition paths

	Fossil fuel prices	Electricity prices	Brown energy consumption	Investments / Funding flows	Emission reduction by 2030	Level of ambition
(S1) Accelerated transition	Immediate but moderate increase with most favorable level in 2030	Increasing in the first half of the period, decreasing afterwards	Immediate and sustained decrease	High and spread over time	-67%	High (+1.5º compatible)
(S2) Late-push transition	Constant until 2025 with a moderate increase in the second half of the period	Highest in the second half of the period, but decreasing toward 2030	Delayed but substantial decrease in the second half of the period	High and concentrated in the second half of the period	-69%	High (+1.5º compatible)
(S3) Delayed transition	Constant until 2025 then increasing linearly	Gradually increasing over time, highest at the end of the period	Moderate decrease in the second half of the period	Medium	-55%	Low (+2.6º compatible)

New scenarios: technical notes



Modelling of green investments

Models

All sectors: investment into carbon mitigation activities

- Based on IPCC estimates
- Carbon sequestration, energy efficient buildings and machinery, carbon capture utilization and storage

Mainly electricity sector: investment into renewable energy capacity

- Based on the modelling of experience curves
- Solar and offshore/onshore wind energy systems

Amortization

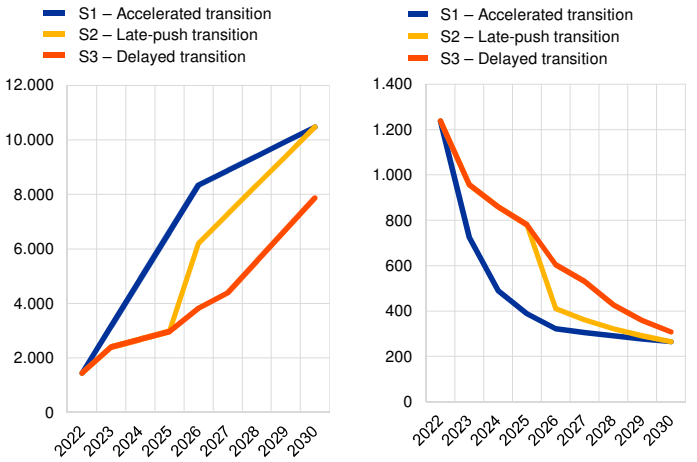
Indebtedness

Profitability

Leverage

Cumulated capacity of renewable-based electricity (left) and renewable investment costs (right)

(left: GwH; right: 2021 USD per KwH)



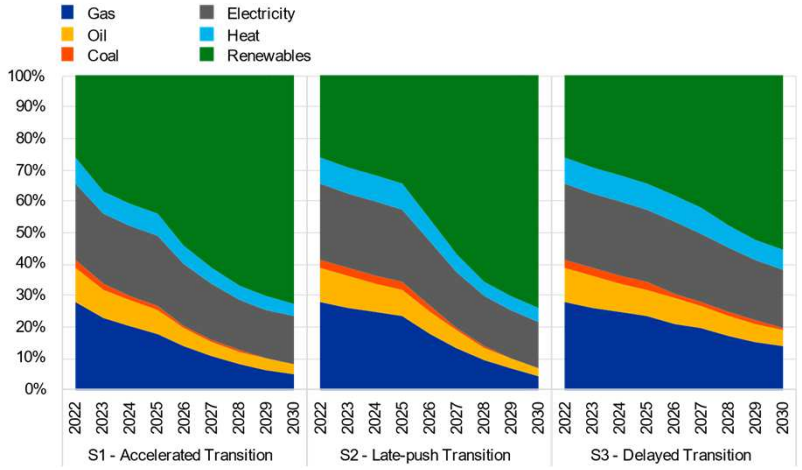
Source: ECB calculations based on Orbis, Urgentem, Eurostat, NGFS, and IRENA (2021).

Investments into solar, onshore and offshore wind energy considered (expected to comprise >80% of renewable-based electricity*)

Transition affects **households' consumption habits**

Households' energy mix (EA aggregate)

(share of total energy consumption represented by each energy input)



Sources: ECB calculations based on Eurostat Energy Balances and NGFS Climate Scenarios.

- Households' transition is mainly driven by the adoption of **photovoltaic and solar energy** technologies
- Investments are needed to increase **buildings energy efficiency**
  - In all scenarios **electricity consumption** shrinks **below 20%**

Expected increase in renewables from 2022 to 2030

S1	+46%	S2	+48%	S3	+29%

Expected decrease in coal, oil and gas from 2022 to 2030

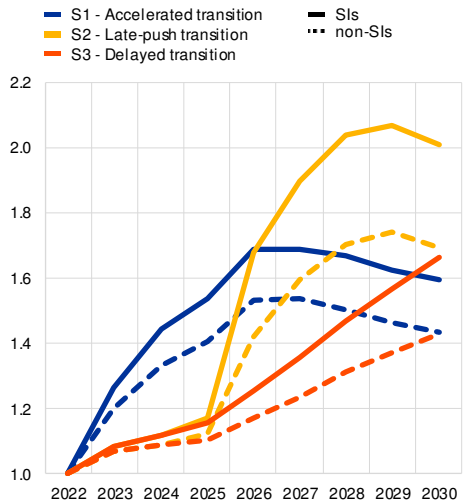
S1	-33%	S2	-34%	S3	-21%

Results for banks: portfolio PD and TCI metric

Result 1: *larger institutions (SIs) are exposed to larger increases in aggregate portfolio PD*
Result 2 : *In 2030, the transition-to-credit risk intensity (TCI) is highest in a delayed transition*

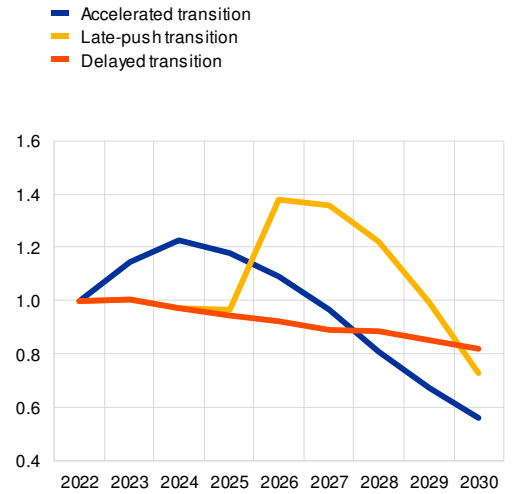
Median portfolio PD

(index; 2022=1)



Median transition-to-credit risk intensity (TCI)

(index; 2022=1, TCI = emission intensity * PD / portfolio size)

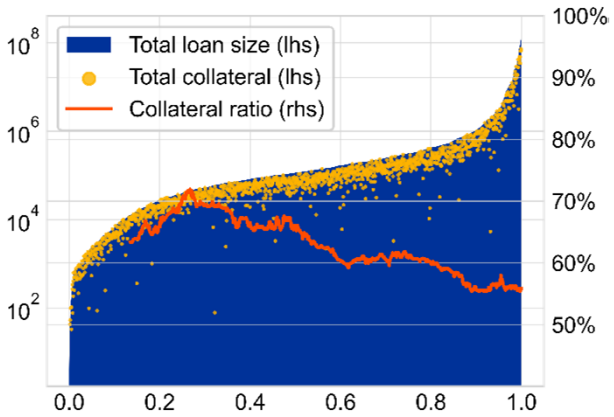


Results for banks: projected PD of corporate credit portfolio

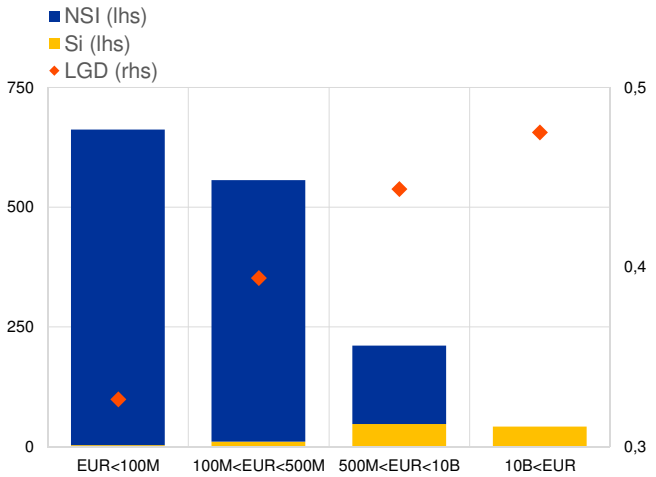
Banks by loan volume and collateral

Banks by loan volume and LGD

LHS panel: Loan volume and collateral on bank-level and moving-median collateral ratio; RHS: LGD and number of banks by loan volume



Note: Banks are ordered according to the sum of their loan volume. Collateral ratio is calculated as the median of total collateral divided by total loan volume in a moving 200-banks window.



Note: Loss given default (LGD) ratios are calculated as the median of 1 minus the ratio of total bank-level collateral divided by the total volume of loans.

Novel models to derive counterparty Probabilities of Default (PDs)

CST v2.0

Transmission channels of transition risk for electricity sector

$$TA(t) = f(TA(t-1), GDP(t), inflation(t))$$

$$REV(t) = f(REV(t-1), green\ revenue\ rate(t), t)$$

$$OPEX(t) = F(OPEX(t-1), TA(t), \Delta cost(brown\ energy)(t), amortization(t), financial\ expenses(t), t)$$

$$Leverage(t) = \frac{Debt(t) + Green\ Investment(t)}{Total\ Assets\ (t)}$$

$$Green\ Investment(t) = Sum(Scope1, Scope2, Scope3)(t) * replacement\ cost + renewable\ energy\ capacity(t) * investment\ costs(t)$$

$$ROA(t) = \frac{REV(t) - OPEX(t)}{Total\ Assets\ (t)}$$

$$PD(t) = F(Leverage(t), ROA(t), Age(t), GDP(t))$$

Novel models to derive counterparty Probabilities of Default (PDs)

CST v2.0

Transmission channels of transition risk for all other sectors

$$TA(t) = f(TA(t-1), GDP(t), inflation(t))$$

$$REV(t) = f(REV(t-1), \text{brown deterioration rate}^{1}(t), t)$$

$$OPEX(t) = F(OPEX(t-1), TA(t), \Delta cost(\text{brown energy})(t), \Delta cost(\text{electricity})(t), amortization(t), financial\ expenses(t), t)$$

$$Leverage(t) = \frac{Debt(t) + Green\ Investment(t)}{Total\ Assets\ (t)}$$

$$Green\ Investment(t) = Sum(Scope1, Scope2, Scope3)(t) * replacement\ cost$$

$$ROA(t) = \frac{REV(t) - OPEX(t)}{Total\ Assets\ (t)}$$

$$PD(t) = F(Leverage(t), ROA(t), Age(t), GDP(t))$$

1) Term included only for firms in the mining and quarrying sector

Novel model to derive HH credit quality deterioration (CQD)

CST v2.0

Transmission channels of transition risk

$$Debt(t) = Debt(t) + Green\ Investment(t) - Investments\ repayments(t)$$

$$Income(t) = Income(t) - Energy\ Costs(t) - Investments\ repayments(t)$$

$$Green\ Investment(t) = Sum(Scope1, Scope2) * replacement\ cost$$

$$Energy\ Costs(t) = Energy\ consumption(t) * Energy\ price(t)$$

$$CQD(t) = F(Interest\ rate(t), RRE\ price(t), Debt(t), Income(t))$$

Measuring transition risk-induced financial risk in bank portfolios with the **transition-to-credit risk intensity (TCI) metric**

Currently, the most **common climate metrics** is ***emissions-to-loans ratio.*** However, it has important **shortcomings** from a financial risk perspective:

- Although simple, it does **not account for the financial risk of loans**
- It can serve to identify to what extent loans finance big polluters, but **less useful for the climate/financial risk assessment** of loans

The new metric can be **used by banks and supervisors** for the combined climate and financial **risk assessment of loans**

Key elements of the new metric:

- ✓ **Simple** enough to **implement** and **analyze**
- ✓ Accounts for the **financial risk inherent in loans**
- ✓ Accounts for **firms' exposure to transition risk** and **puts it** into **perspective with financial risk**
- ✓ Can be conceptually **extended to physical risk**

Key features of the TCI

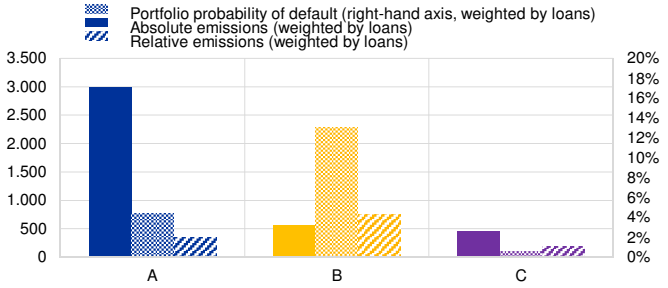
$$\text{TCI score}_j = \sum_i GHG\ emissions_i * Probability\ of\ default_{ij} * \frac{Loans_{ij}}{\sum_i Loans_{ij}}$$

- The TCI serves as a **score** for assessing **the financial risk of a bank *j* due to the transition risk** of a firm *i* through its **loan exposures**
- Can be used with absolute emissions or emission intensities*, each capturing different types of high-risk firms:
  - Using **absolute emissions**, the TCI identifies **large and high emitting firms with the highest financial risk**
  - Using **relative emissions**, the TCI identifies firms with **high financial risk** which might be smaller but have the **highest emissions relative to their size** and are thus most sensitive to a carbon tax

* Defined as GHG emissions over revenues

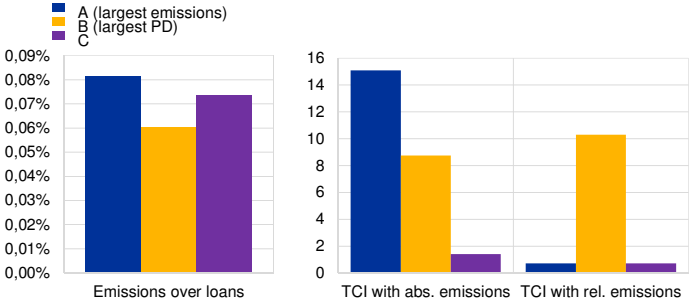
TCI applied on three stylised portfolios

Portfolio characteristics: weighted PDs and emissions of the stylized portfolios



- We selected **three illustrative euro area bank portfolios from AnaCredit with real data on corporate loans**
- All portfolios have same size: **10 assets per portfolio**
- Information on **loan, provisions** and **firm IDs** are sourced from Anacredit
- We matched the assets of these portfolios with **firm-level GHG emissions from Urgentem**

Ranking of portfolios by different metrics*



- **Portfolio A** scores the highest in the **absolute TCI** due to large firms with large abs. emissions

→ Reveals exposure to firms that are especially vulnerable in scenarios of climate policy changes

- **Portfolio B** scores highest in the **relative TCI** due to the higher relative emissions and financial risk

→Reveals exposure to firms with highest financial fragility and high emissions relative to their size

* Portfolio-level metrics are the average of firm-level metrics, weighted by their loan size

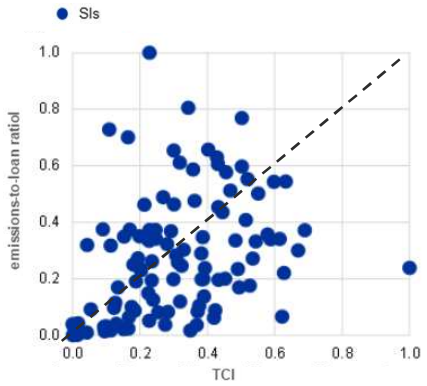
Financial system exposures to transition risk-induced credit risk have remained stable

TCI applied to banks' credit portfolios provide complementary insights to the emissions-to-loan ratio:

- No perfect linearity, banks with large portfolios rank differently in these two metrics
- When accounting for financial risk, the ranking of sectors differs and is less pronounced for mining
- Climate risk has increased over time in the euro area banking system

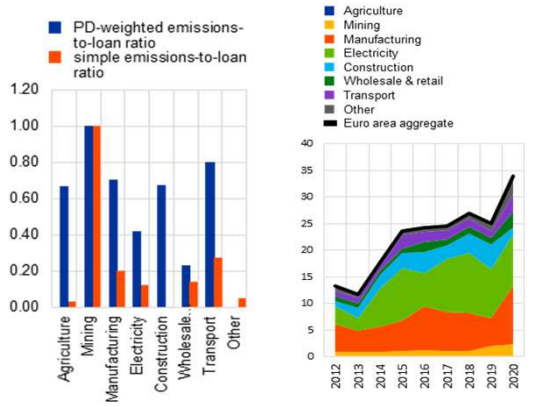
TCI versus simple emissions-to-loan ratio

(bubble size indicates size of banks' corporate loan portfolios; SI = Significant Institution)



PD-weighted measures of emissions can capture the financial component of banks' climate risks

(left chart: normalized PD-weighted (TCI) and simple emissions-to-loan ratio by sector in 2019 (averages weighted by exposures); right chart: sectoral shares)



Source: ECB Financial Stability Review, Special Feature (May 2022)