Chartbook for monitoring financial stability impacts of climate

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by
ECB/ESRB Project Team
on climate risk

EUROPEAN CENTRAL BANK
EUROSYSTEM

ESRB
European Systemic Risk Board
European System of Financial Supervision

Contents

1 Overview

This chartbook contains indicators for regular monitoring of climate-related risks to financial stability. It accompanies the ECB/ESRB (2023) report “Towards macroprudential frameworks for managing climate risk”.

Table 1: Overview of the indicators provided in this chartbook

Framework		Indicator	Description	Report	Annex
Climate change	Temperature check	▶ Global temperatures and CO2 emissions	Historical and projected global temperature anomaly and global CO2 emissions	✗	✗
		▶ European near-surface air temperature	Projected 2100 near-surface air temperature for EU countries, and broken down by scenario	✗	✗
		▶ Global sea temperature and water level	Global sea-surface temperature anomaly and sea water level anomaly	✗	✗
		▶ Antarctic and Arctic ice extent anomaly	Ice extent anomaly for the Antarctic and Arctic regions	✗	✗
		▶ Climate tipping points	Literature-based estimates for temperature thresholds related to Global Core and Regional Impact tipping elements	✗	✗
	Natural hazards	▶ Water stress	Projected level of water stress, by country and by scenario	✗	✗
		▶ River flooding	Projected percentage of flooded areas and projected change in flood intensity, by country and by scenario	✗	✗
		▶ Wildfires	Projected fire weather index, by country and by scenario	✗	✗
		▶ Droughts	Average projected change in number of Consecutive Dry Days (CDD) compared to 2005	✗	✗
Exposures to climate change	Transition events	▶ European energy mix	Historical and projected EU energy mix, and energy mix compatible with current renewable energy targets	✗	✗
		▶ Credit exposure to transition risk	Weighted Average Carbon Intensity (WACI) and Bank Carbon Footprint (BCFP)	✓	✗
		▶ Forward-looking WACI	Change in forward-looking WACI across time and sectors, and WACI components disaggregation	✗	✓
		▶ Carbon financing tilt	Bank loan portfolio tilted towards emission-intensive sectors, and carbon financing tilt indicator	✓	✗
		▶ Concentrated emissions exposure	Estimated transition losses for corporate lending	✓	✗
		▶ Taxonomy alignment	Taxonomy-aligned holdings and distribution across countries	✓	✗
	Physical events	▶ Potential exposure at risk (PEAR)	Potential exposure at risk by hazard and share of portfolio represented by high risk score exposures by country	✗	✗
		▶ Normalized exposure at risk (NEAR)	Normalized exposure at risk broken down by hazard type and sector, and by country	✗	✗
Climate change risk	Transition risk	▶ Forward-looking TCI	Change in forward-looking transition-to-credit-risk intensity, and breakdown by indicator components	✓	✓
		▶ Forward-looking CRS	Bank-level climate risk sensitivity (CRS) and banks’ cumulative share in additional expected losses by CRS ranking	✓	✓
	Physical risk	▶ Forward-looking PCI	Sector-level exposures towards borrowers extremely exposed floods and wildfires, and PCI scores broken down by sector	✓	✓
		▶ Protection gap and exposures	Exposure of euro area banks to firms at high risk from natural hazards and insuranc protection gap, by country	✗	✗
		▶ Protection gap and debt sustainability	Historical losses and protection gap for floods and wildfires	✗	✗
Monitoring markets		▶ Green and sustainable financing (1/2)	Asset under management of euro area ESG funds and outstanding amount of green and sustainable loans	✓	✗
		▶ Green and sustainable financing (2/2)	Issuance of sustainable debt securities by sector and issuance of GSS by maturity	✓	✗
		▶ Green sovereign bonds	Amount outstanding of euro area green sovereign bonds by country and use of corresponding proceeds	✓	✗
		▶ Green bonds greenium	Greenium of euro area corporate and sovereign bonds	✓	✗
Systemic risk assessment		▶ Physical risk amplification via trade (1/2)	GDP losses across world regions due to direct climate physical risk and amplified through trade interconnections	✓	✗
		▶ Physical risk amplification via trade (2/2)	GVA losses across EA sectors and corresponding banks losses as share of total assets	✓	✗
		▶ Overlapping portfolio risk	Country-hazard related portfolio similarity across financial sectors	✓	✗

Source: ECB/ESRB Project Team
Notes: Last two columns indicate if the indicators have been included in the ECB/ESRB Report and/or in the Annex, respectively.

2 Climate shocks

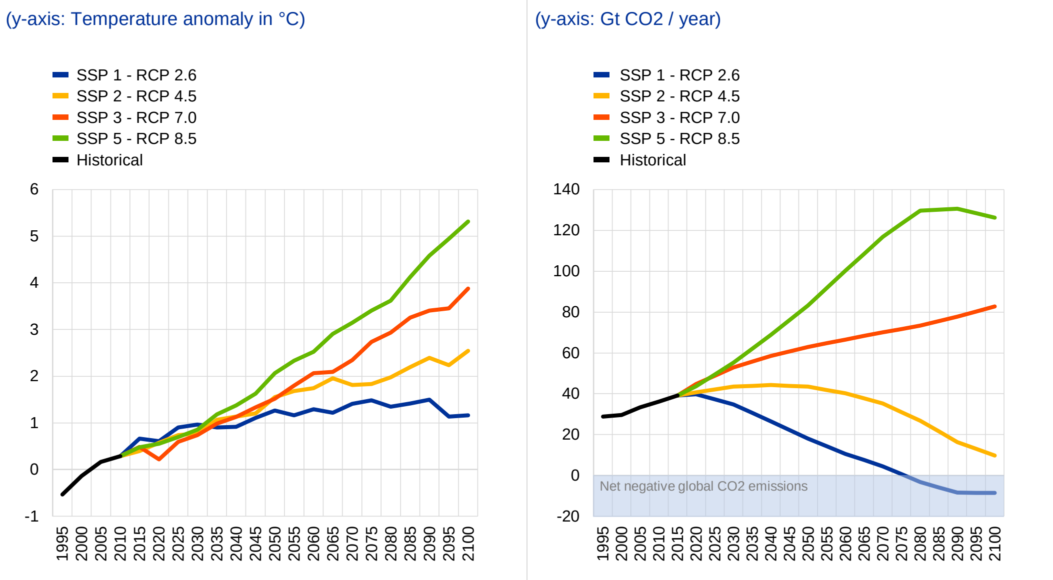
2.1 Temperature check

Chart 1

Climate scenarios and future projections are anchored to global mean temperature and CO2 emissions pathways

(a) Historical and projected global temperature anomaly, with respect to 1995-2014 observed averages

(b) Historical and projected global CO2 emissions



Physical and transition risks are expected to increase, driven by increasing global temperatures and CO2 emissions.

*Sources: Panel (a): World Bank Group Climate Change Knowledge Portal. Panel (b): Gidden, M. J. et Al. 2019. "**Global emissions pathways under different socioeconomic scenarios for use in CMIP6: a dataset of harmonized emissions trajectories through the end of the century**". Geosci. Model Dev., 12, 1443-1475.*

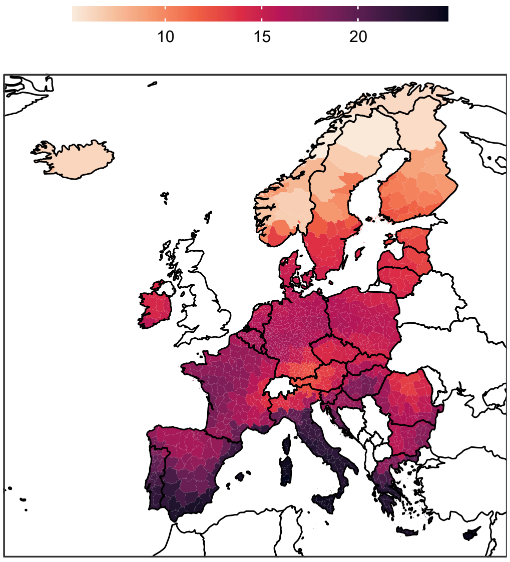
Notes: Panel (a): Temperature anomaly is calculated as deviation from the average observed during 1995-2014. Panel (b): CMIP6 global CO2 emissions projections from IMAGE (SSP 1 - RCP 2.6), MESSAGE-GLOBIOM (SSP 2 - RCP 4.5), AIM/CGE (SSP 3 - RCP 7.0) and REMIND-MAGPIE (SSP 5 - RCP 8.5). Historical global CO2 emissions from van Marle et al. (2017) & Hoesly et al. (2018).

Chart 2

Global temperature rise by the end of the century strongly impacted by timeliness and effectiveness of climate action

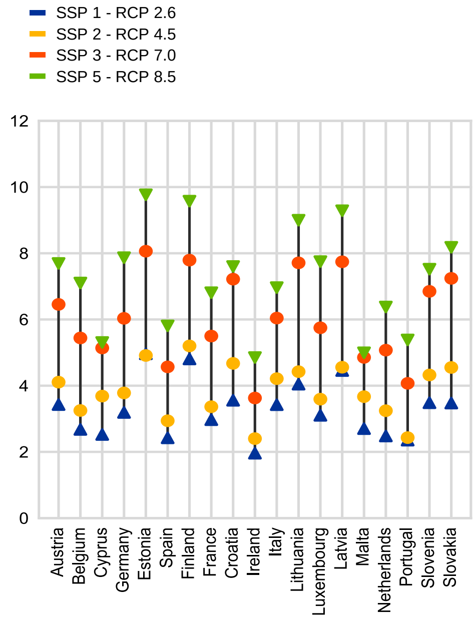
(a) Projected 2100 near-surface air temperature (SSP 5 - RCP 8.5 scenario)

(Average temperature in °C)



(b) Projected 2100 near-surface air temperature deviations from 1995-2014 average, by EA country and by scenario

(y-axis: Temperature anomaly in °C)



Adaptation and mitigation policies needed to avert a substantial and heterogeneous increase in average temperatures across European countries.

*Source: **Copernicus Climate Change Service (C3S) Climate Data Store (CDS)**.*

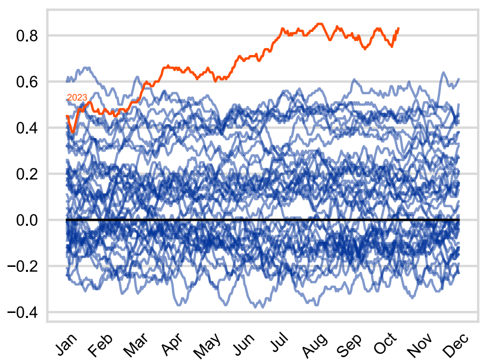
Notes: Panel(a): Projected values from Access-CM2 model. Panel (b): Projected values from Access-CM2 model. Temperature anomaly is calculated as deviation from the average observed during the period 1995-2014.

Chart 3

Global sea level is rising, with recent rates being unprecedented over the past 2,500-plus years

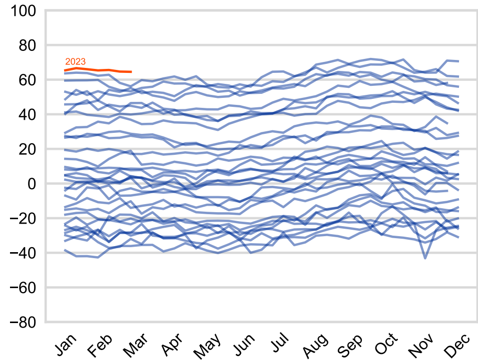
(a) Global sea-surface temperature anomaly

(y-axis: Temperature anomaly in °C)



(b) Global sea water level anomaly

(y-axis: Variation in millimetres)



Economic damages resulting from sea level rise can have a significant impact on the financial system.

Sources: Panel (a): National Oceanic and Atmospheric Administration (NOAA) via Climate Reanalyzer.org. Panel (b): NASA Earth Data.

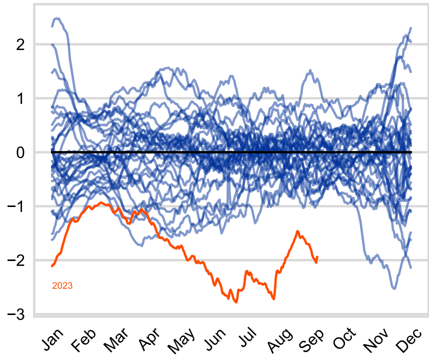
Notes: Panel (a): Temperature anomaly is computed as a difference from 1982-2011 mean. Panel (b): Sea level variation is computed with respect to 1995-2015 mean.

Chart 4

Antarctic and Arctic ice sheets store about two-thirds of the fresh water on Earth, and their melting process is responsible for about one-third of the global average rise in sea level

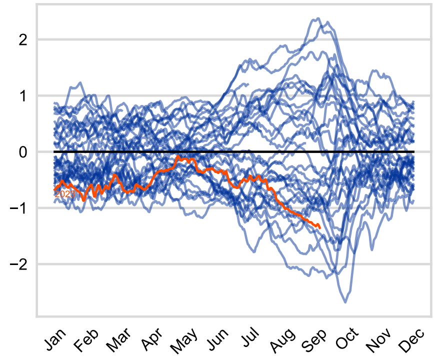
(a) Ice extent anomaly, Antarctic Region

(y-axis: Millions of squared kilometres)



(b) Ice extent anomaly, Arctic Region

(y-axis: Millions of squared kilometres)



Economic damages resulting from polar ice melting could lead to significant and uncertain impact on the financial system.

*Source: **VISHOP** by Arctic Data archive System (ADS).*

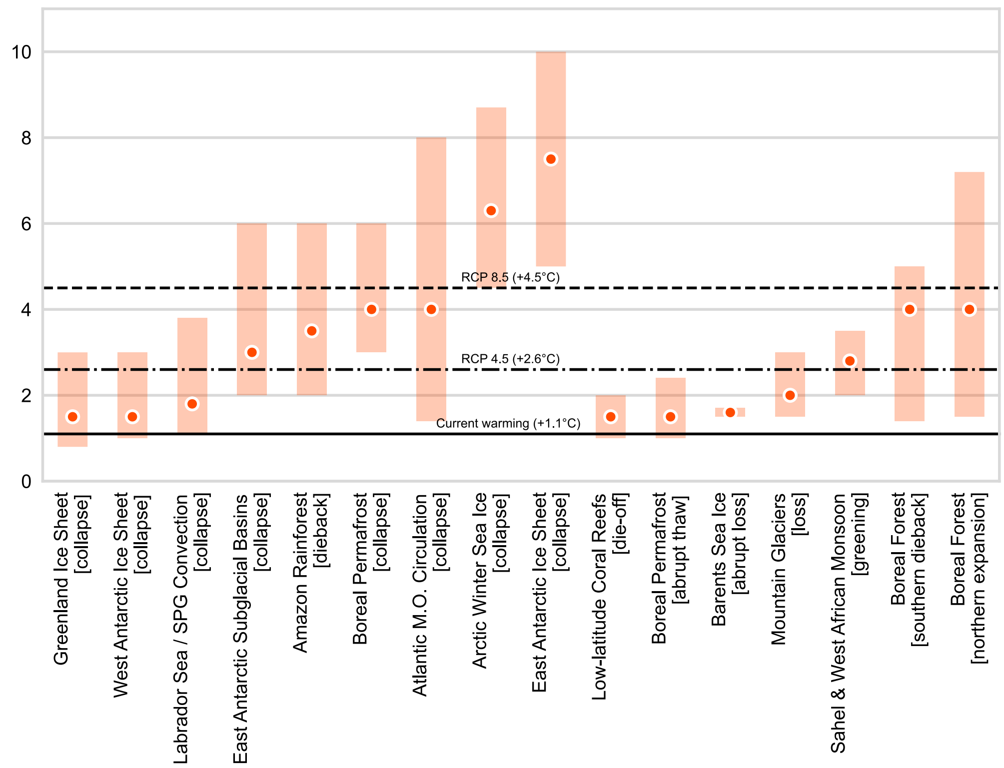
Notes: Ice extent anomalies are computed as a difference from 1990-2020 mean.

Chart 5

Rising global temperature could irreversibly damage multiple climate systems, leading to "tipping points"

(a) Literature-based estimates for temperature thresholds related to Global Core and Regional Impact tipping elements.

(y-axis: Temperature increase in °C, with respect to preindustrial levels)



Triggering climate tipping points can lead to significant policy-relevant impacts to the real economy and the financial system.

Source: ***Armstrong McKay et Al., (2022), Science 377****.*

Notes: Literature-based estimates for temperature thresholds related to Global Core and Regional Impact tipping elements. Climate tipping points (CTPs) occur when change in large parts of the climate system – known as tipping elements – become self-perpetuating beyond a warming threshold. Triggering CTPs leads to significant, policy-relevant impacts, including substantial sea level rise from collapsing ice sheets, dieback of biodiverse biomes such as the Amazon rainforest or warm-water corals, and carbon release from thawing permafrost (Armstrong McKay et al., 2022). See also Dietz, S., Rising, J., Stoerk, T., and Wagner, G. (2021). Economic impacts of tipping points in the climate system (Proceedings of the National Academy of Sciences).

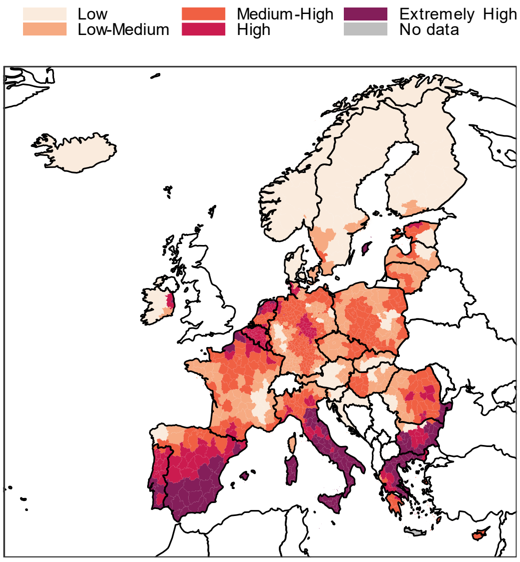
2.2 Natural hazards

Chart 6

The prospect of water stress is uneven across the euro area

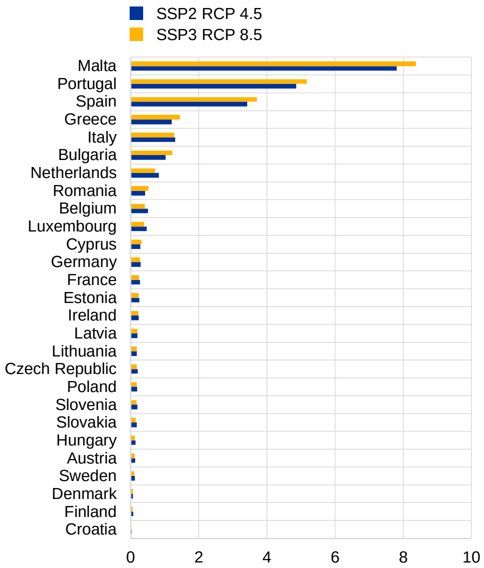
(a) Projected water stress risk in a SSP3 RCP 8.5 scenario for the year 2040

(Water stress risk score)



(b) Projected level of water stress by country and by scenario for the year 2040

(Ratio of water demand to water supply)



Water and heat stress can reduce labour and agricultural productivity, impair logistics and lead to the relocation of economic activity, with significant long-term impact on the GDP.

*Source: **Aqueduct**.*

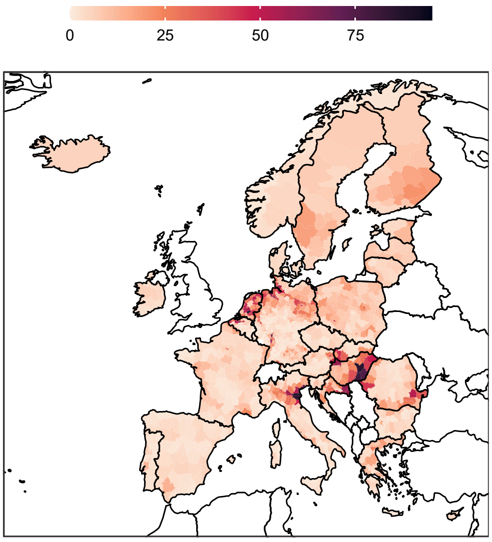
Notes: Water stress is expressed as a ratio between total water withdrawals (water demand) and available renewable surface water (water supply). It measures the level of competition for available water, and estimates the degree to which freshwater availability is an ongoing concern. A higher ratio indicates more competition among users. These ratios are converted into water stress risk scores ranging from low water stress (<10%) to extremely high water stress (>80%). Population development is taken into account. Data are aggregated at NUTS3 (left panel) and country level (right panel) by taking weighted averages across affected areas. Norway and Iceland are excluded from the sample due to data quality issues.

Chart 7

The prospect of river floods are increasing substantially, with flood intensity being a function of adaptation and resilience measures

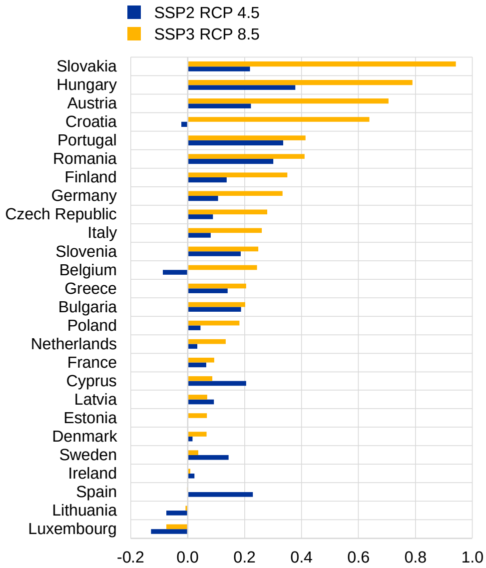
(a) Projected percentage of flooded areas in a SSP3 RCP 8.5 scenario for the years 2021-2050 and for a return period of 100 years

(Percentage points)



(b) Projected change in flood intensity by country and by scenario for the years 2021-2050 and for a return period of 100 years

(Meters)



Increasing flood risk will affect countries unevenly, both through property damage and macro-financial adversity.

*Sources: **TU Delft**.*

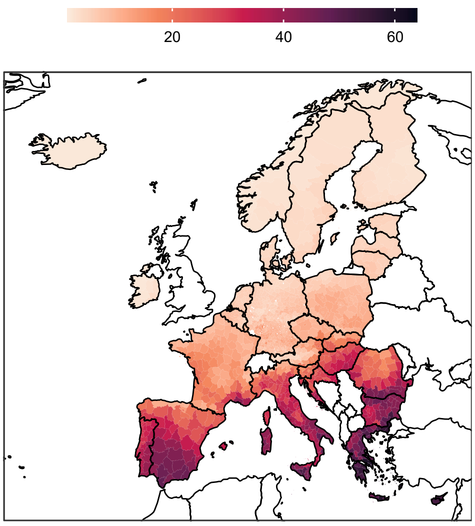
Notes: Flood intensity measures the projected increase in the water depth compared to the average water depth registered during historical flood events. Data are aggregated at NUTS3 (left panel) and country level (right panel) by taking weighted averages across affected areas. Norway, Iceland and Malta are excluded from the sample due to data quality issues.

Chart 8

Wildfire risk expected to rise, alongside drought, heat waves, and high wind

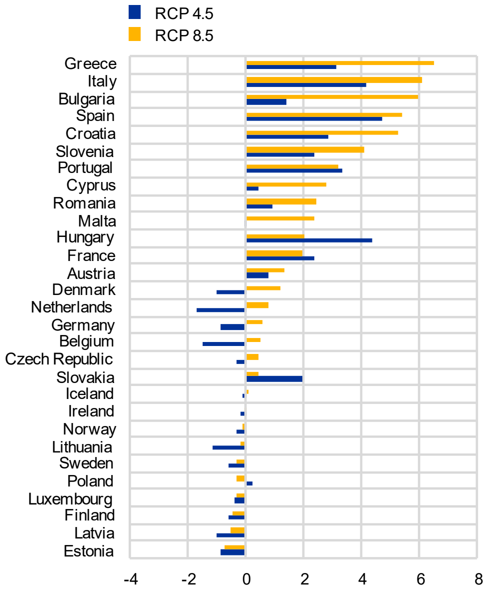
(a) Projected Fire Weather Index in RCP 8.5 scenario, for the year 2040

(Fire Weather Index)



(b) Projected change in Fire Weather Index compared to historical values, by country and by scenario, for the year 2040

(Absolute change in FWI)



Wildfires can pose financial stability risks through property and infrastructure damage, loss of business revenue, decreased property values, government financial burden, and various economic repercussions on industries and communities affected by the events.

*Source: **Copernicus Climate Change Service (C3S) Climate Data Store (CDS)**.*

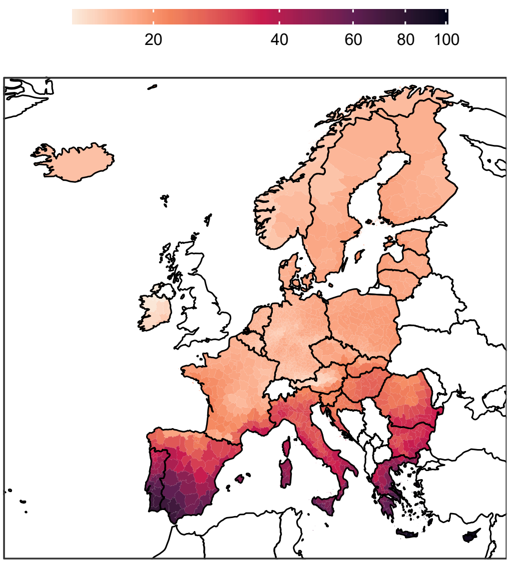
Notes: The Fire Weather Index (FWI) is a meteorologically based index, used worldwide to estimate fire danger in a generalized fuel type (mature pine stands). It consists of different components that assess the responses of moisture to atmospheric forcing at different soil depths and then combine these in order to derive fire behaviour indices in terms of ease of spread and intensity. The score can be interpreted as: “Very low” < 5.2, “Low” 5.2 - 11.2, “Moderate” 11.2 - 21.3, “High” 21.3 - 38.0, “Very high” 38.0 - 50.0 and “Extreme” >= 50.0.

Chart 9

An escalating threat of prolonged droughts

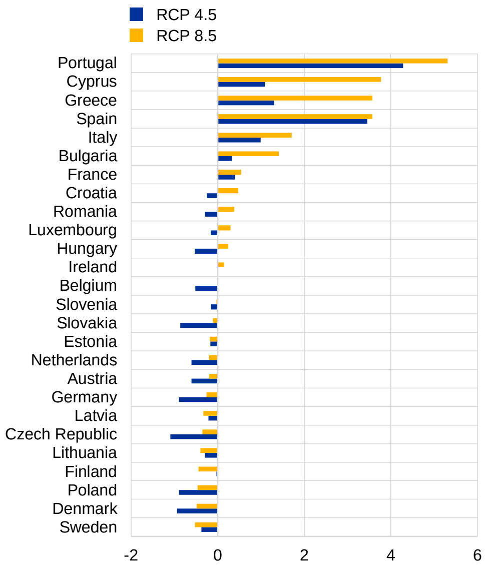
(a) Projected number of Consecutive Dry Days (CDD) in a RCP 8.5 scenario and for year 2040

(Average number of days)



(b) Average change in number of Consecutive Dry Days (CDD) compared to 2005, by country and by scenario (year 2040)

(Average change in number of days)



Water and heat stress can reduce labour and agricultural productivity, impair logistics and lead to the relocation of economic activity, with significant long-term impact on the GDP.

*Source: **IPCC Interactive Atlas**.*

Notes: Consecutive Dry Days (CDD) index measures the maximum number of consecutive days without precipitation (precipitation < 1mm). A drought can be defined depending on region, agricultural patterns, soil moisture and groundwater level. Data are aggregated at NUTS3 (left panel) and country level (right panel) by taking weighted averages across affected areas. Norway, Iceland and Malta are excluded from the sample due to data quality issues.

3 Economic and financial exposures

3.1 Transition events

Real economy

Chart 10

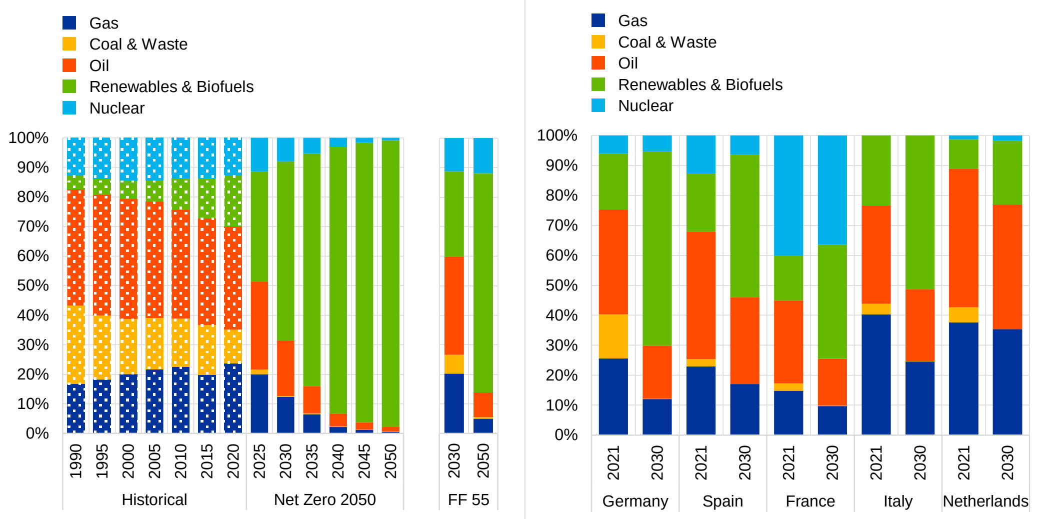
A substantial transformation in the EU energy system, with uneven country impacts

(a) Historical and projected EU energy mix, and energy mix compatible with current renewable energy targets

(b) Historical and projected energy mix, 5 largest EU countries

(y-axis: % of energy mix)

(y-axis: % of energy mix)



The impact related to the implementation of climate transition policies would differ substantially across euro area countries depending on their current energy mix.

Sources: Eurostat Energy Balances, NGFS Climate Scenarios and JRC Energy Scenarios Interactive Tool.

Notes: Panel (a): Projections based on the “Net Zero 2050” scenario from the NGFS. The energy mix compatible with the EU “fit for 55” package (FF 55) is calculated based on the latest projections elaborated by the European Commission and, in particular, on the EU Reference Scenario 2020. Panel (b): Country-level projections based on the “Net Zero 2050” scenario from the NGFS.

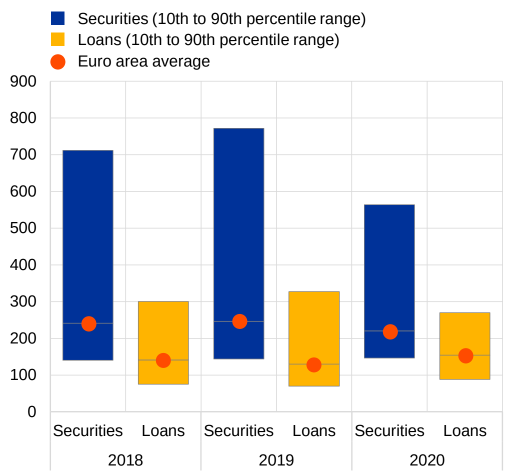
Financial system

Chart 11

Creditor exposures to transition risk

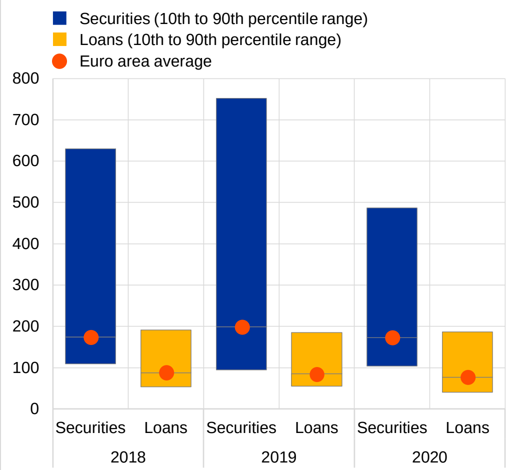
(a) Weighted Average Carbon Intensity (WACI)

(y-axis: tons CO2e per million euro)



(b) Bank Carbon Footprint (BCFP)

(y-axis: tons CO2e per million euro)



The WACI and BCFP indicators provide information on the amount of bank financing of economic activities that may be affected by the transition to net zero.

Sources: STC Expert Group analytical carbon emission indicators based on data from AnaCredit, Securities Holding Statistics (SHSS), Institutional Shareholder Services (ISS), Refinitiv, EU Emissions Trading System (EU ETS), Eurostat Air Emissions Accounts (AEA) and Orbis by Bureau van Dijk.

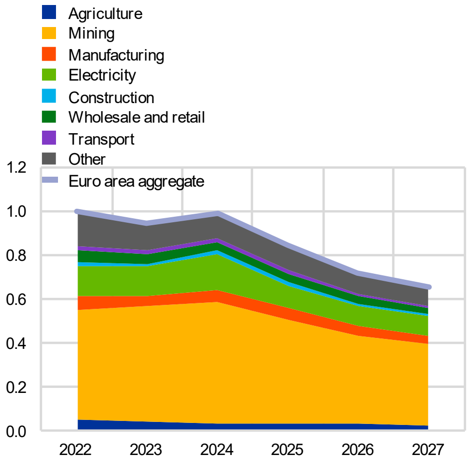
Notes: The chart illustrates the euro area Bank Weighted Average Carbon Intensity (WACI, left panel) and Bank Carbon Footprint (CFP, right panel) of deposit taking cooperations (S122) via loans (yellow) and securities, i.e. debt and equities (blue). The range bars indicate the cross-country range between 90th and 10th percentile. The charts comprise only Scope 1 emissions. The WACI measures the weighted carbon intensity with respect to revenue*: total GHG emissions of a debtor relative to its revenues, weighted by the investment in these activities as a share of the total investment portfolio value covered with emission and financial information;* Carbon footprint measures financed emissions with respect to assets: Financed emissions standardised by the total investment portfolio value *covered with emission and financial information*.

Chart 12

A sudden transition scenario would involve rapid reductions in financed emissions

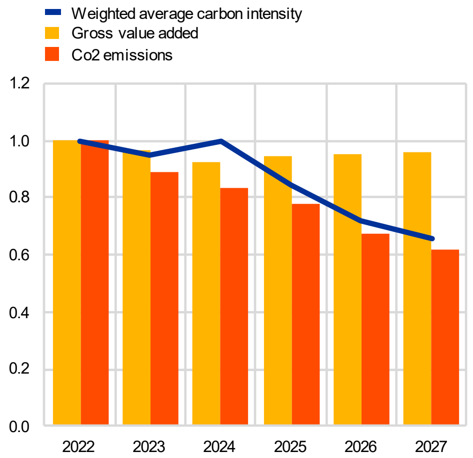
(a) Change in forward-looking Weighted Average Carbon Intensity (WACI) across time and sectors under a sudden transition scenario

(y-axis: Index 2022 = 1)



(b) Evolution of Weighted Average Carbon Intensity components over time under a sudden transition scenario

(y-axis: Index 2022 = 1)



The WACI and CFP indicators provide information on the amount of bank financing of economic activities that may be affected by the transition to net zero.

Sources: ECB calculations on Orbis, Urgentem (acquired by ICE), Eurostat, IRENA, IPCC, BMPE macroeconomic projections, NGFS, Register of Institutions and Affiliates Database and Anacredit.

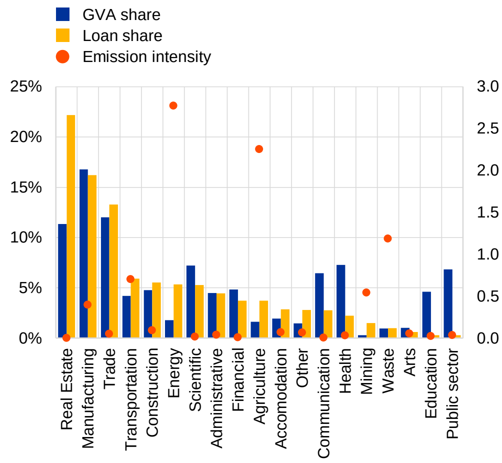
Notes: The charts comprise aggregate information based on a sample of 2.9 million euro are non-financial corporations (NFCs). The forward-looking absolute emissions refer to firm-level scope 1, 2 & 3 absolute emissions as of 2021 from Urgentem aggregated at sector-level and projected forward according to the implied country-sector emission pathways of the sudden transition scenario. Forward-looking GVA refers to country-sector level GVA projected forward based on the GVA.

Chart 13

On average, euro area bank loans are overweight relative to the economy in more emission-intensive sectors

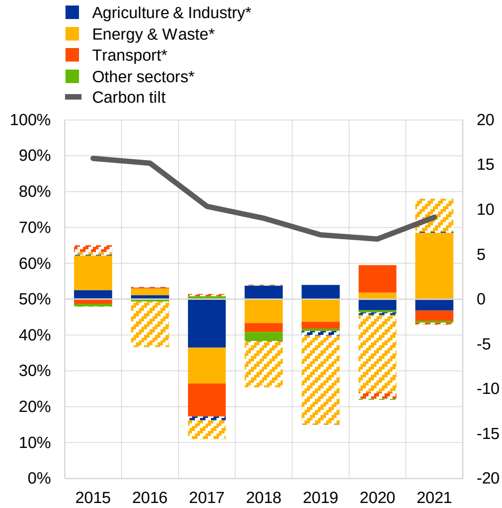
(a) Bank loan portfolio tilted towards emission-intensive sectors

(left-hand scale: percentage; right-hand scale: Kg CO2e / EUR)



(b) Carbon tilt (LHS) and contribution to change, by sector (RHS)

(left-hand scale: percentage; right-hand scale: percentage points)



A bank lending tilt towards higher emission intensive sectors mainly results from lending to transportation, energy, and agriculture sectors.

Sources: Eurostat, ECB Consolidated Banking Data and ECB calculations.

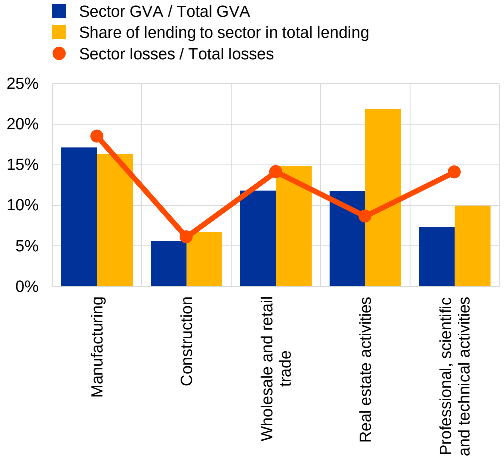
Notes: The carbon tilt is the ratio between loan-weighted emission intensity and GVA-weighted emission intensity. The decomposition of over time stems from changes in emission intensity of each sector as well as relative changes in the share of loans or share of GVA of the respective sector, and from lending shift to carbon-intensive sectors (relative to the change in GVA). The filled area of the bars (panel b) represents the lending shift towards carbon-intensive sectors, while shaded area represents emission intensity.

Chart 14

Concentration risk differs across banks, and could increase transition risk losses

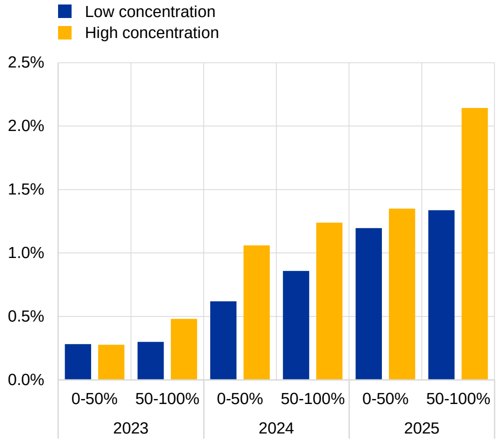
(a) GVA, lending and transition risk losses by sector

(y-axis: percentage share)



(b) Transition risk losses due to concentration risk among banks with similar transition risk exposures

(y-axis: average losses in accelerated transition scenario as percentage of corporate loan portfolio; x-axis: percentile range of share of portfolio allocated to high fossil fuel consumers by year)



A substantial share of expected losses in a disorderly transition scenario is related to the degree of portfolio concentration.

Sources: Anacredit, Urgentem, iBach, Eurostat and ECB calculations.

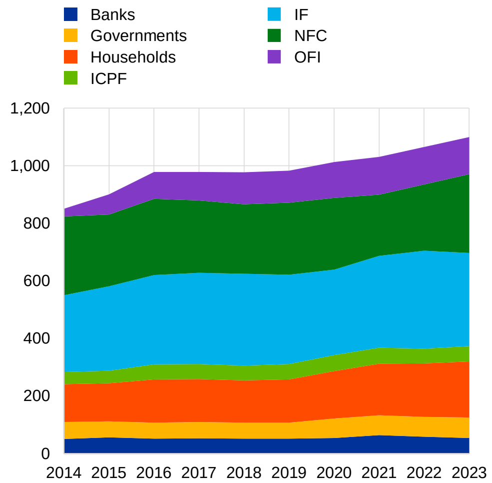
Notes: Losses are calculated based on the 2023 top-down climate stress test. The sample contains 103 eurozone SIs. Eurostat GVA data on NACE level 2 were only available for 2021. Bank-level cwHHIs are calculated using borrowing firms' fossil fuel consumption projections. A firm is classified as a high fossil fuel consumer if it scores above the 75th percentile of fossil fuel consumption in the distribution of unique firms.

Chart 15

Evolution of investors’ exposures to transition risk

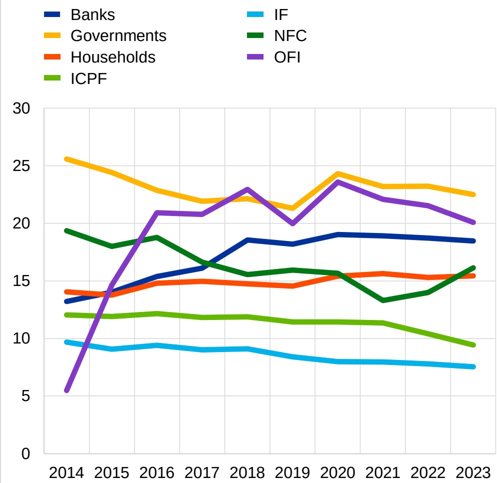
(a) Exposures to transition risk in absolute value

(y-axis: EUR billion)



(b) Exposures to transition risk as share of investors’ portfolios

(y-axis: percentage of sector assets)



High or increasing institutional sector exposures to transition risk could lead to financial vulnerability.

Source: Alessi and Battiston (2023).

Notes: Panel (a): values reported are in real terms (in 2023 euro). Panel (b): TA and TE shares are obtained as ratios of TA or TE holdings over the value of the holdings of a given investor class. The calculations are based on Securities Holdings Statistics (SHS), Last datapoint refers to 2023Q1. ICPF = Insurance corporations and pension funds; IF = Investment funds; NFC = Non-financial corporations; OFI = Other financial institutions.

3.2 Physical events

Financial system

Chart 16

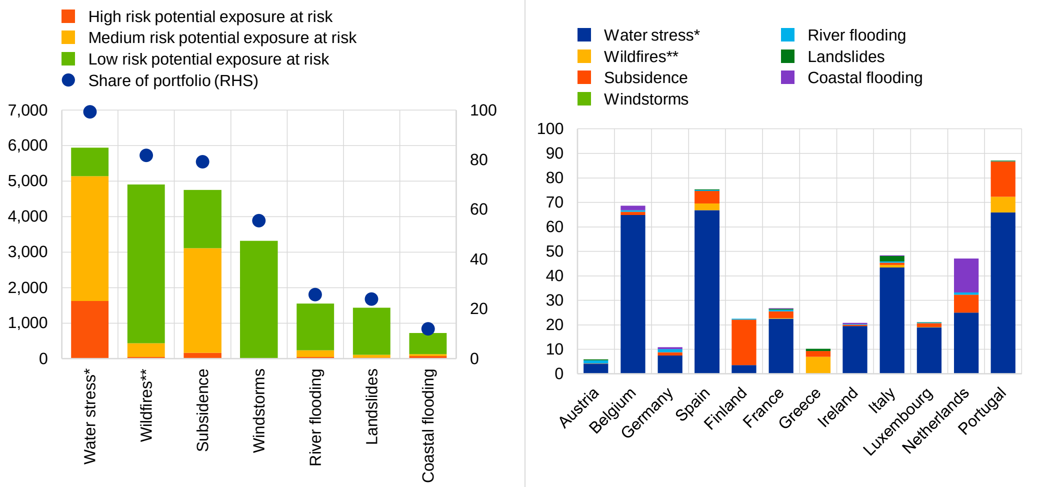
Potential exposure at risk (PEAR)

(a) PEAR by hazard type; loans, debt securities and equity portfolio of euro area banks

(left-hand scale: EUR Bln; right-hand scale: percentage of portfolio)

(b) Share of euro area bank's portfolio (loans, debt securities and equity) represented by high risk score exposures, broken down by hazard and creditor country

(y-axis: percentage of portfolio)



The materialization of broad physical risk can have a significant and heterogeneous impact on banks' portfolio holdings based on potential maximum exposures.

Sources: ESCB calculations based on data from analytical credit datasets (AnaCredit), Securities Holding Statistics (SHS), Joint Research Centre (JRC), Copernicus, World Resource Institute (WRI) and NASA.

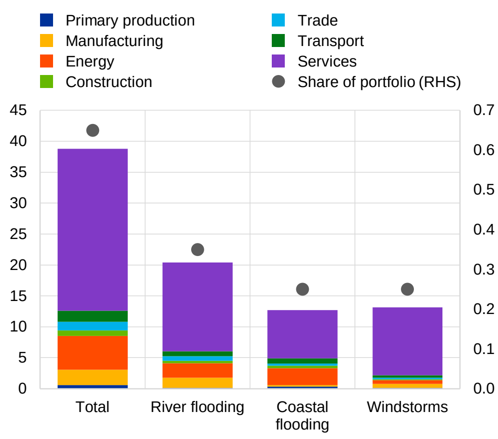
Notes: The potential exposure at risk (PEAR) indicator provides information on the share of financial institutions' portfolios exposed to non-financial corporations located in areas susceptible to specific physical risks, incorporating all exposures regardless of the intensity or likelihood of the hazard occurring. Indicators are computed consolidating corporate group exposures at debtor's level using simple averages across the parent company and its subsidiaries. Risk scores rank exposures according to risk level categories from 1 (low) to 3 (high risk). Risk scores are not comparable across hazard types because the scores rely on different methodologies and sources: water stress (scores derived from WRI based on the ratio between water demand and water supply), wildfires (scores from own calculations based on expected area burned), subsidence (scores from JRC based on the percentage of clay and sand in the soil), windstorms (scores from own calculations based on expected windspeed at return periods of 10, 50, 100 and 500 years), river and coastal flooding (scores from own calculations based on expected water depth of flooding in return periods of 10, 50, 100 and 500 years), landslides (scores from the JRC and adapted according to the return periods of 10, 50, 100 and 500 years). Risk scores are computed at debtor's level for each hazard separately. While a company can be exposed to several risks, country-level exposures are a simple sum of high risk scores for each hazard – leading to possible double counting of exposures, in particular in case of correlated risk such as water stress and wildfires. Risk scores are not available for Cyprus, Estonia, Lithuania, Latvia, Malta, Slovenia and Slovakia. Indicators for water stress and wildfires are based on projected data for 2040 and 2030-2050 respectively. Protection measures, insurance and collateral are not considered. AnaCredit and SHS data are for December 2020. For further details on the methodology, data sources and limitations please consult the ***methodology report*** *and the* ***technical annex*** *of the ECB climate-related indicators.*

Chart 17

Normalized exposure at risk (NEAR)

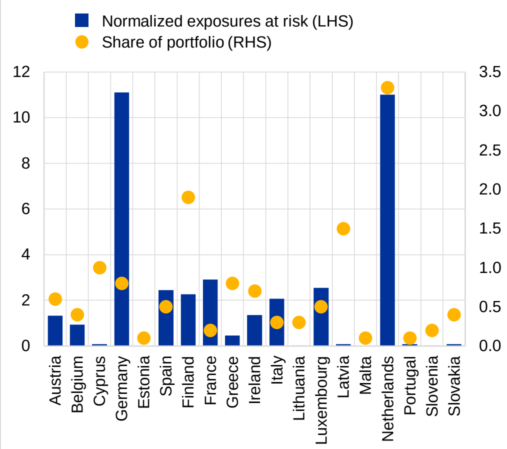
(a) NEAR by hazard type and debtor's sector; loans, debt securities and equity portfolio of euro area banks

(left-hand scale: EUR Bln; right-hand scale: percentage of portfolio, normalised by debtor's total assets)



(b) Total NEAR, by creditor country

(left-hand scale: EUR Bln; right-hand scale: percentage of portfolio)



The materialization of physical risk in the form of flooding and windstorms can have a significant and heterogeneous impact on banks' portfolio holdings based on normalised portfolio (where each debtor/issuer's exposure is weighted by a financial risk ratio).

Sources: ESCB calculations based on data from analytical credit datasets AnaCredit, SHS, JRC, Copernicus and Orbis by Bureau van Dijk.

*Notes: Normalised exposure at risk indicator (NEAR) relates the expected annual damages by each hazard to debtor's tangible fixed assets to total assets (financial risk ratio). It is assumed that the financial exposures (loans, debt securities and debt) decrease in the same proportion as losses to physical assets. Indicators for the consolidated group from the debtor/issuer side are derived by summing up the physical risks and exposures of the group's subsidiaries and attributing them to the parent. Protection measures, insurance and collateral are not considered. AnaCredit and SHS data are for December 2020. For further details on the methodology, data sources and limitations please consult the **methodology report** and the **technical annex** of the ECB climate-related indicators.*

4 Financial risks

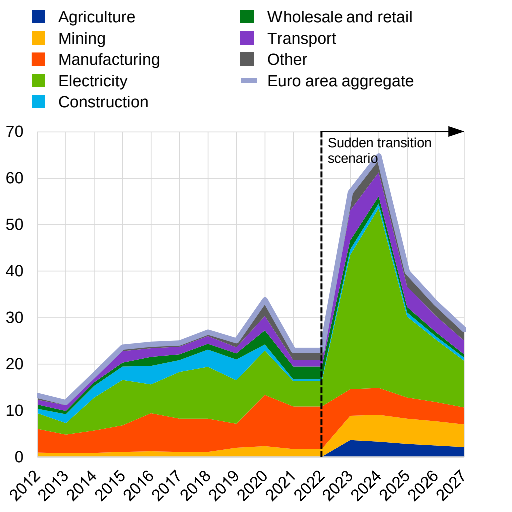
4.1 Transition risk

Chart 18

Forward-looking transition-to-credit risk intensity (TCI) would exhibit only a short-lived spike during the peak of a sudden transition scenario

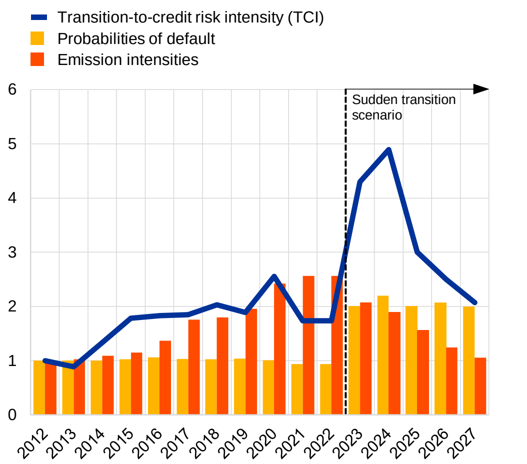
(a) Change in forward-looking transition-to-credit-risk intensity across time and sectors under a sudden transition scenario

(y-axis: EA aggregated TCI)



(b) Evolution of TCI components over time under a sudden transition scenario

(y-axis: Index 2012 = 1)



A sudden net-zero transition combined with insufficient provisioning could expose EA banks' loan portfolios to loan losses, stemming from large exposures to transition risk.

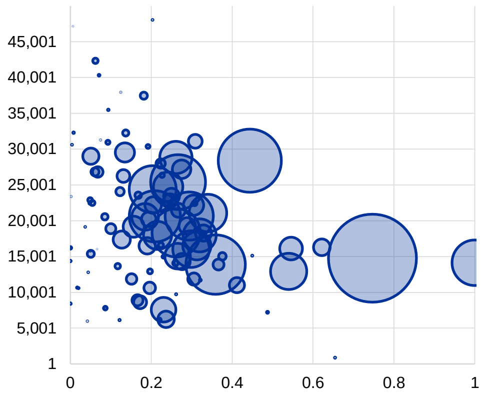
Sources: ECB calculations on Orbis, Urgentem (acquired by ICE), Eurostat, IRENA, IPCC, BMPE macroeconomic projections, NGFS, Register of Institutions and Affiliates Database and Anacredit.

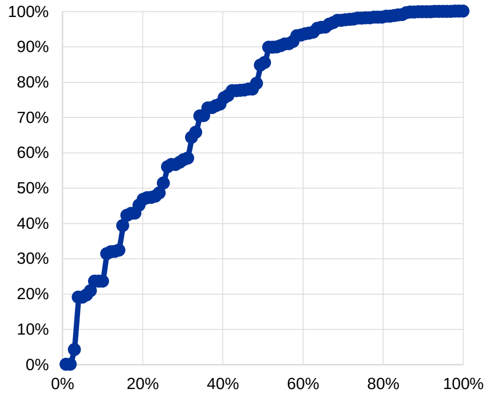
Notes: The time series covers both inferred and reported emissions for 1,250 non-financial corporations (NFCs), which comprise on average 10% of AnaCredit exposures over time. Backward-looking results of the TCI assume that the credit risk component (PDs) does not already consider climate risk. The components of the forward-looking TCI are assumed to follow the pathway of the sudden transition scenario. Two different underlying sources for emissions data are used. Historical TCI uses emissions based on firm-level data from Urgentem (acquired by ICE). The forward-looking emission intensities refer to firm-level scope 1, 2 & 3 absolute emissions over revenues as of 2021 from Urgentem and projected forward according to the implied country-sector emission pathways of the sudden transition scenario and firm-level projection of revenues. Sectors refer to NACE Level-1 letters. "NACE" stands for Nomenclature statistique des activités économiques dans la Communauté Européenne (Statistical classification of economic activities in the European Community).

Chart 19

Climate risk sensitivity (CRS) score suggest impacts of a sudden transition would be highly concentrated among relatively few banks

(a) Bank-level climate risk sensitivity (CRS) and loan-weighted emissions by 2027 under a sudden transition scenario	(b) Banks' cumulative share in additional expected loses by 2027 under a sudden transition scenario, ranked by highest to lowest CRS
(x-axis: min-max normalized CRS score, bubble size indicates size of absolute expected losses until 2027; y-axis: loan-weighted absolute emissions)	(x-axis: share of banks; y-axis: cumulative share of expected losses)





By 2027, around a quarter of total loan portfolios already comprise around 50% of total additional losses due to carbon prices.

Sources: ECB calculations on Orbis, Urgentem (acquired by ICE), Eurostat, IRENA, IPCC, BMPE macroeconomic projections, NGFS and Anacredit.

Notes: Results for corporate loan portfolios of euro area Significant Institutions (SIs) are presented. Panel (a): Absolute emissions refer to scope 1, 2 & 3 Co2 emissions.

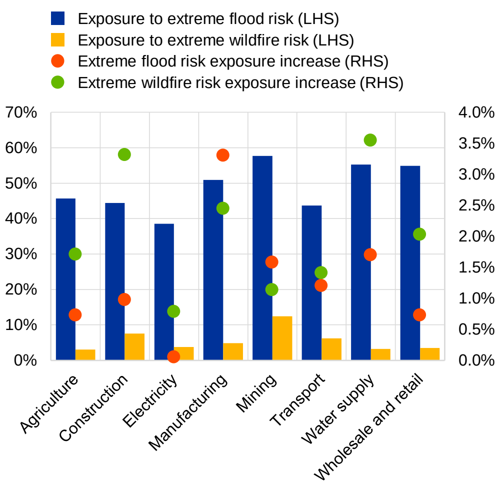
4.2 Physical risk

Chart 20

Physical-to-credit risk intensity (PCI) is concentrated in a few sectors and does not fully overlap with the simple physical risk exposure metric

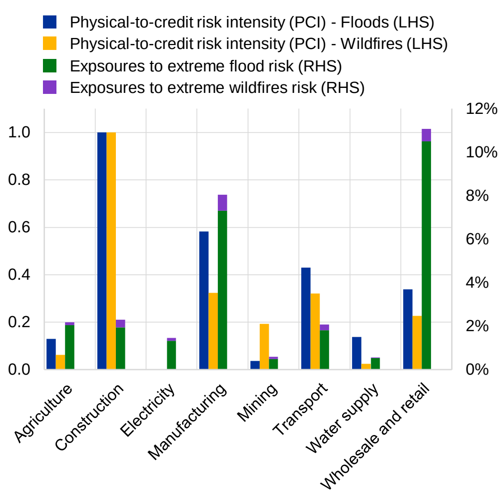
(a) Sector-level exposures towards borrowers extremely exposed floods and wildfires in 2030 and change in exposures by 2050

(left-hand scale: share of sector-level exposures in 2030 in ppt; right-hand scale: increase in sector-level exposures by 2050 in ppt)



(b) Physical-to-credit risk intensity (PCI) score

(left-hand scale: min-max normalized PCI; right-hand scale: share of vulnerable over total corporate loan exposures in percentages)



Up to 50% of sector-level loan exposures are held towards firms exposed to extreme flood and wildfire risk, however, only a subset of sectors is vulnerable to combined credit and physical risk which EA banks should particularly monitor.

Sources: ECB calculations on Moody's 427, Register of Institutions and Affiliates Database and Anacredit.

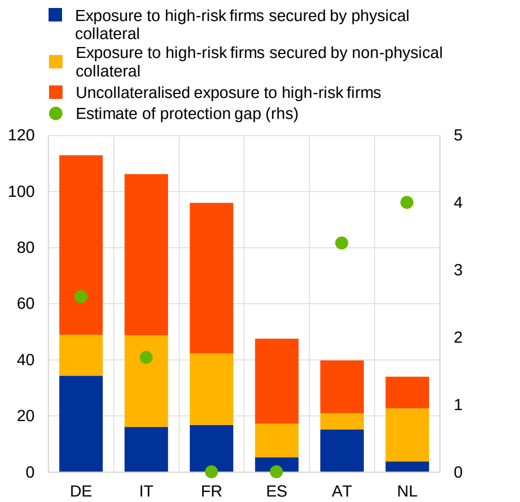
Notes: Exposure to flood and wildfire risk is measured via forward-looking risk scores from Moody's 427. These are normalized scores between 0 and 100 which measure the frequency and intensity of the respective hazard based on firms' geographical location at address-level. Firms are categorized as tail risk firms for floods (wildfires) if their flood (wildfire) score is above 75 (50). Sectors refer to NACE Level-1 letters. "NACE" stands for Nomenclature statistique des activités économiques dans la Communauté Européenne (Statistical classification of economic activities in the European Community).

Chart 21

An insurance protection gap can increase the exposure of banks to physical risk and reduce the value of collateral

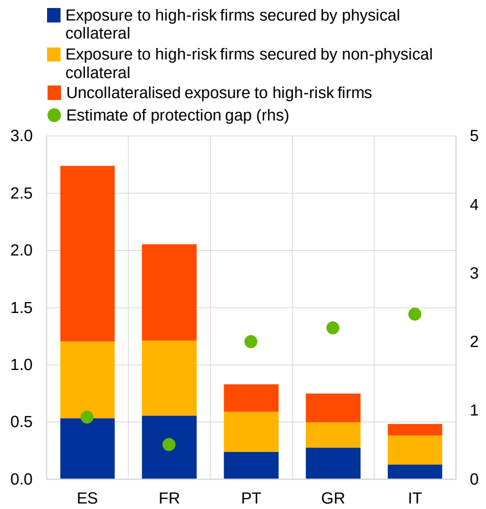
(a) Exposure of euro area banks to firms at high risk from floods

(left-hand scale: EUR billions; right-hand scale: protection gap score)



(b) Exposure of euro area banks to firms at high risk from heat stress, hurricanes, sea level rise, water stress and wildfires

(left-hand scale: EUR billions; right-hand scale: protection gap score)



A consistent share of EA banks exposures to firms subject to high or increasing climate-related risks is uncollateralized or secured by physical collateral, with expected losses potentially exacerbated by large insurance protection gaps.

*Sources: **EIOPA pilot dashboard on insurance protection gap for natural catastrophes**, Moody's 427 and ECB calculations (ECB/ESRB, 2022).*

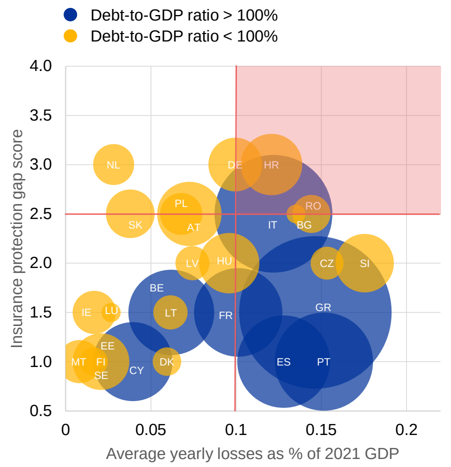
Notes: Credit exposures to non-financial corporations (NFCs) above €25,000 are considered; the NFC location used to assign risk levels refers to the head office and the location of subsidiaries of the largest listed firms. Only NFCs domiciled in areas that are classified as high risk, either present or projected, are included. The country breakdown refers to the firm's domicile. The total collateral value at instrument level is capped at the value of the instrument. The protection gap of firms is proxied by the estimate of today's protection gap score of its country and differs across hazards (0 = no risk, 1 = low risk, 2 = low/medium risk, 3 = medium/high risk, 4 = high risk). Panel (a): flood risk. Panel (b): all other hazards, such as heat stress, hurricanes, sea level rise, water stress and wildfires.

Chart 22

Some countries suffering historically high catastrophe losses as a share of GDP also have a large insurance protection gap, which could weigh on debt sustainability

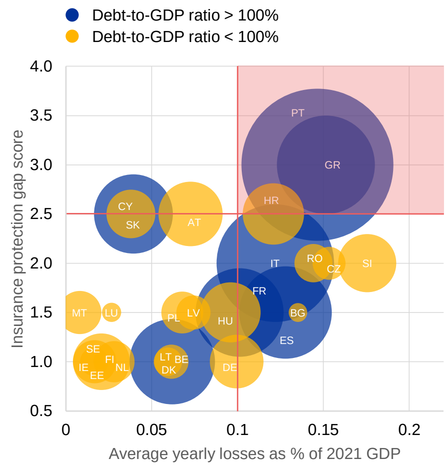
(a) Historical losses and protection gap for floods

(x-axis: average yearly losses (1980-2021), percentages of 2021 GDP; y-axis: protection gap score; bubble size: government debt, percentages of 2021 GDP)



(b) Historical losses and protection gap for wildfires

(x-axis: average yearly losses (1980-2021), percentages of 2021 GDP; y-axis: protection gap score; bubble size: government debt, percentages of 2021 GDP)



Climate-related catastrophes are likely to have asymmetric effects on the fiscal stability of European countries, as economies differ significantly in their climate risk exposures, vulnerabilities and resilience.

*Sources: **EIOPA dashboard on insurance protection gap for natural catastrophes**, EEA, Eurostat, ECB GFS and ECB calculations.*

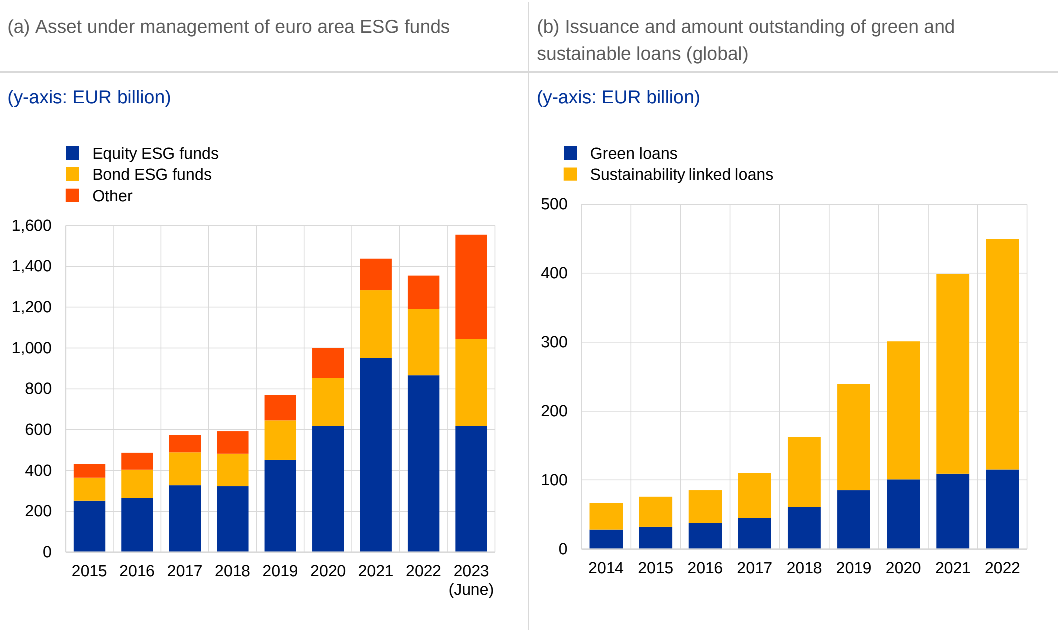
Notes: The x-axes refer to the average yearly losses (data from the EEA) from floods and wildfires respectively between 1980 and 2021 relative to GDP (data from Eurostat). The size of the bubble is proportional to the country's debt-to-GDP ratio. The y-axes refer to EIOPA's estimated protection gap score, ranging from 0 to 4 (0 = no gap, 1 = low, 2 = medium, 3 = high, 4 = very high). Each protection gap score is country and peril-specific. The red shaded areas indicate countries with both a high protection gap and high average losses, the thresholds for which are set at a protection gap score of 2.5 out of 4 and 0.1% of GDP respectively.

5 Monitoring markets

5.1 Financing activities exposed to climate-related risks

Chart 23

Green and sustainable financial markets have grown rapidly in recent years, but maintaining the momentum is vital to increase the total amount of green finance required



Financial markets can help support the transition to a more sustainable economy by helping to channel capital towards sustainable projects and reduce vulnerability to climate-related risks.

Sources: Morningstar, Bloomberg Finance L.P and ECB calculations.

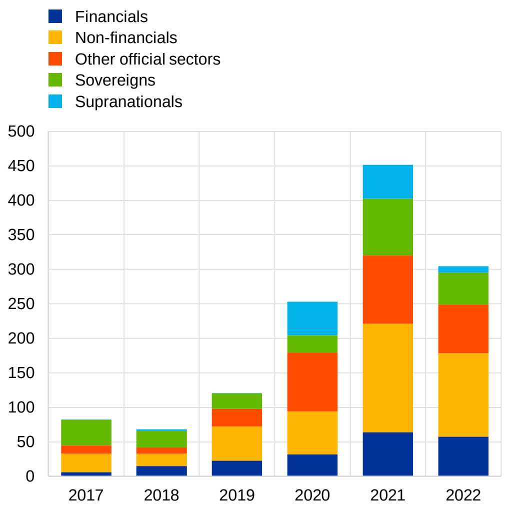
Notes: Panel (a): ESG funds correspond to all sustainable funds identified using Morningstar intentions attributes based on information retrieved from fund prospectuses.

Chart 24

Green and sustainable financial markets have expanded across all institutional sectors, with green sovereign bonds generally having the longest maturities

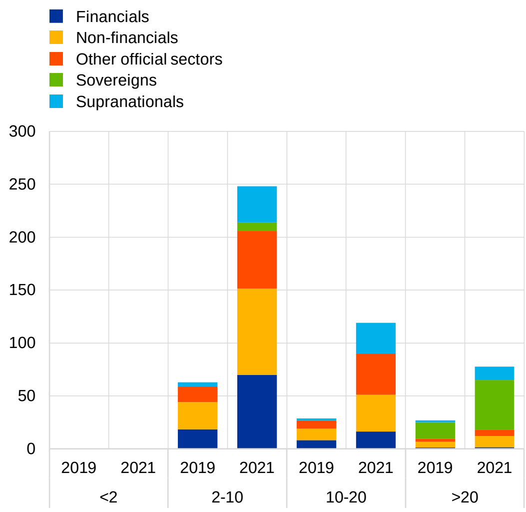
(a) Issuance of sustainable debt securities in the euro area, by sector

(y-axis: EUR billion)



(b) Annual gross issuance of Green, Social, Sustainability (GSS), by maturity

(y-axis: EUR billion)



The political agreement on an European green bond is expected to strengthen the credibility of this asset class, reduce reputational risks for issuers and investors, and mitigate greenwashing. This, in turn, will lead to improved pricing of green bonds, support the further growth of the segment, and strengthen the contribution made by green bonds to the EU's environmental objectives.

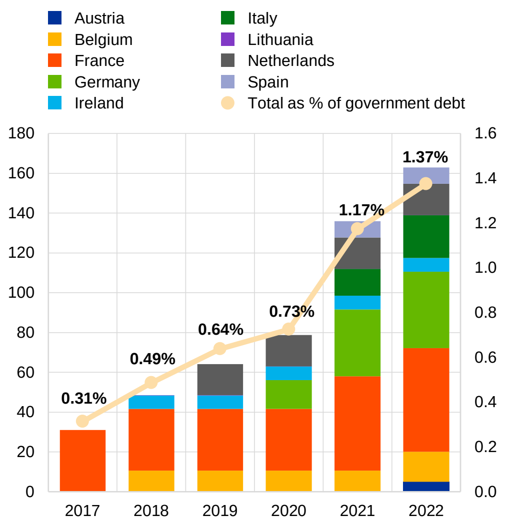
Sources: Morningstar, Bloomberg Finance L.P., and ECB calculations.

Chart 25

Sovereign green bond markets in the euro area continue to develop, with proceeds mainly used for clean transport, renewables, and energy efficiency

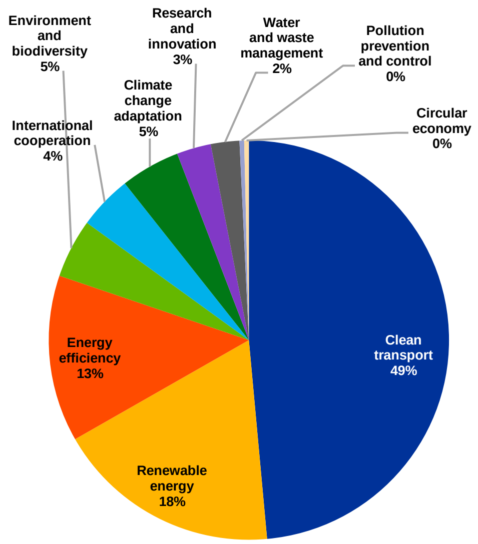
(a) Amount outstanding of euro area green sovereign bonds, by country

(left-hand scale: € billions; right-hand scale: share of government debt)



(b) Use of proceeds from euro area sovereign green bonds

(2022, percentages)



Public sector participation fosters the development of private sector green markets by increasing liquidity and by setting frameworks with best practices that promote standards for green bond classifications and their verification; minimising the risk of greenwashing.

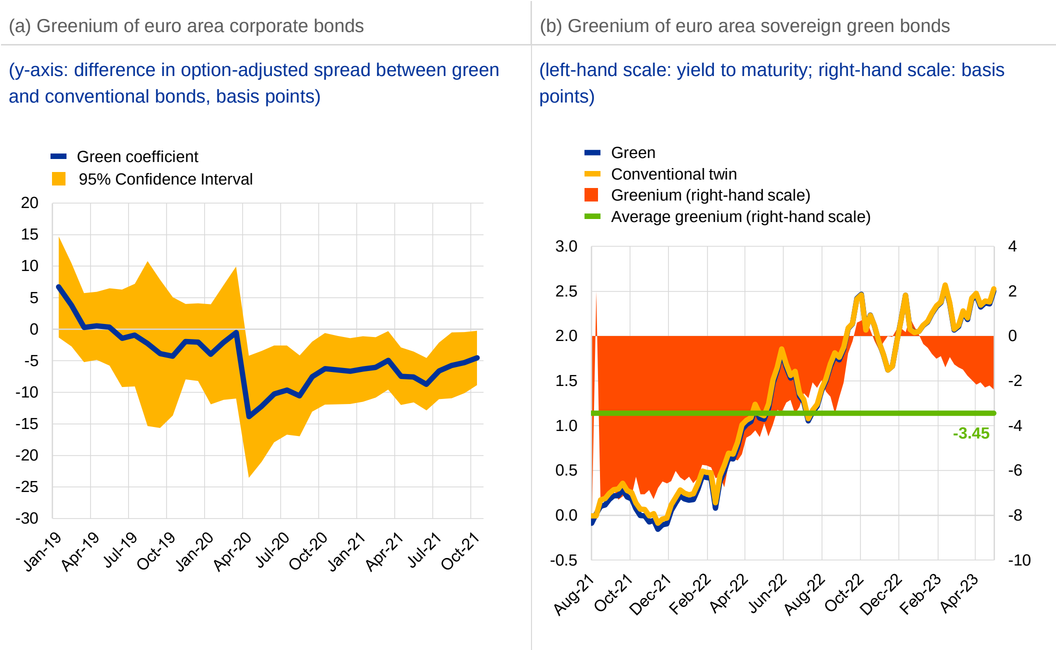
Sources: Bloomberg Finance L.P., debt agencies (allocation reports) and ECB calculations.

Notes: Panel (a): the solid line represents the total amount outstanding of green bonds issued by euro area sovereigns as a share of euro area government debt. Bloomberg classifies bonds as green according to the information provided by the debt agencies. Panel (b): publicly available allocation reports until April 2023 are used.

5.2 Market risk and vulnerability factors

Chart 26

Green bonds' "greenium" has dampened over time, affected by supply-demand balance



Early issuances of green bonds have benefited from the existence of a greenium but has been dissipating with changing supply-demand dynamics alongside some investors concerns about greenwashing.

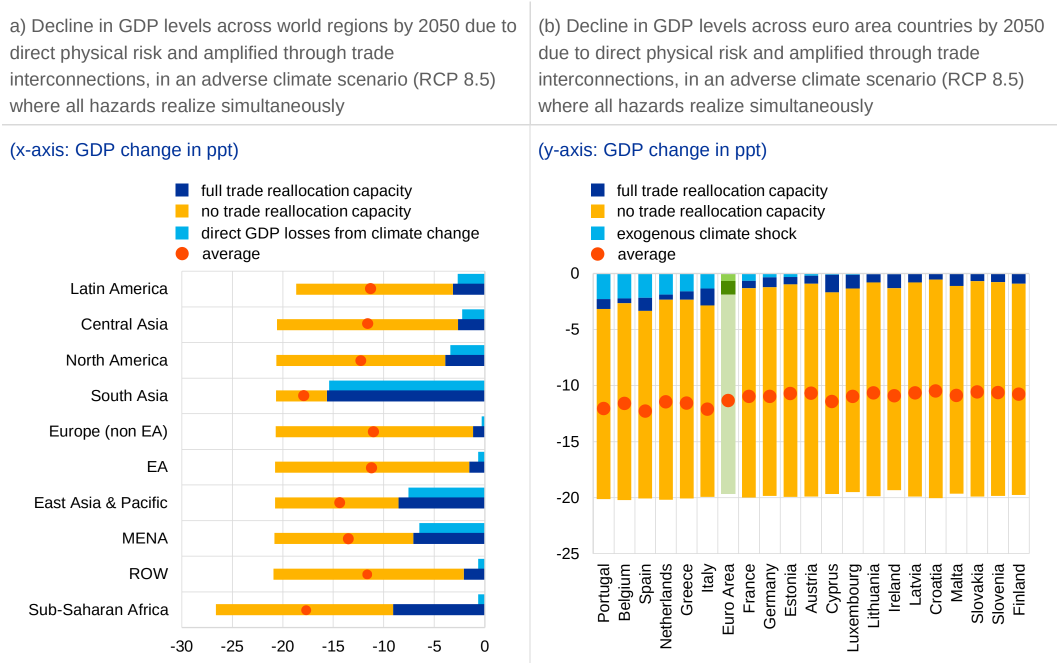
Sources: Bloomberg Finance L.P., ECB calculations and ***Pietsch and Salakhova****.*

Notes: Panel (a): the coefficient of this indicator is depicted for monthly sub-samples. Panel (b): amount outstanding weighted average greenium. The greenium refers to the difference in yield to maturity between green bonds and conventional bonds. Different methods are used in the literature to estimate this discount – for this analysis it has been estimated by matching, when possible, each green bond with a conventional sovereign bond based on similar features such as rating and maturity (the "conventional twin").

6 Systemic risk assessment

Chart 27

Input-output interdependencies can amplify physical risk-related GDP losses



With euro area economic activity highly integrated into global supply chains, climate related shocks can strongly reverberate across borders and increase GDP losses.

Sources: SPGlobal, OECD ICIO, ECB calculations.

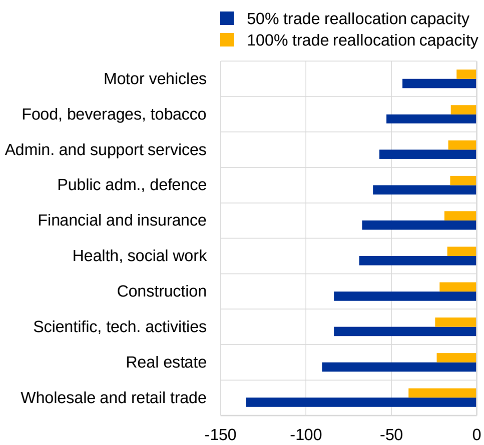
Notes: The GDP losses amplified through trade interconnection are simulated through an Input-Output model developed at the ECB. A 100% Trade Reallocation Capacity (in dark blue) implies no cost in reorganising supply chains across trading partners and 0% precludes trade reorganisation. An adverse climate scenario is considered, i.e. RCP 8.5 scenario by 2050 with no adaptation measures and where all country-specific hazards materialize simultaneously across the world. Panel (a): world regions. Panel (b): euro area countries.

Chart 28

Losses faced by real economy sectors and the financial system losses are significant and heterogeneous

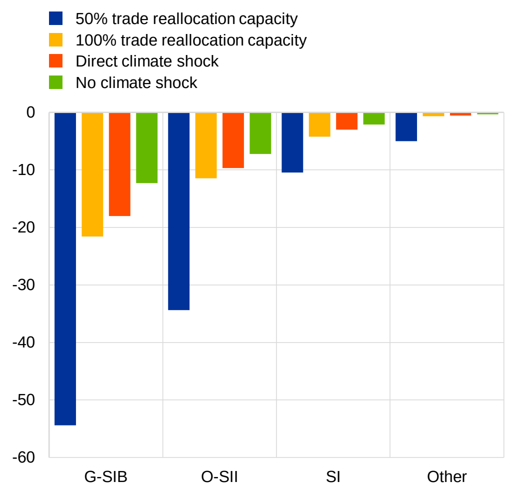
(a) Top 10 sectors with highest absolute GVA losses (by 2050), due to direct physical risk and amplified through trade interconnections, in an adverse climate scenario (RCP 8.5) where all hazards realize simultaneously

(x-axis: EUR billion)



b) Average capital losses per bank type in the 9th most adverse simulation decile; in a conventional stress test scenario and in three adverse climate scenarios by 2050 where all hazards realize simultaneously (percentage of total capital)

(y-axis: Percentage points)



In addition to common exposures, the interlinked nature of the global supply chain network can lead to the transmission and amplification of physical risk events.

Sources: OECD, S&P Global Ratings, AnaCredit, SHSG, FINREP and ECB calculations.

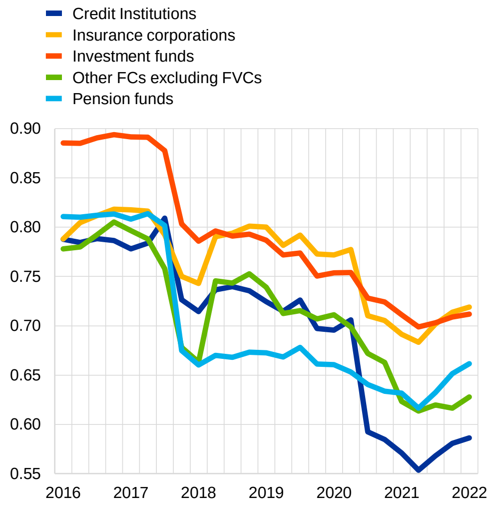
*Notes: Panel (a): the GVA losses are reported for the full trade reallocation capacity and for a scenario where the correspondent parameter is calibrated to be 50%. Panel (b): The conventional scenario (green) is based on EBA stress tests. The three adverse climate scenarios all consider an RCP 8.5 scenario by 2050 where all hazards realize simultaneously. The climate scenarios differ by (i) not taking cross-border linkages into account (red), (ii) taking them into account and allowing for maximum trade reallocation (yellow), and (iii) taking them into account and allowing for some trade reallocation. The data covers a sample of 6308 banks in the Single Supervisory Mechanism (SSM) area. The groups are the following: Global Systemic Important Banks (GSIB, 8 entities), Other Systemic Important Institutions (OSII, 79 entities), Significant Institutions (37 entities), and others (1617 entities). The results for losses are modelled using a multi-layered network model (see **Financial Stability Review, May 2019**, Special Feature B for details (ECB, 2019)).*

Chart 29

Overlapping portfolio risk is highest for NBFI entities, and lowest for banks

(a) Country-hazard related portfolio similarity across financial sectors

(y-axis: Index, 0 = no overlap, 1 = absolute similarity)



(b) Pairwise similarity between different financial sectors

(Index, 0 = no overlap, 1 = absolute similarity)

Q4 2022	Banks	IC	IF
IC	0.57		
IF	0.51	0.83	
PF	0.46	0.75	0.98

Systemic risk may be generated by financial portfolios with overlapping exposures to climate-related risk across financial institutions.

Sources: SHSS, Moody's, own calculations.

Notes: The physical risk-weighted portfolio similarity index measures similarity in overlapping securities portfolios across sectors to capture joint exposures to climate-related risks. More specifically, we calculate the cosine similarity index for each sector with the other sectors and take the average to get an index for each sector. NBFI = non-bank financial intermediaries, IC = insurance corporations, IF = investment funds, PF = pension funds.

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website **www.esrb.europa.eu**

For specific terminology please refer to the **ESRB glossary** (available in English only).

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