EUROPEAN CENTRAL BANK

EUROSYSTEM

# Technical annex

Statistics Committee Expert Group
on Climate Change and Statistics
and Working Group on Securities Statistics

## Climate change-related statistical indicators

November 2025

# Contents

# 1 Introduction

## 1.1 Background

In January 2023 the European Central Bank published for the first time a new set of data series and indicators: the climate-change related indicators. These indicators were subsequently updated in April 2024 and November 2025.

## 1.2 Objective

The objective of this technical annex is to provide detailed methodological explanations of how the indicators are compiled.

## 1.3 Versioning

| Version | Publication date | Key updates |
|---|---|---|
| **Version 3** | November 2025 | Description of the enhancements to transition and physical risks introduced in the November 2025 release and not reflected in the April 2024 statistics paper.<br>For sustainable finance, since November 2025, new aggregates on the issuances of sustainable debt securities are published, i.e. by maturity, currency and interest rate type.<br>For transition risk, this release includes the extension of the time series with nowcasting of indicators up to 2024, the expansion of the time series decomposition to include drivers like inflation, and the addition of captive financial issuers/debtors funding non-financial corporation (NFC) activities. Multiple improvements to data quality and matching algorithms allow for more reliable indicators.<br>For physical risks, the enhancements are covered in Section 5.2. In addition, changes in the documents include updates to data sources for windstorms and water stress, amendments to the financial risk ratio, and the treatment of missing data. |
| **Version 2** | April 2024 | The document summarises the methodology detailed further in the April 2024 statistics paper.<br>For sustainable finance, since November 2023, aggregates on sustainable debt securities are published for two levels of assurance: i) instruments with a second party opinion validating the sustainability claims of the issuer (new data), and ii) all sustainable instruments, i.e. with all degrees of assurance, including only self-labelled instruments. Since September 2024, additional series have been added to the indicators, which are published as official ESCB statistics.<br>For transition risk, this release includes the extension of the time series up to 2021, a correction of weighted average carbon intensity (WACI) for inflation and the exchange rate, the inclusion of Marshall-Edgeworth-type decomposition of the time series, the addition of imputation strategies to increase coverage of portfolios, and the addition of a balancing algorithm for sample balancing.<br>For physical risk, the hazard set was expanded to include drought and rainfall; indicators were broadened to reflect climate scenarios, account for flood adaptation measures, and introduce the collateral-adjusted exposure at risk (CEAR) indicator. |
| **Version 1** | January 2023 | The document summarises the methodology for data users and includes information on data content and structure. |

## 1.4 Contact

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# 2 Sustainable finance indicators

## 2.1 Issuance of debt securities

### 2.1.1 Indicator description

The following sustainability classifications have been added to the Centralised Securities Database (CSDB) Securities Issues Statistics (CSEC):

- green (GRE) – debt securities where the proceeds are used to finance green projects;
- social (SCL) – debt securities where the proceeds are used to finance social projects;
- sustainability (STN) – debt securities where the proceeds are used to finance a combination of both green and social projects;
- sustainability-linked (STL) – debt securities for which the financial and/or structural characteristics can vary depending on whether the issuer achieves predefined sustainability/environmental, social and governance (ESG) objectives.

Aggregates considering all (at least self-labelled) sustainable debt securities and (of which) aggregates for those that have obtained a pre-issuance second-party opinion are being made available for the amount outstanding (stocks) and issuances (financial transactions) of euro area and EU sustainable debt securities, broken down by sustainability classification, sector, country of issuer, maturity, currency and interest rate type. The aggregates of stocks are made available at face, nominal and market value, whereas those of financial transactions are made available at face and market value.

### 2.1.2 Limitations and constraints

The underlying standard/framework against which the sustainability classification of the sustainable debt security is aligned (e.g. the International Capital Market Association (ICMA), the Climate Bonds Initiative (CBI) or the European Green Bond Standard (EUGBS)) is not used to restrict the universe. In other words, all standards are considered, including a small number of securities without a recognised standard.

Further breakdowns based on specific standards, in particular on the EUGBS, will be considered in subsequent extensions of the indicators.

### 2.1.3 Code list

CUST_BREAKDOWN

| Code | Label |
|---|---|
| G_XX | Green (use of proceeds), assurance level unspecified |
| G_SX | Green (use of proceeds), second-party opinion |
| C_XX | Social (use of proceeds), assurance level unspecified |
| C_SX | Social (use of proceeds), second-party opinion |
| S_XX | Sustainability (use of proceeds), assurance level unspecified |
| S_SX | Sustainability (use of proceeds), second-party opinion |
| L_XX | Sustainability-linked, assurance level unspecified |
| L_SX | Sustainability-linked, second-party opinion |

The full code list for the CSEC dataset is available in the metadata section of the ECB Data Portal.

### 2.1.4 Data sources

Centralised Securities Database (CSDB)

### 2.1.5 Compilation method

The sum of all debt securities issuances flagged as green, social, sustainability or sustainability-linked. The indicators are calculated directly from the CSDB as part of the CSEC compilation. All calculations are based on attributes associated with individual securities, which are then used to calculate aggregate series.

### 2.1.6 Periodicity/update frequency

Data are published at a monthly frequency and disseminated at around t+10 working days after the end of the reference month.

## 2.2 Holdings of debt securities

### 2.2.1 Indicator description

As for the issuance of sustainable debt securities, the following sustainability classifications are available for securities holdings statistics by sector (SHSS):

- green (GRE) – debt securities where the proceeds are used to finance green projects;
- social (SCL) – debt securities where the proceeds are used to finance social projects;
- sustainability (STN) – debt securities where the proceeds are used to finance a combination of both green and social projects;
- sustainability-linked (STL) – debt securities for which the financial and/or structural characteristics can vary depending on whether the issuer achieves predefined sustainability/environmental, social and governance (ESG) objectives.

Aggregates considering all (at least self-labelled) sustainable debt securities and (of which) aggregates for those sustainable debt securities that have obtained a pre-issuance second-party opinion are made available for euro area holdings (stocks and financial transactions) of sustainable debt securities, broken down by sustainability classification and counterpart issuing area (euro area, EU, rest-of-the world and total). A breakdown by individual holder country is available for all sustainable classifications. Additionally, a breakdown by holder sector is available for euro area aggregates for all sustainable classifications, and for individual country aggregates for green bonds only. The aggregates of stocks are made available at face and market value, whereas those of financial transactions are made available only at market value. Additional breakdowns by maturity, currency and interest rate type are expected to be made available by 2027. Aggregates flagged as confidential are not published externally.

### 2.2.2 Limitations and constraints

The underlying standard/framework against which the sustainability classification of the sustainable debt security is aligned (e.g. ICMA, CBI or EUGBS) is not used to restrict the universe. In other words, all standards are considered, including a small number of securities without a recognised standard.

Further breakdowns based on specific standards, in particular on the EUGBS, will be considered in subsequent extensions of the indicators.

### 2.2.3 Code list

**CUST_BREAKDOWN**

| Code | Label |
|---|---|
| G_XX | Green (use of proceeds), assurance level unspecified |
| G_SX | Green (use of proceeds), second-party opinion |
| C_XX | Social (use of proceeds), assurance level unspecified |
| C_SX | Social (use of proceeds), second-party opinion |
| S_XX | Sustainability (use of proceeds), assurance level unspecified |
| S_SX | Sustainability (use of proceeds), second-party opinion |
| L_XX | Sustainability-linked, assurance level unspecified |
| L_SX | Sustainability-linked, second-party opinion |

The full code list for the SHSS dataset is available in the metadata section of the ECB Data Portal.

### 2.2.4 Data sources

Securities Holdings Statistics by Sector (SHSS)

Centralised Securities Database (CSDB)

### 2.2.5 Compilation method

The sum of all debt securities held and flagged as green, social, sustainability or sustainability-linked in the CSDB. The indicators are calculated directly from the CSDB as part of the SHSS compilation. All calculations are based on attributes associated with individual securities, which are then used to calculate aggregate series.

### 2.2.6 Periodicity/update frequency

Data are published on a quarterly basis and disseminated at around t+2 months after the end of the reference quarter.

# 3 Common framework for transition and physical risk indicators

**Current value of the investment:**

- Loan-based indicators: all loans and lines of credit for general corporate purposes to NFCs that are on the balance sheet of the financial institution.[1]
- Securities-based indicators: securities (excluding short positions) issued by an NFC and held by euro area financial institutions.

**Coverage:**

- Loan-based indicators: loans from euro area credit institutions (S122) granted to NFCs (S11) (for the physical risk indicators, only NFCs located in the EU; for the transition risk indicators, either for the euro area for single entity-level indicators or with a global scope for group-level indicators).
- Securities-based indicators: securities (listed shares and debt securities) issued by NFCs (for the physical risk indicators, only NFCs located in the EU; for the carbon emission indicators a global scope) and held by euro area deposit-taking corporations except central banks (S122), non-money market fund investment funds (S124), insurance corporations and pension funds (S128+S129).
- For transition risk group-level indicators, in addition to entities belonging to the S11 sector (non-financial corporations), entities in the group belonging to the S127 sector (captive financial institutions and money lenders) are included in the sample.

**Common data sources:**

Analytical credit dataset (AnaCredit)

Register of Institutions and Affiliates Data (RIAD)

Securities Holdings Statistics by Sector (SHSS)

Centralised Securities Database (CSDB)

[1] The threshold for an instrument to be subject to reporting is a total commitment amount of €25,000 at debtor level at any point within the reference period. For additional derogations in reporting, see Regulation (EU) 2016/867 on the collection of granular credit and credit risk data (ECB/2016/13) (AnaCredit Regulation).

# 4 Carbon emissions and transition risk indicators

## 4.1 Indicator description and data source

Three sets of carbon emission indicators are compiled focusing on:

(i) entity-level (local) emissions and financial information of euro area-based NFCs in the corporate loan portfolio of the euro area banking sector;

(ii) consolidated group-level (global) emissions and financial information of NFCs and captive financial institutions in the corporate loan portfolio of the euro area banking sector;

(iii) consolidated group-level (global) emissions and financial information of NFCs and captive financial institutions in the corporate securities portfolio of the euro area financial sector.[2]

For each set, four indicators are compiled, relying on the following notation.

- $b$ denotes a given financial institution out of set $B$ within country $c$.
- $c$ denotes a country within the euro area.
- $i$ denotes the respective debtor/issuer (an NFC).
- $e_i$: emissions of firm $i$;
- $r_i$: measure of company production value, i.e. revenues of firm $i$;
- $v_i$: value of the firm $i$ (total assets for loan-based indicators and enterprise value including cash (EVIC) for securities-based indicators);
- $l_{b,c,i}$: loan of a bank or security holding of a given financial institution $b$ in country $c$ to firm $i$.

The following indicators are compiled:

- The financed emissions (FE) of country $c$ are computed by taking the greenhouse gas (GHG) emissions of debtor/issuer $i$ over $i$'s enterprise value (EV), weighted by $b$'s investment in these activities, summed over all debtors/issuers $i$ and all financial institutions $b$.

[2] The distinguishing factor between entity-level and group-level indicators is not the entities or financial instrument being covered but the consolidation level at which financial and emissions information is considered.

$$FE_c = \sum_{b \in B} \sum_{i \in N} \frac{l_{b,c,i}}{v_i} e_i \; \forall \; c$$

- The carbon intensity (CI) of country $c$ is its FE divided by the country's "invested share in the revenue", where the latter is calculated by taking the revenue of each debtor/issuer $i$ over its EV, weighted by $b$'s investment in these activities, summed over all debtors/issuers $i$ and all financial institutions $b$. Essentially, CI is FE over financed revenue at country level.

$$CI_c = \sum_{b \in B} \sum_{i \in N} \frac{l_{b,c,i}}{v_i} e_i / \sum_{b \in B} \sum_{i \in N} \frac{l_{b,c,i}}{v_i} r_i \; \forall c$$

- The weighted average carbon intensity (WACI) of a country $c$ is the GHG emissions of a debtor/issuer standardised by the debtor's/issuer's revenue, weighted by the financial institution's investment in these activities over the total investment portfolio value in the country, summed over all debtors/issuers $i$ and all financial institutions $b$.

$$WACI_c = \sum_{b \in B} \sum_{i \in N} \frac{e_i}{r_i} (l_{b,c,i} / l_c) \; \forall c$$

- The carbon footprint (CFP) of country $c$ is its FE standardised by the total investment portfolio value of financial institutions in the country, $l_c$.

$$CFP_c = \frac{1}{l_c} \sum_{b \in B} \sum_{i \in N} \frac{l_{b,c,i}}{v_i} e_i \; \forall c$$

**Carbon emissions and transition risk indicators' specific components:**

- Portfolio value:
  - For loan-based indicators: the sum of all loans and lines of credit as defined in Section 2.
  - For securities-based indicators: the sum of all listed shares and debt securities as defined in Section 2.
- Company value:
  - For loan-based indicators: the total assets of a company.
  - For securities-based indicators: EVIC, i.e. the market capitalisation of ordinary and preferred shares at the fiscal year-end plus the book values of total debt and minority interests. Where the EVIC is not available, the EV or total assets is used as a proxy.
- Debtor's/issuer's revenue: invoicing-based turnover.

Debtor's/issuer's Scope 1 (i.e. only direct) GHG emissions and Scope 2 emissions for securities-based indicators:

- Single-entity indicators: verified CO2-equivalent emissions for companies participating in the EU Emissions Trading System (EU ETS); imputed emissions based on sectoral air emissions accounts data for remaining companies using average sector-country-year intensities multiplied by the size of a firm (measured by the number of employees). Where the sector information and/or number of employees for an entity is not available for a specific year but is available in either a subsequent or preceding year, the missing values are imputed using a forward or backward-filling method.

- Group-based indicators: CO2-equivalent emissions reported by companies disclosing such information stemming from the commercial data provider Institutional Shareholder Services (ISS). Missing data are imputed using a split approach employing a fixed effects model and region-sector-year-specific medians as described in Section 3.2.2 of the statistics paper.

**Available breakdowns:**

- Loan-based indicators: euro area and selected country-level aggregates by industrial sector of the debtor and reference year.[3]

Securities-based indicators: euro area and selected country-level aggregates by financial instrument (listed shares and debt securities both separately and jointly for the euro area, listed shares and debt securities jointly for country-level aggregates), sector of the holder (S122, S124, and the aggregate of S128 and S129), scope of emissions (Scope 1 and Scope 2), industrial sector of the issuer and reference year.[4]

**Data sources used for carbon emission indicators only:**

**For single entity-level loan-based indicators:**

- EU Emissions Trading System (ETS)
- Eurostat air emissions accounts (AEA)
- Eurostat national accounts employment data

**For group-level indicators:**

- Institutional Shareholder Services (ISS)

[3] The following nine categories are defined: Primary production, Manufacturing, Energy and utilities, Construction, Trade, Transport, Hospitability, Services, Missing. For further information, please refer to Annex 6.2 of the statistics paper.

[4] S122: Deposit-taking corporations except central banks, S124: Non-money market fund investment funds, S128-129: Insurance corporations and pension funds.

## Table 1: Description of compilation

| Steps | Single entity-level loan-based indicators | Group-level loan-based indicators | Group-level securities-based indicators |
| --- | --- | --- | --- |
| 1 | AnaCredit is used to frame the population of debtors. | | SHSS for euro area financial institutions is used to frame the population of issuers. |
| 2 | The current value of investment for loans (outstanding nominal amounts of domestic and euro area loans for single entity-level compilations, and of non-euro area loans for group-level compilations) is inferred from AnaCredit. | | The investment value for securities (market value of listed shares and debt securities issued by non-financial companies and held by euro area financial institutions) is acquired from SHSS. |
| 3 | AnaCredit is matched with RIAD using RIAD identifier. | | CSDB is used to match SHSS with RIAD using the International Securities Identification Number (ISIN) and RIAD identifier. |
| 4 | | The group structure is inferred on the basis of RIAD information. The group head of an issuer/debtor is defined as either the direct group head or, if the former is missing, the ultimate group head. | |
| 5 | Financial information (company value proxied by total assets, revenue, number of employees) and the industrial sector in which the debtor is operating are obtained from RIAD.<br>When no firm-level information is available, financial information is imputed using a median approach. | Financial information (revenue and EVIC) is sourced from ISS.<br>Missing data are imputed using a split-level approach that combines a fixed-effect model and a median approach. | |
| 6 | EU ETS data on Scope 1 emissions are used where available. For debtors/issuers not included in EU ETS, the Scope 1 emissions are imputed to a single entity in proportion to the entity's employment share in the given sector using sector-level AEA Scope 1 emissions. Therefore, the imputation procedure requires the availability of employment data and a sector classification and can only be conducted to the extent that this information is jointly available. | Self-reported emissions (Scope 1 or, for securities-based indicators, Scope 1 and Scope 2) are obtained from ISS or, if missing, imputed using a split-level approach that combines a fixed-effect model and a median approach. | |
| 7 | Several methodological enhancements are performed, such as the flex-balancing method that accounts for compositional changes in the sample over time, correcting the WACI indicator for price and exchange rate effects, and a time-series decomposition to elicit the drivers of intertemporal variation. | | |
| 8 | For each type of indicator (single entity-level loan based, group-level loan-based, and group-level securities-based), four sets of indicators (FE, CI, WACI and CFP) are calculated using the formulas provided near the beginning of this section. | | |

### Nowcasting:

- To enhance the timeliness of the indicators, values for entity-level financial information and emissions until the end of December 2024 have been nowcasted. These values are thus preliminary and will be updated once observed data become available. Currently, only indicators based on equity and debt securities include aggregated nowcasted indicators. Nowcasts for indicators based on bank loans need further quality assurance and will be addressed in future work.

- The nowcasting procedure uses a combination of last observation carry-forward for the majority and a rating agency-based approach (S&P, Moody's, Fitch) which uses the difference in the rating of companies between 2023 and 2024 as a proxy for trends in financial data.

### Captive financial institutions:

- In previous publications, the debtors and issuers were limited to the NFC sector (S11). For the current release, this scope has been expanded to include captive financial institutions that are part of a group structure within NFCs. The rationale for this extension is that captive financial institutions often issue securities to finance the non-financial activities of their group. This change increases exposure data for several large firms, including energy companies.

- Captive financial institutions are only included as debtors or issuers if they are part of a group in which over 80% of the companies belong to the S11 sector. This is to isolate captive financial institutions that fund the business of NFCs from the rest.

**Time series decomposition:**

To disentangle the main drivers of the indicators, expanding on the methodology already proposed in the previous publication, the new time series are decomposed into additional components using the Marshall-Edgeworth-type decomposition. The decomposition is performed on all four indicators (FE, WACI, CFP and CI) and distinguishes between greening of the underlying assets, changes in firms' financial characteristics, changes due to investment decisions and revaluation effects (inflation and exchange rate):

- Changes in emissions, investment portfolio reallocation, and exchange rate effects on loan and securities holding amounts apply to all indicators.
- Nominal changes in firms' company value apply to FE, CI and CFP.

For intensity-based indicators (WACI, CI), revenue effects are included in nominal terms and real terms disentangled for inflation and exchange rate effects.

### Grossing-up of AnaCredit using BSI and iBSI

The coverage of loans in AnaCredit (total outstanding nominal amount to S11 debtors) is lower than the loan amount reported in the ECB's balance sheet items (BSI) statistics and individual bank-level BSI (iBSI) datasets for the period 2018-24. This discrepancy arises from differences in the scope of the two data collections, as well as potential underreporting in the earlier years of AnaCredit. As a result, this may lead to an underestimation of the loan volumes in the economy and thus of FE when AnaCredit alone is used for the computation.

To correct for this underestimation, AnaCredit loans are grossed-up to BSI levels using a combination of creditor-level multipliers based on iBSI data and a subsequent country-level multiplier based on BSI data.

The FE indicator at AnaCredit single entity level and group level is calculated using the adjusted outstanding nominal amounts.

### Data sources used for carbon emission indicators only:

### For single entity-level loan-based indicators:

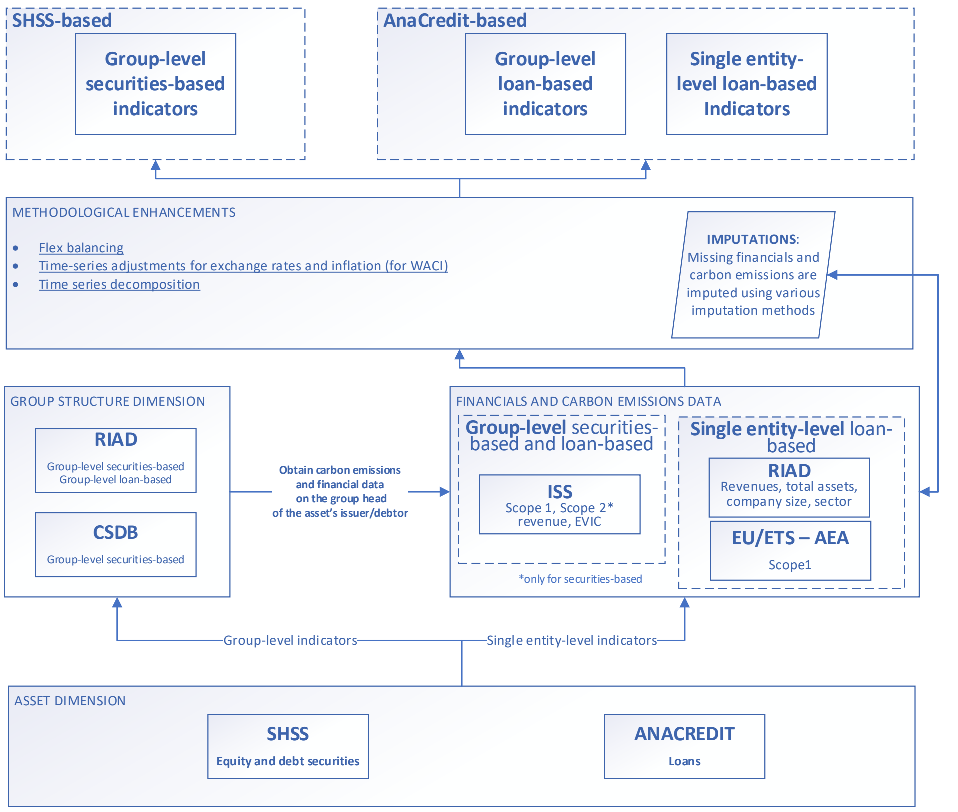
- EU Emissions Trading System (ETS)
- Eurostat air emissions accounts (AEA)
- Eurostat national accounts employment data

### For group-level indicators:

- Institutional Shareholder Services (ISS)

### Methodology for compilation of carbon emission indicators:

### Figure 1: Overview of compilation



### Table 2: Description of compilation

| Steps | Single entity-level loan-based indicators | Group-level loan-based indicators | Group-level securities-based indicators |
|---|---|---|---|
| 1 | AnaCredit is used to frame the population of debtors. | | SHSS for euro area financial institutions is used to frame the population of issuers. |
| 2 | The current value of investment for loans (outstanding nominal amounts of domestic and euro area loans for single entity-level compilations, and of non-euro area loans for group-level compilations) is inferred from AnaCredit. | | The investment value for securities (market value of listed shares and debt securities issued by non-financial companies and held by euro area financial institutions) is acquired from SHSS. |
| 3 | AnaCredit is matched with RIAD using RIAD identifier. | | CSDB is used to match SHSS with RIAD using the ISIN and RIAD identifier. |
| 4 | | The group structure is inferred on the basis of RIAD information. The group head of an issuer/debtor is defined as either the direct group head or, if the former is missing, the ultimate group head. | |
| 5 | Financial information (company value proxied by total assets, revenue, number of employees) and the industrial sector in which the debtor is operating are obtained from RIAD.<br>When no firm-level information is available, financial information is imputed using a median approach. | Financial information (revenue and EVIC) is sourced from ISS.<br>Missing data are imputed using a split-level approach that combines a fixed-effect model and a median approach. | |
| 6 | EU ETS data on Scope 1 emissions are used where available. For debtors/issuers not included in EU ETS, the Scope 1 emissions are imputed to a single entity in proportion to the entity's employment share in the given sector using sector-level AEA Scope 1 emissions. Therefore, the imputation procedure requires the availability of employment data and a sector classification and can only be conducted to the extent that this information is jointly available. | Self-reported emissions (Scope 1 or, for securities-based indicators, Scope 1 and Scope 2) are obtained from ISS or, if missing, imputed using a split-level approach that combines a fixed-effect model and a median approach. | |
| 7 | Several methodological enhancements are performed, such as the flex-balancing method that accounts for compositional changes in the sample over time, correcting the WACI indicator for price and exchange rate effects, and a time-series decomposition to elicit the drivers of intertemporal variation. | | |
| 8 | For each type of indicator (single entity-level loan based, group-level loan-based, and group-level securities-based), four sets of indicators (FE, CI, WACI and CFP) are calculated using the formulas provided near the beginning of this section. | | |

## 4.2 Limitations and constraints

### Data-related aspects:

- As emission and financial data are not available for the full loan debtors and securities issuers population, imputations are applied for missing data. However, the imputation methods employed operate on the assumption that the auxiliary data used for imputation have a robust correlation with the missing values and that the observed data accurately represent the missing values. As these assumptions are not always fully met, the outcomes are susceptible to bias. Moreover, imputed values inherently carry uncertainty, influencing the overall reliability of the compiled indicators. The imputation strategies for financial information are outlined in Annex 6.3 of the statistics paper.

- The company value, revenue, market value of listed shares and debt securities, and outstanding nominal amount of loans are affected by valuation effects, including both price (i.e. inflation) and exchange rate effects. Before calculating the indicators, corrections to revenue, market value and outstanding nominal amount are applied to the WACI. For the SHSS-based calculations, revenues are corrected for inflation and exchange rate effects (the latter are only applicable to issuers outside the euro area). The market values of listed shares and debt securities are only adjusted for exchange rate effects. For the AnaCredit-based data, revenues are adjusted for inflation only, since the debtor population is restricted to the euro area. Outstanding nominal amounts are adjusted only for exchange rate effects.

- The euro-area aggregate indicators are provided with a changing composition, which includes Croatia from 2023 onwards—namely, EA19 for 2018–2022 and EA20 for 2023–2024. This approach does not result in major breaks in the time series, as the Croatian outstanding nominal amounts account for only 0.3% of the euro-area ONA in AnaCredit and 0.01% of the EA market value of securities in SHSS S124. The national series for Croatia include all available SHSS-based data (2018–2024) and AnaCredit-based data (2023).

### Limitations related to all indicators:

- The indicators on the securities portfolio may be sensitive to changes in market prices, which affect the market value of securities and company values.

### Limitations related to the FE indicator:

- Even though coverage has increased substantially compared to the first release of the indicators due to imputation, there is still some heterogeneity in coverage across countries that should be considered when making cross-country comparisons of financed emissions.
- The indicator is not normalised by production value of the firm and hence leaves out efficiency considerations.

### Limitations related to the CI, WACI and CFP indicators:

- The data are sensitive to exposures to companies with volatile input prices, for example owing to a high energy component in their operations.
- The data are sensitive to outliers and composition changes in the underlying sample. This is particularly the case for WACI.

## 4.3 Code list

### Table 3: Overview of the metadata for the transition risk indicators

| Name | Description |
|---|---|
| **indicator_class** | Indicator class, single entity or group level |
| **ghg_protocol_class** | Scope of covered emissions according to the GHG protocol – Scope 1 or Scope 2 |
| **holder_creditor_country** | Euro area country of holder/creditor |
| **year** | Year of transaction |
| **holder_creditor_sector** | Sector of the holder/creditor |
| **issuer_debtor_sector** | Sector of the issuer/debtor |
| **financial_instrument** | Financial instrument |
| **panel_mode** | Sample composition – balanced or unbalanced |
| **fe** | FE indicator (tonnes) |
| **cint** | CI indicator (tonnes/EUR millions) |
| **waci** | WACI indicator (tonnes/EUR millions), adjusted for exchange rates and inflation |
| **waci_unadj** | WACI indicator (tonnes/EUR millions), unadjusted |
| **cfp** | CFP indicator (tonnes/EUR millions) |
| **holder_creditor_country_coverage** | Coverage of country nominal outstanding amount or market value with emissions and financial data, either observed or imputed (%) |
| **status_flag** | Status flag for data row indicating confidentiality (“C”) |

### Table 4: Overview of the metadata for time series decomposition of transition risk indicators

| Name | Description |
|---|---|
| **indicator_class** | Indicator class |
| **ghg_protocol_class** | Scope of covered emissions according to the GHG protocol |
| **holder_creditor_country** | Euro area country of holder or creditor |
| **year** | Year of transaction |
| **holder_creditor_sector** | Sector of the holder/creditor |
| **financial_instrument** | Financial instrument |
| **panel_mode** | Sample composition |
| **attribute_metrics** | Name of the component |
| **indicator_metrics** | Name of the indicator |
| **observation_value** | Value of the component |

For additional metadata, please refer to the statistical metadata file for the carbon emissions indicators.

# 5 Physical risk indicators

## 5.1 Indicator description and data sources

Four types of physical hazard indicators are developed for the portfolios of financial institutions toward non-financial corporations. Two of these indicators are based on physical risk level categories: risk scores (RS) and potential exposure at risk (PEAR), while the other two – normalised exposure at risk (NEAR) and collateral-adjusted exposure at risk (CEAR) – are based on estimates of expected losses. All metrics are presented as a percentage of the portfolio and in monetary values (serving as a numerator in the respective formulae), i.e. a portfolio value classified in each risk category in the case of risk scores, or potential financial loss in the case of expected loss indicators.

Physical risk scores cannot be compared directly across different hazard types because the methodologies and data sources used are different in each case.[5] However, they do provide valuable insights for assessing relative risk levels across countries, climate scenarios and variations within the same hazard type, such as comparing flood risks with and without flood defences.

Conversely, expected loss (EL) indicators quantify risk in monetary terms, thus allowing for comparisons across different hazards. However, they also happen to suffer from data limitations and require assumptions as to how hazard intensities convert into physical and monetary damage for affected companies and how they subsequently propagate into the financial system. If these businesses hold debt with financial institutions, the resulting damage at the company level could impair their repayment ability. This, in turn, may lead to financial losses for those banks exposed to the debtors affected by the natural disaster. Similar to the risk scores, while the absolute values might be sensitive to various assumptions, the process of compiling the indicators follows a consistent methodology and relies on harmonised sources. This enables comparisons across different specifications and countries, thus ensuring a coherent analytical framework.

First, **physical risk scores (RS)** denote both the value and the percentage of the portfolio associated with debtors located in areas with physical risk varying from 0 (no risk) to 3 (high risk):

- $$RS_{j\in[0,3]} = \frac{\sum_{i=1}^{N}(EXPOSURE_i|SCORE_{i,j})}{\sum_{i=1}^{N}(EXPOSURE_i)}$$

where *j* is the risk score and $EXPOSURE_i$ is the exposure volume for a specific portfolio (loans, debt securities and equities) towards company *i* (single entity level).

The risk scores are computed at debtor level for each hazard separately and different types of hazards are not additive. A company may be exposed to several

5 Except for floods and windstorms that are based on damage functions and incorporate aspects of expected loss.

risks, which could result in the counting of exposures multiple times, especially in the case of correlated risks, such as water stress and wildfires.

**Table 4** provides an overview of the hazards used in this publication, while more technical details, including the exact thresholds used for the risk scores, can be found in **Table 5**.

## Table 5: Overview of physical hazards data sources and specifications

| Hazard | Source | Methodology/original unit | Resolution | Time period | Climate scenario |
|---|---|---|---|---|---|
| **Coastal flooding** | Delft University of Technology (TUD) | Water level rise (m) based on the extreme events intensities (per return period) | 100 m | 1971-2000 (baseline)<br>2021-2050<br>2071-2100 | RCP 4.5<br>RCP 8.5 |
| **River flooding** | Delft University of Technology (TUD) | Water level rise (m) based on the extreme events intensities (per return period) | 100 m | 1971-2000 (baseline)<br>2021-2050<br>2071-2100 | RCP 4.5<br>RCP 8.5 |
| **Windstorms** | Own calculations, based on Copernicus EWS | Wind gust speed (m/s) based on the extreme events intensities (per return period) | ~2 km | 1940-2025 | - |
| **Landslides** | DRMKC RDH (JRC) | Score (1-5) based on characteristics of the terrain combined with daily maximum precipitation (per return period) | 200 m | - | - |
| **Subsidence** | DRMKC RDH (JRC) | Score (1-5) based on soils' clay content | 100 m | - | - |
| **Wildfire** | Own calculations, based on Copernicus | Probability of a fire event based on Fire Weather Index, land cover and burned areas | 2.5 km | 2001-2022 (baseline)<br>2023-2050 | RCP 4.5<br>RCP 8.5 |
| **Water stress** | Aqueduct WRI | Ratio of water demand and water supply | Hydrological sub-basins (5 arc-minute) | 1960–2019 (baseline)<br>2015-2045, 2035-2065, 2065-2095 | SSP3 RCP 7.0<br>SSP5 RCP 8.5 |
| **Consecutive dry days** | IPCC | Maximum number of consecutive dry days (with precipitation < 1mm per day) | 12.5km (11 arc-minute) | 1986-2005 (baseline)<br>2021-2040<br>2041-2060 | RCP 4.5<br>RCP 8.5 |
| **Standardised Precipitation Index** | IPCC | Index comparing cumulated precipitation for 6 months with the long-term precipitation distribution | 12.5km (11 arc-minute) | 1986-2005 (baseline)<br>2021-2040<br>2041-2060 | RCP 4.5<br>RCP 8.5 |

Notes: RCP stands for Representative Concentration Pathways. RCP 4.5 corresponds to radiative forcing of 4.5 W/m² by the end of the century and is considered a moderate scenario. RCP 8.5 assumes a high GHG emissions scenario, leading to radiative forcing of 8.5 W/m² by 2100, and is considered a worst-case scenario.

## Table 6: Methodology and technical details for physical hazards

| Hazard | Return period used | Damage function | Score calculation method | Data sources (download) |
|---|---|---|---|---|
| **Coastal flooding** | 10, 30, 100, 300, 1000 | Based on intensity and area type | Based on the damage functions/return periods | Geospatial data (Paprotny, 2020)[6] |
| **River flooding** | 10, 30, 100, 300, 1000 | Based on intensity and area type | Based on the damage functions/return periods | Geospatial data (Paprotny, 2016)[7] |
| **Windstorms** | 10, 30, 100, 300, 1000 | Based on intensity and building type | Based on the damage functions/return periods | Own calculations[8] on Copernicus EWS[9] geospatial data |
| **Landslides** | 10, 50, 100, 500 | Not available | Based on original scores/return periods | Available from DRMKC RDH contact point |
| **Subsidence** | - | Not available | Original score rescaled:<br>No risk: Coarse soil texture (clay < 18% and sand > 65%)<br>Low risk: Medium (18% < clay < 35% and sand >= 15%, or clay > 18% and 15% < sand < 65%)<br>Medium risk: Medium fine (clay > 35% and sand < 15%)<br>High risk: Fine (35% < clay < 60%) and Very fine (clay > 60%) | Available from DRMKC RDH contact point |
| **Wildfires** | - | Not available | Based on the probability of a fire event:<br>No risk: <0.001 (frequency less than every 1,000 years)<br>Low: 0.001-0.002 (between 500 and 1,000 years)<br>Medium: 0.002-0.004, 0.004-0.01 (between 500 and 100 years)<br>High: 0.01-0.02, >0.02 (more frequent than every 50 years) | Own calculations[10] based on: (i) Copernicus Fire Weather Index; (ii) Copernicus land cover (distance to city, railway and road); and (iii) MODIS burned area and land cover |
| **Water stress** | - | Not available | Based on original score:<br>Low (1-20%)<br>Medium (20-40%)<br>High (40-80%, >80% or low water use) | Geospatial data (version 4.0, 2023)[11]<br>Methodology |
| **Consecutive dry days** | - | Not available | Thresholds based on the number of days:<br>No risk: < 15 days<br>Low: 15-20<br>Medium: 20-30, 30-40<br>High: 40-50, >50 days | Geospatial data (IPCC Interactive Atlas)[12] |
| **Standardised Precipitation Index** | - | Not available | Based on index thresholds:<br>No risk: -1 to 1<br>Low: (-1.5 to -1), (1 to 1.5)<br>Medium: (-2 to -1.5), (1.5 to 2)<br>High: <-2 (extremely dry), > 2 (extremely wet) | Geospatial data (IPCC Interactive Atlas) |

Notes: The "return period" is a statistical concept used in hydrology and disaster risk assessment and represents the average interval of time between events of a certain intensity. The original scores are usually available on a scale of 0-5. For the purpose of the statistical climate indicators, they were rescaled to 0-3 and the column "Scores calculations" shows the individual original categories assigned to each risk score. The recoding of Standard Precipitation Index indicators has been amended in the 2025 release: the score 3 "extremely wet", is now correctly classified as "High risk" (from "Medium risk" previously).

6 Paprotny, D. and Morales Nápoles, O. (2020), Pan-European data sets of coastal flood probability of occurrence under present and future climate, Version 2, 4TU.ResearchData, dataset: https://doi.org/10.4121/uuid:e06ca666-90e2-4a2c-a1d0-4c39f815b04d.

7 Paprotny, D. and Morales Nápoles, O. (2016), Pan-European data sets of river flood probability of occurrence under present and future climate, Version 1, 4TU.ResearchData, dataset: https://doi.org/10.4121/uuid:968098ce-afe1-4b21-a509-dedaf9bf4bd5.

8 Herzberg, J., *Extreme wind return levels over Europe for portfolio risk assessment*, forthcoming

9 Copernicus EWS (Enhanced Windstorm Service): https://cds.climate.copernicus.eu/datasets/sis-european-wind-storm-reanalysis?tab=overview.

10 Burger C., Herzberg, J. and Nuvoli, T. (2024), Climate Change Risk Indicators for Central Banking: Explainable AI in Fire Risk Estimations, Working paper.

11 WRI Aqueduct: aqueduct.wri.org.

Second, **the potential exposure at risk (PEAR)** indicator is formulated as a sum of positive risk scores related to a specific hazard (categories from 1 – Low risk to 3 – High risk) and reveals financial exposure to debtors in at-risk areas regardless of the intensity or frequency of the hazard:

- $$PEAR = \frac{\sum_{i=1}^{N}(EXPOSURE_i | RS_{i,j}(j>0))}{\sum_{i=1}^{N}(EXPOSURE_i)}$$

The PEAR is computed at debtor level for each hazard separately. It can be considered as a measure of the prevalence of a natural phenomenon, encompassing all exposures but without considering the vulnerability of affected debtors should an event occur. Thus, coastal floods, with their limited geographical extent, tend to have lower PEAR exposure levels compared to more widespread hazards like heat stress, even though coastal floods may result in significantly higher physical damage.

Third, **normalised exposure at risk (NEAR)** provides an estimate of the anticipated losses in a financial institution's portfolio if debtors are unable to honour their repayment obligations in the wake of a natural disaster. It is assumed that the company's debt to financial institutions will be impaired in proportion to the expected losses to the debtor's physical assets relative to its total assets.

- $$NEAR = \frac{\sum_{i=1}^{N}(FINANCIAL\ RISK\ RATIO_i \cdot EXPOSURE_i)}{\sum_{i=1}^{N}(EXPOSURE_i)};$$

where the financial risk ratio is a proportion of expected physical losses to total assets at entity level:

- $$FINANCIAL\ RISK\ RATIO_{i,hazard} = \frac{Physical\ assets_{\ i}}{Total\ assets_{\ i}} \cdot EL_i(m)$$

The term $EL_i(m)$ is the expected loss (expressed as a share in the value of the exposed asset) over the remaining maturity of an instrument.

This indicator incorporates an estimation of monetary losses and allows for aggregations across hazards. At the current stage, the quality and availability of the underlying data are not always sufficient to calculate EL-based indicators for all hazards and the estimates are currently only available for windstorms and for coastal and river flooding.

Fourth, **the collateral-adjusted exposure at risk (CEAR)** indicator, similar to the NEAR metric, offers an estimate of expected losses within a financial institution's portfolio and also considers the mitigating effect of collateral pledged with a loan commitment. In physical risk assessments, the type of collateral must be taken into account. Financial protection is included in the full amount. However, when evaluating physical collateral, it is crucial to factor in the potential reduction in collateral value due to the destruction of physical assets by natural hazard – and notably these aspects are reflected in the CEAR indicator.

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[12] Gutiérrez et al., 2021: Atlas. In *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. In Press. Interactive Atlas available here.

- $$CEAR = \frac{\sum_{i=1}^{N} \max\,[0, FINANCIAL\ RISK\ RATIO_i \cdot EXPOSURE_i - CV_i]}{\sum_{i=1}^{N}(EXPOSURE_i)},$$

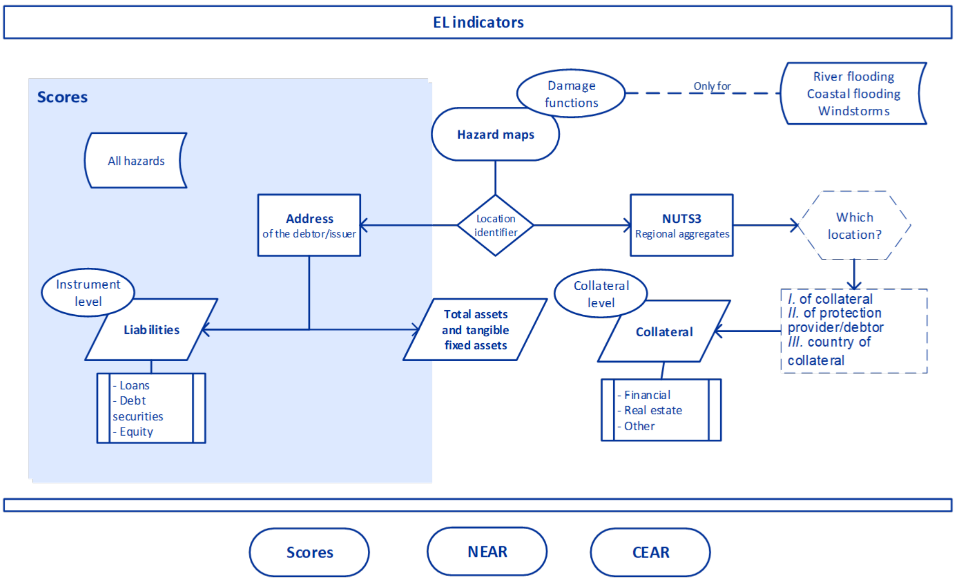
where $CV_i$ is the collateral allocated to each creditor-debtor-instrument combination.

The two EL-based indicators follow the same methodology, which allows for a comparison of expected losses under NEAR with those under CEAR, reduced by the value of collateral, thus illustrating the effect of collateralisation. To facilitate this benchmarking exercise, the current indicators are compiled only for loans, as collateral is not available for securities. The expected damage is calculated over the instrument's maturity, capturing potential differences in the maturity structure of banks' portfolios. Moreover, the indicators are presented on the basis of expected annual loss to enable a comparison with estimates of natural disasters found in the literature, which are usually expressed on an annual basis.

Further information on the technical aspects of the indicators can be found in the statistics paper.

**Figure 2** provides an overview of the inputs needed to compile each type of indicator.

### Figure 2: Overview of the compilation framework for the physical risk indicators



## 5.2 Enhancements to the 2025 publication

In the 2025 release, several methodological enhancements were implemented to improve the accuracy and analytical robustness of the physical risk indicators, covering three key areas:

(i) more precise location information for debtors and real estate collateral;

(ii) an improved estimation of potential damages;

(iii) refined physical hazard estimates.

### 5.2.1 Increased geospatial accuracy

**Geocoding**

The geocoding process has been significantly enhanced across several key dimensions.[13]

First, by working closely with national central banks to improve reporting and clean the address fields to make them more standardised.

Second, by incorporating national geocoded address registers, wherever these are available as an addition to OpenStreetMap (OSM), which was previously the sole source of geocoding information.[14] The use of national registers is the main driver of gains in location precision, resulting in an increased coordinates match rate, owing to their highly standardised fields and broad coverage.

Finally, house number approximation was employed to increase the precision of matches in cases where the exact house number was not available in the geocoded address registers (either from the OSM or national registers). Overall, as a result of these enhancements, the proportion of precise address coordinates for debtors has increased substantially – from 10% to 55%. **Table 7** shows the address fields used for the coordinates.

[13] For details on the initial implementation of geocoding, see Franke, J., Aurouet, D. and Osiewicz, M. (2023), “Geocoding millions of addresses in a reproducible manner for Big Data Climate Risk analysis”, Conference on New Techniques and Technologies for Statistics.

[14] This was successfully implemented for Denmark, France, Croatia, Latvia, Lithuania, Luxembourg, Netherlands, Slovenia and Finland.

**Table 7:** Geocoding precision for debtors' addresses

| Address fields used in geocoding matches | Percentage of observation (%) |
|---|---|
| House number, street, postcode | 55 |
| Street, postcode and/or city | 10 |
| Postcode | 32 |
| City | 2 |
| No match | 1 |

Notes: The matching procedure uses a waterfall approach: it first attempts a match using the full address, and if unsuccessful, progressively falls back to subsets of the address. For example, if a street-and-postcode match fails, the location is approximated using the postcode alone. December 2024 reference period.

### Real estate collateral location and risk assessment

A reporting of real estate collateral locations is required at the level of NUTS3 region, while debtors and protection providers are identified at the address level (see Section 3.3.2 of the statistics paper). Since the last release, several national central banks have improved their reporting of collateral information and around 30% of the portfolio secured by real estate is now available at a postcode level (December 2024 reference period). To ensure a harmonised approach, the compilation of CEAR indicators remains based on NUTS3 regions risk profiles.[15] However, the estimation of expected damage to physical collateral has been enhanced using geospatial processing and is now based on the mean expected loss calculated for each region and hazard (rather than the previously applied median within the affected area).

## 5.2.2 Enhanced estimation of potential damages

The damage functions, which translate hazard intensity into expected losses, have been refined to better reflect the vulnerability of physical assets to floods and windstorms. For these two hazards, the approach applied in the April 2024 release (see Section 6.4.1 of the statistics paper: Methodology for calculating risk scores and expected loss-based physical risk indicators) has been enhanced by incorporating inventory data.[16] Additionally, the methodology for flooding has been improved by smoothing damage curves and accounting for the building height.

### Accounting for inventories

Inventories, which include movable assets such as raw materials, work-in-progress, and finished goods, are a critical component of economic exposure, particularly in non-service sectors. Previously, the estimates solely focused on tangible fixed assets, such as buildings, land, machinery and equipment (see Section 6.4.2 of the statistics paper: Imputation of the tangible fixed assets ratio for the previous

[15] To reference different regions of countries for statistical purposes, the EU has developed a classification known as the Nomenclature of territorial units for statistics (NUTS). Level 3 denotes the smallest entities at regional level. The definition of a NUTS region is based on the territorial administrative divisions of EU countries and population size.

[16] For the compilation of the expected loss indicators, damage functions for flooding (Huizinga, 2017) and for windstorms (Koks, 2020) are used.

methodology). Both categories of physical assets are derived from various business registers, including national business registers, iBACH, and, when unavailable, Orbis.[17]

In the absence of detailed firm-level data, Huizinga (2017) proposed a generalised approach to account for inventories by assuming that they constitute 50% of the maximum damage value for residential buildings, 100% of this value for commercial buildings and 150% for industrial buildings.[18] While these ratios serve as broad estimates, they do not capture the actual value or specific characteristics of inventories at the firm level.

The methodology used in the ESCB indicators is more robust as it incorporates firm-specific inventory values. If firm-level information is not available, the ratios of tangible fixed assets to total assets and inventories to total assets are estimated using averages based on country, sector and firm size. When data on size or sector are missing, higher-level aggregates are used. **Table 8** shows the imputation rates by aggregation level for each physical asset type.

**Table 8:** Imputation rates for physical assets by aggregation level

| Imputation level | Inventories ratio | Tangible fixed assets ratio |
|---|---|---|
| **Firm-level (reported)** | 42.3% | 39.8% |
| **Sector-size** | 28.1% | 29.6% |
| **Sector** | 22.7% | 23.5% |
| **Country** | 6.9% | 7.1% |

Notes: The imputation procedure uses a waterfall approach. If available, sector-size aggregates are used first, and if these are not available, it falls progressively back to sector and country aggregates. The balance sheet data from Orbis. iBACH and national sources have a reference year of 2023.

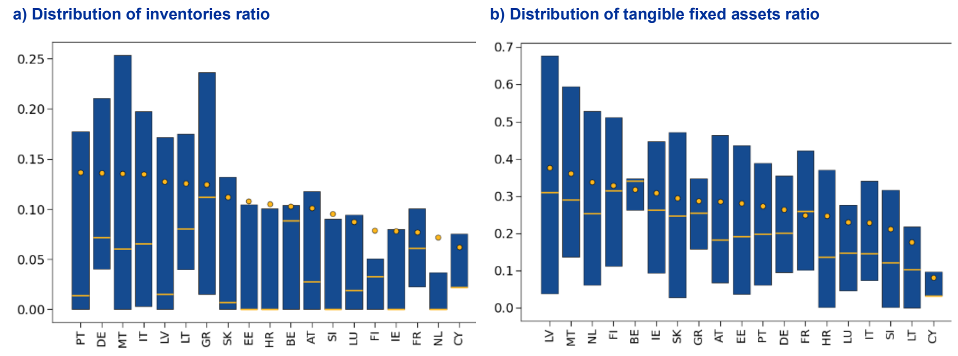
Currently, only key accounting variables are available in RIAD (total assets, revenues), so to obtain the amounts of tangible fixed assets and inventories, data from Moody's "Orbis" database were used. For five countries (Belgium, Spain, Croatia, Italy and Latvia) national business register data were available and used in preference to Orbis.

In the current publication, national aggregated data for imputations were provided for Belgium, Germany, Spain, France, Croatia, Italy, Latvia, Austria and Slovenia. The resulting inventories to total assets ratios and tangible fixed assets to total assets ratios at country level are presented in Figure 3.

[17] The Bank for the Accounts of Companies Harmonized (BACH) Working Group gathers information and harmonises accounting data of non-financial corporations at individual level in iBACH.

[18] The assumption behind this is that inventories, such as intermediate goods, in most industrial manufacturing plants exceed the monetary value of the damages to the buildings.

### Figure 3: Distribution of inventories ratio and tangible fixed assets ratio to total assets across countries




Sources: Orbis, national business registers (when available), ESCB and own calculations.
Notes: The interquartile range is defined as the difference between the 75th percentile and the 25th percentile. The yellow lines indicate medians and the yellow dots indicate means. Box plots are in descending order by mean.

### Linearisation

For a more accurate representation of the relationship between flood depth and damage, a linear interpolation has been implemented in this release. Previously, damage functions for flooding were designed as stepwise functions, defined at specific flood depth thresholds. Smoothing the damage curve helps mitigate potential underestimation of damage values, especially for lower hazard levels (see Figure 4, panel a).

### Building height

Building height information is used to refine the estimation of expected flood losses, since flood depths typically do not exceed the first floor of a building. Consequently, for buildings exceeding a height of six metres, it is assumed that only a portion of the building's value is impacted. To account for this, a correction factor is applied to the tangible fixed assets.

To obtain building height data, we use the publicly available Global Human Settlement Layer (GHSL) dataset. The most recent built-up height dataset (GHSL R2023) was chosen, which provides global estimates of vertical built-up structures derived from digital elevation models through multi-scale linear regression modelling. Among the available metrics, the average net building height was used, as it excludes non-built areas and aligns closely with the presence of registered company addresses in the financial datasets.

The enhancements to the damage estimations affect the financial risk ratio applied to the indicators as follows:

- $FINANCIAL\ RISK\ RATIO_{i,\text{hazard}} = \frac{Physical\ assets_{\ i}}{Total\ assets_{\ i}} \cdot EL_i(m),$
- *EL* is now linearised, while physical assets depend on the hazard:
- for floods: $\text{Physical assets} = \frac{min(building\ height, 6m)}{building\ height} * tangible\ fixed\ assets + inventories$

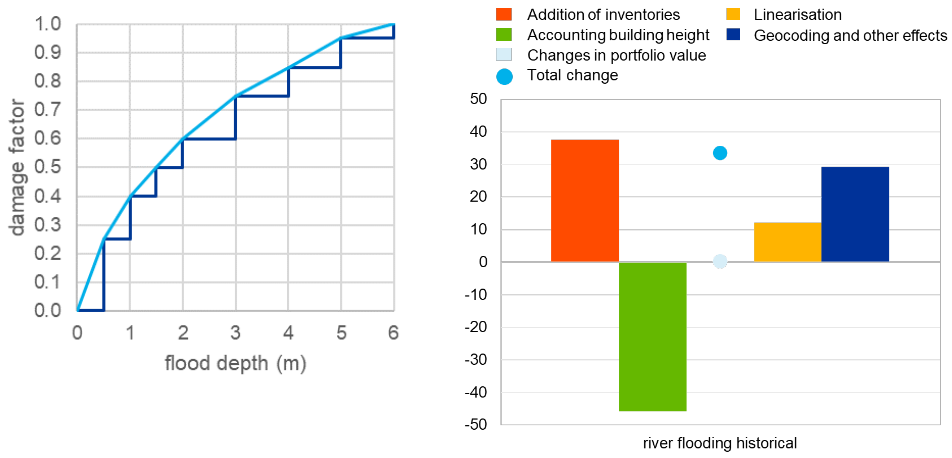
- for windstorms: $\text{Physical assets} = \textit{tangible fixed assets} + \textit{inventories}$

**Figure 4: Illustration of the impact of methodological enhancements**

**a) Illustration of linear interpolation for flood damage function**

**b) Example of impact on the NEAR for river flooding, historical baseline**

(percentage changes, %)




Source: ESCB own calculations based on AnaCredit, Orbis, OpenStreetMap and national business register data; river flooding data from the Delft University of Technology and Joint Research Centre (JRC); building height data from Global Human Settlement Layer (GHSL).
Notes: The baseline for changes refers to published data with an AnaCredit, RIAD and SHSS reference date of December 2022.The impact of "Geocoding and other effects" is deducted from overall change subtracting the impact of all other enhancements. The directional impact of inventories, linearisation (which increases damage estimates) and accounting for building height (which decreases damage estimates) is well defined. The impact of more precise location identification through geocoding as well as other factors (e.g. sample composition) is more complex and may vary in direction depending on the specific hazard being analysed.

Overall, the addition of inventories as well as accounting for lower-level damages by smoothing the damage function, increases the damageable components in the data. However, limiting losses to the lower parts of buildings counterbalances these effects. It should be noted that portfolio changes between reference years have a negligible impact on the indicators. The disentanglement of various methodological enhancements is illustrated using the example of river floods (see Figure 4, panel b).

## 5.2.3 Physical hazards – data updates and modelling

### Windstorms

Two major enhancements have been introduced to the windstorm estimates: a switch to a more granular, regularly updated data source and the adoption of a more flexible hazard modelling approach.

First, the estimates are now based on the novel Copernicus windstorm dataset, which provides the most comprehensive coverage of high-impact European storms at high resolution (approximately 2 km).[19] It ensures that short-lived, intense gust events are captured consistently across Europe. The dataset offers continuous temporal coverage from 1940 to the present, is updated monthly and, importantly, extends beyond the winter season to cover all months of the year.

Second, the hazard modelling of extreme wind gusts has been redesigned. Whereas the previous approach employed a Gumbel distribution fitted to annual maxima, the new framework uses a Peaks-over-Threshold approach with a Generalised Pareto Distribution. By modelling all threshold exceedances instead of a single annual maximum, it uses data more efficiently, improves tail estimates for rare events and reduces uncertainty, especially when records are short.

The new approach represents a coherent, updatable foundation for windstorm modelling at a higher spatial resolution. Further details on the dataset, parameter calibration and validation are provided in the forthcoming publication “Extreme Wind Return Levels over Europe for Portfolio Risk Assessment”.

### Water stress

The water stress indicator has been updated using the World Resources Institute’s Aqueduct 4.0 dataset (Kuzma et al., 2023), which integrates advanced hydrological modelling and incorporates new Shared Socioeconomic Pathway scenarios derived from CMIP6 models.[20] Consequently, water stress scores have generally increased across most European countries. For more details, see Aqueduct 4.0.

## 5.3 Treatment of missing data

Overall, the underlying financial datasets provide a high level of coverage. In terms of amounts excluded from the financial dataset, 1.8% of exposures are excluded in the current estimates due to missing geographic coordinates of debtors or issuers, while an additional 0.8% are excluded due to missing NACE sector classifications. These observations have been removed from the dataset.

For the CEAR indicator, location information is also required for real estate collateral. Less than 1% of the portfolio is missing this information. Additionally, 0.02% of the portfolio value is secured by non-EU real estate. In such cases, no collateral is assumed as part of a conservative approach.

19 The dataset “Windstorm tracks and footprints derived from reanalysis over Europe between 1940 to present” was first published in June 2025. It was developed as part of Copernicus Climate Change Service’s (C3S) Enhanced Windstorm Service (EWS) and, in response to requirements from users in the insurance sector, this dataset extends the previous C3S Windstorm Service (WISC) to include the entire year and is frequently updated.

20 CMIP6 – Coupled Model Intercomparison Project Phase 6 is an international initiative under the World Climate Research Programme that coordinates simulations from multiple global climate models. Its results form a key scientific basis for the climate projections assessed by the IPCC’s Sixth Assessment Report (AR6).

The hazard maps provide near-complete coverage across the EU; however, the overseas territories of France and Netherlands are excluded. Depending on the specific hazards, additional territories may also be excluded, primarily islands such as the Canary Islands, Madeira and the Azores. If a hazard value is missing, observations are removed from the total portfolio only for the respective affected hazard. **Table 9** presents the share of excluded portfolio value and number of debtors.

**Table 9: Share of excluded portfolio value and number of debtors per variable**

| Variable | % of portfolio value excluded | % of debtors excluded |
|---|---|---|
| Unknown debtor/issuer location (only) | 1.27 | 1.32 |
| Unknown NACE economic sector (only) | 0.84 | 0.58 |
| Unknown coordinates and NACE | 0.49 | 2.06 |
| Unknown collateral location | 0.69 | 1.78 |
| | | |
| Hazards: | | |
| CDD | 0.26 | 0.72 |
| SPI6 | 0.26 | 0.72 |
| landslides | 0.00 | 0.00 |
| coastal flooding | 5.52 | 3.18 |
| river flooding | 0.10 | 0.08 |
| subsidance | 0.20 | 0.60 |
| wildfires | 1.65 | 2.11 |
| windstorms | 0.00 | 0.00 |
| water stress (current) | 0.25 | 0.39 |
| water stress (projections) | 0.28 | 0.39 |

## 5.4 Climate scenarios

### The RCP and SSP climate scenarios

Climate scenarios are conceptual models designed to explore how the world might evolve under varying greenhouse gas emission, socioeconomic dynamics and policy pathways. To compile our indicators, we use climate scenarios expressed through representative concentration pathways (RCPs) or shared socioeconomic pathways (SSPs) depending on the specific hazard.

**The representative concentration pathways (RCPs)**, introduced in the IPCC Fifth Assessment Report (AR5), assess climate change risks based on different greenhouse gas concentration trajectories and associated radiative forcing targets, a physical measure of how much additional energy the Earth retains due to those gases (e.g. 4.5 W/m² or 8.5 W/m² by 2100). RCP4.5 reflects an intermediate emissions scenario in which global warming is limited to 3°C, while RCP8.5 is a high emissions scenario leading to global warming exceeding 4°C.

To refine climate projections, a new framework was developed – **the shared socioeconomic pathways (SSPs)** – to describe alternative societal futures in terms of population, education, technology and policy capacity. The SSPs are a set of socioeconomic narratives that can be linked to different radiative forcing targets. They were central to the IPCC Sixth Assessment Report (AR6). For instance, SSP1 outlines a sustainable future with low emissions and strong global cooperation and typically leads to an RCP1.9 trajectory. SSP5, on the other hand, depicts a fossil fuel-intensive world with high emissions and no climate policies, potentially leading to an RCP8.5 trajectory.

### The NGFS climate scenarios

In addition, the Network for Greening the Financial System (NGFS) develops climate scenarios to support risk analysis in the economy and financial system.

The **NGFS long-term climate scenarios** go beyond SSPs by assessing economic impacts. They start with integrated assessment models, which model carbon prices, energy and land system shifts and their outcomes in terms of global warming trajectories, also taking SSP assumptions (e.g. population) as inputs. A macroeconomic model then estimates the economic impact of those pathways in terms of transition and physical risks up to 2050 (covering GDP, inflation, unemployment, etc.).

The seven NGFS long-term scenarios present different mixes of transition and physical risks resulting from different assumptions on policies (timing, coordination), technology improvements, etc. The temperature trajectories of NGFS long-term scenarios do not directly map to RCPs but range from being close to RCP2.6 (NGFS Net Zero 2050) to being close to RCP4.5 (NGFS Current Policies).

The NGFS also provides **short-term climate scenarios** spanning a five-year horizon to support prudential and supervisory stress testing. The outputs of those scenarios also include financial and sectoral granularity. For further details on the NGFS scenarios, see the ECB blog post "Climate risks: no longer the tragedy of the horizon".

The NGFS scenarios assess the impact of "chronic" and "acute" physical risks. For "acute" physical risks, there are methodological commonalities with the ESCB statistical indicators, as the NGFS makes use of natural catastrophe models. However, the difference is that the NGFS uses the outputs from those natural catastrophe models to calibrate macroeconomic shocks (e.g. impact of floods and windstorms on capital aggregates), while ESCB statistical indicators directly compute the impact at firm level.

In summary, the NGFS scenarios provide a globally comprehensive and internally consistent macroeconomic – and, in the case of short-term scenarios, also sector-level – assessment of the economic and financial impacts of climate-related physical and transition risks. By contrast, climate-related statistical indicators adopt a bottom-up approach, quantifying firm-level risk from location-specific data and high-resolution hazard maps based on RCP or SSP scenarios. These provide rich, detailed climate and financial data for Europe that are not available globally.

### The relationship between climate scenarios

Although it may appear counterintuitive, in some regions and for some hazards climate impact may be more severe under the moderate RCP4.5 scenario than under the higher-emission RCP8.5 scenario, particularly around the middle of this century. This is not an error; it reflects the non-linear dynamics of the climate system. Internal climate variability, regional atmospheric circulation patterns, local vegetation and hydrological processes can outweigh the relatively small temperature gap between RCP4.5 and RCP8.5 in the near to mid-term.

A similar effect appears in projections under SSPs: the outcomes depend not only on climate forcing but also on socioeconomic assumptions. A pathway with higher emissions but strong economic capacity and technology adoption (e.g. SSP5) may sometimes show smaller risk than a lower-emission pathway with weaker institutions and limited investment (e.g. SSP3). This reflects differences in adaptation, efficiency and governance, and is not due to errors in the projections.

In short, higher emissions do not always produce stronger local extremes. The pattern of hazards changes as well as their magnitude.[21]

## 5.5 Limitations and constraints

### Coverage:

- The indicators cover euro area creditors (in the case of loan portfolios)/holders (for equity and debt securities). With respect to debtors/issuers of equity and debt, the indicators cover the non-financial corporations (ESA sector S11) resident in the EU.

### Caveats:

- The developers of climate models often caution against their application at local level, as these models are constructed with broader geographic areas in mind. Moreover, the framework for compilation of indicators is rooted in statistical methodologies and should not be directly applied to single entities. Instead, for analyses at the individual firm level, it is crucial to account for vulnerabilities of key physical assets, incorporating adaptation and mitigation measures in place to obtain more nuanced understanding of climate risk.

[21] For further information see: Seneviratne et al., 2020 (section 3.2-3.4 on regional extremes); Shrestha and Roachanakanan, 2021 (variability of extremes under different scenarios and short vs long term), Ebers et al., 2023 (regional patterns and differences between RCP4.5 and RCP8.5 are non-linear and vary strongly by location).

- The location information of firms is based on RIAD, which collects information at the level of the legal entity. In the event of multiple locations of a single company (e.g. production sites that are at a different location from the headquarters), the assessment of physical risk suffers from mismeasurement: if one of the company facilities is affected but the headquarters is not, the indicators will underestimate the risk, whereas the risk will be overestimated if the headquarters is exposed and other locations are not.

- The value of physical assets reported on a company's balance sheet is used as a benchmark for estimated losses. In the case of larger companies, the physical assets might be distributed across various locations with different exposure to physical hazards. In addition, the data on physical assets to total assets ratio has a low coverage and a high share of values are imputed which might result in mismeasurement. More generally, financial statements at firm level currently suffer from limited coverage in the sources available (in particular, smaller companies are often excluded), reporting lags, missing or inaccurate information.

- The current methodology includes indicators that account for present adaptation measures, such as dykes to prevent flooding. For the future time horizon and climate scenarios, it is assumed that future flood defences will protect an area up to the same water levels as existing flood defences. If the flood severity intensifies without investment in current flood defence structures, the indicators will lead to an underestimation of the future risk.

- The expected loss-based indicators only account for the direct damage to assets and not for secondary effects such as business interruptions, an increased cost of operations or damage across the supply chain. Other sources of underestimation could include, for example, the impact of heat stress on labour productivity, and a broader risk to the economy in which a company generates revenue.

- Individual hazards and their related damages are currently considered separately. However, the co-occurrence of events, such as windstorms and coastal flooding, can intensify their impact, leading to greater damage than implied by summing the individual hazards. Compound events are challenging to model, also for climate scientists, given the limited historical data owing to the low frequency of such high impact events.

## 5.6 Code list

### Table 10: Overview of the metadata for the physical risk indicators

| Name | Description |
|---|---|
| HZRD_TYP | Hazard identifier |
| DT_RFRNC | Reference date |
| CRDTR_CNTRY | Country of the creditor |
| AGGRGTD_ECNMC_ACTVTY_NAME | NACE sector |
| CRDTR_INSTTTNL_SCTR_MRGD | Institutional sector of the creditor |
| INVESTMENT_TYPE | Investment type |
| PHYSCL_RSK_NEAR_MTRTY_EXPCTD_LSS_PRCNTG_PTFL | Normalised exposure at risk (NEAR), expected loss over the maturity of instrument, as a percentage of portfolio |
| PHYSCL_RSK_CEAR_MTRTY_EXPCTD_LSS_PRCNTG_PTFL | Collateral-adjusted exposures at risk (CEAR), expected loss over the maturity of instrument, as a percentage of portfolio |
| PHYSCL_RSK_NEAR_ANNL_EXPCTD_LSS_PRCNTG_PTFL | Normalised exposure at risk (NEAR), expected annual loss, as a percentage of portfolio |
| PHYSCL_RSK_CEAR_ANNL_EXPCTD_LSS_PRCNTG_PTFL | Collateral-adjusted exposures at risk (CEAR), expected annual loss, as a percentage of portfolio |
| PHYSCL_RSK_NEAR_MTRTY_EXPCTD_LSS_VL | Normalised exposure at risk (NEAR), expected loss over the maturity of instrument, EUR million |
| PHYSCL_RSK_CEAR_MTRTY_EXPCTD_LSS_VL | Collateral-adjusted exposures at risk (CEAR), expected loss over the maturity of instrument, EUR million |
| PHYSCL_RSK_NEAR_ANNL_EXPCTD_LSS_VL | Normalised exposure at risk (NEAR), expected annual loss, EUR million |
| PHYSCL_RSK_CEAR_ANNL_EXPCTD_LSS_VL | Collateral-adjusted exposures at risk (CEAR), expected annual loss, EUR million |
| EXPCTD_LSS_CNFDNCLTY_INDCTR | Flag for confidentiality - NEAR/CEAR |
| PHYSCL_RSK_PEAR_VL | Potential exposure at risk (PEAR), EUR million |
| PHYSCL_RSK_PEAR_PRCNTG_PTFL | Potential exposure at risk (PEAR), as a percentage of total portfolio |
| PHYSCL_RSK_SCR0_VL | Risk score 0 |
| PHYSCL_RSK_SCR1_VL | Risk score 1 |
| PHYSCL_RSK_SCR2_VL | Risk score 2 |
| PHYSCL_RSK_SCR3_VL | Risk score 3 |
| PHYSCL_RSK_SCR0_PRCNTG_PTFL | Risk score 0, as a percentage of total portfolio |
| PHYSCL_RSK_SCR1_PRCNTG_PTFL | Risk score 1, as a percentage of total portfolio |
| PHYSCL_RSK_SCR2_PRCNTG_PTFL | Risk score 2, as a percentage of total portfolio |
| PHYSCL_RSK_SCR3_PRCNTG_PTFL | Risk score 3, as a percentage of total portfolio |
| PEAR_CNFDNCLTY_INDCTR | Flag for confidentiality - pear |
| SCR_CNFDNCLTY_INDCTR | Flag for confidentiality - risk scores |

## Table 11: Metadata for hazard type

| Dimension | Code | Description |
|---|---|---|
| **Hazard code** | | |
| | cf | Coastal flooding |
| | rf | River flooding |
| | wi | Windstorms |
| | ls | Landslides |
| | sb | Subsidence |
| | wf | Wildfires |
| | ws | Water stress |
| | cdd | Consecutive Dry Days |
| | spi | Standardised Precipitation Index |
| **Data source** | | |
| | ud | Delft University of Technology |
| | ipcc | Intergovernmental Panel on Climate Change |
| | jrc | Joint Research Centre of the European Commission |
| **Scenario** | | |
| | rcp/r | Representative Concentration Pathway |
| | ssp | Shared Socioeconomic Pathway |
| **Time horizon** | | |
| | hist/current | Historical baseline |
| | p/proj | Projection |
| **Measures** | | |
| | a | Annual |
| | v | Absolute value |

For additional metadata, please refer to the statistical metadata file for the physical risk indicators.

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