# Assessing Multi-Dimensional Nature Dependencies in the EU

# ENCORE Insights: Country Dashboard Methodology

November 2025


Abstract

This paper outlines the methodology supporting the development of *ENCORE Insights: Country Dashboard*, an online platform funded under the Horizon programme and launched in December 2025. The Dashboard enables users to explore the dependence of the 27 European Union (EU) member states on nature, combining data on economic structure and nature-related dependency to identify critical sectors most exposed to ecosystem degradation. The methodological framework builds on existing approaches that link ENCORE's nature dependency data with the EXIOBASE global input–output database. At the same time, we establish an alternative, multi-dimensional framework that explicitly differentiates between domestic and imported exposure to nature degradation, a distinction informed by the broader value-added in trade literature (Koopman et al., 2013). This distinction provides a more nuanced understanding of national vulnerabilities and supports the design of targeted regulatory policies. The resulting analysis and visualisations — fully transparent and open-access — will help policymakers, regulators, civil society, and financial institutions identify sectors and supply chains most at risk from nature degradation, thus informing strategies for sustainable economic resilience across the EU.



**JEL Classification**: Q57, C67, F18, 013

**Keywords**: Nature-related economic dependency, Input–output analysis, Ecosystem degradation risk, Value-added trade exposure

# 1 Introduction

This paper presents the detailed methodology underpinning the Nature-3B Horizon-funded online platform *ENCORE Insights: Country Dashboard* being developed by Global Canopy.[1] This website – whose first version launched in December 2025 – will enable regulators, policymakers, civil society and financial institutions to understand how each of the European Union (EU)'s 27 economies are exposed to nature degradation.[2]. While in many respects the methodology follows the existing literature on national-level nature dependencies, it also expands on previous research by clearly differentiating between countries' domestic and foreign exposure. As regulation, conservation and restoration initiatives need to be adapted to national contexts, distinguishing between domestic and imported dependence will allow a more targeted policy response. In this paper we explain our approach to analysing exposure at the national and sector level, shedding light in particular on the decomposition of domestic and imported value added. Our methodology draws on the broader 'trade in value-added' literature (e.g. Koopman et al. 2013), which has to the best of our knowledge, not yet been applied in nature-related risks research designs. We establish a multi-dimensional framework that allows us to quantify dependencies based on origin (domestic vs. imported value-added) and final use (gross exports vs. domestic final demand), covering both the production and consumption dimensions of the economy.

---

[1] This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101182455 (Nature-3B). It is part of Work Package 1 and benefits from collaborations with the International Institute for Applied Systems Analysis (IIASA), the University of Oxford and the London School of Economics.

[2] The Country Dashboard is the first of the ENCORE Insights websites. These are satellite projects of ENCORE, produced by the ENCORE partners Global Canopy, United Nations Environment Programme World Conservation and Monitoring Centre (UNEP-WCMC) and United Nations Environment Programme Finance Initiative (UNEP FI). They combine the ENCORE knowledge base with other data to bring new insights about the economy's dependency on nature and its impact on it.

The core methodology follows the existing literature by combining ENCORE's nature dependency data (ENCORE, 2024) with the EXIOBASE global input-output database (Stadler et al, 2018). Whilst ENCORE provides an indication of an economic activity's dependence on nature, EXIOBASE, (a global dataset based on national accounts) assigns a monetary value to economic sectors in each country (Stadler et al, 2018). By bringing these two datasets together, we can analyse sectors and subsectors' monetary exposure to nature loss. EXIOBASE also describes supply chain linkages within and between countries, which allows us to quantify exposure across a country's international supply chain.

This type of analysis has been the starting point of several studies. The initial research by van Toor et al. (2020) used ENCORE and financial asset data to determine the Dutch financial sector's exposure to nature loss. The Banque de France's pioneering study by Svartzman et al. (2021) went further by combining ENCORE with EXIOBASE to understand not only French financial institutions' exposure to nature degradation but also their indirect exposure through their upstream supply chains. It found that, overall, 42% of the value of their securities came from issuers that are highly or very highly dependent on one or more ecosystem services. In further pioneering work, Ranger et al. (2024) combined ENCORE, EXIOBASE and other sources to construct a Nature Value-at-Risk (NVaR) framework for UK financial assets. They found that environmental degradation could result in UK Gross Domestic Product (GDP) being 6% lower by the 2030s under two scenarios, including indirect effects through supply chains around the world. Boldrini et al. (2023) and Ceglar et al. (2025) from the European Central Bank analysed Anacredit financial portfolio data to show that 72% of corporate loans in the euro area are highly dependent on at least one ecosystem service. Finally, Hirschbuel et al. (2025) focused on a similar question to ours, analysing the EU economy’s dependence from a Gross Value Added (GVA) perspective, and found that between 19% and 36% of

it was highly reliant on ecosystem services. Nearly all the studies mentioned above distinguished between direct and indirect exposure further up the supply chain. However, they did not differentiate between exposure to domestic and foreign nature degradation in the supply chain.[3]

This paper therefore presents a novel, multi-dimensional framework to quantify nature dependencies at the macro-economic scale combining total upstream dependencies with an 'origin of trade' perspective (Figure 1). This allows us to quantify dependencies based on the origin (domestic vs. imported value-added) and final use (gross exports vs. domestic final demand), covering both the production and consumption dimensions of the economy. Furthermore, we incorporate employment and wages data to include the dependency of wider socio-economic factors. This comprehensive decomposition allows the analysis to move beyond simple direct and indirect exposure to nature loss, providing a complete and granular picture of a country's total economic and social exposure via its whole supply chain, distinguishing between domestic and foreign imported components.

[3] 'Indirect' exposure usually includes any upstream exposure, which can be either domestic or foreign.

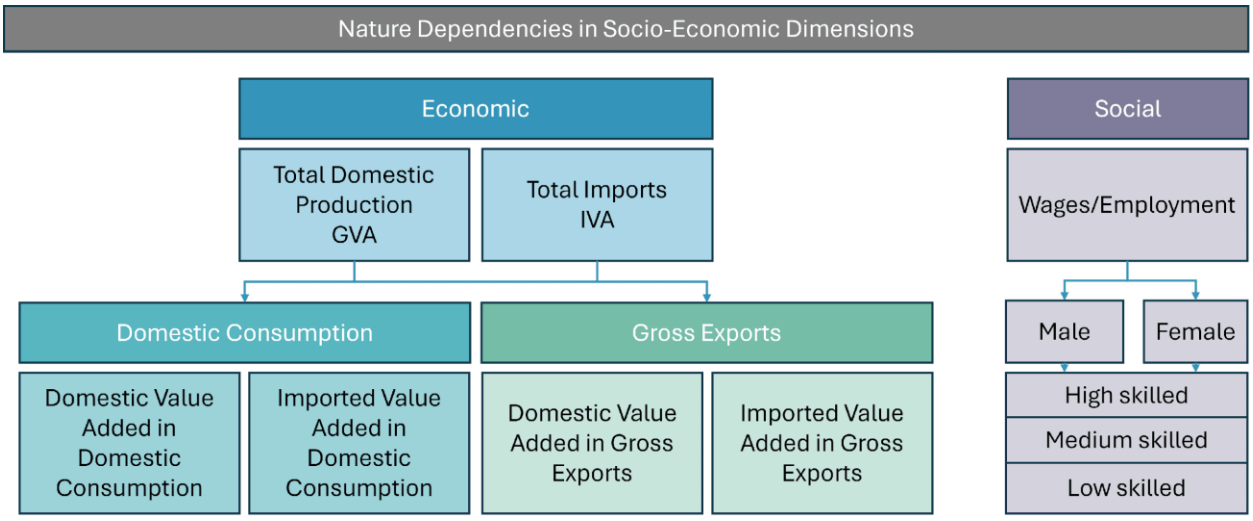



*Figure 1: Schematic of the multi-dimensional framework across an 'origin of trade' perspective and social dimensions. GVA stands for 'Gross Value Added' while IVA stands for 'Imported Value Added'.*

The first version of the Dashboard, launched in December 2025, focuses exclusively on the GVA vs IVA dimension (blue squares in Figure 1). Future iterations in 2026 and 2027 will incorporate gross exports, domestic consumption and social components (jobs and employment). For each domestic or foreign imported component, we map the size of an economic sector or subsector against its dependency on nature, thereby helping to identify sectors in domestic production and imports that are both large and highly exposed to nature degradation, which we call 'critically exposed sectors'.

This paper sets out the methodology used to calculate the exposure metrics across our proposed framework. We begin by describing the necessary data sources and setting out the calculation of the materiality ratings in both direct and upstream supply chain dimensions. Next, we present the method for calculating each of the socio-economic components before calculating the exposure metrics in these multiple dimensions, aggregating to the sector, country, and EU levels. Finally, we preview the Version 1 dashboard elements concluding with our future work.

# 2 Data and Method

## 2.1 Overview

The core of the methodology involves the following steps:

- **Total supply chain dependencies**: Calculating consolidated materiality and total upstream supply chain ratings from the ENCORE direct materiality ratings.
- **Monetary value decomposition**: Calculating economic value-added components (decomposed across Domestic Production and Foreign Imports that contribute to Gross Exports and Domestic Final Demand) and socio-economic components (wages and employment) from EXIOBASE to represent the economic significance of different parts of the supply chain.
- **Derived Metrics:** Combining the economic components with the materiality ratings to derive the monetary value, or proportion, of a sector or country under high nature dependency.

The subsequent sections detail each step of this analytical process (summarised in Figure 3), from data preparation, core calculations to the final derivation of exposure metrics and use in the Country Dashboard. The whole analysis is implemented in Python v3.13.2.

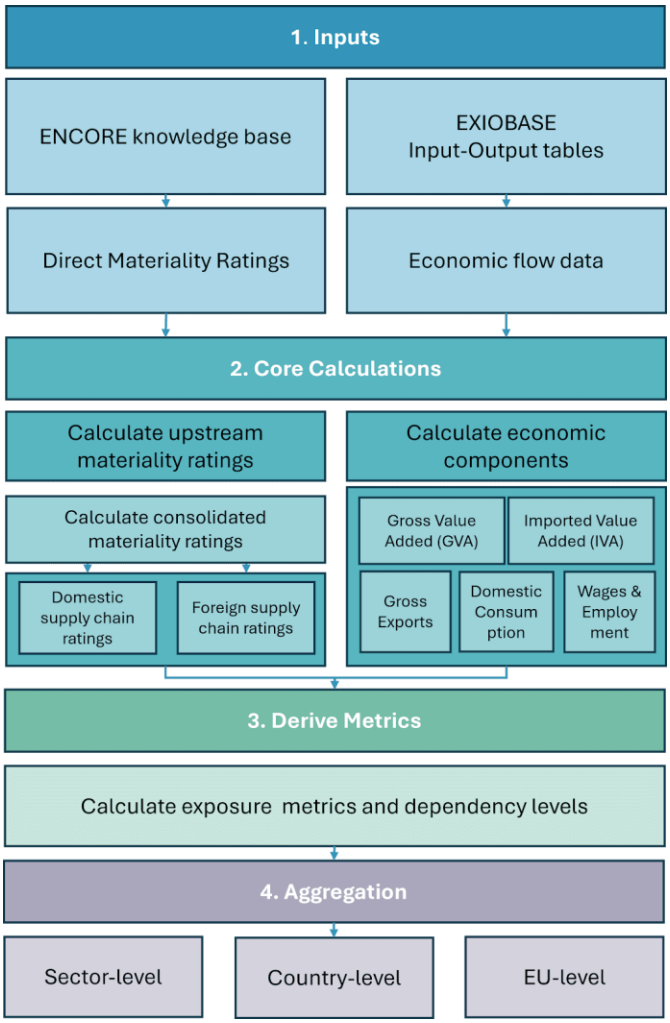



*Figure 3: Summary of analysis workflow showing input data, core calculations, derived metrics and aggregation.*

## 2.2 Data

The analysis of nature dependencies uses two main datasets: ENCORE and EXIOBASE3 as described below.

### 2.2.1 ENCORE

ENCORE was developed by Global Canopy, the UN Environment Programme Finance Initiative (UNEP-FI) and UN Environment Programme World Conservation Monitoring

Centre (UNEP-WCMC) with funding from the Swiss State Secretariat for Economic Affairs (SECO) and the MAVA Foundation. ENCORE was launched in 2018 with the original aim to support financial institutions and companies to understand how their activities rely on nature. The ENCORE knowledge base provides linkages between economic activities and the ecosystem services upon which they depend. In 2024, it was updated under the SUSTAIN project. The 2024 updated version has been used in this analysis[4].

The ENCORE economic activities are categorised using the UNs International Standard Industrial Classification of All Economic Activities (ISIC Rev 4). ISIC divides economic activities into Sections, which are further broken down into Divisions, Groups and Classes. This provides materiality ratings for 271 economic activities based on either ISIC group or class level (levels 3 and 4). In ENCORE, ecosystem services are defined as the connections between nature and business with each ecosystem service representing a benefit that nature provides to enable or facilitate economic activities. Ecosystem services are classified according to the UN System of Environmental Economic Accounting Ecosystem Accounting (United Nations et al, 2021) categorisation of ecosystem services (also used by the TNFD framework), comprising 25 ecosystem services[5] within the three categories: Provisioning services, Regulating and maintenance services, and Cultural services.

ENCORE assesses the dependency materiality rating for each of the 25 ecosystem services and 271 ISIC economic activities. Materiality ratings provide an indication of the significance of a sector's potential nature-related dependencies at a typical global level. The term 'material' in this context refers to "*significant or important to consider in the*

[4] For further information, see ENCORE methodology here

[5] For the full list and definitions of ecosystem services see: https://www.encorenature.org/en/data-and-methodology/services

*decision-making process*" (ENCORE, 2024)[6]. Materiality ratings use a rating scale of Very High (VH), High (H), Medium (M), Low (L) and Very Low (VL). If an economic activity does not depend on a given ecosystem service, it is assigned Not Applicable (NA) or No Data (ND) where there is insufficient evidence to assign a rating. These ratings are not location-specific, meaning an economic activity is assigned the same materiality rating regardless of its geographic location.

### 2.2.2 EXIOBASE

EXIOBASE[7] is a global multi-regional input-output (MRIO) database that relates economic flows between industries across countries (Stadler et al., 2018). Data from national Supply-Use Tables are harmonised and linked with international trade data to enable analysis of the global production and interconnectedness of goods and services within the global economy. Data is provided for 163 sectors using the NACE categorisation system (Statistical Classification of Economic Activities in the European Community: NACE code, revision 1). Coverage is provided for 44 countries and 5 'rest of the world' regions. EXIOBASE version 3.9.6 (compiled 2020) has been used in the analysis. The core EXIOBASE 3.9 model uses supply and use tables up to 2020 and now-casted[8] up to 2022 using global trade and macro-economic data. As EXIOBASE relies heavily on 'now-casting' economic structure, the reliability of more recent years decreases due to the reliance on estimations. The current analysis uses now-casted data to 2022 based on 2020 data. It should therefore be noted that the impact of the Covid

[6] https://encorenature.org/resources/explanatory-note-on-the-updated-encore-knowledge-base-outlining-business-dependencies-and-impacts-on-nature

[7] https://exiobase.eu/

[8] Now-casting in EXIOBASE is the process of updating the multi-regional input-output (MRIO) database to more recent years for which official, fully compiled data is not yet available. It uses macroeconomic data and bilateral trade statistics as proxies to estimate the current economic structure, bridging the time gap between the latest complete database (e.g., 2020) and the present.

pandemic is not adequately captured in post-pandemic years as well as more recent changes in the geopolitical climate and global trade tariff impacts.

## 2.3 Data preparation

### 2.3.1 Sector Concordance

As EXIOBASE sectors and ENCORE sectors use different classification systems, a crosswalk table is used to map the ISIC economic activities of ENCORE with the EXIOBASE NACE sectors. Firstly, ENCORE's categorical materiality ratings are converted to numerical ratings as per Table 1. Then the data is merged on ENCORE materiality ratings and EXIOBASE sectors using the ENCORE provided EXIOBASE NACE-ISIC crosswalk table. Matches were made at the 'ISIC level used for analysis' column in the ENCORE Dependency Ratings dataset, specifically for 'Class' and 'Group' level data. After the merge, the data is grouped by EXIOBASE sector and the mean materiality rating calculated where multiple ISIC sectors map to a single EXIOBASE sector.

| **Materiality Rating** | **Assigned Numerical Score** |
|---|---|
| Very High (VH) | 1 |
| High (H) | 0.8 |
| Medium (M) | 0.6 |
| Low (L) | 0.4 |
| Very Low (VL) | 0.2 |

| Materiality Rating | Assigned Numerical Score |
|---|---|
| No Data (ND) | 0 |
| Not Applicable (NA) | NaN |

*Table 1: Values applied when converting the categorical ENCORE ecosystem service materiality ratings to numerical scores.*

Based on this approach, ENCORE ratings are mapped to EXIOBASE NACE sectors (not the other way around) which means we lose the granularity of ecosystem service ratings at the ISIC sector level. However, this approach was selected to meet the requirements of users expressing a preference for NACE sectors and also ensures the precision of EXIOBASE data is retained, as the alternative (mapping of EXIOBASE onto ENCORE) would require splitting the EXIOBASE values between ENCORE ISIC sectors.

## 2.4 Materiality Ratings

### 2.4.1 Direct Materiality Ratings

As the ENCORE materiality ratings do not vary geographically (e.g. the sector '*Cultivation of wheat*' in Country A will have the same materiality rating for each ecosystem service as '*Cultivation of wheat*' in Country B), a matrix representing direct materiality ratings, $D_{direct}$, was generated to reformat the data into a country-sector format for subsequent calculations. This results in a matrix with the 25 ecosystem services on the rows and EXIOBASE country-sectors on columns. Materiality ratings for each ecosystem service are then duplicated to produce a matrix of direct materiality ratings for each country-sector pair.

### 2.4.2 Consolidated Dependency Rating

As a subsector has materiality ratings for each 25 ecosystem services, a single Consolidated Materiality Rating is calculated to summarise its overall dependency. This consolidated rating is derived from aggregating Direct Materiality Ratings using the method defined by Hirschbuehl et al. (2025) integrating three key aspects of dependency to give a more comprehensive score compared to a simple average or maximum:

i. **Breadth of Dependency** (score 1): Measures the diversity of a subsector's reliance on nature by counting the number of different ecosystem services it depends on normalised by the total number of ecosystem services. A high score here indicates a sector is exposed to a wide range of potential physical dependencies.

ii. **Average intensity of dependency** (score 2): Captures the typical level of reliance across all services, preventing the score from being skewed by a few low- or high-impact services.

iii. **Peak Dependency** (score 3): Highlights the single most critical exposure. It captures the assumption that a high dependency on a single ecosystem service poses a significant, concentrated risk, even if other dependencies are low. This ensures that the most significant dependency is not understated.

The equation used for the consolidated dependency score is:

$$Consolidated\ Materiality\ Rating\ = \frac{1}{3}\text{Score}_1 + \frac{1}{3}\text{Score}_2 + \frac{1}{3}\text{Score}_3$$

Where:

$Score_1$ = Number of different sectoral ecosystem dependencies

$Score_2$ = Mean materiality rating of all ecosystem service dependencies

$Score_3$ = Maximum strength of any individual dependency

The '*water supply*' ecosystem service is excluded from this calculation to avoid double counting. As a final ecosystem service, '*water supply*' reflects the combined contributions of other ecosystem services—including water flow regulation and water purification—which are already separately included in the ENCORE knowledge base (United Nations et al, 2021).

### 2.4.3 Upstream Materiality Ratings

Whilst the Direct Materiality Ratings provides a measure of a subsector's direct physical dependencies on ecosystem services, we require the total dependency across a subsector's supply chain in order to understand the economic value exposed. Nature dependencies across the whole supply chain are therefore calculated to represent the average dependency score of a subsector's suppliers, weighted by their total economic importance to the sector using each supplier's share of inputs from the Leontief Inverse matrix (B). This captures the importance of a supplier within the supply chain as well as their dependency on nature, giving more weight to a larger supplier than a smaller one.

Whilst the Direct Materiality Ratings provides a measure of a subsector's *direct* physical dependencies on ecosystem services, we require the total dependency across a subsector's supply chain in order to understand the economic value exposed. Nature dependencies across the whole supply chain are therefore calculated to represent the average dependency score of a subsector's suppliers, weighted by their total economic importance to the sector using each supplier's share of inputs from the Leontief Inverse matrix (*B*). This captures the importance of a supplier within the supply chain as well as their dependency on nature, giving more weight to a larger supplier than a smaller one.

For a subsector, Nature Dependencies are calculated in two different dimensions:

1. The **Domestic Nature Dependency Rating** ($D_{domestic}$) is the mean weighted **Consolidated Materiality Rating** of its producer and all its upstream domestic suppliers, representing the mean dependency embodied in goods and services sourced from within the same country;

2. The **Foreign Nature Dependency Rating** ($D_{foreign}$) is the mean weighted **Consolidated Materiality Rating** of all its foreign suppliers, representing the mean dependency embodied in goods and services sourced from other countries.

Specifically:

$$D_{\mathrm{j}}^{\text{supply chain}} = \frac{\sum_{\mathrm{i}} D_{\mathrm{i}} B_{\mathrm{i,j}}^{\mathrm{comp}}}{\sum_{\mathrm{i}} B_{\mathrm{i,j}}^{\mathrm{comp}}}$$

Where,

$D_{\mathrm{i}}$ is the Consolidated Materiality Rating from the $D_{consolidated}$ matrix of the supplier subsector *i*,

$B_{\mathrm{i,j}}^{\mathrm{comp}}$ is the total output required from supplier *i* to satisfy demand from *j* from the Leontief Inverse, filtered for either domestic or foreign suppliers,

$\sum_{\mathrm{i}} B_{\mathrm{i,j}}^{\mathrm{comp}}$ is the total Leontief Inverse coefficients from all supplier subsectors *i*, filtered for either domestic or foreign suppliers.

Whilst Direct Materiality Ratings ($D_{direct}$) do not vary geographically, Upstream Dependency Ratings ($D_{domestic}$) and ($D_{foreign}$) are influenced by the location and mix of suppliers within a subsector's supply chain. This results in varying upstream nature dependencies for the same subsector in different countries, reflecting regional variations in economic structures. The chosen method for calculating total supply chain nature

dependencies is a weighted mean to provide an estimate of the overall risk profile embodied in a subsector's supply chain. This method can dilute the influence of highly dependent subsectors and smooths the overall dependency profile. Therefore, the result from this analysis provides an indicative comparative assessment of exposure between subsectors within countries and further analysis would be required to identify critical single dependencies within supply chains.

Nature Dependencies are averaged across subsectors to obtain their corresponding sector-level Nature Dependency.

## 2.5 Socio-Economic Decomposition

To quantify the economic significance of different parts of the global supply chain, we calculate economic value-added components from the EXIOBASE input-output tables. GVA is calculated for each country-sector to quantify the domestic production. We also quantify the value added from imported supply chains (IVA) to capture the value-added that is generated in another country from which domestic production is dependent on. This 'origin of value-added' perspective allows for a more granular analysis of nature dependencies across supply chains.

i. **Gross Value Added (GVA)** captures the value created by domestic industries and labour that ultimately serves either domestic consumption or exports. It directly measures the value -added generated *within the country's borders* that is linked to a subsector's activity. It also contributes to a country's GDP.[9]

[9] GVA does not completely decompose into Domestic Value Added in Final Demand (DVA_fd) and Domestic Value Added in Exports (DVA_e) as DVA_e includes some double counting terms as a full accounting decomposition was not undertaken. Therefore, the sum of DVA_fd and DVA_e is slightly greater than GVA.

ii. **Imported Value Added (IVA)** is the economic value generated in *another country* that is embodied in a country's final demand or exports. Whilst not part of GDP, this captures a country's economic reliance on upstream production occurring abroad. This is calculated as the sum of Foreign Value Added in Domestic Final Demand ($FVA_{fd}$) and ForeignValue Added in Gross Exports ($FVA_e$).[10]

Domestic value-added components directly measure the value-added generated *within the country's borders* that is linked to a sector's activity, which is the definition of GVA[11]. Whilst IVA is excluded from the target country's GVA, a country's economy is indirectly dependent on these. Therefore, IVA tells us about the dependence of a national economy on imports.

These economic components are calculated from core matrices and vectors in EXIOBASE: the A matrix (direct requirements), Z matrix (intermediate consumption), Y matrix (final demand), B matrix (Leontief inverse) and x vector (total outputs); as per the calculations detailed below.

### 2.5.1 GVA Calculation

GVA for each country-sector is calculated from EXIOBASE using the factor income approach by multiplying the diagonal matrix of direct value-added coefficients ($\hat{V}$) by the total output vector (x) as detailed below[12].

$$GVA = \hat{V}\ x$$

[10] This is equivalent to the term Foreign Content (FC) in Koopman et al. (2013)'s decomposition of Trade in Value-Added Exports.

[11] GVA does not completely decompose into DVA_fd and DVA_e as DVA_e includes some double counting terms as a full accounting decomposition was not undertaken. Therefore, the sum of DVA_fd and DVA_e is slightly greater than GVA.

[12] Alternatively GVA can be calculated using the production method where GVA is the total output of a sector (x vector) minus the value of intermediate goods and services (column sums of Z matrix).

Where:

$\hat{V}$ (Value-Added Coefficient Matrix) *i*s a diagonalised matrix of value-added coefficients where each diagonal element $v_{(r,i)}$ is the ratio of value-added to gross output for the producing country *r,* sector *i*. This is derived by summing the direct input coefficients for sector *i* (column *i* of the A matrix) and subtracting from 1. The resulting vector of value-added shares is then diagonalised.

$$v_{(r,i)} = 1 - \sum_{(s,j)} a_{(s,j),(r,i)}$$

$x$ is the total output vector for each country-sector.

### 2.5.2 Economic Value-Added Components

IVA is calculated from the sum of the Foreign Value Added in Final Demand ($FVA_{fd}$) and Foreign Value Added in Gross Exports ($FVA_e$) for each country, sector (c,j):

Total IVA = FVA in final demand + FVA in Gross Exports

Additionally, GVA is further decomposed into Domestic Value Added (DVA) in Final Demand ($DVA_{fd}$) and DVAin Gross Exports ($DVA_e$). These decomposed Gross Exports and Final Demand components are calculated using the *VB* matrix which links value-added to final demand via the Leontief Inverse matrix, representing the underlying value-added production structure of the global economy. An element $VB_{(r,j)(s,k)}$ from this matrix represents the total value-added originating from producing sector *j* in country *r* that is required to produce one unit of final demand from consuming sector *k* in country *s*.

The VB matrix is the product of two key matrices:

$$VB\ matrix\ =\ \hat{V}\ B$$

Where:

$\hat{V}$ (Value-Added Coefficient Matrix) is a diagonalised matrix of value-added coefficients as defined above. The use of $\hat{V}$ is designed to avoid double counting in the A matrix by representing the value-added by primary factors of production excluding intermediate inputs i.e. it captures the value created at each stage of production rather than the total value of the output.

*B* (Leontief Inverse Matrix) is the matrix $(I - A)^{-1}$, where I is the identity matrix and A is the Direct Requirements Matrix. B captures all direct and indirect intermediate linkages showing the total output required from every sector to satisfy one unit of final demand from any sector.

The *VB* matrix is multiplied by the relevant final demand or gross export vector as per the formulae below, representing the value-added originating in sector *i* of country *r*, to calculate $DVA_{fd}$, $DVA_{e}$, $FVA_{fd}$ and $FVA_{e}$*:*

$$DVA_{fd(r,i)} = \sum_{(r,j)} v_{(r,i)}\ b_{(r,i)(r,j)}\ Y_{D(r,j)}$$

$$DVA_{e(r,i)} = \sum_{(s\prime,j)} v_{(r,i)}\ b_{(r,i)(s\prime,j)}\ E_{(s\prime,j)}$$

$$FVA_{fd(r,i)} = \sum_{(r,j)} \sum_{(s\neq r)} v_{(s,k)}\ b_{(s,k)(r,j)}\ Y_{D(r,i)}$$

$$FVA_{e(r,i)} = \sum_{(s\prime,j)} \sum_{(s\neq s\prime)} v_{(s,k)}\ b_{(s,k)(s\prime,j)}\ E_{(s\prime,j)}$$

where:

- *r, i* is the *producing* country *(r)* and, sector *(i)*
- *s, j* is the *consuming* country *(s)* and sector *(j)* of final output
- *s,k* is used as a summation index, representing a foreign country *(s)* and sector *(k)* supplying value-added to country r
- $s \neq r$ indicates that the value-added originates in a foreign country *(s)* that is different from the country under analysis *(r)*
- $Y_D$ represents the domestic final demand vector
- $E$ represents the gross exports vector, where:

Gross exports are calculated using the fundamental input-output identity which states that a country's total output ($x$) must equal the sum of domestic intermediate use ($Z_{domestic}$), domestic final demand ($Y_{domestic}$), and exports ($E$)[13]. Rearranging this identity allows for the calculation of exports for each country-sector:

$$E = x - (Z_{domestic} + Y_{domestic})$$

### 2.5.3 Wages and Employment Components

Beyond GVA, the analysis also quantifies the potential dependency of a country's employment and wages on nature. This provides a more complete picture of the socio-economic exposure to nature-related risks. The approach for calculating these components mirrors the value-added decomposition logic above, simply replacing the direct value-added coefficients ($\hat{V}$) with employment ($\hat{e}$) or wage ($\hat{w}$) coefficients extracted from EXIOBASE:

[13] Alternatively, gross exports (E) can be calculated as the sum of all sales to foreign entities, encompassing both foreign intermediate sales (sales of intermediate goods to other countries) and foreign final demand sales (sales of final goods to other countries):
E=Z_foreign-intermediate-sales+Y_foreign-final-demand-sales

Gross employment and gross wages are analogous to the GVA calculation:

$$Gross\ employment\ =\ \hat{e}\ x$$

$$Gross\ wages\ =\ \hat{w}\ x$$

where:

- $\hat{e}$: a diagonal matrix of direct employment coefficients (i.e., the number of people employed per unit of total output in that sector)
- $\hat{w}$: a diagonal matrix of direct wage coefficients (i.e., the total wages generated per unit of total output in that sector). This is calculated using the number of hours of employment per unit of total output extracted from EXIOBASE multiplied by an average wage for each skill level-gender in each country.
- $x$ is total output vector

To decompose the employment and wage flows into their final demand-driven components (e.g., domestic final demand), the EBY (Employment by Final Demand) or WBY (Wages by Final Demand) matrix is calculated:

$$EBY\ matrix\ =\ \hat{e}\ B\ \ \hat{Y}\ component$$

$$WBY\ matrix\ =\ \hat{w}\ B\ \hat{Y}\ component$$

Where:

- $\hat{e}$: a diagonal matrix of direct employment or wage coefficients as above
- $\hat{w}$: a diagonal matrix of direct wage coefficients as above
- B: the Leontief inverse matrix
- $\hat{Y}\ component$: the specific final demand component of interest (e.g. domestic final demand or gross exports vector) using the same decomposition method detailed above.

## 2.6 Exposure Metrics

In order to calculate how much monetary value is exposed to nature degradation for each country and sector, the Upstream Dependency ratings for each subsector is scaled, within each country, to between 0 and 1 using min-max scaling and then categorised into high, medium or low dependency groups using the bandings in Table 2 below[14]. Domestic Dependencies are used to categorise the country-sectors GVA and the Foreign Dependencies used to categorise the country-sectors IVA. The 163 EXIOBASE subsectors are aggregated into 23 sector groups for each country using the groupings and sector mapping in Appendix 6.3[15]. The total value of the sector group's economic value (e.g. GVA or IVA) that is categorised as high, medium or low dependency is summed and the proportion calculated as a percentage of the sector's total value. This provides a comparison of a sector's dependency *relative* to other sectors within the country.

| **Dependency Level** | **Bandings** |
|---|---|
| High | ≥0.66 |
| Moderate | ≥0.5 and <0.66 |
| Low | <0.5 |

*Table 2: The score bandings used to apportion the consolidated ecosystem scores into high-medium-low groups. The bandings for our analysis were informed by the distribution of consolidated dependency scores across all country-sectors.*

[14] It should be noted that it isn't appropriate to use the original ENCORE rating scale from Table 1, as the consolidated materiality ratings are not comparable in distribution to the direct materiality ratings.
[15] This is aligned with the method used by the Joint Research Committee Hirschbuehl et al. (2025) and Evison et al. (2023) based on industry groups from the World Economic Forum (WEF) Strategic Intelligence.

Finally, results are aggregated to country- and EU-level by simply summing the total economic value across all sectors and EU27 countries respectively.

# 3 Results and Discussion

The analysis presented here is visualised within a freely available Country Dashboard hosted by NGO Global Canopy to enable the user to easily visualise and interrogate nature dependencies across multiple economic and socio-economic dimensions (wages and employment). The first version of the Country Dashboard launched in December 2025 presents dependencies at the GVA and IVA level, with further iterations planned for release through 2026 incorporating the remaining economic and social dimensions. Here we present a sample of results that will be available for GVA and IVA at the country and sector-level for each EU27 country.

## 3.1 Sample Dashboard Elements

**Country-level Headline Figures**

Headline figures are presented on the Country Dashboard using the sector-level Exposure Metrics to provide users with a summary view of each EU27 country's dependency on nature. Specifically:

- **GVA Highly Exposed:** The proportion of a country's domestic economic activity that is highly dependent on nature. This value is calculated by summing the GVA of all subsectors whose Consolidated Materiality Rating falls within the 'high

dependency' category (i.e. a rating of ≥ 0.75). It is presented as both a monetary value and as a percentage of a country's total GVA.

- **IVA Highly Exposed:** The proportion of a country's imported economic activity that is highly dependent on nature. This value is calculated by summing the IVA of all subsectors whose Consolidated Ecosystem Rating falls within the 'high dependency' category (i.e. a rating of ≥ 0.75). It is presented as both a monetary value or percentage of a country's total IVA.
- **Total Value Highly Exposed:** The aggregate monetary value of a country's economy that is highly dependent on nature. This value is calculated by summing the GVA and IVA for all subsectors whose Consolidated Ecosystem Rating falls within the 'high dependency' category. The high dependency threshold is defined as a Consolidated Ecosystem Rating of ≥ 0.75.

- **Country Dependency Score:** A consolidated score capturing the country's overall dependency on nature calculated by summing the percentage of GVA exposed with the percentage of IVA exposed to high nature degradation. This enables for a high-level comparison of exposure between countries.

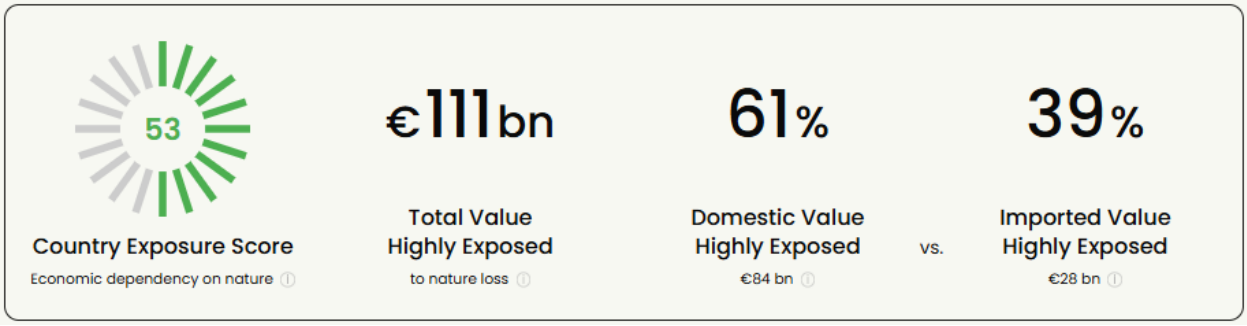



*Figure 4: Country-level headline figures on the Country Dashboard (showing sample data).*

**Country Exposure Profile**

A matrix view of a country's exposure profile provides a disaggregated view of nature dependencies by breaking down the two components that influence a sector's level of exposure: the extent of nature dependency and the size of the sector. This scatter plot maps each sector within a country of interest based on its economic value on the x-axis (i.e. either GVA or IVA) and its Consolidated Materiality Rating (either direct or total) on the y-axis. By plotting sectors across these dimensions, this visualisation enables users to effectively prioritise and identify 'critically exposed sectors' based on their relative risk profile. 'Critically exposed sectors' are found in the upper-right quadrant of the exposure matrix, having a large economic size (GVA or IVA) and a high nature dependency. These sectors are highly significant to the economy and also acutely exposed to nature-related risks. Any disruption to the ecosystem services they depend on could have a widespread and severe impact at the national level. Sectors in the upper-left quadrant (named 'exposed niche') are characterised by a high nature dependency but a smaller economic size. Whilst less significant at the national level, these sectors are highly dependent on nature. Their high exposure could have significant impacts due to potential knock-on effects through the supply chain or due to their strategic economic importance beyond their size (for instance in the food supply chain leading to inflation). The lower two quadrants represent sectors with a relatively low reliance on nature. However, those in the lower-right quadrant, whilst less exposed, are large in size and key contributors to the economy, requiring consideration for monitoring and proactive risk management due to their systemic importance to the national economy.

**Sector-level Dependency Breakdown**

A table view allows the user to interrogate the exposure of sectors down to the subsector level. At the sector-level, a dependency breakdown (horizontal bars) shows the proportion of the sector's GVA or IVA that has a high, medium and low dependency on nature. Furthermore, the user can expand each sector to view the dependencies at the subsector level.

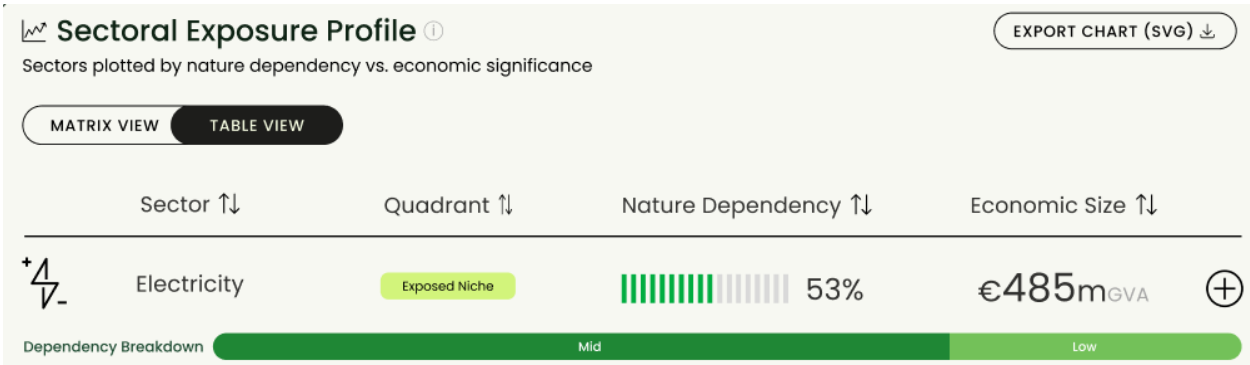



*Figure 5: Sample table view of Sectoral Exposure Profile showing sector-level dependencies and dependency breakdown with ability to expand to subsector view (showing sample data).*

## 3.2 Limitations

**Potential exposure**

The Country Dashboard only provides measures of potential exposure to nature loss based on sectors and subsectors' economic size and the extent to which they theoretically and generally depend on nature. The qualitative links between economic activities and ecosystem services in the ENCORE knowledge base are high-level, global links. Therefore, where there is a dependency link recorded for an economic activity, it does not mean that all production engaging in that activity has that dependency[16].

[16] You can read more about the limitations in the ENCORE knowledge base here

ENCORE materiality ratings are not location specific. The actual materiality of dependencies and impacts is likely to vary significantly based on the specific context, company and location that is assessed. Currently the Country Dashboard does not include data on the precise location of economic production (aside from country or world region of production – see below), the state of nature in that specific location, the probability of future nature degradation, the vulnerability of economic assets and the risks they may face as a result in the short, medium or long-term future.

**Domestic and supply chain value inferences**

The mapping of economic value along the upstream supply chain, both domestically and abroad, relies on the use of EXIOBASE, a global economic dataset that models production, domestic and international supply chains using input-output methods. Input-output databases may weigh certain value chain links differently to other assessment approaches.

As a model, EXIOBASE is a representation of a complex global economy, and its outputs are estimates rather than accurate measurements. It is constructed by integrating various national accounts and trade datasets, which involves adjusting data from different sources, time periods and classification systems. Furthermore, the geographical coverage of EXIOBASE is limited to 44 major economies, mostly based in the EU and the OECD with all other countries grouped into five "Rest-of-the-World" regions by continent. As the official data used to construct the model only extends to 2020, with now-casting to 2022 by extrapolation, it may not fully capture the rapid shifts in global supply chains that have occurred in recent years due to the COVID-19 pandemic, geopolitical tensions and trade policy changes. These factors all affect the reliability of data.

**How economic terms are calculated**

Central to the method for calculating nature dependencies in different parts of the economy, is the calculation of economic terms from EXIOBASE decomposed into domestic and foreign production (GVA vs IVA) and destination (consumed as final demand or exports). The adopted approach follows the calculation logic presented by Aslam et al., (2017) to calculate the content of domestic and foreign value added in exports (equivalent to Domestic Content and Foreign Content in Koopman et al., (2014) terms). As a result, these do include some double-counting due to complex supply chains and re-importing goods as intermediate inputs. Therefore, the sum of Domestic Value Added in final demand and gross exports is marginally greater than GVA). Similarly, the sum of FVA in final demand and gross exports marginally overestimates total IVA. Rather than undertaking a full decomposition of exports, this 'simplified' decomposition was selected to be relevant and interpretable for end-users. This approach aims to provide insights into nature dependencies within different parts of a national economy's supply chain by origin for policy analysis, whilst acknowledging it contains elements that would be excluded in a strict national accounting (GDP) context.

**Financial and insurance activities' materiality**

In ENCORE, the materiality rating of economic activities purely relates to *direct, physical* exposure of a sector's own *operations*. In the case of the financial and insurance industry, this means that the materiality of investments, loans or underwriting activities is not taken into account. This indirect, financed exposure is excluded by this macro-economic assessment and should be calculated separately using financial portfolio data to trace exposure across the whole portfolio. Furthermore, this analysis does not include forward looking, non-physical exposure such as transition or litigation risks that may arise from new regulations or legal actions related to nature protection.

# 4 Conclusion and Future Work

This paper has presented the methodological foundation for *ENCORE Insights: Country Dashboard*, a novel platform designed to illuminate how each EU member state's economy depends on nature. By integrating ENCORE's ecosystem-service dependency data with EXIOBASE's monetary and supply-chain information, the approach provides a transparent and reproducible framework for assessing economic exposure to nature degradation. Crucially, the methodology advances existing research by distinguishing between domestic and foreign dependencies, offering policymakers and financial institutions a clearer understanding of where vulnerabilities lie within and beyond national borders. This distinction allows for more precise targeting of regulation, conservation, restoration, and risk-management strategies across Europe's interconnected economies. The openly accessible Dashboard will not only support evidence-based policy and investment decisions but also foster greater accountability and collaboration among regulators, civil society, and the private sector. The methodology and derived data will be made fully open and transparent to drive system change by fostering accountability, enabling scrutiny and reproducibility and accelerating the adoption of data-informed action toward mitigating global nature degradation risks.

Looking ahead, future iterations in 2026 will incorporate the remaining elements of the framework, such as the exposure of gross exports and employment, deepening insights into the socioeconomic dimensions of nature risk. Nature-3B is a three-year project ending in August 2027, during which we will work closely with users, in an iterative way, to deliver actionable insights that directly address market and policy demands. In doing so, we hope that *ENCORE Insights: Country Dashboard* will contribute an essential analytical tool for promoting resilient, nature-positive economic systems within the European Union and beyond.

# Acknowledgements

This research was undertaken as part of the European Union's Horizon Europe research and innovation programme under grant agreement No. 101182455. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

# 5 References


Aslam, A., Novta, N., Rodrigues Rodrigues Bastos, F., 2017. Calculating Trade in Value Added (IMF Working Papers). IMF.

Ceglar, A., Marques, A., Boldrini, S., Lelli, C., Toreti, A., Parisi, L., Heemskerk, I., 2025. European banks face significant vulnerability to ecosystem degradation and climate change. Commun. Earth Environ. 6, 750. https://doi.org/10.1038/s43247-025-02543-3

ENCORE, 2024. Explanatory note on the updated ENCORE knowledge base outlining business dependencies and impacts on nature. UNEP-WCMC.

Evison, W., Low, L.P., O'Brien, D., 2023. Managing nature risks: From understanding to action. PWC.

Hirschbuehl, D., Petracco, M., Neuville, A., Sanchez, A.I., 2025. The EU economy's dependency on nature [WWW Document]. JRC Publ. Repos. URL https://publications.jrc.ec.europa.eu/repository/handle/JRC140003 (accessed 8.27.25).

Koopman, R., Wang, Z., Wei, S.-J., 2014. Tracing Value-Added and Double Counting in Gross Exports. Am. Econ. Rev. 104, 459–494. https://doi.org/10.1257/aer.104.2.459

Stadler, K., Wood, R., Bulavskaya, T., Södersten, C.-J., Simas, M., Schmidt, S., Usubiaga, A., Acosta-Fernández, J., Kuenen, J., Bruckner, M., Giljum, S., Lutter, S., Merciai, S., Schmidt, J.H., Theurl, M.C., Plutzar, C., Kastner, T., Eisenmenger, N., Erb, K.-H., de Koning, A., Tukker, A., 2018. EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables. J. Ind. Ecol. 22, 502–515. https://doi.org/10.1111/jiec.12715

United Nations et al, 2021. System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA).

# 6 Appendix

## 6.1 Sector Groups and Subsectors

Table 4 provides the mapping of EXIOBASE3 NACE sectors to Sector groups used for aggregation from subsector to sector-level.

| **Sector Group** | **Subsector (EXIOBASE3 NACE classification)** |
|---|---|
| Forestry | Forestry, logging and related service activities (02) |
| Agriculture | Cultivation of paddy rice<br>Cultivation of wheat<br>Cultivation of cereal grains nec<br>Cultivation of vegetables, fruit, nuts<br>Cultivation of oil seeds<br>Cultivation of sugar cane, sugar beet<br>Cultivation of plant-based fibers<br>Cultivation of crops nec<br>Cattle farming<br>Pigs farming<br>Poultry farming<br>Meat animals nec<br>Animal products nec<br>Raw milk<br>Wool, silk-worm cocoons |

| | |
|---|---|
| | Manure treatment (conventional), storage and land application<br>Manure treatment (biogas), storage and land application |
| Fishery and aquaculture | Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing (05) |
| Food beverages and tobacco | Processing of meat cattle<br>Processing of meat pigs<br>Processing of meat poultry<br>Production of meat products nec<br>Processing vegetable oils and fats<br>Processing of dairy products<br>Processed rice<br>Sugar refining<br>Processing of Food products nec<br>Manufacture of beverages<br>Manufacture of fish products<br>Manufacture of tobacco products (16) |
| Heat utilities | Steam and hot water supply |
| Construction | Construction (45)<br>Re-processing of secondary construction material into aggregates |

| | |
|---|---|
| Electricity | Production of electricity by coal<br>Production of electricity by gas<br>Production of electricity by nuclear<br>Production of electricity by hydro<br>Production of electricity by wind<br>Production of electricity by petroleum and other oil derivatives<br>Production of electricity by biomass and waste<br>Production of electricity by solar photovoltaic<br>Production of electricity by solar thermal<br>Production of electricity by tide, wave, ocean<br>Production of electricity by Geothermal<br>Production of electricity nec<br>Transmission of electricity<br>Distribution and trade of electricity<br>Manufacture of gas; distribution of gaseous fuels through mains |
| Water utilities | Collection, purification and distribution of water (41)<br>Waste water treatment, other |
| Supply chain and transport | Transport via railways<br>Other land transport<br>Transport via pipelines<br>Sea and coastal water transport<br>Inland water transport |

| | |
|---|---|
| | Supporting and auxiliary transport activities; activities of travel agencies (63) |
| Chemical and materials industry | Manufacture of textiles (17)<br>Manufacture of wearing apparel; dressing and dyeing of fur (18)<br>Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear (19)<br>Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (20)<br>Re-processing of secondary wood material into new wood material<br>Pulp<br>Re-processing of secondary paper into new pulp<br>Paper<br>Plastics, basic<br>Re-processing of secondary plastic into new plastic<br>N-fertiliser<br>P- and other fertiliser<br>Chemicals nec<br>Manufacture of rubber and plastic products (25)<br>Manufacture of glass and glass products<br>Re-processing of secondary glass into new glass<br>Manufacture of ceramic goods |

| | |
|---|---|
| | Manufacture of bricks, tiles and construction products, in baked clay<br>Manufacture of cement, lime and plaster<br>Re-processing of ash into clinker<br>Manufacture of other non-metallic mineral products n.e.c.<br>Manufacture of basic iron and steel and of ferro-alloys and first products thereof<br>Re-processing of secondary steel into new steel<br>Precious metals production<br>Re-processing of secondary precious metals into new precious metals<br>Aluminium production<br>Re-processing of secondary aluminium into new aluminium<br>Lead, zinc and tin production<br>Re-processing of secondary lead into new lead, zinc and tin<br>Copper production<br>Re-processing of secondary copper into new copper<br>Other non-ferrous metal production<br>Re-processing of secondary other non-ferrous metals into new other non-ferrous metals<br>Casting of metals |

| | |
|---|---|
| | Manufacture of fabricated metal products, except machinery and equipment (28) |
| Aviation travel and tourism | Air transport (62)<br>Hotels and restaurants (55) |
| Real estate | Real estate activities (70) |
| Mining and metals | Mining of coal and lignite; extraction of peat (10)<br>Mining of uranium and thorium ores (12)<br>Mining of iron ores<br>Mining of copper ores and concentrates<br>Mining of nickel ores and concentrates<br>Mining of aluminium ores and concentrates |

| | |
|---|---|
| | Mining of precious metal ores and concentrates<br>Mining of lead, zinc and tin ores and concentrates<br>Mining of other non-ferrous metal ores and concentrates<br>Quarrying of stone<br>Quarrying of sand and clay<br>Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c. |
| Retail consumer goods and lifestyle | Retail sale of automotive fuel<br>Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)<br>Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52) |
| Oil and gas | Extraction of crude petroleum and services related to crude oil extraction, excluding surveying<br>Extraction of natural gas and services related to natural gas extraction, excluding surveying<br>Extraction, liquefaction, and regasification of other petroleum and gaseous materials<br>Petroleum Refinery |
| Automotive | Manufacture of motor vehicles, trailers and semi-trailers (34)<br>Manufacture of other transport equipment (35)<br>Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motorcycles parts and accessories |

| | |
|---|---|
| Healthcare delivery | Health and social work (85) |
| Electronics | Manufacture of office machinery and computers (30)<br>Manufacture of electrical machinery and apparatus n.e.c. (31)<br>Manufacture of radio, television and communication equipment and apparatus (32)<br>Manufacture of medical, precision and optical instruments, watches and clocks (33) |
| Information technology | Computer and related activities (72) |
| Insurance and asset management | Insurance and pension funding, except compulsory social security (66)<br>Activities auxiliary to financial intermediation (67) |
| Banking and capital markets | Financial intermediation, except insurance and pension funding (65) |
| Digital communications | Post and telecommunications (64) |

| | |
|---|---|
| Public services and others | Publishing, printing and reproduction of recorded media (22)<br>Manufacture of coke oven products<br>Processing of nuclear fuel<br>Manufacture of machinery and equipment n.e.c. (29)<br>Manufacture of furniture; manufacturing n.e.c. (36)<br>Recycling of waste and scrap<br>Recycling of bottles by direct reuse<br>Renting of machinery and equipment without operator and of personal and household goods (71)<br>Research and development (73)<br>Other business activities (74)<br>Public administration and defence; compulsory social security (75)<br>Education (80)<br>Incineration of waste: Food<br>Incineration of waste: Paper<br>Incineration of waste: Plastic<br>Incineration of waste: Metals and Inert materials<br>Incineration of waste: Textiles<br>Incineration of waste: Wood<br>Incineration of waste: Oil/Hazardous waste<br>Biogasification of food waste, incl. land application<br>Biogasification of paper, incl. land application<br>Biogasification of sewage sludge, incl. land application |

| | |
|---|---|
| | Composting of food waste, incl. land application<br>Composting of paper and wood, incl. land application<br>Waste water treatment, food<br>Landfill of waste: Food<br>Landfill of waste: Paper<br>Landfill of waste: Plastic<br>Landfill of waste: Inert/metal/hazardous<br>Landfill of waste: Textiles<br>Landfill of waste: Wood<br>Activities of membership organisation n.e.c. (91)<br>Recreational, cultural and sporting activities (92)<br>Other service activities (93)<br>Private households with employed persons (95)<br>Extra-territorial organizations and bodies |

*Table 4: A list of Sector Groups mapped against EXIOBASE NACE sectors used for aggregation.*