EUROPEAN CENTRAL BANK

EUROSYSTEM

Technical annex

Climate change-related statistical indicators

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

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Contents

1 Sustainable finance indicators

1.1 Issuance of debt securities

1.1.1 Indicator description

The following sustainability classifications have been added to the 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 where the issuers are committed to future improvements in sustainability outcome(s) with no restrictions on how the proceeds can be used.

Four groups of experimental indicators are being published. For each group, 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:

The amount outstanding of euro area and EU issuances of sustainable debt securities by sustainability classification:

1. total amount outstanding (at face, nominal and market value) of all (at least self-labelled) sustainable debt securities issued by residents in the EA/EU, broken down by sustainability classification;
2. total amount outstanding (at face, nominal and market value) of sustainable debt securities with a second party opinion issued by residents in the EA/EU, broken down by sustainability classification;

The amount outstanding of EA issuances of green debt securities by institutional sector:

1. total amount outstanding (at face, nominal and market value) of all (at least self-labelled) green debt securities issued by residents in the EA broken down by institutional sector;

2. total amount outstanding (at face, nominal and market value) of green debt securities with a second party opinion issued by residents in the EA broken down by institutional sector;

The amount outstanding of issuances of green debt securities by individual EA country:

1. total amount outstanding (at face, nominal and market value) of all (at least self-labelled) green debt securities, issued by individual EA countries;

2. total amount outstanding (at face, nominal and market value) of green debt securities with a second party opinion, issued by individual EA countries;

Net EA issuances (financial transactions) of green debt securities:

1. net issuances (at face and market value) of all (at least self-labelled) green debt securities issued by residents in the EA;

2. net issuances (at face and market value) of green debt securities with a second party opinion issued by residents in the EA.

1.1.2 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 very minor number of) securities without a recognised standard.

Further breakdowns based on specific standards, in particular on the European green bond standard (EUGBS) will be considered in subsequent extensions of the indicators.

1.1.3 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.

1.1.4 Data sources

Centralised Securities Database (CSDB)

1.1.5 Compilation method

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.

1.1.6 Periodicity / update frequency

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

1.1.7 Contact

statistics@ecb.europa.eu

1.2 Holdings of debt securities

1.2.1 Indicator description

As for the issuance of sustainable debt securities, the following sustainability classifications will also be 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 where the issuers are committed to future improvements in sustainability outcome(s) with no restrictions on how the proceeds can be use.

Five groups of experimental indicators are being published. For each group, 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 being made available:

EA holdings of sustainable debt securities by sustainability classification and counterpart area:

1. total holding amount (at face and market value) of all (at least self-labelled) sustainable debt securities held by residents in the EA, broken down by sustainability classification and counterpart issuing area (EA, EU, Rest-of-the-world and Total);
2. total holding amount (at face and market value) of sustainable debt securities with a second party opinion held by residents in the EA, broken down by sustainability classification and counterpart issuing area (EA, EU, Rest-of-the-world and Total)

EA holdings of green debt securities by institutional sector:

1. total holding amount (at face and market value) of (at least self-labelled) green debt securities held by residents in the EA, broken down by institutional sector;
2. total holding amount (at face and market value) of green debt securities with a second party opinion held by residents in the EA, broken down by institutional sector;

Holdings of green debt securities by individual EA country:

1. total holding amount (at face, nominal and market value) of (at least self-labelled) green debt securities, broken down by individual EA country;
2. total holding amount (at face, nominal and market value) of green debt securities with a second party opinion, broken down by individual EA country;

Net EA acquisitions (financial transactions) of green debt securities:

1. total net acquisitions (at market value) of (at least self-labelled) green debt securities held by residents in the EA;
2. total net acquisitions (at market value) of green debt securities with a second party opinion held by residents in the EA.

1.2.2 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 very minor number of) securities without a recognised standard.

Further breakdowns based on specific standards, in particular on the European green bond standard (EUGBS) will be considered in subsequent extensions of the indicators.

1.2.3 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.

1.2.4 Data sources

Securities Holdings Statistics by Sector (SHSS)

Centralised Securities Database (CSDB)

1.2.5 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.

1.2.6 Periodicity / update frequency

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

1.2.7 Contact

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2 Common framework for carbon emissions and physical risk indicators

Current value of the investment:

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

Coverage:

- Loan-based indicators: loans from euro area credit institutions (S122) granted to non-financial corporations (S11) (for the physical risk indicators only non-financial corporations located in the EU; for the carbon emission indicators either euro area for the single entity-level indicators or a global scope for the group-level indicators).
- Securities-based indicators: securities (listed shares and debt securities) issued by non-financial corporation (for the physical risk indicators only non-financial corporations located in the EU, for the carbon emission indicators a global scope) and held by euro area deposit taking corporations except the central bank (S122), non-money market fund investment funds (S124), insurance corporation and pension funds (S128+S129).

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 AnaCredit Regulation (EU) 2016/867 on the collection of granular credit and credit risk data (ECB/2016/13).

3 Carbon emissions indicators

3.1 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 non-financial corporations in the corporate loan portfolio of the euro area banking sector, (ii) consolidated group-level (global)[2] emissions and financial information of non-financial corporations in the corporate loan portfolio of the euro area banking sector, and (iii) consolidated group-level (global) emissions and financial information of non-financial corporations in the corporate securities portfolio of the euro area financial sector.

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 (a non-financial corporation).
- 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, 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:

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

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

- Carbon intensity (CI) of country c: Financed emissions 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 enterprise value, weighted by b's investment in these activities, summed over all debtors/issuers i and all

[2] Notably, 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.

financial institutions b. Essentially, CI is Financed emissions over Financed revenue, at country level.

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

- Weighted average carbon intensity (WACI) of a country c: 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 a country, summed over all debtors/issuers i and all financial institutions b.

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

- Carbon footprint (CFP) of country c: Financed emissions standardised by the total investment portfolio value among financial institutions in a 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 indicator specific components:

- Portfolio value:
  - For the loan-based indicator: the sum of all loans and lines of credit as defined in Section 2.
  - For the securities-based indicators: the sum of listed shares and debt securities as defined in Section 2.
- Company value:
  - For the loan-based indicators: total assets of a company.
  - For the securities-based indicators: enterprise value including cash (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. When EVIC is not available, the enterprise value (EV) or total assets are 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 (EU ETS) for companies participating in the EU ETS; imputed emissions based on sectoral air emissions accounts data for remaining companies using an

average sector-country-year intensities times the size of a firm (measured by the number of employees).

- Group based indicators: CO2 equivalent emissions reported by companies disclosing such information stemming from the commercial data provider ISS. Missing data is 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[3] and reference year.
- Securities-based indicators: euro area and selected country-level aggregates by financial instrument (listed shares and debt securities separately as well as jointly for 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)[4], scope of emissions (Scope 1 and Scope 2), industrial sector of the issuer and reference year.

Time series decomposition:

To disentangle the main drivers of the indicators, the time series are decomposed into their various components using the Marshall-Edgeworth-type decomposition. The decomposition is performed on the FE, WACI and CFP indicators and distinguishes between greening of the underlying assets, changes in firms' financial characteristics and changes due to investment decisions.

- Changes in FE are decomposed into the impact of changes in investment share (loan or holding size relative to total assets or enterprise value) and changes in firms' carbon emissions.
- WACI is disaggregated into changes due to an issuer's/debtor's emissions, revenue, and portfolio reallocation performed by the creditors/holders.
- CFP is split into changes due to an issuer's/debtor's emissions, value of the non-financial corporation, and capital reallocation.

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

[4] S122: Deposit-taking corporations except central banks, S124: Non-Money market funds investment funds, S128-129: Insurance corporations & Pension funds.

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 on compilation

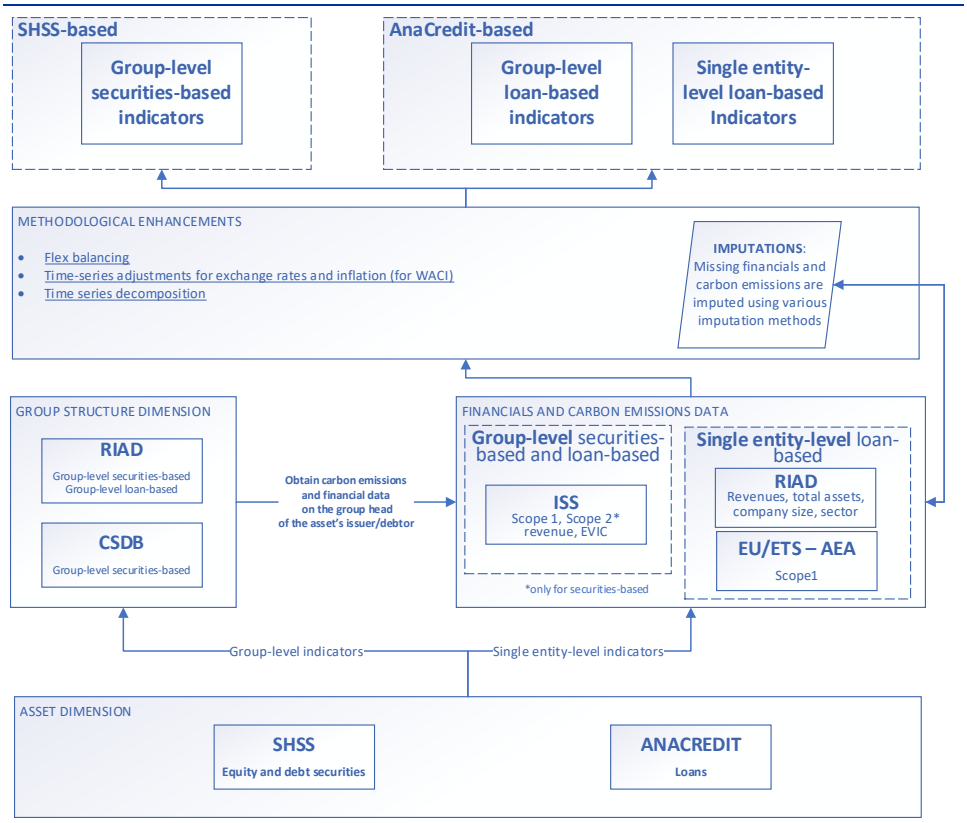

Table 1: Description of compilation

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 in addition also 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 International Security Identification Number and RIAD identifier.
4		The group structure is inferred based on RIAD information. The group head of an issuer/debtor is defined as either the direct group head or the ultimate group head if the former is missing.	
5	Financial information (company value proxied by total assets, revenue, number of employees) as well as the industrial sector in which the debtor is operating is obtained from RIAD. When no firm level information is available, financial information is imputed using a median approach.	Financial information (revenue and EVIC) is sourced from the commercial data provider ISS. Missing data is 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 hence can only be conducted to the extent that this information is jointly available.	Self-reported emissions (Scope 1 and for securities-based indicators also Scope 2) are obtained from ISS and 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 indicators (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 further up.		

3.2 Limitations and constraints

Data-related aspects:

- Emission and financial data are not available for the full loan debtors and securities issuers population therefore, imputations are applied for missing data. However, the imputation methods employed operate on the assumption that the auxiliary data used for imputation has a robust correlation with the missing values and that the observed data accurately represents 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 as well as the market value of listed shares and debt securities is affected by valuation effects, including price (i.e., inflation) and exchange rate effects. Corrections are exclusively applied to the WACI and not extended to all its components (Revenues are adjusted for inflation and

exchange rate effects, whereas the market values of listed shares and debt securities are only adjusted for exchange rate effects).

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.

3.3 Code list

Table 2: Overview of the metadata for the carbon emissions 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/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
fe	Financed emissions indicator (tons)
cint	Carbon intensity indicator (tons/mn EUR)
waci	Weighted average carbon intensity indicator (tons/mn EUR), adjusted for exchange rates and inflation
waci_unadj	Weighted average carbon intensity indicator (tons/mn EUR), unadjusted
cfp	Carbon footprint indicator (tons/mn EUR)
holder_creditor_country_coverage	Coverage of country nominal outstanding amount or market value with emission and financial data (%)
status_flag	Status flag for data row indicating confidentiality (“C”)

Table 3: Overview of the metadata for time series decomposition of carbon emissions 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
dc_fe_coeff	Decomposition of FE - investment share
dc_fe_emission	Decomposition of FE - carbon emission component
delta_fe	Yearly change in Financed emissions indicator (tons)
dc_waci_adj_emission	Decomposition of WACI adjusted - carbon emission component
dc_waci_adj_revenue	Decomposition of WACI adjusted - revenue component
dc_waci_adj_pv_weight	Decomposition of WACI adjusted - portfolio value component
delta_waci_adj	Yearly change in Weighted average carbon intensity indicator (tons/mn EUR) - inflation and exchange rate adjusted
dc_waci_unadj_emission	Decomposition of WACI unadjusted - carbon emission component
dc_waci_unadj_revenue	Decomposition of WACI unadjusted - revenue component
dc_waci_unadj_pv_weight	Decomposition of WACI unadjusted - portfolio value component
delta_waci_unadj	Yearly change in Weighted average carbon intensity indicator (tons/mn EUR) - unadjusted
dc_cfp_emission	Decomposition of CFP - carbon emission component
dc_cfp_compvalue	Decomposition of CFP - company value component
dc_cfp_pv_weight	Decomposition of CFP - portfolio value component
delta_cfp	Yearly change in Carbon footprint indicator (tons/mn EUR)
status_flag	Status flag for data row indicating confidentiality (“C”)

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

4 Physical risk indicators

4.1 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[5] and data sources used are different in each case. 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 aspect 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 4: 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) 2021-2050 2071-2100	RCP 4.5 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) 2021-2050	RCP 4.5 RCP 8.5
Windstorms	Own calculations, based on Copernicus WISC	Wind gust speed (m/s) based on the extreme events intensities (per return period)	NUTS3	1979-2020	-
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) 2023-2050	RCP 4.5 RCP 8.5
Water Stress	Aqueduct WRI	Ratio of water demand and water supply	Hydrological sub-basins (5 arc-minute)	1960–2014 (baseline) 2030-2050	SSP2 RCP 4.5 SSP3 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) 2021-2040 2041-2060	RCP 4.5 RCP 8.5
Standardized Precipitation Index	IPCC	Index comparing cumulated precipitation for 6 months with the long-term precipitation distribution	12.5km (11 arc-minute)	1986-2005 (baseline) 2021-2040 2041-2060	RCP 4.5 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 5: 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, 50, 100, 500	Based on intensity by NUTS3 and area type	Based on the damage functions/return periods	Based on Copernicus WISC[8] 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: No risk: Coarse soil texture (clay < 18% and sand > 65%) Low risk: Medium (18% < clay < 35% and sand >= 15%, or clay > 18% and 15% < sand < 65%) Medium risk: Medium fine (clay > 35% and sand < 15%) 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: No risk: <0.001 (frequency less than every 1,000 years) Low: 0.001-0.002 (between 500 and 1,000 years) Medium: 0.002-0.004, 0.004-0.01 (between 500 and 100 years) High: 0.01-0.02, >0.02 (more frequent than every 50 years)	Own calculations[9] 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: No risk: Arid and low water use, ratio of water demand to water supply <10% Low: 10-20% Medium: 20-40%, 40-80% High: >80%	Geospatial data (version 3.0, 2019)[10] Methodology
Consecutive dry days	-	Not available	Thresholds based on the number of days: No risk: < 15 days Low: 15-20 Medium: 20-30, 30-40 High: 40-50, >50 days	Geospatial data (IPCC Interactive Atlas)[11]
Standardized Precipitation Index	-	Not available	Based on index thresholds: No risk: -1 to 1 Low: (-1.5 to -1), (1 to 1.5) Medium: (-2 to -1.5), (1.5 to 2) 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.

6 Dominik Paprotny, O. (Oswaldo) Morales Nápoles (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 Dominik Paprotny, O. (Oswaldo) Morales Nápoles (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.

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:

$$FINANCIAL\ RISK\ RATIO_{i,Total\ assets} = \frac{Tangible\ fixed\ assets_{Orbis,\,i}}{Total\ assets_{Orbis,\,i}} \cdot EL_i(m)$$

The term $\mathrm{EL_i(m)}$ 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

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8 Copernicus WISC (Windstorm Information Service): https://climate.copernicus.eu/windstorm-information-service.

9 Burger C., Herzberg, J., Nuvoli, T., *Explainable AI in fire risk estimations*, forthcoming.

10 WRI Aqueduct: aqueduct.wri.org.

11 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.

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.

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

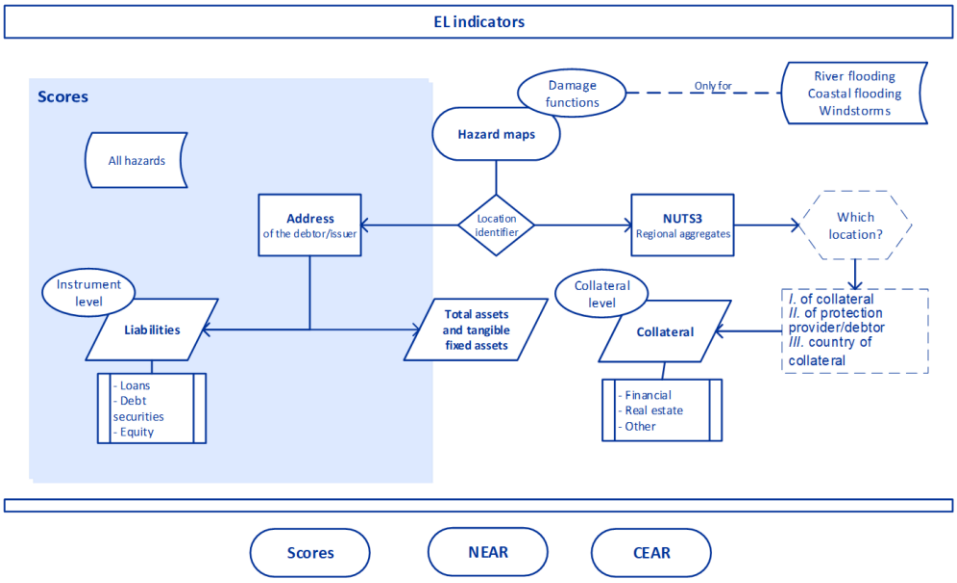
where CV_i is the collateral allocated to each creditor-debtor-instrument combination.

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. All indicators are based on financial variables from AnaCredit, SHS and RIAD, refreshed with reference to December 2022.

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



4.2 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.
- Hazard maps have an almost full coverage for the EU (overseas territories of France and Netherlands, Canary Islands, Madeira, Azores are excluded). In terms of entities in the financial dataset, at least 95% of RIAD entities registered in the EU are covered for each hazard type. Coverage of counterparty addresses in RIAD is also almost complete[12].

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.
- The location information of firms is based on RIAD, which collects information at the level of the legal entity. In case 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 total value of fixed assets is used as a benchmark for estimated losses. In the case of larger companies, the fixed assets might be distributed across various locations with different exposure to physical hazards. In addition, the data on tangible fixed 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

[12] However, specific address attributes, such as the country, city, postal code, street and house number, are reported with varying levels of quality. Georeferencing tools, such as OpenStreetMap, used to translate address information to latitude and longitude, can also suffer from low coverage and inconsistencies. These elements collectively influence the precision of the geocoding.

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.

4.3 Code list

Table 6: 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 7: 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	Standardized 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 analytical physical risk indicators.

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